PROCEEDINGS

OF THE

NINTH MEETING OF THE

CANADA SOIL SURVEY COMMITTEE

UNIVERSITY OF SASKATCHEWAN

SASKATOON, MAY 16 - 18, 1973

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COMPTE RENDU

DE LA 9ème REUNION DE LA COMMISSION

PEDOLOGIQUE DU CANADA.

UNIVERSITE DE LA SASKATCHEWAN

SASKATOON, les 16, 17 et 18 mai, 1973

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FOREWORD

J.S. Clark, Chairman

The ninth meeting of the Canada Soil Survey Committee was held May 16-18, 1973 at the University of Saskatoon. The Committee and the guests were welcomed to the university by Dr. R.W. Begg, Principal, Saskatoon Campus and by Dean W.J. White of the Faculty of Agriculture.

Mr. Joe D. Nichols represented the United States Department of Agriculture, Soil Conservation Service, and provided much useful background on the USDA approaches and points of view.

During the technical sessions 24 reports were delivered. The majority of these were concerned with non-taxonomic subjects. For example the subcommittee on soil interpretations tabled a lengthy report on soil ratings and techniques used in Canada or elsewhere. The subcommittee on mapping units in surveys of forest land and permafrost areas, after presenting its report, was instructed to continue its activity in the form of a working group subsequent to the meeting. Similarly, the working group on cryoturbated soils was also instructed to proceed as rapidly as possible with the development of a classification system for soils in arctic and subarctic regions.

The committee also focused considerable attention on soil taxonomy because the five-year moratorium on changes in the taxonomy had ended. Modifications were made in nearly all orders.

Prior and during the meeting concern was expressed for the number of classification changes that continue to be made and for the difficulty of finding adequate time for discussion and evaluation at the meeting. Circulation of material and development of subcommittee recommendations prior to the meetings were attempted, but were not entirely successful. In order to achieve the highest degree of efficiency in this process, the committee agreed to transfer the responsibility for future development of the soil taxonomy to a member of the Soil Resource group, S.R.I. Under his leadership working groups would develop recommendations for the committee instead of the subcommittee structures used in the past. In this way it would be possible for the Soil Survey Committee to devote attention to new program directions and approaches to an increasing involvement in land use problems, in closer coordination of Soil Survey with Forestry, Geology, Environment and landuse planning agencies. Some restructuring of subcommittees to achieve these ends is to be developed over the next two years.

Appreciation is expressed to the many participants from a number of agencies who attended the meetings. It is hoped that kind of participation will be expanded.

The stimulating and amusing talk by Dr. Spinks at the committee dinner was very much appreciated. Appreciation is also extended, on behalf of all the participants, for the hospitality and thoughtful arrangements made by the host group at Saskatoon.

AVANT-PROPOS

J.S. Clark, Président

La 9ème réunion de la commission pédologique du Canada a eu lieu à l'Université de Saskatoon les 16, 17 et 18 mai, 1973. Le Dr. R.W. Begg, Principal du Campus de Saskatoon et le Doyen W.J. White de la Faculté d'Agriculture ont souhaité la bienvenue aux membres et invités.

Monsieur Joe D. Nichols du Soil Conservation Service, U.S.D.A. a contribué grandement au succès de cette réunion en exposant les points de vue de nos voisins.

Au cours des sessions on a examiné 24 rapports traitant surtout de sujets non-taxonomiques. Ainsi, le comité des interprétations des sols a soumis un volumineux rapport sur l'évaluation des sols et les techniques utilisées à cette fin au pays et ailleurs. Après la présentation de son rapport, le comité traitant des unités cartographiques a utilisé pour les relevés des pergelisols ou des terrains sous couvert forestier, a reçu le mandat de continuer ses activités sous forme d'atelier. De même, l'atelier sur les sols cryoturbés doit poursuivre ses travaux et soumettre le plus tôt possible un système de classification des sols des régions artique et subartique.

La commission a également apporté une attention particulière à la taxonomie des sols alors que le moratoire de cinq ans sur les changements taxonomiques était révolu. Presque tous les ordres ont subi des modifications.

Avant et pendant la rencontre plusieurs ont regretté que tant de modifications à la classification soient encore effectuées et qu'il soit difficile de trouver tout le temps voulu aux réunions pour discuter et évaluer la porté de ces changements. On a essayé, sans y réussir complètement, de faire circuler les rapports avant les réunions, pour pouvoir soumettre des recommendations précises à l'assemblée. Dans le but d'atteindre une plus grande efficacité d'un tel processus, on a convenu qu'à l'avenir la taxonomie relèverait d'un seul responsable, soit d'un membre du groupe des Ressources du Sol à l'Institut de Recherche des Sols. Ce leader, à la tête d'un atelier de travail, soumettra directement ses recommendations à la Commission, éliminant ainsi la procédure suivie jusqu'ici. La Commission pourra ainsi se tourner davantage vers les directions et approches nouvelles de programmes exigeant une attention accrue aux problème d'utilisation des terres et effectuer une meilleure coordination entre elle-même et les organismes de forestrie, de géologie et d'environnement s'occupant de la planification dans l'utilisation des terres. Pour atteindre cet objectif, il faudra remanier les comités au cours des deux prochaines années.

Il faut se réjouir de la participation de nombreux organismes à ses assises et espérer qu'une telle attitude se répandra encore plus.

La causerie, stimulante et amusante à la fois, donnée lors du diner par le Dr. Spinks a été grandement appréciée. Au nom de tous les participants, nous exprimons notre gratitude à nos hôtes de Saskatoon pour leur hospitalitée et tous les services rendus.

RELEVES MODERNES DES SOLS AUX ETATS-UNIS

J.D. Nichols

Résumé

Le nouveau système de classification des sols des Etats-Unis devant paraître bientôt dans "Soil Taxonomy" introduit de nouveaux concepts. Parmi ceux-ci, il y a les horizons diagnostiques et les critères qui sont étroitement liés au comportement des sols. De ce fait, beaucoup de nouvelles interprétations sont rendues possibles aux divers nivaux ou catégories taxonomiques. De telles interprétations touchent l'administration des fermes, la forestrie, la planification édaphique, la lutte antipollution et divers aspects de l'utilisation du sol..

THE MODERN SOIL SURVEY IN THE UNITED STATES[1]

J.D. Nichols

Summary

The new U.S. Soil classification system soon to be published in "Soil Taxonomy" introduces new concepts. Among these are diagnostic horizons, and criteria that relate closely to the soils' behavior. As a result, many more kinds of interpretations can be made at the various taxonomic levels or categories. Interpretations are made of soil for farm management, for forestry, for edaphic planning, for pollution control, and other uses.

The Soils We Classify

A soil is an intimate mixture of rock particles and organic matter capable of supporting plant life. This was written in Mississippi by William N. Logan over half a century ago. (Agricultural College, Mississippi. Logan, William N., 1916. The Soils of Mississippi; Miss. Agri. Expr. Sta. 81 pp.) Soil, as used in Soil Taxonomy,[2] is the collection of natural bodies on the earth's surface containing living matter and supporting or capable of supporting plants out-of-doors. It

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1 Prepared by Lindo J. Bartelli, Principal Correlator, Ft. Worth, Texas and presented by Joe D. Nichols, Assistant Principal correlator, Ft. Worth, Texas at the Canada Soil Survey annual meeting, May 16-18, 1973; Saskatoon, Saskatchewan, Canada.

2 Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Soil Survey Staff, Agri. Handbook No. 436, USDA, SCS, in print.

is easy to overlook the trials of the early scientists, but basically the changes are not greatly different. We are still using the same definition for soil.

Soil Classification

We have introduced a new system of soil classification. This, in many ways, follows long-established principles of older systems. For example, (Slide 1) it does not discredit the role of the soil-forming factors -- parent material, organisms, climate, relief, and the age of landforms -- a role accepted by soil scientists for more than half a century. Nor does it change the concept of the soil series as used in the United States, although the differentiae used have caused the refinement and revision of many old, established series.

The new system (Slide 2) does introduce new concepts. Diagnostic horizons are the differentiating features. These are the building blocks of the system (Aandahl 1965). In addition, they serve to differentiate features that are important to man's use and manipulation of soils. The relationship of diagnostic horizon properties to soil behavior carries throughout the system. Oxic horizons, (Slide 3) for example, indicate a highly advanced degree of weathering. There are few or no primary minerals remaining to release nutrients for plant use. These horizons are related to infertile soils that require special management practice if they are to remain productive under cultivation. In most instances, diagnostic horizons reflect the environment in which the soil formed. (Slide 4) The system, like most systems in taxonomy, is a pyramid, with few classes at the highest level and many at the lowest level. Soil Taxonomy has introduced criteria that relate closely to the soil's behavior. Resultantly, we can make many more kinds of interpretations at the various categories. Engineering properties are reflected at the family level.

Use of Soil Maps in Farming

Soil surveys continue to be an integral part of the farm management system. (Slide 5) The soil survey input has become more sophisticated. In addition to predictions of yields, fertilizer drainage, and other requirements, the soil's capacity to lock up excess phosphate, pass nitrates, and degrade pesticides is considered. The impact of the management system on the environment is evaluated. In addition to having a favorable cost input/output ratio, farming should not pollute the environment. Farming practices need to be geared more closely to the soil's behavior pattern. (Slide 6) Work in Louisiana shows that denitrification rates are related to drainage. Well drained permeable soil passes nitrates into the ground water readily. (Slide 7) Yield response curves should be formulated for each major soil. Application rates should not exceed the plants' requirement for optimum growth. Nitrogen (Slide 8) applied in excess of the point of maximum return in this soil with a "flushing" moisture regime has a good chance of polluting the ground water. (Slide 9) Nitrates will not flush out of this soil; the second gray layer indicates perched water and a good chance for denitrification. (Slide 10) Pesticides also have unique interactions with soils. Atrazine passes through Fayette silt loam readily. (Slide 11) Soils vary in their ability to tie up phosphate. Soils high in Al, Fe, and clay are efficient fixers. (Slide 12) An Haplaquod in North Carolina, devoid of Al, passes most of the phosphate applied.

Use of Soil Maps in Forestry

The use of soil survey in forestry also has grown (Bartelli and Dement, 1968). (Slide 13) In evaluating the woodland resource in an RC and D project, Case (1971) includes the soil-site index, yields, and woodland cost-return estimates. The soil-site index indicates the amount of wood products a soil can produce under a specified set of management practices. The soil potential for wood production can be developed and used to determine the most suitable woodland management. Being under tree cover is not the only justification for woodland management; it must provide economic incentive and contribute to the economic growth. If not sufficiently productive, woodlands can be managed for aesthetic values, water storage, or recreation and still enhance the environment. Not all woodland is treated the same.

Edaphic Planning

(Slide 14) The serious attempt to clean up the rivers, lakes, countryside, seashores, and cities and the urge to set aside refuge for wildlife and havens for city dwellers have rejuvenated land use planning. (Slide 15) People also are taking a critical view of land pollution. This leads to seeking sites that are most suitable. It means matching a use with the proper soil to prevent pollution of land, ground waters, lakes, or rivers. This is edaphic planning of the landscape. (Slide 16) The soil scientists predict the behavior on the basis of the soil qualities. This is not land use planning, but it is an important input. The soil map is an introduction to the landscape. (Slide 17) It reveals landscape characteristics. In addition, it provides adequate soil behavior predictions to formulate the plan. (Slide 18) The landscape can now be placed into the computer. The landscape is divided into grids which form the unit planning cell. (Slide 19) The soil map is translated into the landscape language by noting the most significant and dominating soil in the unit planning cell. The unit planning cell becomes the vehicle for expressing the properties of the landscape. (Slide 20) It highlights the limitation of each square. (Slide 21) It also can be used to characterize the physiography of the landscape. (Slide 22) More sophisticated interpretations can be generated. The potential for croplands reflects the summary of various inputs. These kinds of maps are printed by the computer. They are cheap and can be printed quickly, and they tell a story. In edaphic planning, farming should be geared to the potential of the soil. (Slide 23) Farmland with the best potential requires level, productive soils with a climate that is not limiting (Bartelli, 1968). If rainfall is restricting, supplemental water must be available. (Slide 24) Potential for recreation use also is determined for each cell. The soil's capacity for producing food and cover, its ability to stand foot traffic wear, and its aesthetic value are some of the considerations. (Slide 25) Potential for urbanization includes an appraisal of the limitations, the cost of overcoming these limitations, and the impact that urbanization will have on the environment. Based on these edaphic features, (Slide 26) the computer produces an edaphic land use plan. True, some areas are well suited for all uses, but edaphic planning highlights the conflicts. It tends to encourage harmony between the selected use and the soil. This kind of planning benefits society in two ways -- it prevents soil misuse and land pollution, and it uses soils to their full potential.

Land Spreading of Waste

(Slide 27) The disposal of waste has become a critical problem. Flushing down the streams and blowing into the atmosphere are not in favor. The complexity of the waste products makes the problem more acute. (Slide 28) Secondary treatment is not successful in removing viruses, phosphorous, nitrogen, and heavy metals. (Slide 29) The soil does provide an adequate facility, and in many cases it is much cheaper than chemical treatment. Resultantly, scientists are studying the behavior between waste material and soil properties. (Slide 30) We are learning to select the good performing soils. Soils high in 2:1 clays, low sand content, and with high cation exchange capacities and low base saturations are the good performers in the removal of cations from effluent. (Slide 31) Soils high in aluminum and iron, low in acidity, and with slow permeabilities are good removers of anions from effluent.

Accelerating Publication

(Slide 32) The ability to predict soil behavior for the many new uses has placed a heavy demand on soil maps and reports. We can make a significant contribution to environmental planning with the proper timing of soil survey release. (Slide 33) We are placing coordinated interpretive data for each series into the computer. With the use of equipment that has text-editing capabilities, (our equipment is the IBM 2741 Communication Terminals and IBM 360 model 50) we are able to adapt standardized stored data to local surveys. Interpretations are now being fed into a computer at Ames, Iowa. This will serve as a national bank. This is being done for phases of series. We hope to get the original drafts of tables from this source. (Slide 34) A yield table for significant phases of the identified series is recalled from the storage unit. It is adjusted to fit the local conditions. (Slide 35) The adjustments are fed into the computer, and the final yield table is produced -- which is ready for printing. (Slide 36) Other tables also can be produced to fit the particular survey area in a like manner. (Slide 37) Modular writing also saves time and money. A model from an edited manuscript of a nearby survey area is stored in the computer. It is recalled and given to the party chief for adaptation to his survey area. Results from our pilot project show that 60 to 75 percent of manuscripts can be automated. Time in preparing a manuscript (through RTSC) was reduced from 12 to 2 months. Party chief time was reduced by 50 percent. Quality control is exercised prior to storing data. Interim or special reports are produced from the same storage. Map drafting also is being automated. (Slide 38) The SCS Advance Mapping System is designed to produce press negatives of soil survey atlas sheets, ready for the printer. Digitizing and automatic drafting equipment is now being used in production and developmental work.

Challenge

(Slide 39) As we wonder about the potentials of remote sensing and photographs from outer space, land-use legislation currently being considered by our Congress and many states will have far-reaching effects on management of public and private lands. Government control of land use will vary among the regions. Several states have regulatory measures tied directly to the soil map. Colorado requires a soil map prior to issuing any permit for subdivision development. Septic tanks are allowed only on soils rated suitable by the soil scientist in Wisconsin. All development around Lake Tahoe in California are based on soil map suitability ratings. Hard political and economic choices must be made if land development is to lead to better environmental and social results. (Slide 40) But adequate data properly analyzed are a necessary base for sound regulatory actions in land use. We must learn to predict the impact of such land uses on the environment. We need to develop means for predicting soil behavior in all uses of land. In addition, our recommendations must be more quantitative. This is the challenge of modern soil surveys.

RAPPORT DU COMITE DES PRIORITES D'UTILISATION DES TERRES

J.S. Clark, Président

Résumé

Les relevés des sols doivent servir le mieux possible les besoins de la planification. Les scientistes du sol doivent participer aux prises de décisions sur la planification dans l'utilisation des terres; ils doivent aider les planificateurs dans cette tâche. Les cartes de possibilités des sols ne peuvent être utilisées qu'au niveau général de la planification; pour la planification détaillée, il faut consulter les relevés pédologiques. La plupart des scientistes du sol ont besoin d'entrainement supplémentaire et d'expérience dans ce domaine de la planification. On doit réserver pour l'agriculture les terres qui offrent un bon potentiel pour cette utilisation.

REPORT OF SUBCOMMITTEE ON POLICY ON LAND USE PRIORITIES

J.S. Clark, Chairman

Summary

Soil surveys should be made as useful as possible for planning purposes. Soil scientists should be actively engaged in assisting planning specialists to make land planning decisions. Soil capability maps are only satisfactory for land planning at a general level, and soil survey information is required for detailed planning. Most soil scientists require additional training and experience in land planning. High capability land should be reserved for agriculture.

For many years Canada has been regarded as a country with adequate and perhaps even unlimited land resources by most Canadians. It has become all too evident that this is not the case and that because of geological and climatic limitations the land resources of Canada and particularly those suitable for agriculture are extremely limited. For this and other reasons there is growing realization that steps must be taken to preserve and manage our lands more efficiently than has been done in the past. It is timely that we as soil scientists review our attitudes to these changing concerns and to review the role we are or should be playing. I do not know if we can reach too many definite decisions at this meeting. Perhaps we can use the replies obtained from the question as a basis for discussions on this topic.

In your replies regarding land use priorities you made it fairly clear that:

1. Soil scientists should be actively engaged in planning.

2. Soil surveys should be made as useful as possible for planning purposes.

3. High capability land should be reserved for agriculture.

4. Soil capability maps were only satisfactory for land planning at a general level and that soil survey information was required for any detailed planning.

5. The soil data bank was a useful tool for land planning.

6. Most pedologists believed that soil scientists alone should not make land planning decisions but that they should work with other specialists.

7. Most soil scientists could use additional training and experience in land planning.

8. Soil scientists should make it clear that they have information that is useful not only to agriculture.

What I believe we should address ourselves to is how the developing land use policies in this country will affect the soil survey activities in the country. Some questions I suggest we address ourselves to are:

1. Are there any changes in CSSC that would allow us to take a more effective role in land planning?

2. Are there any organizational changes that would make the soil survey groups more effective?

3. We frequently talk of making a greater impact outside agriculture. How are we doing and is there anything more that we should be doing?

4. How are the land policies being introduced in the provinces going to affect soil survey? Will the demand for soil surveys increase or will the need be for interpretive maps and reports using existing information.

5. Are there any kinds of maps or soils information we should be putting out that would help in formulating attitudes and policies on land?

6. Are our standard maps and reports adequate or should we develop new ways of reporting soil surveys?

7. Should the Federal Soil Survey take a more active role in non-agricultural soils work. What kinds and to what extent?

8. How does soil survey fit into resource systems approaches. Do we wish to take an active role and how?

In the six months since the land policy questionnaire was sent out to CSSC members there have been profound changes in this country's attitude towards its land resources. Land policies and land use zoning has been introduced in many provinces. There is finally a general awareness of the land pressures that exist in Canada. Even in agriculture there is a growing realization that soils and land form the basis of the agricultural industry and there must be some conscious management and conservation of the agricultural land resource. Whereas six months ago one of our major concerns may have been how to make the country aware of its land problems. Today our problem is how we can best ensure that rational land planning does take place. I think there are going to be as rapid changes in the next few months as well. Little would be gained therefore by discussing the answers to the questionnaire on land policy or by developing any fixed policy or direction with respect to land use planning.

In the short time that we have available I would like your opinions on these or any related topics. Over the next few months I anticipate a number of changes and developments to which we will have to react and your opinions and ideas will be helpful. If we don't have time to give everyone an opportunity to express an opinion please write. Should there be any definite recommendations or resolutions that you wish to have taken to CASC these can be brought up now or in the time allotted for resolutions.

The following is a summary of replies generated from the above Questionnaire dated February 20, 1973.

1) What is the viewpoint of Canadian pedologists on the soil resource and its use?

   a) Should pedologists be involved actively in land use policy formulation?

      Responses were unanimously affirmative (except for Heringa) ranging from an unqualified yes to qualified supportive statements:

   The soil resource is being unnecessarily abused, wasted and lost for all time because of attitude and lack of acceptable policy at all governmental levels. It is the responsibility of the pedologist to influence public opinion and change, in concert, with pedological knowledge. We should strive to accomplish this in an effective and efficient manner as opposed to the crisis to crisis approach that seems to increasingly confront society and be required to initiate action. The pedological influence should be loud and strong enough to focus attention and hopefully procure acceptable regulation.

   Pedologist should be actively involved in land use policy formulation. As a start in focusing attention in various areas it would be useful to publish data for public information regarding past losses of the classes of agricultural land in specific areas with analysis of alternatives and priorities (MacDougall). The pedologist can best serve their interest by producing an awareness among the relevant bodies and the public that soil is in fact a limited resource and that soil scientists can assist in showing how it can be used wisely (Humphrey).

b) If land use planning is accepted as being multidisciplinary action, what should be the specific contribution of the pedologist?

This question brought forth a great volley of ideas many of which are summarized below:

The specific contribution of the pedologist should be the proper design of soil surveys to meet planning needs and to prepare accurate, well documented, intelligible, soil and soil terrain maps from which interpretive maps can be prepared (Ellis group). He must stay involved at a level that will ensure that the information is being fully and properly utilized in decision making. He must continually be integrating at the surface of the physical and biological environments (Acton).

Some felt that the specific contribution of the pedologist is soil resource data collection in areas of basic soil characterization and soil behavior under different systems of land management (Smith).

Many felt that the pedologist must make himself available (go more than half way) to serve in multidisciplinary groups and attempt to sell the idea that land use planning cannot be done without consideration of the effects of soil on the potential (Langmaid, Rochfort, Smith). In many cases people cannot ask intelligent questions if they do not know what information is available. Therefore if we play a passive role and wait until questions are asked, we may never get a chance to respond, i.e., when the pedologist has waited to be asked, he has often waited too long (Dean, Nowland).

A most important step to playing a more effective role is to gain an understanding of the planning process. Once the mechanism is understood, the pedologist must impress upon the relevant bodies the usefulness of soils information to their endeavor, i.e., we must stop defending our profession and begin to enroll its virtues. Just as we could not be effective in an agricultural role without some agricultural background, neither can we expect to effectively contribute to land use planning without at least appreciating the purposes and aims of planning (Unknown respondent).

Another indicated pedologists should accept the virtual impossibility of publishing soil survey reports that will be utilized to their full potential by planners. - No matter how simple and straight forward the presentation, the planner will require special help from the pedologist. Most planners are overworked individuals having insufficient time or inclination to process raw soil information (Nowland).

c) Can you supply specific examples of an involvement in land use planning?

Peters - 1) Development of irrigation schemes;
2) Urban development for towns and cities;
3) Opening up of new agricultural areas in northern Alberta;
4) Forestry - site classification;
5) Rural land assessment;
6) Trafficability studies at Suffield;
7) Parks planning - suitability of areas for trails, campsites, viewpoints, etc.

Smith - 1) Multidisciplinary ecology studies on the MacKenzie River, Churchill-Nelson River and Roseau River Basin.

Langmaid - Moncton, N.B. - Ecological survey.

Nowland - Specific examples of pedologist involvement in Nova Scotia

LOCAL

1) Area: Halifax-Dartmouth

Planning agency: Metropolitan Area Planning Commission (MAPC)
Activity:

Supply of extra interpretive information beyond survey report No. 13, channelled through a geographer/planner of N.S. Dept. of Development. Used for planning and zoning recreation, industry, housing and sanitary landfill facilities. Continuing infrequent involvement.

2) Area: Dartmouth City

Planning agency: City Planning Dept.
Activity:

Erodibility rating of areas surrounding lakes within city boundaries, in order to designate fragile areas. Planners are confident that Council will enact by-laws controlling development and construction practices on the basis of this information. Continuing involvement, possibly including limited fieldwork in doubtful areas.

3) Area: Kings County

Planning agency: Joint Planning Commission
Activity:

Supply of extra interpretive information beyond Soil Survey Report No. 15. Extensive preparation of single-use interpretive overlays and frost hazard maps, etc. Work mostly done by Land Use Supervisor, N.S. Dept. of Agriculture (ex-Soil Survey). Maps prepared by Maritime

Resource Management Services. Information used for total planning in an area of extreme land use conflict and urbanization among most viable agriculture. Involvement intermittent.

4) Area: Strait of Canso Ocean Terminal and Industrial Area

Planning agency: Special area planning authority being set up with assistance of N.S. Dept. of Development.

Activity:

Supply of interpretive information beyond that available in Survey Reports 6, 12 and 14. Active involvement not yet commenced, but demand for information on areas suitable for housing and sanitary landfill sites imminent. Request for detailed soil survey in the offing. Pedologist has been invited by the Director of Community Planning to sit on the Area Planning Authority when established.

5) Area: Truro-Central Colchester Co.

Planning agency: Joint Planning Advisory Committee
Activity:

Routine semi-detailed re-survey of this area is presently underway. The soil survey supplies manuscript maps and provisional ratings of all soils for all uses. Pedologist holds periodic briefing sessions with the resident planner and the whole committee, and participated in a two-week land use planning Short Course at the N.S. Agricultural College.

Much soil survey information has been declared too sophisticated by the planner who is unable to convince the Councils of the most elementary planning principles. Public education, to which the pedologist has contributed is producing better results. Representatives of almost all other departments of governments are contributing to this process, and the absence of soil survey would be inadvisable. Involvement continuing.

6) Area: Industrial Cape Breton

Planning agency: Development Planning Committee
Activity:

Additional interpretations beyond Soil Report No. 12 to assist N.S. Dept. of Development Planners in preparation of maps rating soils for housing expansion and solid waste disposal. Involvement limited and completed 1972.

7) Area: North Shore of Nova Scotia

Planning agency: Northumberland Development Association
Activity:

At the request of DREE and N.S. Dept. of Agriculture, the scale of routine mapping was changed from 1:50,000 to 1:20,000 for the purpose of a detailed indicative land use planning exercise. Soil survey supplied manuscript maps from which many single use overlays were prepared for local use. Pedologist developed explanatory lectures for local groups. Involvement terminated 1971.

8) Area: Musquodoboit River Floodplain

Planning agency: Musquodoboit Rural Development Board and Canada Dept. of Environment

Activity:

At the request of the Development Board, the soil survey undertook a detailed survey in 1969 and issued maps at 1:15,840 and a Report. These demonstrated that the small acreage of good soils that would benefit from flood control dams and other works did not warrant the expenditure if justified for purely agricultural reasons. The control works were halted after $700,000 had been spent in advance of the survey. Soil information was used in the preparation of a full scale development report presently being published by Canada Dept. of Environment.

PROVINCIAL AND REGIONAL

1) Nova Scotia Housing Policy

A study group representing several provincial government departments is currently preparing recommendations for a complete overhaul of housing policy. The pedologist participates and in cooperation with a planner has prepared soil ratings and maps demonstrating a major constraint imposed by soils on housing; 92% of the province is unsuited to septic tank systems, and a high proportion of installed systems have failed. Involvement continuing.

2) Recreation/Tourism Plan for Nova Scotia

A master plan is being prepared by private consultants. The pedologist assists with problem interpretations from existing soil maps, monitors recommendations and supplies a variety of data on file. A few joint field trips to specific development sites are envisaged. Camp sites and golf courses are prominent in discussions. Involvement continuing.

2) Does the CLI soil capability for agriculture constitute a suitable base for land use decisions?

It was generally agreed that the CLI maps constitute a suitable base for land use planning at the broad scale level but not at the more detailed planning scale. Two groups indicated that even in terms of broad scale planning, it is necessary to know the soils as well as the capability (Ellis). Another group felt that although the CLI maps were helpful for planning purposes additional maps were required to show drainage, topography, land occupancy and land tenure (Heringa).

In reviewing the responses to this question (and others) it becomes apparent that clarification is required as to what planning level (National, Provincial, Regional, Municipal) we are attempting to service. Land use planning takes place at many different scales (or levels); the planning scale developed will determine both the kinds of policies formulated and the contribution pedologists should make. The different planning levels (or scales) are ranged from national down to municipal (Humphrey).

2a) Is it desirable or necessary to demand that Class 1, 2 and 3 be reserved for agriculture? What about special purpose soils which may be related as Class 4?

There was almost unanimous agreement that Class 1, 2 and 3 should be reserved for agriculture purposes. The reasons to substantiate this decision are best summed up by Dean who was quick to point out that Agriculturalists and Pedologists have a professional role to play in advocating the reservation of agricultural land in Canada for use in agriculture. This resource is of limited quality in the settled regions of Canada and from the viewpoint of long range planning, we should advocate that resources as far as possible be utilized for agricultural purposes. Obviously, there are many specific occasions when prime agricultural land will be utilized for a greater economic return than from the agricultural business. However, the professional agricultural viewpoint should constantly be brought forward. We will reach a time in Canada, when the supply of prime agricultural land will become critical and we should begin conditioning planners to this viewpoint so that when the time comes, the decisions will be much easier (Dean).

Obviously we are going to have to be extremely vocal when Class 1, 2 and 3 is used for other purposes. These eruptive noises will have to be justified by supportive evidence on present misuse as exemplified by the disappearance of the fruit belt in southern Ontario and Urban and Industrial development on the Plain of St. Lawrence in the Montreal area.

There were only a few definite statements concerning special purpose soils rated as Class 4. Two groups indicated that Class 4 should also be reserved for agricultural purposes particularly where it was suited for special crops including tobacco, apples, small fruits or grapes, etc. (Rochefort, Heringa).

2b) In areas where there is no Class 1 soil should Class 2 or even Class 4 soils be zoned exclusively for agricultural use?

Except for Ellis and Peters, the replies indicated an unqualified yes in the case of Class 2 and 3 soils with some reservations on Class 4 soils. It was summed up by Nowland who indicated that according to N. Pierson and others, the 25 million acres of climatically favored Class 1 and 2 soils in Canada will be urbanized by 2000 AD. Therefore the Class 2 and 3 soils in Nova Scotia will be needed for agricultural purposes eventually even though there are presently large areas which are uncleared.

In contrast one group felt that it was wishful thinking to demand that Class 1, 2 and 3 soils be reserved for Agriculture as this would demand on the individual situation, i.e., Does the Dept. of Highways avoid Class 1, 2 and 3 soils (Ellis)?

Peters group suggested that it is not necessary to demand that Class 1, 2 and 3 be reserved for agriculture but that it was preferable. Many towns and cities are situated on Class 1 or 2 agricultural land and they have nowhere else to go. Legislation should be brought in that the better lands about a city should be reserved for agriculture if the city has no other area to expand into, but not otherwise.

Another response suggested that any arguments we advance for the preservation of agricultural land will have to be justified socially, economically and environmentally. Policies giving agriculture prior claim to the land might be the best solution. Such a policy would ensure that new users justify their proposals and would also lead to justification for agricultural enterprises.

2c) Is class and subclass adequate for agricultural interpretations and planning? For detailed planning are capability units essential?

There were mixed feelings on this question with about half the responses indicating that Class and Subclass were not adequate for agricultural interpretations and planning. The remainder indicated that they were adequate for broad regional planning but that a new concept is required for detailed planning. There were no concrete alternatives proposed although it was indicated that economics must be taken into consideration.

One respondent suspected that what is alluded to in this question concerning the necessity of capability units in detailed planning, is their usefulness in establishing zoning ordinances, where the type of endeavors permitted is more specifically controlled. There is a difference between a land's potential to produce and the economic viability of the operation situated on it. The intent of a plan is likely to be better served if zoning ordinances attempt to qualitatively control the activities rather than specifically control them. For instance, if the potential of the land for production is low but its potential to cause environmental damage (erosion, etc.) is high, then regulations might discourage intensive operations. Similarly, ordinances regulating building and subdivision practices would encourage development on suitable areas for the use. Whether it be capability units or not, some measure of a land's ability to accommodate a use is required at all planning scales.

2d) Is the CLI base (general field crops) too narrow, or insufficiently inclusive for planning purposes; should the suitability for special crops also be evaluated in the land use planning action?

Replies indicated a unanimous yes. There was general concern for inclusion of speciality crops indicating that economics has to be brought into the picture. Some thought that single crop capability maps are required.

3) What should be the role of the soil data bank relative to soil survey and soil research? Land use planning?

The role of the soil data bank was highly regarded in soil survey and soil research but somewhat questionable in land use planning.

It was felt that the data bank will provide a more effective communications link between pedologists (as producers of soil resource data) and potential users of the data. This is the critical link in the logical sequence of data acquisition, data analysis and evaluation and integration of results with other related studies necessary for developing land use priorities (Smith). Another felt that it has tremendous potential in soil survey, soil research and land use planning provided that credible and standardized means of accepting or rejecting data are devised. Full utilization of interpretive information and computer graphics would make the data bank's application to land use planning limitless (Unknown).

Data banks may fail us completely if they cannot play a role in land use planning. To be effective in such planning, pedological fertility, productivity and other information must all be accessible and capable of integration. This back log of information should make it possible to develop and test models of alternate land use systems to facilitate the decision making process (D. Acton).

In contrast one respondent challenges that you cannot do any planning with the soil data bank. Land use planning is not the same across Canada (Peters). This was definitely a minority poll.

4) Are present methods of analysis (e.g. transparent overlays) adequate for land use planning? Are other procedures available and how do these compare?

There are several methods of analysis utilized in land use planning. Transparent overlays is an adequate procedure under certain conditions. Likewise computer analysis of planning programs is also an adequate procedure under other conditions. The answer to this question cannot be a simple statement. The planning team for each problem area will have to examine the possibilities and decide on its own method of analysis (Dean).

The most important factor is a group of technocrats who have a knowledge of the area and respect the integrity of each other and are willing to yield if necessary to obtain the best overall plan possible with the resources available (Langmaid).

Nowland points out that overlays have a role to play, but too often the presentation material is in fact the only analysis used in the planning process. They are a useful first step in recognizing broad patterns. Their greatest drawback is that they give each factor overlain equal weight, an implicit assumption usually forgotten.

Such simplistic approaches have led to unworkable rural zoning and similar planning that we are now stuck with.

5) Would pedologists require any additional training in order to work effectively in a land use planning role?

It was generally agreed that more training was required depending on the planning level (or scale) of involvement.

In broad terms any pedologist who is on a land planning role had better be familiar with the area under study and the best way to do this is by field inspection. There is not sufficient information on the inventory maps for office planning at the federal provincial level (Ellis). In short the prerequisite to all this is to be up in your own field of pedology (Peter).

Nowland draws attention to the fact that effectiveness is learned by participation in planning programs, not in the classroom. The area of doubt is - if land use planning involves social inputs, is any physical scientist the best person to weigh these values against soil properties? A professional working in any planning process is a servant of the process and should be able to judge when to relinquish the floor to a colleague more qualified. Any contribution can be nullified by weak leadership.

It is important to acknowledge that pedologists would benefit from a better understanding of the broad planning process and likewise they could probably have a more effective input with such a knowledge (Dean). Such training could be intensive, short terms and concerned mainly with techniques, methods and past experience (MacDougall).

To this point, the above comments could be applied land use planning at the broad national and provincial level. What about Regional and Municipal planning?

In terms of regional planning, i.e. regions within a province, the pedologist will have to do his homework on his geomorphology and physical resource training (Dean).

There was greater concern for more training when committed to planning projects at the municipal level. It was felt that additional training in hydrology would equip the soil scientist with a broader resource base and extend his expertise beyond the bounds of pedology to include all the physical land resources. Knowledge of water management and soil interpretations for soil mechanics are also essential at the municipal level (Dean).

6) Should the responsibility for making statements of the suitability of land for various uses rest with pedologists?

Responses indicated a nearly unanimous No. and pointed out the responsibility should not rest with the pedologists alone. The pedologist has a role to play by offering his advice and information. But the sole responsibility for the final statement of the suitability of land rests with the broad group of specialists of which the pedologist is one (Dean, Smith).

A pedologist may be well qualified to assess capability of soils, which is their inherent ability to perform but he is on more tenuous ground assessing their suitability, which is acquired ability to perform. The acquired ability involves the approval of society presumably through the process of planning for various alternate uses, i.e. any planning in isolation stands a good change of falling short of the goals (Nowland).

In contrast, why shouldn't pedologists be responsible for making statements on the suitability of land for various uses? It is our duty as a profession to make statements concerning those areas in which we have expertise. If our recommendations are ignored by the decision makers our only recourse is to increase our efforts - it is neither professional nor logical to relax our efforts or to ignore our potential contribution (Unknown).

One last bit of philosophy is that one of the greatest hang-ups the pedologists serve under is that they have been associated with agriculture for so long that the general public sees us only in this respect. We have a great deal of information on soils which can be used effectively by other disciplines but we are reluctant to do so because of these agricultural tie-ups. Agriculture has got us on our feet but we now have grown up and can face other areas of interest confidently. (Peters).

RAPPORT DU COMITE DES CARTES PROVINCIALES ET INTERPRETIVES

P.G. Lajoie, Président

Résumé

Il existe un besoin de cartes provinciales à petite échelle, produites à échelle uniforme, d'après les mêmes critères et entièrement compatibles d'une province a l'autre à travers tout le pays. A cet effet, nous proposons la préparation de cartes au 1:1000,000, en utilisant des symboles connotatifs du genve suivant

$$\frac{A}{B}4\frac{C}{s}$$

ou les deux premières majuscules indiquent les Grands groupes de Sols; le numéro, la texture des matériaux du sol; la majuscule suivante, le relief ou le modelé du terrain et les deux lettres minuscules, les deux plus importantes caracteristiques des matériaux du sol.

Cette méthode peut être considérée adaptée à la compilation des données des cartes, mais la publication de cartes comportant une si complexe symbolisation est susceptible de detourner les utilisateurs eventuels. Pour obvier a cet inconvenient, les membres de la Commission ont en majorité opté pour une symbolisation très simple associée à une légende détaillée.

REPORT OF THE SUBCOMMITTEE ON PROVINCIAL SOIL AND INTERPRETATION MAPS

P.G. Lajoie, Chairman

Summary

There is a need for provincial small scale maps produced at uniform scale with the same criteria and entirely compatible from one province to another across the country. For this purpose, it has been proposed to prepare maps at 1:1000,000 using connotative symbols of this kind

$$\frac{A}{B}4C\frac{c}{s}$$

where the first capital letters refer to Great Soil Groups; the number to the texture of the soil materials; the following capital letter to the relief or landform pattern and the two lower case letters to the most important characteristics of the soil materials.

Such a method may be considered adapted to the compilation of map data, but such a complex symbolization on published

maps may rebut potential users. To avoid this handicap, the members of the Committee have in a vote, expressed their preference for a very simple symbolization referring to an expanded legend.

The purpose of provincial soil and interpretation maps is to serve as instruments of education, research and soil resource evaluation at broad national, provincial and regional levels. National co-ordination is required to define uniform map units or groupings and prepare a single legend acceptable by the various provincial soil organizations.

A letter sent in January to the subcommittee members contained specific proposals concerning: scale, area, soil boundaries, map content and symbolization. The scale proposed was 1:1,000,000 and the area to be covered in the first phase of the project would be that of the Canada Land Inventory. It was suggested to take advantage of the boundaries drawn on the Agricultural Capability Maps at 1:1,000,000 as a possible starting point to delineate the main components that might occur on these maps. (The Agr. Cap. Maps are available - or will soon be available - for the whole of the C.L.I. area, except for British Columbia and Newfoundland).

The following content was originally proposed for the Maps:

1) Parent Materials
2) Great Soil Groups
3) Soil Climates

The Parent Materials were to be grouped in ten main classes and indicated by numeric symbols from 0 to 9. (Because we are in a glaciated country, the tills were to be subdivided into 3 or 4 subgroups). Lower case letters could be associated with the numbers to indicate various important characteristics (chemical, physical, textural, relief) of the materials.

Materials	Modifiers
0 - organic	a - acid
1 - till, ground moraine	c - calcareous
2 - till, ablation moraine	g - gravelly
3 - till, terminal + recession	h - clayey
4 - shallow till and rock, colluvium	k - alkaline
5 - glacio-fluvial (outwash, kames, eskers)	l - loamy
6 - deltaic + beach materials	m - mountainous
7 - lacustrine or marine sediments	n - saline
8 - alluvial material	p - stony
9 - eolian material	r - rocky
	s - sandy
	t - steeply sloping
	z - frozen

To indicate the Great Groups the following alphabetic symbolization was proposed:

Order	Proposed Symbols	Great Group	Other Methods of Symbolization	
Chernozemic	A	Brown	11	C1
"	B	Dark Brown	12	C2
"	C	Black	13	C3
"	D	Dark gray	14	C4
Solonetzic	E	Solonetz	21	S1
"	F	Solod	22	S2
Luvisolic	G	Gray Brown Luvisol	31	L1
"	H	Gray Luvisol	32	L2
Podzolic	J	Humic Podzol	41	P1
"	K	Ferro Humic Podzol	42	P2
"	L	Humo Ferric Podzol	43	P3
Brunisolic	M	Melanic Brunisol	51	B1
"	N	Eutric Brunisol	52	B2
"	P	Sombric Brunisol	53	B3
"	Q	Dystric Brunisol	54	B4
Regosolic	R	Regosol	61	R1
Gleysolic	S	Humic Gleysol	71	G1
"	T	Gleysol	72	G2
"	U	Eluviated Gleysol	73	G3
Organic	V	Fibrisol	81	F
"	W	Mesisol	82	M
"	X	Humisol	83	H

Two capital letters could have been used after the numeric symbol to indicate the dominant (upper) and the subdominant (lower) Great Groups on each map unit. A complete symbol would have been $8s_U^S$ indicating an alluvial material of sandy nature on which we find humic and eluviated gleysols.

Just before the meeting a revised proposal was made concerning the Map Content and Symbolization. It was based on: 1) the Texture of the Materials and 2) Landforms or Relief Patterns as the two essential components of the map. The mineral Materials are symbolized by Numbers from 1 to 9 according to their Texture and the Relief or Landform by a Capital Letter. Up to two Modifiers indicated by Lower Case Letters could be adjoined. An example of the complete symbol would be:

$$4C_s^c$$

Dominant (upper) and Sub-dominant (lower) indicators of Great Groups could be added as proposed at the meeting:

$${}_S^G4C_s^c$$

or in one of the following fashions:

$$4C_{s71}^{c31} \;,\; {}_{G1}^{L1}4C_s^c$$

Symbolization proposed for the Texture of Parent Materials

0 - Organic
1 - Clays
2 - Silty clays
3 - Clay loams
Sandy clay loams
4 - Loams, Very fine sandy loams
Silty loams
5 - Gravelly loams
6 - Fine sandy loams
7 - Coarse sandy loams
8 - Fine to very fine sands
9 - Gravels + coarse to medium sands
11 - Rock Outcrops

Symbolization proposed (Capital Letters on Left) or alternative (Capital Letters on Right) for Reliefs or Landform Patterns

A	depressional	D
B	flat to depressed	F
C	undulating	U
D	hilly	H
E	rolling	R
F	steeply sloping	S
G	mountainous	M
H	knob and kettle	K
I	dissected or gullied	G

The following were given as some of the possible Modifiers to be adjoined to the Materials.

Modifiers

Reaction + salts

a - acid
b - alkaline
c - calcareous
d - saline
e -

Stoniness + rockiness

r - rocky (shallow)
s - stony
t - rocky and stony
u - bouldery
v - excessively stony

Moisture (average status)

m - moisture deficient
n - non-deficient
o - often wet
p - permanently wet
q -

Other

w - Cryic
x - Impermeable Layer
y - Restrictive Layer
z -

Originally it was proposed to represent the various Soil Climates by screen overprints on the map. The proposal had little support and was discarded before the meeting. This information which is not considered essential by many could be added later if there is need for it.

The replies to the January memorandum indicated a fairly general concensus concerning the selection of 1:1,000,000 as the most appropriate scale. The small provinces would prefer 1:500,000 scale. The area delineated under the Canada Land Inventory was also accepted as the area to complete in the first phase of the project. Two provinces indicated their desire to cover the whole of their territory even if the area outside the CLI is done with less details.

The suggestion that the Soil Boundaries shown - or to be shown - on Agricultural Capability Maps at 1:1,000,000 be used as a base to work from in the first stage of the maps compilation, was accepted - or seemed to be - by all except one province.

The main criticism of the proposed symbolization is its complexity making it inaccessible to many users. A simpler type of symbolization referring to an expanded legend has been proposed as an alternative. (The 1973 Generalized Soil Map of Texas was exhibited as an example of this type of symbolization with expanded legend).

When asked to vote on their preference for the symbolization proposed or for an approach like the one used on the Texas Map a majority of the members preferred the latter. However, no matter what symbolization is used on the published maps, there is still a need for a uniform approach for the gathering of the information and the compilation of the maps. The proposed method may be a good one for that purpose. To test its value, pilot projects could be initiated in different parts of the country.

Following the brief presentation of the mapping method described above, there were many comments made by members. The following is a summary of the comments recorded on tape.

D. Acton - When is the General Soil Map of Canada at 1:5,000,000 going to be published? We need to appraise this general map before rushing to the next step.

J. Day - The basic map is done. The report needs final editing. The Soil Climate Map is in the same state. There is also a 1:10,000,000 Generalized Soil Map of Canada prepared for the Atlas of Canada.

R. Baril - Favors the map with expanded legend because it can show both cartographic and taxonomic details.

G. Millette - Maps should not be made just as academic exercises, but should have a specific purpose. Would rather favor a system of data bank making possible the grouping of soils in different ways and allowing for the production of maps at different scales for specific needs.

P. Lajoie - Acreages and percentages of classes and subclasses have been - or are being - calculated from the Capability Maps at 1:1,000,000 for each and every province. These are important data for broad planning purposes. We had to make the maps before we could measure the areas and obtain these fundamental data.

J.S. Clark - Emphasizes the need of such maps for educational purposes. Also, as experienced in Ontario and B.C. they serve as background for the philosophy of the Land Use Programs. Our politicians and public do not realize where we stand with respect to (the shortage of) soil resources and agricultural land.

G. Millette - Disagrees. Since we have the computer we should not work on maps but on a program that will make the information available at the "flip of a finger".

P. Lajoie - There are many things a computer cannot show. We have a communication gap with the public and the politicians. They think we have an unlimited supply of agricultural land. We need the visual impact of maps to show our politicians and the public - our children in particular - what the real situation is.

J. Dumanski - These maps are for educational purposes but also serve as the first approximation for compiling the information we have now. It will be a considerable time yet before we have a really informed data bank. In the meantime, if we feel these maps are useful, we still have to compile them.

A. Raad - Maps and computers are complementary.

J. Nichol - Stress the need for maps at all scales - broad scales for quick look or for higher order officials. We can computerize certain kinds of information. We cannot yet computerize detailed soil maps; we are close to being able to do it.

J. Nowland - Stress the need for regional flexibility.

P. Lajoie - The system proposed is a crude approach which can be refined to suit different needs.

G. Millette - Much harm is done by maps because people take them at their face value.

A. Raad - The scale of 1:1,000,000 is adequate. It is the scale of ERTS imagery.

G. Mills - Favors a combination of two systems.

T. Peters - Favors single purpose maps.

P. Lajoie - Many kinds of single purpose maps could be derived from the master maps proposed.

T. Peters - By having all your soil information on one map you confuse the non-initiated.

P. Lajoie - Agreed, but you still have to make your master map before you make the single purpose one.

J.S. Clark - Ask for a vote on open or closed system.

R. Protz - What do you mean by open or closed system, what are we voting on?

P. Lajoie - The rigid or closed system is coded all the way, like the one proposed. By reading the coded symbol you immediately know what is in the area. In the open or non-coded system you have to refer to an expanded legend.

L. Lavkulich - You are looking for a connotative symbolization on the map and I see no problem there at all. I do not even see a reason for voting.

P. Lajoie - Agreed, but a vote is wanted to indicate the preference of the members on the type of maps we should produce.

L. Lavkulich - Is it not just a matter of having a connotative symbol superimposed and more description in the legend?

P. Lajoie - Yes, it is possible to have a combination of both.

R. St-Arnaud - With the open system you regroup that additional information where you want, but you record on a rigid system.

P. Lajoie - That's right.

J.S. Clark - Vote ... More numerous voters for the open system.

RAPPORT DU COMITE DES UNITES CARTOGRAPHIQUES POUR LES RELEVES DES TERRAINS FORESTIERS ET DES PERGELISOLS

L.M. Lavkulich, Président

Résumé

Pour obvier aux biais régionaux causés par des objectifs et des philosophies variables, on recommande la formation d'un comité d'étude chargé de développer un système de cartographie pratique pour les cartes à petite échelle.

REPORT OF THE SUBCOMMITTEE ON MAPPING UNITS IN SURVEYS OF FOREST LAND AND PERMAFROST AREAS

L.M. Lavkulich, Chairman

Summary

It is recommended, as a result of regional biases caused by varying objectives and philosophies, that a small working committee develop a useful system for small scale mapping.

This subcommittee has considered the approaches possible and the methodology by which surveys of forest land and permafrost areas could be conducted. Special attention was focussed on defining mapping units for small scale inventory programs. With this consideration in mind, the subcommittee decided to orient their deliberations towards "Mapping Units for Small Scale Soil Resource Inventories" and suggested to the C.S.S.C. that this be their official function.

During the deliberations of the subcommittee, it became evident that a nationally accepted landform classification was necessary prior to the development and definition of mapping units. With this prerequisite, a uniform system of defining and employing mapping units could evolve so that information collected would be of uniform quality and terminology. This was felt to be extremely urgent at this time because of the demand for information about the soils resource for land use planning and management and the advent of the essential and important computerization of soils information into CanSIS.

At the second meeting of the Western Section of the Canada Soil Survey Committee an attempt was made to define the objectives, the scale of mapping for exploratory and broad reconnaissance soil surveys, level of categorical detail appropriate to the objectives and scale and terminology, mapping units, biophysical approach as applied to exploratory and broad reconnaissance surveys. A suggested approach dealing with mapping intensity, scale and mapping units was also presented.

A consensus of opinion on a number of topics studied is outlined in the following section.

1. Small Scale Maps

The subcommittee was in favour of the need for small scale maps of soils and related terrain features. Although not stated directly it became apparent that the need for small scale inventories were different. Some respondents felt that small scale maps were required only for the biological aspects of agriculture and forestry, whereas others felt the need for an overall or "environmental" approach. Thus, it became evident that there were at least two requirements that had to be met; namely, small scale soil resource maps and small scale land classification maps. (The latter includes more aspects of vegetation).

2. Change of Subcommittee Name

It was suggested by the chairman that the name of the subcommittee be changed to: "Mapping Units for Small Scale Soil Resource Inventories". This met with general acceptance with one committee member being opposed because of the connotation that "Small Scale Soil Inventories" indicated a single disciplinary approach whereas a workable system for the north country must follow a multi-disciplinary approach. However, another committee member strongly suggested that although an integrated approach was essential a discipline must be responsible for the program. I personally believe that integrated or interdisciplinary programs are required, probably more than multi-disciplinary approaches and that the pedologists of Canada should take the leadership.

3. Mapping Criteria and Hierarchy

In the earlier memorandum a simplified approach to mapping criteria and land was given. Crudely, the land may be broken down as follows:

Static Elements	Dynamic Elements
Geologic materials	Biota
Landforms	Water regime
Climate (gross)	Climatic regime
Soils	

These two categories "static" and "dynamic" are relative terms only. This breakdown is useful only in focusing our attention onto the more stable aspects of the earth's features which can be inventoried with a greater chance (statistically) that the inventory will not be outdated quickly, unless there is a catastrophic event. In inventory of soil resources, one can begin with the most stable features and work progressively to the less stable features. In doing so one can also go from very generalized information, e.g. geologic materials to more specific information, e.g. soils. For example:

Geologic Material   Landforms   Soils   Associated Vegetation
(general)   (more specific)

In some cases geologic material is not required.

In this manner climate and water are not necessarily spelt out but inherent in soils taxonomy and vegetation. I am certain one can argue about the terms static and dynamic but I think this is of little importance to the general concept.

Inherent in this approach are the recognition of the pedon as a sampling tool and the polypedon as the real think in nature that encompasses a "relatively homogeneous landscape" or "ecosystem". The problem that must be resolved in small scale maps is how can we group these polypedons into meaningful map units that reflect the character of the soil resource in terms of biological production and physical capacity in terms of engineering properties.

The question of the necessity of hierarchical arangements met with varied response. In general, the subcommittee favoured a hierarchical approach although some respondents felt that this could become too rigid. Several examples of different hierarchical arrangements were submitted along with some suggestion that the approach set out in the Second Western Meeting of the C.S.S.C. on pages 129-130 may have merit. The suggested approaches are abstracted below:

a. Western Meeting of C.S.S.C. 1971 (Kelowna)

Type of Survey	Scale	Mapping Units	Location of Mapping Unit Boundaries	Acreage Mapped /man year
Detailed	1:31,680 to 1:63,360	series, complexes and phases	all prelocated stereoscopically, greater than 50% field checked	20,000
Reconnaissance High Intensity	1:63,360 to 1:100,000	catenas or associations or families	all prelocated stereoscopically at least 50% field checked	250,000
Reconnaissance Medium Intensity	1:100,000 to 1:125,000	catenas or associations complex families	all prelocated stereoscopically, at least 30% field checked	750,000 to 1,000,000
Reconnaissance Low Intensity	1:125,000 to 1:250,000	associations catenary families or subgroup and texture	all prelocated stereoscopically, at least 25% field checked	3,000,000 to 4,000,000
Exploratory	1:250,000 to 1:500,000	associations great group and texture	all prelocated stereoscopically, at least 10% field checked	10,000,000 to 15,000,000
Schematic	1:500,000 to 1:1,000,000	associations of great groups	all prelocated stereoscopically, 5% field checked	20,000,000

b. Soil Research Institute No. 1

Map Scale	Soil Classification	Land Classification
>1:1,000,000	Order Great Group	Soil Region (Pedoclimatic Region)
1:150,000 to 1:1,000,000		Soil District Soil Association or Catena
1:20,000 to 1:150,000	Family	Soil Association Mapping Unit

Soil Series

↓

Interpretations (This is the why? of it)

This approach recognizes and places primary emphasis on the soil element but includes other elements of the earth's surface.

c. Soil Research Institute No. 2

Use landform classification and tie features to landform classification to serve the widest spectrum of users-planners. This, not concerned necessarily with the soil element being of premier importance. Favoured open ended legend and approach taken by Poulton (Poulton, C.E. 1971. A comprehensive remote sensing legend system for the ecological characterization and annotation of natural and altered landscapes. Techn. Paper No. 3435. Oregon Agr. Exp. Sta., Oregon State Univ., Corvallis, Oregon).

This approach, although having very complex symbols for each mapping unit (see Proceedings of Second Western Meeting of C.S.S.C. Kelowna, 1971, page 137) apparently does not require agreement over names and philosophy.

d. Soil Research Institute No. 3

Category	Name	Basis for Delineation
V	Geoclimatic region (Section*)	Regional climate and physiography
VI	Biogeoclimatic subregion (Subsection*)	Subregional climate, physiography and vegetation
III	Land Type Association	Vegetation, landform, soils, drainage (repetitive pattern of soils or a range of materials within the family range of textures). Soils may be recognized at the Great Group taxonomic level.
II	Soil Association or Catena	Soils, materials, texture (Grouping of related subgroup soils on a material under similar climatic conditions).
I	Soil Associates	Soil components of mapping individual (subgroup on a material under a given climate)

* equivalent term used by Wertz and Arnold. This approach also recommended that a new taxonomic level be introduced between the soil series and family that would fit the landscape just as the soil series does through the polypedon.

e. Manitoba

Please see Table 2 "Hierarchical Ordering of Landform, Soil and Vegetation Components Utilized in Environmental Inventory".

f. Saskatchewan

The consensus from the Saskatchewan group was that requirements of a mapping unit for small scale surveys should:

i. the soil component of the unit must reflect natural occurrences of soils;

ii. the soil component of the unit must facilitate the recognition of an assemblage of materials - a unit cannot be restricted to parent material as recognized at the series level of the taxonomic system;

iii. the soil component of the unit must appear in association with a geomorphological or landform component.

These suggestions were added to by a discussion of terminology by Darwin Anderson which follows:

SUBMISSION TO SUBCOMMITTEE ON MAPPING UNITS IN SURVEYS OF FOREST LANDS AND PERMAFROST AREAS

It is proposed that two categories, cartographic in nature, be established to facilitate and lend a certain level of homogeneity to small scale soil and terrain mapping in Canada. The terms consociates and consociation are proposed as the names of these two categories. These words may be found in any English dictionary. They are essentially synonyms of associate and association but they are suggested as alternatives in that the latter have been, and are being used in a more restricted sense. Within soil cartography the following definitions are proposed.

Consociate: - A non-taxonomic or cartographic grouping of soils or land segments which groups related soil series or polypedons which have a similarity in many, or all of the following characteristics.

1. Geomorphic position, landform and, to lesser degree, the geological nature of the soil material.

2. Features important in determining the edaphic and mechanical properties of the soil, such as soil climate, drainage, texture, presence and depth to lithic contacts or permafrost, stability of soil materials, slope rockiness or stoniness and special features such as an unusual mineralogy.

3. To some degree, the taxonomic classes of the polypedons included within.

Table 2

Hierarchical Ordering of Landform, Soil and Vegetation Components Utilized in Environmental Inventory

CARTOGRAPHIC CHARACTERISTICS			ENVIRONMENTAL CHARACTERISTICS (Level of Taxonomic Detail Necessary to Describe Environmental Components)		
Category	Size Range	Mapping Scale			
Zone	>100,000 sq. mi.	<1:10,000,000	Ecologically significant zones described in terms of dominant soils (Order Level), vegetation (type or association) and climate relations. These zones may override or transgress major physiographic and landform unit boundaries.		
			LANDFORM	SOIL	VEGETATION
Sub-zone	10,000's - 1,000's sq. mi.	1:10,000,000-1:1,000,000	1.0 Southeastern Lake Terrace	1.0 Luvisolic, Brunisolic and Organic	1.0 Great Lakes-St. Lawrence Region
Region	1,000's-100's sq. mi.	1:1,000,000-1:500,000	1.1 Lp Lacustrine Plain 1.2 Sprague Peatland 1.3 Moodie Peatland 1.4 Gp Glacial Fluvial Plain	1.1 Grey Luvisols 1.2 Mesisols and Fibrisols	1.1) 1.2) 1.3) Rainy River Section 1.4)
Sub-region	100's-10's sq. mi.	1:500,000-1:250,000	1.11 cLp/C Clayey lacustrine plain, gently sloping	1.11 Orthic Grey Luvisol; Gleyed Grey Luvisols and Rego Humic Gleysols	1.11 Wh.Sp.-tA-Balsam Fir Forest
			1.21 Swamp	1.21 Terric & Typic Mesisols and Sphagnic types	1.21 Cedar-Bl.Sp. Forest and tamarack, sedge-swamp birch forest
			1.22 Fen	1.22 Terric & Typic Mesisols	1.22 Sedge-Shrub Meadows
			1.23 Transitional Bog	1.23 Terric & Typic Mesisols and Sphagnic types	1.23 Bl.Sp. Forest
			1.24 Bog	1.24 Sphagno Fibrisols, Mesic Fibrisols and Typic Mesisols, sphagnic type	1.24 Bl.Sp. Forest
Types and Sub-types	10's-1/10's sq. mi.	1:100,000-1:40,000	1.211 Lowland		
			.2111 Hydric	1.2111 Katimik Series	1.2111 Tamarack-<u>carex</u>-mixed moss, swamp birch
			.2112 Mesic	.2112 South Junction Series	.2112 Cedar-Mixed Moss-Bl.Sp.
			1.221 Lowland		
			.2211 Mesic	.2211 Stead Series	.2211 <u>Carex</u>-<u>Drepanocladus</u>
			1.222 Patterned		
			.2221 Watertrack		
			.2222 String		
			.2223 Wooded Island and Fen Complex	.2223 Stead Series Waskwei Series	.2223 <u>Carex</u>-<u>Drepanocladus</u> Bl.Sp.-Feathermoss
			1.241 Raised		
			.2411 Domed	.2411 Julius Series	.2411 Bl.Sp.-<u>Sphagnum</u>-<u>Cladonia</u>-<u>Ledum</u>
			.2412 Plateau	.2412 Whithorn Series Santon Series	.2412 Bl.Sp.-<u>Sphagnum</u>-<u>Ledum</u>

It is thought that the above category would represent a natural group of land segments based partly on soil properties but including certain non-soil parameters that will facilitate their delineation by aerial photo interpretation and the use of allied geographical maps. It is usual that maximum rate of change of soil properties (and hence natural soil boundaries) corresponds with changes in landform, geomorphic position, drainage and vegetation; and that taxonomic soil classes based on important soil genetic properties are related to the soil environment. Therefore, consociate map areas may be expected to have a relatively high level of homogeneity with respect to taxonomic soil groups. It is possible that many consociates would be soil families.

It is likely that consociates cannot be delineated on small scale maps. In this case a combination of consociates are likely. It is proposed that the term consociation be utilized for a combination of consociates. Consociations may include two, three or four consociates provided they all are present in significant (say >15%) proportions. Consociations should represent a natural association of the consociates, as defined by physiographic parameters. This is relatively similar to the U.S.D.A. concept of association.

Consociations could be named by combining the consociate names. The relative proportion of consociates could be shown by deciles.

A second possibility, perhaps preferable to many pedologists, is to name consociations with local geographical names. They could be described in terms of their component consociates which could remain unnamed. Different proportions of consociates could be identified by utilizing a consociation-map unit system like the association-map unit (based on proportion of series) now used in Saskatchewan.

Within a hierarchical system consociations could be regarded as divisions of physiographic regions, not soil zones, and an aggregation of related soil series or polypedons. The term combination as proposed by J.H. Ellis[1] may be used to describe related consociations occurring within a physiographic region.

Example of a possible mapping legend:

- (Within Amisk (63L) map area)

Physiographic region. Churchill River Plains Region of the Canadian Shield

[1] Ellis, J.H. 1932. A field classification of soils for use in soil survey. Can. J. Agr. Soc. Vol. XII.

Consociates:

1. Jan Lake (Jn): Hummocky to rolling, sometimes ridged, glacially eroded exposures of intrusive acidic, gneissic and volcanic rocks of Precambrian age; unconsolidated sediments and organic material less than 10 cm in depth may occur; as well as slight proportions of lithic Podzolic soils on sandy, acid till; sparse jack pine vegetation.

2. Kistapiskow (Kp): Flat to gently undulating deposits of weakly to non-calcareous lacustrine clay or clay till; shallow to deep; generally occurs in depressional areas between bedrock (Jn) uplands particularly near large lakes; Orthic Gray Luvisol (Gray Wooded) and Gleyed Orthic Gray Luvisol (Gray Wooded) subgroups; mixed stands of aspen, white spruce, white birch and black spruce most common.

3. Wildnest Lake (Wn): Roughly undulating to moderately rolling deposits of coarse textured glacial till derived from igneous rocks; very shallow to keep; extremely stony; most commonly Orthic Humo-Ferric Podzols and Lithic Humo-Ferric Podzols; usually associated with Jn in upland positions; jack pine vegetation most common.

4. Flat Bog (Bf): Flat lying, shallow to very keep deposits of peat derived primarily from mosses and woody vegetation; acidic; fibric over mesic in lower control section; permafrost generally not present; occurs in enclosed depressions; Mesic and Terric Fibrisol subgroups; black spruce-labrador tea vegetation.

Possible consociations shown on map:

Jn^8 -Wn^2, Jn^4-Kp^4-Wn^2, Jn^5-Bf^5, etc.

g. Quebec

The consensus of opinion from Quebec were in favour of the points raised in the February memorandum. In particular they were in favour of the suggested name change of the subcommittee as they felt that agricultural maps should be different from forest lands. They emphasized that when dealing with small scale mapping units we no longer map soil units, per se but patterns of soil units. Patterns reflect the distribution of soil units that are not erratic and are known; while complex indicates that the soil components are distributed in an irregular and erratic fashion. When mapping small scale soil maps it is patterns of soils that are mapped. With this, I completely agree; as I believe strict definition and uniformity of approach is essential.

The system recommended included:

i. a symbol for the climatic region in which the units fall;

ii. a symbol for the relief of the unit;

iii. a symbol for the depth of unconsolidated surface materials above bedrock;

iv. two symbols giving the major classes of soil parent materials occurring in the unit.

In this way the soil does not appear in the symbol but the pattern of the soil series occurring in the unit appears in the description of the mapping unit with an estimate of the percentage area covered by each soil series.

The mapping units are considered Land Systems but they are also Soil Associations and Associations of Plant Communities. In this approach they recognize the stable features and work progressively to less stable features as indicated earlier in my memorandum. They also recognize that the soil series is the individual which ties soil taxonomy to land classification or "taxonomic units" to "mapping units".

4. Comparison of Soil-Vegetative Classifications

Except for what was discussed above there was little discussion regarding trying to integrate soil and vegetative taxonomy and classification.

5. Other Examples of Small Scale Inventories

Except for general comments regarding the necessity of an integrated approach, the importance of defining and employing the soil element and a general need to broaden the restrictions on units on one material, no firm recommendations were forthcoming.

RECOMMENDATIONS

As a result of the regional biases caused by varying objectives and varying philosophies, it is recommended that the Chairman of the C.S.S.C. strike a small working committee to develop a system useful for small scale mapping and for the presentation of information. This working committee must have the opportunity to meet and develop the approach and methodology consistent with remote sensing and CANSIS.

LITERATURE CITED

Canada Soil Survey Committee, 1971. Second Meeting of the Western Section, Kelowna, B.C.

Ellis, J.H. 1932. A field classification of soils for use in soil survey. Can. J. Agr. Sci. Vo. XII.

Poulton, C.E. 1971. A comprehensive remote sensing legend system for the ecological characterization and annotation of natural and altered landscapes. Techn. Paper No. 3435. Oregon Agr. Exp. Sta. Oregon State Univ., Corvallis, Oregon.

Wertz, W.A. and Arnold, J.A. 1972. Land systems inventory. U.S.D.A., Forest Service Intermountain Region, Ogden, Utah.

RAPPORT DU COMITE DE LA DEGRADATION DES SOLS

J.A. Shields, Président

Résumé

Suite à la Conférence de Stockholm sur l'Environnement les représentants canadiens de l'UNESCO ont été chargés de la préparàtion de cartes indiquant les diverses sources de dégradation des sols. Un comité a donc été mis sur pied pour étudier cette question en ce qu'elle touche notre organisms. Ce comité recommende le développement d'un système national de classement des causes visuelles de dégradation des sols dans le but d'en inventorier les causes. Le système proposé doit subir l'essai dans des zones d'étude régionales en C.B., aux Prairies, en Ontario, au Québec et aux Maritimes avant d'être appliqué sur une base nationale. Ce projet doit s'ajuster au classement proposé pour les Types divers de terrains, de même qu'avec CanSIS et les projets connexes du ministère de l'Environnement.

REPORT OF THE SUBCOMMITTEE ON SOIL DEGRADATION

J.A. Shields, Chairman

Summary

As a result of the Stockholm Conference on Human Environment, Canadian Representatives of UNESCO have been requested to prepare maps for the various causes of soil degradation. Consequently, a subcommittee was activated to study this topic and its relevance to the CSSC. Recommendations of this subcommittee include the development of a national system of classifying the visual causes of soil degradation with a view to preparing an inventory of degradation causes. The classification scheme developed is to be tested in Regional Study Areas within B.C., Prairies, Ontario and Quebec and the Maritimes prior to its application on a national basis. The soil degradation project must also be interfaced with the proposed classification on Miscellaneous Land types, CanSIS and with related projects in Department of Environment.

INTRODUCTION

As indicated by Dr. Clark in his initial memorandum concerning these meetings, this topic was injected into the agenda due to pressure from Canadian representatives of UNESCO for the preparation of maps and a classification scheme for the various causes of soil degradation. Recommendation No. 20 of the United Nations Conference on Human Environment, Stockholm during June, 1972, stated:

It is recommended that FAO, in cooperation with other international agencies concerned, strengthen the necessary machinery for international acquisition of knowledge and transfer of experience on soil capabilities, degradation, conservation and restoration, and to this end:

a) Cooperative information exchange should be facilitated among those nations sharing similar soils, climate and agricultural conditions:

   (i) The Soil Map of the World being prepared by FAO, UNESCO and the ISSC should serve to indicate those areas among which transfer of knowledge on soil potentialities and soil degradation and restoration would be most valuable;

   (ii) This map should be supplemental through establishment of international criteria and methods for the assessment of soil capabilities and degradations and collection of additional data based on these methods and criteria;

   (iii) This should permit the preparation of a World Map of Soil Degradation Hazards as a framework of information exchange in this area.

Having established that the federal government has a firm commitment to this project, the next step is to see what Soil Degradation is all about. The international concept on soil or land degradation is presented in a recent FAO publication by R.S. Rawschkold entitled Land Degradation. The various causes of degradation are grouped into three categories:

Category I: Causes of soil degradation requiring immediate application of available technology and the development of new technology to prevent degradation reaching a state of emergency.

<u>Causes:</u> Erosion and sediments, salts and alkali, organic wastes and urban encroachment, infectious diseases and insects.

Category II: These causes of soil degradation represent a lower order of magnitude in importance because of their lesser extent, intensity and rate of increase.

<u>Causes:</u> Industrial inorganic wastes, pesticides, radioactivity and heavy metals.

Category III: These causes of degradation which are of lowest priority. They constitute no widespread hazard to soil nor are there numerous isolated areas requiring attention.

Causes: Fertilizers and detergents.

It is generally realized that within any particular region, one or more of the above causes may assume a greater influence in relation to others within a given category. The degradation causes are expanded upon in Appendix I.

Subcommittee Activities

In January a memo was sent out to subcommittee members. A summary of the replies from this memo indicated that:

a) There was general agreement to the suggested priorities of soil degradation as proposed by Rawschkolb.

b) The causes of soil degradation should be inventoried on a regional basis (B.C., Prairies, Ontario and Quebec, Maritimes) with respect to location, extent and severity. However, there was some skepticism in regard to the mapping mechanics and map scale.

c) The above inventory be restricted to the visual causes of soil degradation that are presently indicated on soil survey maps and reports, or which can be readily interpreted from air photos or by remote sensing techniques. This inventory should be interfaced with:

- related projects in the Dept. of Environment (garbage and refuse dumps, sanitary landfills, mine tailings, areas of sewage sludge disposal);
- the proposed classification of Miscellaneous Land Types;
- research projects which would provide predictive capacity to forecast future degradation hazard (i.e. systems approach to generate data for erosion capacity equations);
- CanSIS whereby this information can be stored on a geographic base. Storing this information in a digitized form in the CanSIS system is highly desirable as an alternative to publishing and distributing a complete set of inventory maps.

d) A classification scheme be generated for the visual causes of soil degradation to facilitate a national inventory of these causes.

Further support for the inventory of degradation causes has arisen from recommendations of the Canada Department of Agriculture Task Force Report on the Contribution of Agriculture to Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River. This report was prepared in 1972 in support of the International Joint Commission. Recommendation No. 4 states that support be extended to the Ontario Soil Survey to provide maps of the susceptability to erosion of those soils in Southern Ontario where runoff is likely to contribute sediment to water courses.

In conclusion, this subcommittee requests the involvement of the CSSC on this project. Recommendations at the local and international levels have already indicated that we must not take this project too lightly. If we are not prepared to respond to the inventory needs of degradation causes then some other discipline will and we as the CSSC will have to accept the consequences of their recommendations. In undertaking this project we must be prepared to do a reasonable job of inventorying the visual causes of degradation not only to meet the needs of FAO at a scale of 1:5 million, but equally important to provide information required to supplement present knowledge of our soil resource base which is so vital to the provincial, regional and municipal planning levels. Therefore, this subcommittee proposes the following recommendations:

1. The CSSC in cooperation with the Dept. of Environment undertake the responsibility for development of a national system of classifying the VISUAL CAUSES of soil degradation with a view to an inventory of these causes. This classification scheme should be operational by May, 1974 and must be compatible with the FAO system.

2. Commencing May 1974, the Classification scheme will be interfaced with current soil survey projects with a minimum of one dual (soil degradation - soil survey) project undertaken in each of British Columbia, the Prairies, Ontario and Quebec, and the Maritimes regions. The inventory phase of these projects should be completed within a one year period.

3. On completion of the regional study areas, the classification scheme should be revised according to acquired experience and the revised system used to map and inventory the visual causes of soil degradation on a national basis.

4. That the CSSC submit a request to the Dept. of Agriculture for additional professional, technical and cartographic support (a minimum of 1 professional and 1 technical man-year) for each regional study area. Submission of a second major request is also required to facilitate expansion of the program within a national framework.

5. Since there is presently no system for gathering, storing and processing data obtained from an inventory of degradation causes, it is recommended that CanSIS establish a soil degradation file in addition to its present files. This file should be on a geographic base.

DISCUSSION

Hedlin: I have a general comment concerning the terminology. I find this term degradation a little unfortunate. For example, in terms of soil salinity, most people in Manitoba agree that there probably has not been a significant change in salinity during cultivation. So in Manitoba, is salinity a form of soil degradation? In using the term degradation we are implying that farming practises are gradually damaging the land.

Clark: Nevertheless, we as agrologists are faced with the situation where there are some claims that salinization is increasing as a result of farming practises. So there is pressure within the Department to come to grips with this.

Peters: In Alberta, the Department of Municipal Affairs is utilizing remote sensing to study salinity. They are sending their men out to map out those areas affected by salts because it effects the Municipal Assessment. They are also looking at feed lots. So we have a built-in source of detailed information of this type. However, there is a strong need for standards to be set up in order to evaluate the varying degree of the problem.

Shields: Yes, the crux of the problem regarding the classification scheme is to come up with sensible guidelines that will be meaningful on these particular aspects of soil degradation.

Raad: This is a very timely subject, especially in the Maritimes. We have some agricultural committees who recommend that we establish certain guidelines of soil degradation. For example, an experiment has been recently set up to determine the erodability of the Charlottetown soils. This is part of a 6 year project financed completely by the provincial and federal Departments of Environment to determine the erodability of the major soil types in P.E.I. and to be followed later by New Brunswick and Nova Scotia. So I would support your recommendation that soil survey in cooperation with the Dept. of Environment carry out an inventory of the degradation and erodability for soils across Canada.

Shields: I am very pleased to know that you are collecting information on erosion which will serve as guidelines for the classification scheme.

Millette: We are not entirely new comers to this field. I have been teaching land use occupation work that has been published in 1966 by the City of Montreal Planning Board where they showed all the quarries, sandpits and garbage dumps within a radius of 80 miles of Montreal. If we are going to do any work like that then we must be prepared to revise these maps periodically.

I would also draw attention to the point that we are using the term degradation in a bad sense. I think what we really mean here is soil modification, not degradation. For example, when they modified St. Helene Island which was mainly bedrock and they put soil on top to grow lawn and plant trees, - they did not degrade it, but instead they upgraded the island. To me, this is not degradation, but is a modification of the soil.

Shields: I realize that this term degradation lends itself to a little misunderstanding. But until we can come up with a better term we had better go along with the International concept. At least, this is where we should start from.

In regard to your other comment Gerry, it does not particularly concern me that we will have to update the inventories on garbage dumps, quarries or the like because the Dept. of Environment will have to deal with this problem anyhow and as long as the information is stored on a geographic base, it should present no great problem.

Coen: I'm unsure as to whether your thinking in terms of simply recording or are you predicting what kinds of degradation would occur if certain uses were made of the area.

Shields: It has to show both because a degradation cause such as erosion lends itself not only to be inventoried, but also to some type of prediction of susceptability if a change in use occurred. In contrast, garbage dumps will only be recorded as isolated sites on the map in order to evaluate their intensity and distribution.

Johnson: What we have to be concerned about more than anything else is that we do not simply regard this exercise as one of cataloguing degradation causes. It is very important that we also have some predictive potential with the emphasis on prevention. The positive aspect that we are looking for is to prevent degradation or in other words to promote aggradation.

MOTION: The motion to accept the recommendations of the subcommittee on soil degradation was passed unanimously.

APPENDIX

DEGRADATION CAUSES

1. Erosion
   - erosion of sediment from agric soils and its associated effects on crop production and water pollution.
   - surface runoff and
   - soil drifting both result in loss of plant nutrients.
   - contribution of absorbed nutrients make to degradation of surface water supplies.
   - organic matter and sediment load destroys reservoirs and makes water treatment for domestic use more costly.

2. Salts and Alkali
   - generally associated with irrigated lands.
   - dry land salinity.
   - solonetzic soils.

3. Organic Wastes
   - refuse including domestic municipal and industrial wastes.
   - sewage
   - concentrated animal wastes
   - sawdust
   - canning and processing wastes.

4.	Infectious Organisms	- insects and diseases cause billions of dollars of crop losses per year. Require development of tolerant varieties.
5.	Industrial Inorganic Wastes	- stack gases including fly ash, SO_2 fluorides. - disposal of inorganic residues.
6.	Pesticides	- primarily concerned with their persistence in soils adsorption to soil particles and subsequent deposit in streams and entry into food chain of various wildlife.
7.	Radioactivity	- fallout from nuclear explosions.
8.	Heavy Metals (Pb, Hg, Cd)	- from industrial and domestic uses and from industrial wastes.
9.	Fertilizers	- concerned with contaminants associated with them i.e. radioactive elements in rock phosphates.
10.	Detergents	- detrimental effects from sewage effluents.

RESOLUTIONS

Whereas there is presently no system for gathering, storing and processing data obtained from an inventory of degradation causes, be it resolved that CanSIS establish a soil degradation file additional to its present files. This file should be on a geographic base.

Whereas the project on soil degradation is of relatively high priority and whereas the present pedological staff is committed to soil survey programs, therefore be it resolved that a request is submitted to the Department for additional professional, technical and cartographic staff to support existing staff in collating, processing and presenting such data.

REFERENCES OF INTEREST

1. Rawschkolb, R.S. 1971. Land Degradation. Soils Bulletin No. 13 prepared by FAO, Rome.

2. MacLean, A.J. and MacDonald, E.M. 1972. Agriculture Contributions to nutrient enrichment of waters in watersheds of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River. Part of a report of the Canada Dept. of Agric. Task Force in support of the International Joint Commission.

RAPPORT DU COMITE DU SYSTEME CANADIEN D'INFORMATIQUE DU SOL: "CANSIS"

J. Dumanski et B. Kloosterman, Présidents

Résumé

Grâce à une entente sur l'organisation, les fichiers et les codes, de même que par la coordination assurée par l'organisme central, CanSIS réunit et relie entre elles sur une base coopérative, la totalité des banques nationales et provinciales des données sur les sols. Sa fonction principale est de receuillir les données fondamentales sur les sols. Il est conçu pour s'accomoder et répondre aux besoins d'information sur les sols au Canada. Les fichiers de CanSIS pour l'entrée des données sont les suivants: 1) fichier des données des sols, 2) fichier cartographique, 3) fichier géographique/administratif et de performance/gestion, 4) fichier interactif des relevés de sols, aussi appelé fichier des descriptions de sols. Présentement, CanSIS n'a qu'un seul fichier de sortie, celui des noms de sols, mais d'autres sont prévus.

Les concepts, la structure et les modes d'opération du du fichier cartographique et de celui des données des sols ont été mis à l'essai, en 1972-73 dans une région pilote, soit celle que couvrent les cartes Hinton-Edson et Chip Lake dans le centre-ouest de l'Alberta. On a opéré l'entrée et la codification des données de 185 sites différents et fait la lecture des coordonnées (digitizing) sur les cartes de sols. Du fichier des données, l'ordinateur a pu reconstruire des descriptions de profils de sols et produire divers rapports tabulaires. La carte originelle des sols, de même que quelques cartes interprétatives, ont également été produites à partir du fichier cartographique. Les résultats obtenus indiquent, au moins de façon superficielle, que le programme de CanSIS est réalisable et convenablement structuré, mais, qu'une planification prudente et réaliste doit être appliquée pour empêcher qu'il ne devienne excessivement coûteux. Il est aussi apparu que du personnel supplémentaire ainsi que des crédits pour le développement et le matériel (hardware) sont nécessaires.

Bien que le projet pilote ait demandé beaucoup de temps et d'efforts, un certain progrès a également été réalisé sur le fichier performance/gestion, celui des descriptions de sols et celui des noms de sols.

CanSIS est d'une grande importance pour le programme de relevés des sols et pour la science du sol en général.

Dans le domaine des données sa contribution principale sera de les rendre compatibles et d'en assurer la qualité.

REPORT OF THE SUBCOMMITTEE ON THE CANADA SOIL INFORMATION SYSTEM: "CANSIS"

J. Dumanski and B. Kloosterman, Co-chairman

Summary

CanSIS is a collection of cooperative soil data banks, national and provincial, that are linked together through agreement on organization, files and codes, with coordination provided by the central data bank. It is dedicated primarily to the collection of basic soil data, and tailored to accommodate and respond to the needs for soil information in Canada. CanSIS has four basic input files, i.e. soil data file, soil cartographic file, geographic/administrative file and performance/management file, and one soil survey-interactive input file. The latter is called the soil description file. At the moment it has only one output file and this is called the soil names file, but others are planned.

Concepts, structure and working relationships of the soil data file and soil cartographic file were tested on a pilot project area in 1972-73. The area chosen covered the Hinton-Edson and Chip Lake map sheets of west-central Alberta. 185 soil sites were coded and entered into the system, and the soil maps were digitized. Computer-generated soil profile descriptions and a series of tabular reports were generated from the soil data file. The original soil map as well as a small number of interpretive maps were generated from the soil cartographic file. The results of this work indicated, at least in a cursory manner, that the CanSIS program is feasible and adequately structured, but that careful, realistic planning will be necessary to prevent the program from becoming excessively costly. It has indicated also that additional staff, and budgets for development and hardware are required.

Although the pilot project commanded considerable amounts of time and effort, some progress was achieved in the performance/management file, the soil description file, and the soil names file.

CanSIS has considerable implications to the soil survey program in Canada, and to soil science in general. One of its major contribution will be in the realm of data compatibility and quality control.

The report from the Canada Soil Information System (CanSIS) consists of 3 parts. The first, a review of concepts, philosophy and objectives of the system, will refresh memories of the various ideas which have been written in the past. The second is a progress report on the activities which have gone on in the various files. The third is an attempt to underline the implications of the system to the overall soils programs in Canada and to forecast come future developments.

1. Review of Concepts

In 1970 the Subcommittee on Handling Soil Data recommended that Canada set up a soil data bank, that it be located in Ottawa and that it function within the broad realm of soil correlation. This was accepted, and active work began in 1972.

Deliberations of the Subcommittee on Data Handling were centered around the desirability of establishing a system for storage and retrieval of soil data. Upon beginning work on the CanSIS project it soon became apparent that storage of data without procedures for evaluating data quality and compatibility was insufficient. At the same time it was realized that to design quality control and compatibility procedures without investigating procedures of data collection would be redundant. Consequently, CanSIS was structured not simply as a soil data bank but as a complete program of soil data capture, processing and retrieval. Its base was set as broad as soil science itself. As such should work effectively within the time tested concepts of the information pyramid (Fig. 1).

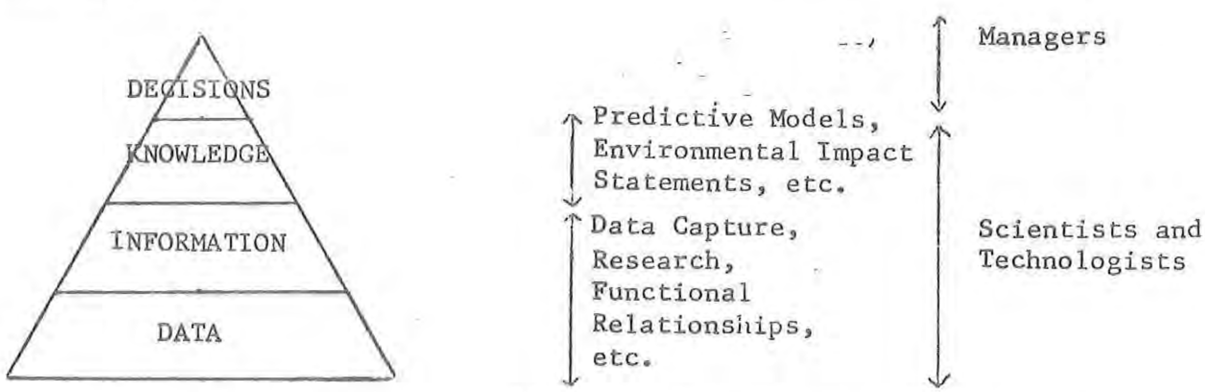

Fig. 1 Relationships among data collectors, data flow and data usage.

A series of operational concepts were formulated for the CanSIS program, and these are summarized as follows:

- CanSIS is a collection of cooperative soil data banks, national and regional (provincial), that are linked together through agreement on organization, files and codes, with coordination provided by the central data bank.

- CanSIS is dedicated primarily to the collection of basic soil data. It will accept also data that affects and depicts soil use.

- CanSIS has an open-ended structure with the ability to accept new files at anytime in the future.

- most of the input will be compiled by provincially situated units.

- CanSIS is tailored to accommodate and respond to the needs for soil information in Canada.

Four basic input files were established for CanSIS at its inception. These were the soil data file, soil cartographic file, administrative/geographic file and performance/management file. To this the soil description file has since been added. The soil data and performance/management files are national/provincial files in that they will be maintained in Ottawa and in regional centers; the cartographic and administrative/geographic files will be maintained primarily in Ottawa. The soil description file is purely regional in that it is designed as a personalized system of data collection for individual survey projects and thus is local in application. Objectives of each file, as well as interrelationships among the files and various cooperative data systems, are shown in Fig. 2.

Common to most input files of CanSIS is the objective of soil characterization and quantification. This statement immediately brings to mind the use of statistical and mathematical techniques for summarizing soil analytical and morphological data. Many papers have been written on this subject. This, however, is only the tip of the iceberg, in that true quantification includes also concepts, theories and criteria of soil genesis and classification, and techniques, purposes and information obtained from soil survey and soil evaluation studies. For example, means and standard deviations of individual soil properties for a particular series, although a form of quantification, is an approximation only. To this must be added information as to whether that series was established on a small or large scale survey, the vintage of the series as a check on classification and series concepts, and quantitative information on the use implications of that series.

Quantification of soil individuals becomes then the common denominator among these related activities. It is of paramount importance because once defined these units become mutually comprehendable to suppliers and users of soil information, and they introduce a degree of precision into soil interpretations that would otherwise be impossible.

CanSIS will have many uses. The most obvious of these is the facility for storage and manipulation of massive quantities of data. Above this it will have considerable application for evaluating data in a soil survey area, research into concepts of pedology, parametric land evaluation, etc. It will serve also as a means of data interchange with various other government departments, particularly those with automated planning facilities.

In that the CanSIS system is being developed as a collection of national and regional, mutually supportive soil data banks, a set of objectives and work functions for each is necessary. Fig. 3 illustrates that CanSIS and its regional data banks function under the auspices of the national committees of CASCC. The national data bank and its staff will undertake responsibility primarily for development of the system, data compatibility in relation to coding, data collection and entry, program coordination and research on methodology. They will assist in the establishment of regional data banks, and they will undertake pilot studies if such are defined in relation to methods of analysis for

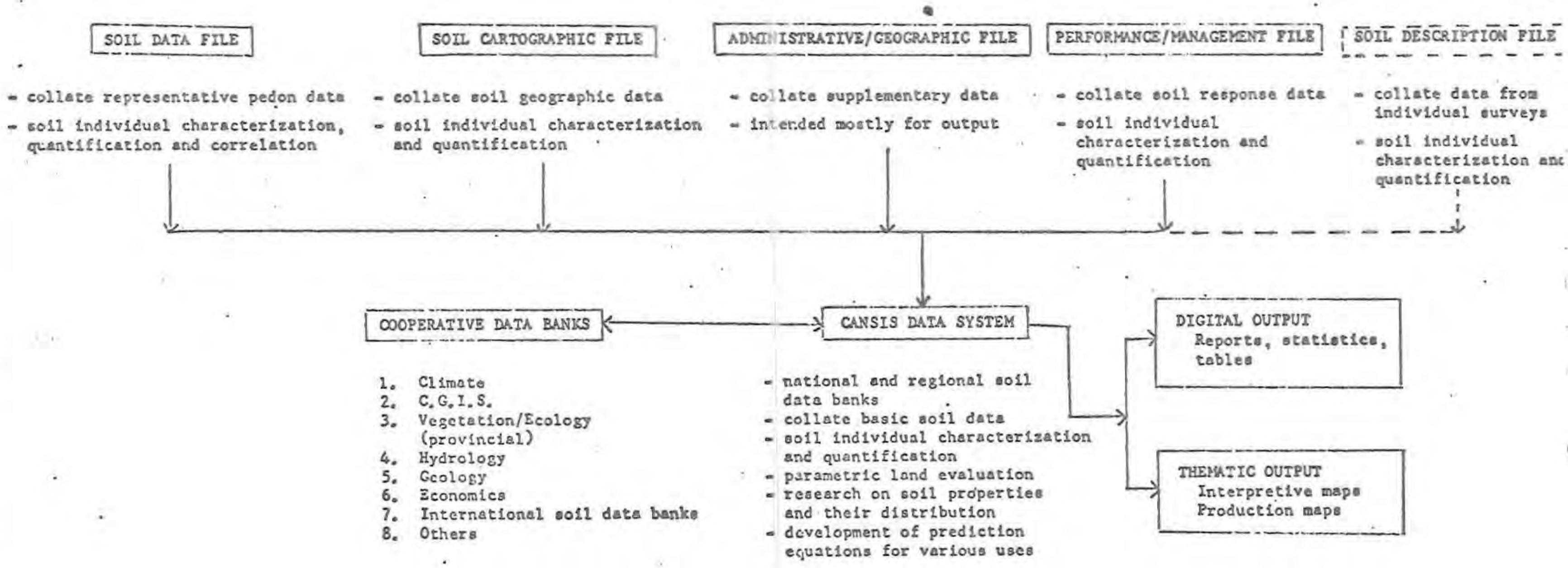

Fig. 2. Objectives and interrelationships of the CanSIS system.

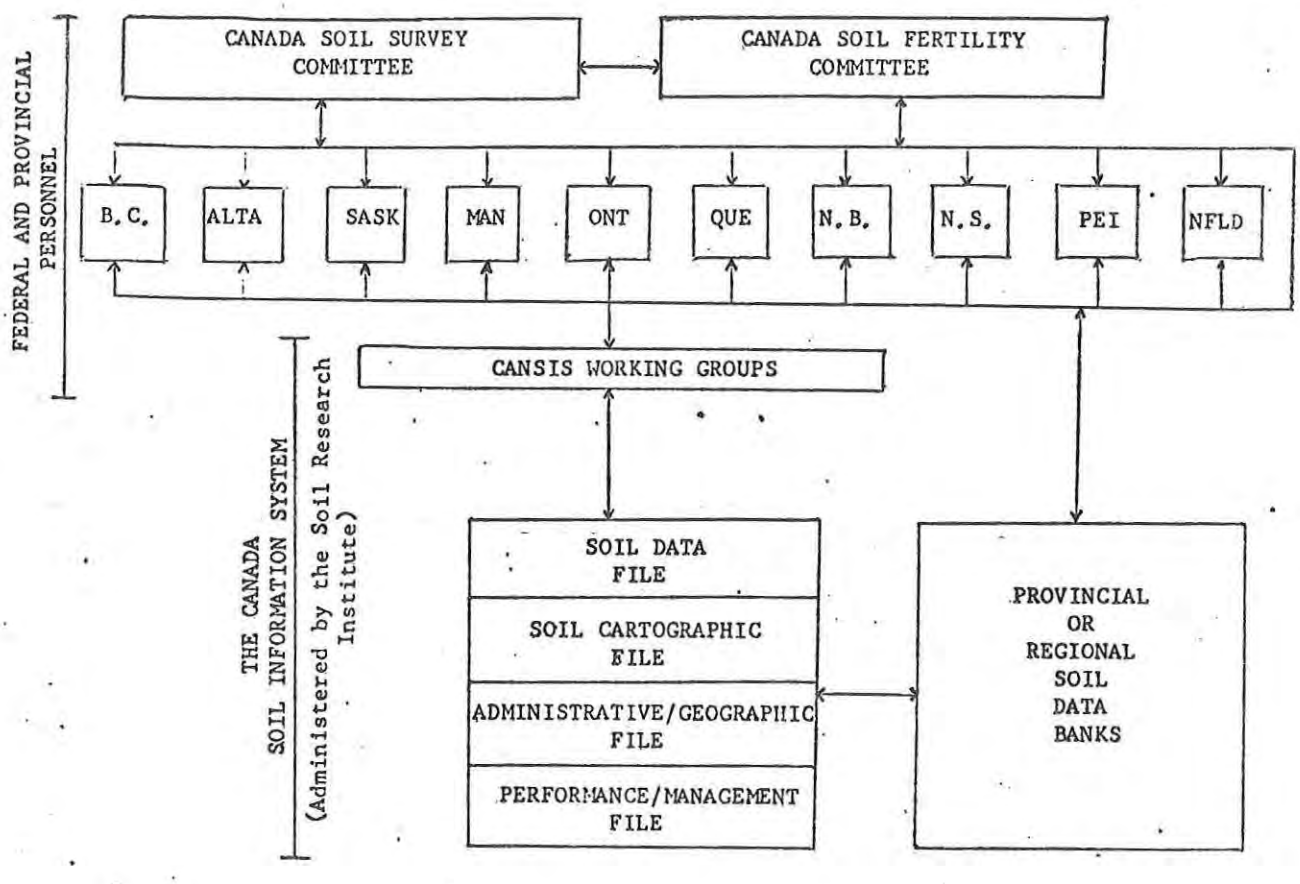

Fig. 3. Schematic representation of the data gathering and coordination structure for the Canada Soil Information System.

stated uses. Regional and provincial data banks, because of their close contact with local situations, will have more specific applications. It is likely that they will analyse their own data, undertake systems research with cooperative agencies and derive methodology for specific local uses and soil interpretations.

Avenues of communication between national and regional data banks will be through the CanSIS working groups. These consist of one representative from each province for each of the soil data file and performance/management file for the moment; more working groups will be organized in the future if they are needed. The responsibility of each individual in the working groups is to ensure that data is entered and coded according to the built-in concepts of that file. Each group will operate only as long as it is working effectively.

2. Progress on the CanSIS Program

a) Pilot Area Study.

Concepts, structure and working relationships of the soil data file and the soil cartographic file of CanSIS were tested on a pilot project area. The study was completed in one year, and was done in cooperation with Data Processing Services of C.D.A. The pilot area extended over about 4.5 million acres in west central Alberta (Hinton-Edson and Chip Lake map sheets). This region was chosen because it represented a diversity of landforms and land uses, it involved two distinct styles of mapping, it contained a considerable amount of supplementary data, and it was very familiar to the CanSIS staff. The results of this work have indicated, at least in a cursory manner, that the CanSIS program is feasible and adequately structured, but that careful realistic planning will be necessary to prevent the program from becoming excessively costly. It has indicated also that additional staff, and budgets for development and hardware are required. Specific activities and results of the pilot study are as follows:

i) Soil Data File

Data from 185 sites were coded and entered according to the 1972 CanSIS forms. This work indicated that content in the forms was adequate but that classes were described inadequately very often, and that the coding forms were too compact, difficult to work with and difficult to keypunch. This has prompted some developmental work in document design using form reduction and color coding techniques. It has resulted also in an accelerated effort to revise the 1972 CanSIS format paying particular attention to better describing and quantifying various classes of data. This latter point has been a focus of the CanSIS working meeting held on May 15. Highlights of this meeting were:

- A convention for style and kinds of codes was achieved. Parametric and/or defined increment variables get numeric codes; non-parametric or undefined increment codes get alpha or alphanumeric codes.

- A set of instructions for data input to CanSIS are to be compiled and sent to regional units. The units will correct data according to this, then send to Ottawa for input.

- A question was raised as to whether climate could be an acceptable deviation for a pedon description. There was divided opinion; decision necessary from the general assembly or from correlators.

- A question arose on the soil group. Now have catena, complex, association, series. Many indicated that additional groups are needed re varying scales of surveys, etc. A decision on this is needed as this has considerable implications for quality control.

- Vegetation module needs a catalogue of key indicator species. C.S.S.C. should impose on ecologists and forestors to compile this list.

- The 1972 format and book remains in effect until such time as a new format and book is available.

Computer programming for the soil data file has centered primarily around the establishment of a file management system. Because the study was to be curtailed in a year, a packaged file management system called Mark IV was selected. This proved to be somewhat less than optimal due to the business orientation of Mark IV. Other systems are being investigated but Mark IV will be used until a better one is available.

Examples of report programs that have been written on the basis of the pilot area data are the following:

a) computer derived, three-letter, mnemonic soil series codes. These have been published in the soil names file.

b) conversions of horizon depths from inches to cm; correction of values for hygroscopic moisture.

c) series of checks on horizon designations.

d) reporting selected data on the basis of predetermined criteria.

e) computer-generated soil profile description.

f) soil series summarizations and trend analysis programs are yet to be written.

It is interesting to note that the computer-generated print-out of a profile description takes only 2 seconds of processor time. The cost of this is $48.00 (for 10 descriptions; including overhead). Without overhead the cost is reduced to about $18.00, representing a real cost/description of about $1.80. Preparing a profile description by hand takes about 2 hours and in terms of real time costs about $25.00. This indicates that using a computer for writing such descriptions results in a benefit ratio of about 14:1 on the basis of the present system. At the same time, however, it shows that discretion on demand must be exercised if excessive costs are to be avoided. A single pass through the soil data file costs a minimum of about $10.00.

To date the soil data file has occupied 1.7 m/yr professional and 1.0 m/yr technical support. Development of the file management system took about 14 m/m of programmer time; writing the output programs took about 6 m/m. Investment into development of this file has been about $10,000 over the past year.

ii) Soil Cartographic File

A full report on developments in the cartographic file will be given by Dr. Kloosterman at the end of this report. It is sufficient to indicate that continued activities in the cartographic file will be dependent on the availability of budgets and support positions.

b) Other Activities

Although the pilot study commanded considerable amounts of time and effort, some progress was achieved in several of the other files. These activities are summarized below:

i) Administrative/Geographic File

No activity other than general discussions with the Plant Research Institute on the establishment of a climatic data bank, and with the Canada Geo-Information System (C.L.I.) as to sharing of data.

ii) Performance/Management File

This file is intended for the collation of data on soil response, productivity and management relative to specific crop under specified levels of management. Originally the emphasis will be on agricultural crops, but eventually this file is to be expanded to include woodland, recreation, engineering, etc. uses. Ideally such information will need to be collected on a soil and/or area basis to allow for the interfacing of this file to the soil data and soil cartographic files.

The underlying objective of the performance/management file is to define concise relationships among soils, climate, productivity and response to management. The working theorem by which this will be attempted is stated as follows:

- if a base level of production (yield without intensive management inputs, agricultural or woodland) can be defined for each soil or soil capability performance unit,

- if management increments possible on that soil can be defined in terms of cost and edaphic effect,

- if expected response of that soil to each management increment can be defined,

- then soil information can be transformed into land management evaluations in the form of alternatives in relation to costs and benefits.

The performance/management file promises to be large and complicated. To accommodate to the various disciplines considered as well as the multifarious data types within a discipline, an open-ended system of subfiles is being developed. Those which have been given some consideration are outlined briefly:

Agricultural Subfiles

Agricultural Small Plot Subfiles

This subfile is designed to accommodate variety trials and fertilizer response experiments. It is tailored to projects whereby treatments and levels are varied but soil type is kept constant. A first approximation of a coding format has been prepared and revised, and is available for distribution. This consists of 10 site descriptor cards, and 40 yield cards, arranged in 10 modules. Up to 5 treatments, 20 treatment levels and 6 yield replicates can be accommodated. The coding format is designed to be input on a yearly basis.

Agricultural Soil-Test Subfile

This will be created when the small plot subfile is operational. In addition to its normal use this file will be evaluated as to the possibility of its serving as a monitor of land quality changes relative to specific land uses and management practices.

Agricultural Canfarm Subfile

Creation of this subfile is dependent on suitable working relationships being defined with Canfarm, and their agreement to collect data on a field or lot basis.

Other Agricultural Subfiles

Other subfiles will be created as the need arises. This may include Canada Statistics, Farm Credit Corporation, special purpose crops, etc.

Forestry Subfiles

Subfiles created to collate forestry yield data will be patterned on usual procedures employed in forest mensuration. Several forestry stations have expressed an interest by offering cooperation.

Engineering Subfiles

These will consist probably of computerized tables of engineering interpretations taken from soil survey reports.

iii) Soil Description File

The soil description file is being designed as a personalized data collection procedure tailored to individual soil survey projects. It consists of a daily field sheet record on which certain, predetermined, repetitive data are collected, supplemented by "mini" soil descriptions. The "mini" forms, which are a condensation of the long forms of the soil data file, are intended to be used a certain number of times each day on catenas representative of the areas surveyed. The intention of such a data collection procedure is to provide a permanent record of site observations, and to supplement data collected in the soil data file. In this way it is hoped that adequate data will be available for soil unit characterization and quantification.

It is important to keep the purpose of each form in the soil description and soil data file in perspective. In summary the soil description file consists of:

- daily field sheet record used for each survey observation site,
- "mini" form used for abbreviated site and profile descriptions. The purpose of these is for extending the data source; they are not to be used at sampling sites.

In contrast the soil data file consists of CanSIS long forms. These are used for proper profile descriptions, at highly representative sites from which samples are taken for analysis.

The soil description file is intended to be local rather than national in scope. Reasons for this are the tremendous amounts of data that it could generate, and the particularly local relevance of this data. Any unit interested in the procedure would receive assistance in setting up their own descriptive file.

The soil description file is presently in the experimental stage. It is being developed for the survey of the National Capital Region around Ottawa, and will be used by three field parties this summer. Also the "mini" forms will be used by certain of the correlators and will be evaluated as a correlation aid. Results of these experiments should be available this fall.

iv) Soil Names File

The List of Canadian Soil Names, 1971, has been computerized and renamed CanSIS, Canadian Soil Names File, 1973. The format of the new listing is similar to that used in 1971 except that mnemonic soil series codes, C.S.S.C. numeric subgroup codes and French subgroups have been added. This file has generated a considerable amount of interest, and it is anticipated that a revision will be printed in the near future.

The listing of Canadian soil names has been made a file of CanSIS because of its possible future potential to serve as a catalogue to several other files. This, however, will not be possible without adequate consideration of the following:

- an indication as to whether the names are established, tentative or in reserve. Inherant in this is a procedure of quality control for establishing soil names,
- cooperation of all soil survey units in naming their soil individuals,
- an indication of the number of profile descriptions that are available for any soil individual. This will serve to direct sampling effort to those soils for which data is inadequate.

3. Implications of the CanSIS Program to Soil Science

CanSIS is both a new and an old program. It is new in that it focuses on the use of computers as an aid or a tool in soil data collection, processing and retrieval; it is old in that it is structured to reflect the time tested concepts, criteria and technologies of soil science. CanSIS, in effect, strives to define the optimal man: computer relationship pertinent to soil science in Canada to-day.

The structure of CanSIS accommodates as much as possible to conventions employed in current soil programs, particularly if such conventions are both historic and useful. At the same time it recognizes many of the peculiarities pertinent to the computer industry. The implications of this are that both soil scientists and computer programmers must recognize and observe each other's requirements if the system is to be useful and successful. Restraints on individual freedoms are inevitable when a machine-oriented program is instituted on a national scale. It is estimated, however, that collective benefits of the program will outweigh the inconveniences that the system will cause.

Use of computers in soil survey and soil use studies is a technique that has considerable potential for standardizing and streamlining our data gathering and soil evaluation procedures, and it will be used for this purpose throughout the future developments of our science. That this is true is evident in the deliberations of the subcommittee on soil samples and method of analysis, the discussions of the subcommittee on small scale surveys, the expressed need for more and better correlation, the need for a standard procedure of landscape description, the need for standard nomenclature and quantitatively defined classes for soil profile descriptions, etc. CanSIS plays a part in all of these, and so it must if it is to reflect and accommodate to our ever-changing state of technology.

It is safe to say that one of the major contributions of the CanSIS program to soil survey will be to secure the data source (data compatibility). Never in the history of soil survey in Canada has it been more important that the same variable be identified in the same manner by different practitioners. To have it otherwise would be to create a nonsensical system full of chaos and confusion. The C.S.S.C. through its many committee deliberations, has come a long way towards this goal, but this work remains still to be finalized and put into perspective as to the CanSIS program. Additional to this is the need for procedures of quality control covering such aspects of soil survey as establishment of mapping units on small and large scale surveys, establishment of soil series and other soil individuals, minimal data requirements for input, naming soil individuals, soil correlation, etc. This is a major undertaking, and one that would be effective only if it was structured through the C.S.S.C. Considerable amounts of travel, contact, publication, education and diplomacy would be necessary.

My concluding remarks are intended for soil researchers. Considerable volumes of published research on Canadian soils is available in various scientific journals. Much of this, however, is on disassociated subjects and little of it has been compiled and summarized. Because data banks and computer systems thrive on mathematical models, and because the CanSIS staff will remain small within the foreseeable future, I suggest therefore, that the soil research community consider means whereby results on a particular subject can be summarized in a form that would make such results effective for predictive purposes. I suggest further that the systems approach to research be considered as an effective alternative to many aspects of our present research effort.

CanSIS is not the responsibility of a select group of individuals nor of one institution. We all have a part to play; the system will be as successful as our effort is sincere.

General Recommendations

1. Whereas the CanSIS working group on soil descriptive data is concerned that national data compatibility is inadequate, this group recommends that:

   (a) urgent action be taken to promote such compatibility by the compilation of a handbook on procedures, terminology and codes to be used for describing soil data in Canada. It recommends further that responsibility for compilation of the handbook rest with the aforementioned group, and responsibility for implementation be shared with the correlators.

   (b) the C.S.S.C. strengthen and establish where necessary appropriate machinery to investigate and implement procedures of quality control for soil survey operations. Items to be considered should include, among others, such activities as systems of soil surveys, establishment of soil mapping units, establishment of series and/or other soil individuals, naming of soil individuals, procedures and criteria for national and regional soil interpretations, computerization and quantification of soil data, and cartographic implications to soil survey operations.

2. Whereas progress over the past year has indicated the CanSIS program to be useful to soil survey and soil science in general, and whereas it is desirable to maintain a continual and acceptable rate of progress in the

future, the CanSIS working group on soil descriptive data recommends that the C.S.S.C. investigate further appropriate sources of funds so that the program can be adequately provided for in terms of support staff, hardware, developmental and operational budgets, and travel funds.

THE CARTOGRAPHIC FILE OF CANSIS

Introduction

Work on the Cartographic File started in February 1972 when it became apparent that concurrent development of a computer map system was essential for full evaluation and utilization of CanSIS. The full potential of a soil information system can only be realized when information from site specific data can be manipulated and extrapolated over the landscape.

The purpose of this report is to briefly describe the system, its philosophy, its usefulness and its general impact on soil survey operations.

Philosophy and Rationale for Present System

Entering spatial data (or maps) onto the computer has taken two distinct forms with distinct end products. The first type of system is illustrated by the Canadian Geographic Information System, where maps are input manipulated and output for various purposes. The second type is represented by the EMR automated cartography unit where the eventual end product is a published map, the prime purpose of the system being to automate the cartographic processes.

Both the Automated Cartography system and Geographic Information system are heavily dependent on maps being input to the system. Fundamentally two basic procedures exist:

a) Digitizing - the recording by hand of X and Y coordinates at frequently spaced intervals along the boundaries of features or entities using electronic equipment.

b) Scanning - the automatic recording of map data by an electronic device that scans a map with a photo sensitive head sensing lines versus non-lines.

As a general rule identification data (the symbolization in the case of soil maps) is entered manually onto punchcards or encoded directly onto tape.

The choice of which of the two data capture procedures to adopt depends on:

a) map density

b) map volume.

It is generally agreed that as a rule of thumb that high volume low density maps are best served by scanning and anything else by digitizing.

After data has been captured, it is processed or manipulated by the computer to:

a) Detect and correct errors.

b) Convert data to a form that effects either:

i) storage of the data in a bank form,

ii) output data onto a CRT, line printer or plotter.

It is at this point that the two types of systems diverge. For the automated cartography system, the data is generally output on a plotter for scribing or photo composing. In the Geographic Information System, the data is stored in such a manner that each bit of information can be accessed quickly and easily.

For data bank storage a number of methods are available but breakdown categorically into what are termed:

a) Direct access - using an address, the data can be pulled out directly from the storage device.

b) sequential access - the computer has to sequence item by item through the data set until the right one has been encountered.

Since direct access is expensive to set up and slow to get data from (i.e. milliseconds vs microseconds) a number of criteria may be used to decide on method of access:

a) Size of the file.

b) Number of data items required from the file at random.

c) The frequency with which items are required.

For most of the system alternatives discussed, the Cartographic File represents a compromise. The prime purpose of the Cartographic File is to put maps in such a form that any part of the map may be quickly and easily manipulated for interpretations of the basic data. An indirect purpose is to serve the cartographic process in such a way to achieve an optimum man-machine mix. Figure 1 illustrates in part the close relationship among Soil Survey, CanSIS and Cartography.

For the volume of maps to be put on the computer (approx. 360 maps since the beginning of soil survey in Canada) with a density of approximately 2000 soil areas per map, digitizing the soil maps seems to be the logical approach at the present time. Scanners are not being considered at the moment because of scanner technology which is still in the infantile stage and costs for our considerations are prohibitive. They may, however, become useful in the future.

File management considerations were based on the following:

a) Very large files - e.g., Chip Lake sheet, 5.8 million characters for line data and approximately 270,000 characters of information for symbolization.

b) Number of data items required would depend on what was required from the file. A few examples are:

   i) Pulling one number from the file (acreage of organic soils in the map sheet).

   ii) Accessing and plotting all soils that are potentially suitable for gravel pits.

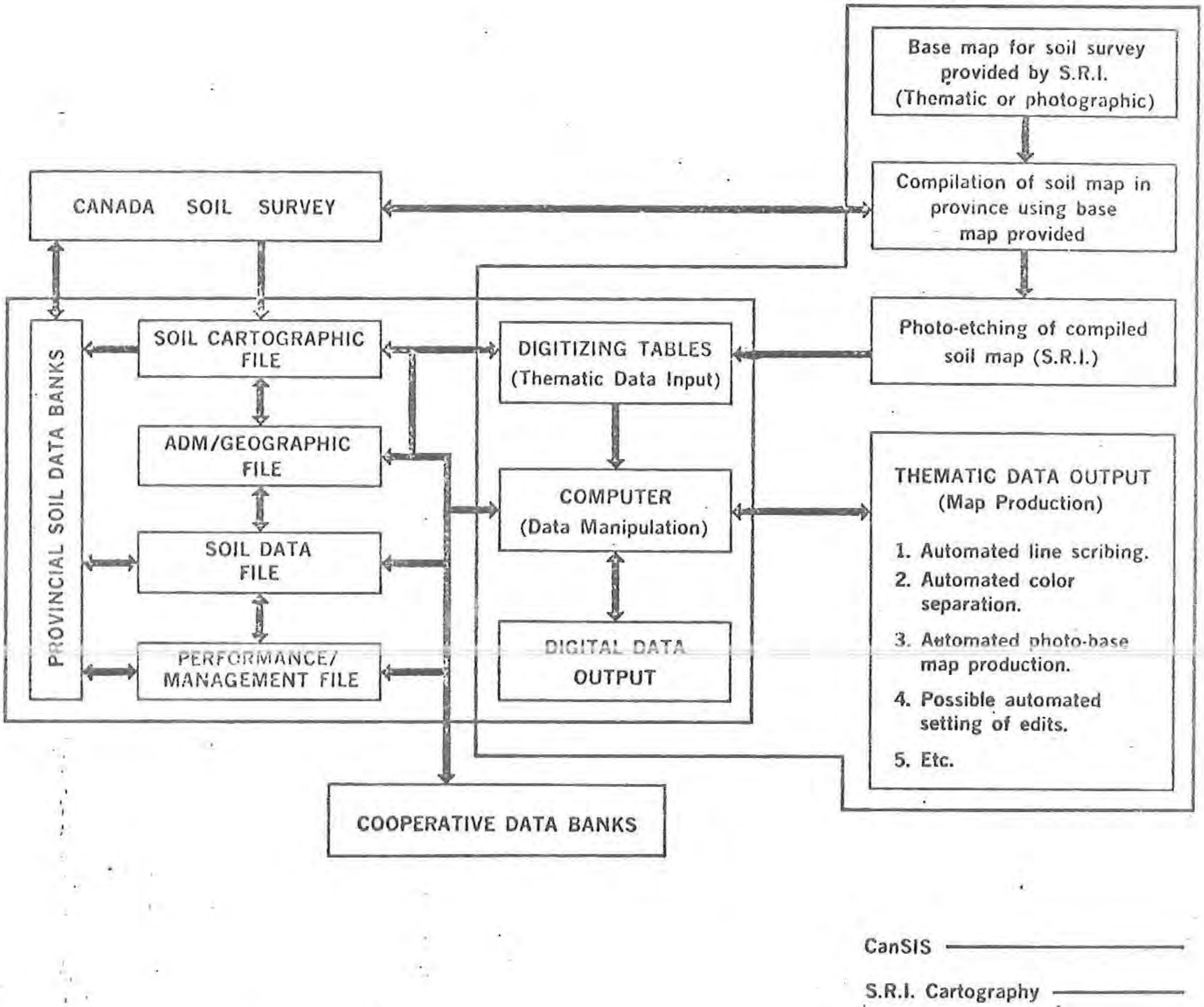

Fig. 1. Schematic diagram showing relationships among soil survey operations, CanSIS, S.R.I. cartography and cooperative data banks.

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iii) Accessing, organizing and plotting lines to represent a drainage, slope, texture or depth of bedrock map.

iv) Plotting the entire map, etc.

The number of times the file for one area would be accessed would be great initially but would probably decrease with time. For this reason it was felt that the system should be designed for direct access but in such a way that the information could be accessed sequentially as well.

Through all stages of the system an attempt was made to retain a semblance of simplicity, practicality and versatility with the cost factor being a prominent consideration.

System Description

The next series of figures will illustrate very briefly and generally the following three areas of system concentration.

a) Data Capture.

b) Data Processing.

c) Output.

The generalized schematic is presented in Figure 4.

Data Capture

Stable base copy of the soil map is placed on the digitizing table as illustrated in Figure 5. The data on the map is captured in two passes. On the first pass all line data is collected and the symbolization data is collected on the second pass.

a) Line digitizing

The four corners of the maps are first digitized in the manner illustrated to establish the border and the frame of reference. The southwest corner of the map is normally preset to 0.0, 0.0. To begin line digitizing, an intersection identifier "P" is recorded (Fig. 6). Starting almost anywhere, the operator starts digitizing the first line segment, recording points along the line at a constant rate of approximately 10 coordinates per record. (Figure 7). Although the sequence of line digitizing is non-critical as far as the system is concerned, the operator generally prefers digitizing the map in sections in some logical manner. When the operator reaches the end of a line segment, another P is entered after which the next line may be digitized. In this manner the entire map is digitized. Two acceptions occur: first, the straight line segments on the boundary are not digitized; and second, for inclusions or self-enclosed areas an artificial intersection is identified and digitizing starts and stops here. Since the computer later finds the line segments that encloses each area on the basis of the intersection points, it is imperative that operators define these points to within approximately 0.010 inches.

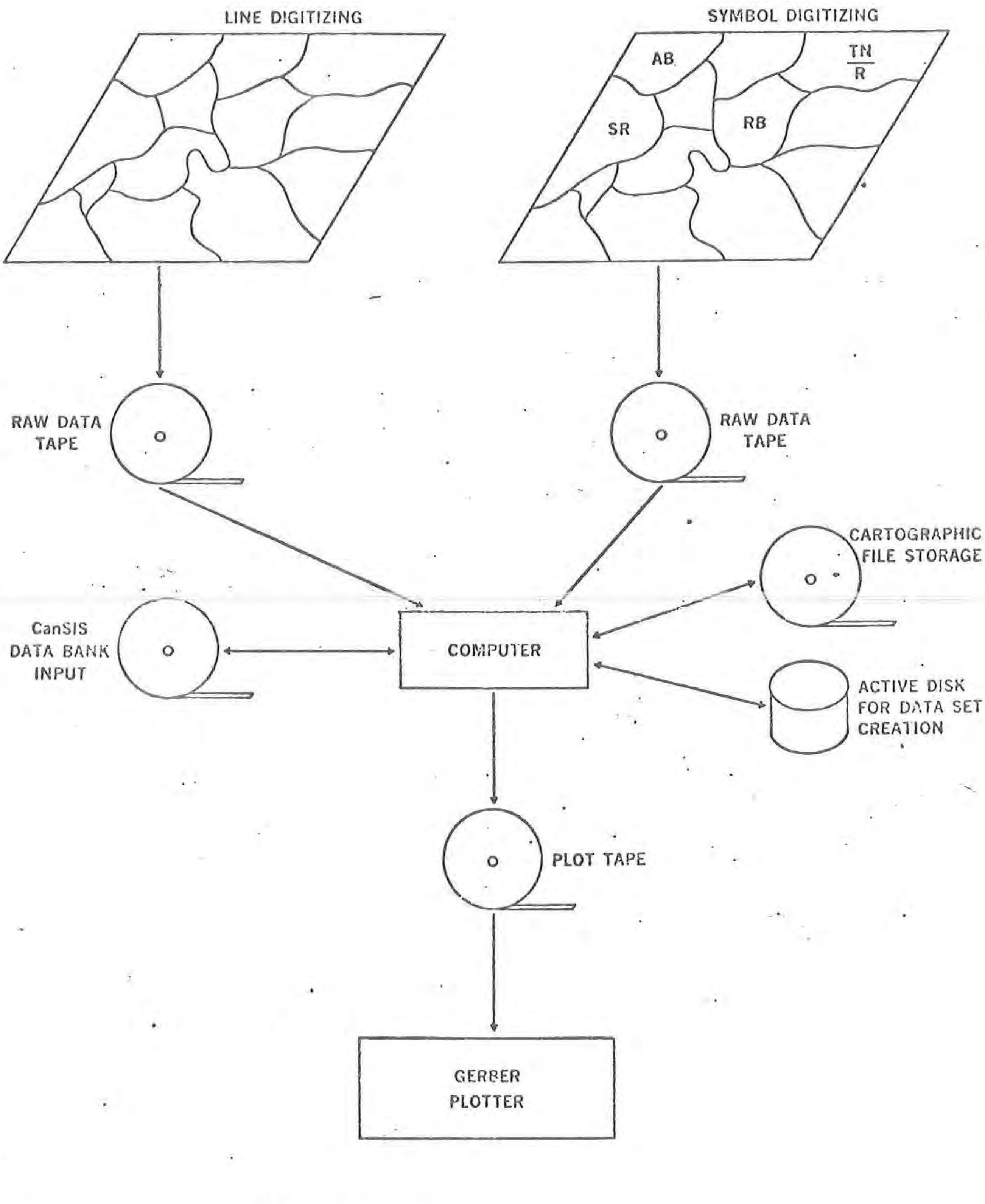

Fig. 4. Schematic diagram of cartographic data bank generation.

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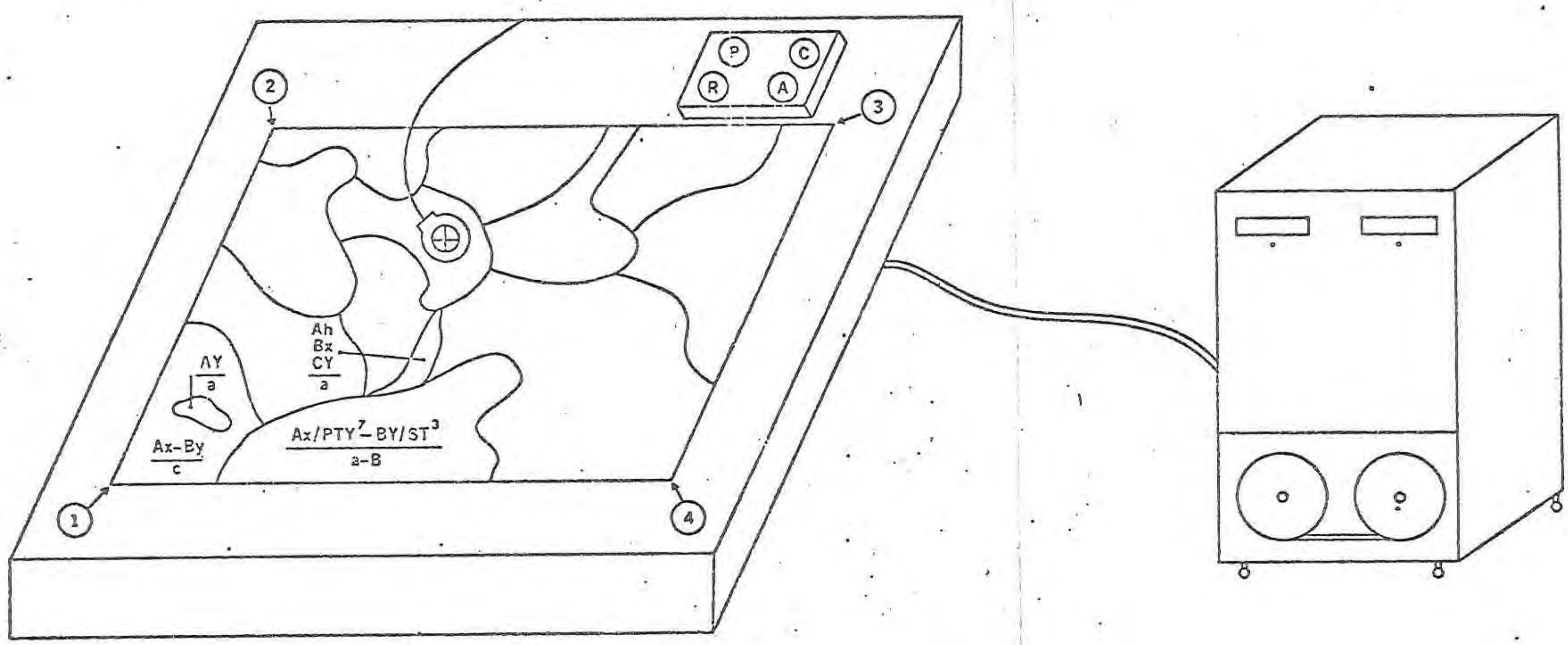

Fig. 5. Four corners of the map are digitized to form the border.

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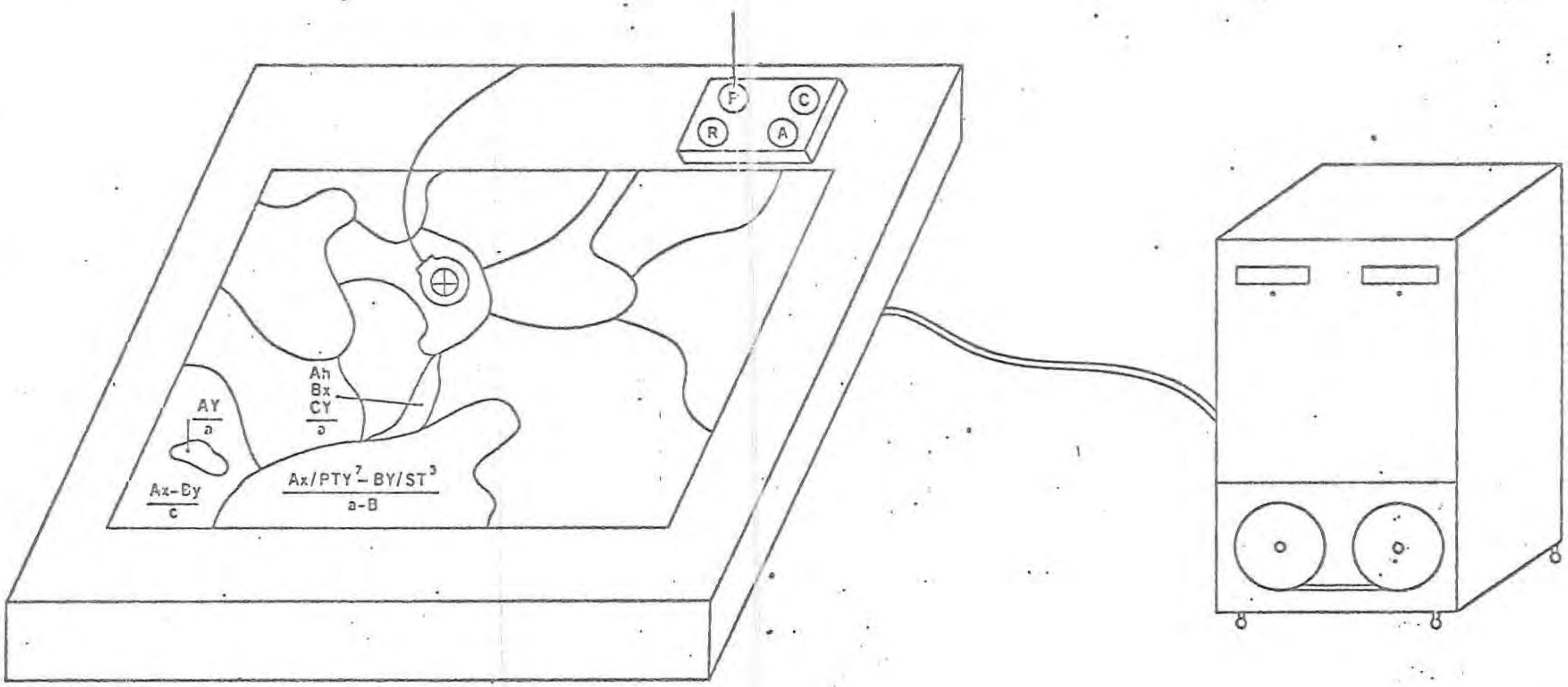

Fig. 6. An intersection identifier "P" is recorded.

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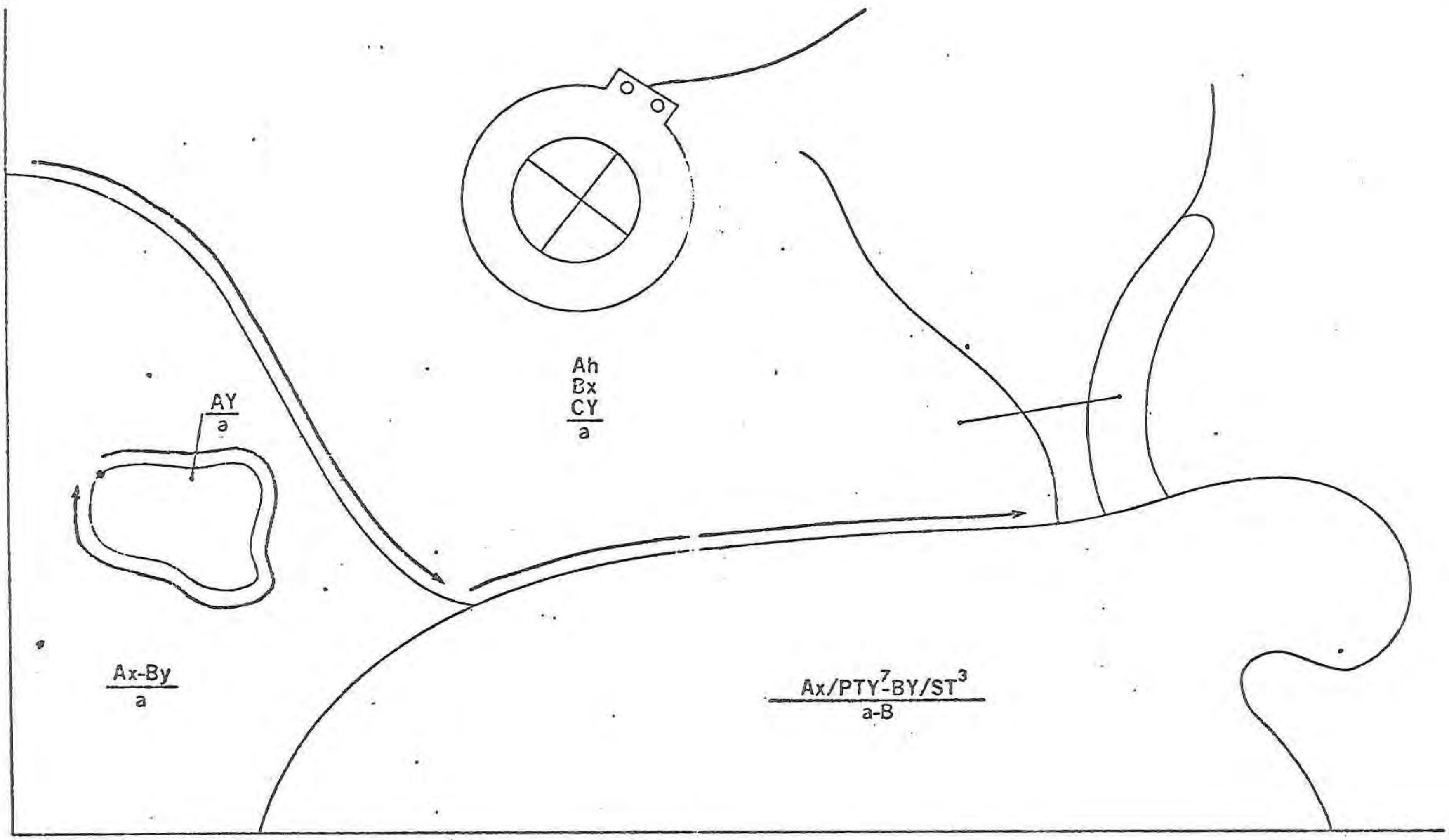

Fig. 7. A line segment is digitized taking the X and Y of points along the line at a rate of 10 coordinates a second.

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b) Symbolization

This procedure begins in a manner identical to line digitizing in that the four corners of the map are digitized.

A small data set consisting of the following elements is collected for each symbol on the map:

- 4 orientation coordinates.
- 3 coordinates on one line segment.
- number 1 orientation coordinate for each inclusion.
- type of symbol
- symbolization.

The four orientation coordinates are used to give a location within the soil area, indicate start and angle of symbol printing, and also indicate to the computer if the symbol is normal (Figure 8), the symbol is leadered in (Figure 9) or if the area carries the symbol of another area (Figure 10). As a general rule the functions of the 4 coordinates are as follows:

No. 1 - identifies a location within the soil area.

No. 2 - identifies the end of a leader if applicable.

No. 3 - identifies the location where printing starts.

The above three coordinates are one and the same for a normal symbol.

No. 4 - is used in conjunction with No. 3 to calculate the angle on which the symbol is to be printed. In most cases the angle is 0^{o}.

Examples of this and the various exceptions to the basic procedure are presented in figures 8, 9, 10.

Three coordinates are identified on one line segment that encloses the area (Figure 11). The three coordinates are taken as follows:

No. 1 - location of the start of the line segment and coincides with the intersection at that point.

No. 2 - a coordinate on the line just a fraction of an inch beyond the start of the line.

No. 3 - location of the end of the line segment and coincides with the intersection at that point.

It is important to note that these three points are taken following the line in a CLOCKWISE DIRECTION around the perimeter of the area in question. These points on the line are used by the computer to locate the correct line segment in the line data set and provides the key to finding all the others.

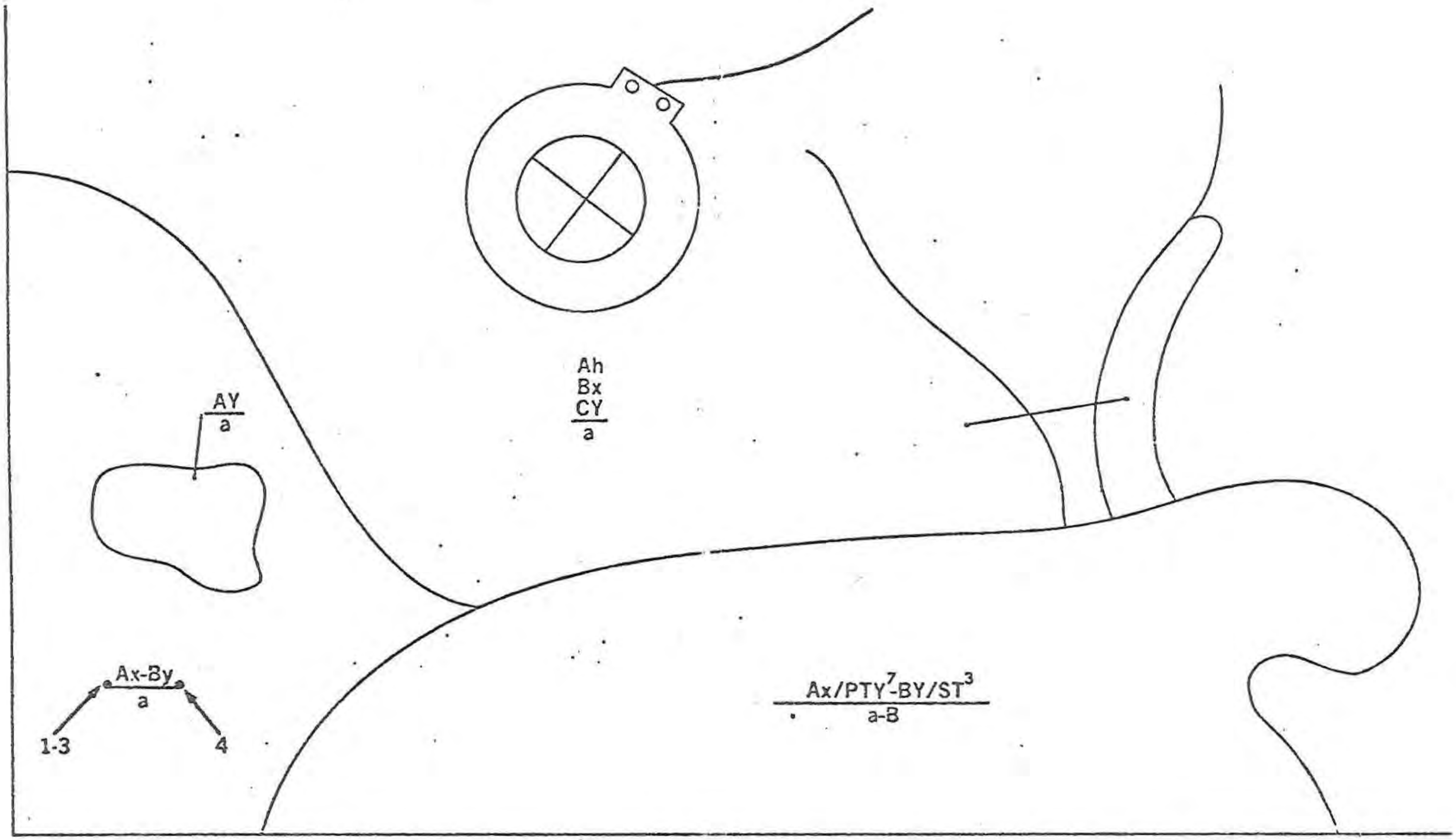

Fig. 8. Symbolization orientation coordinates are digitized (4 coordinates).

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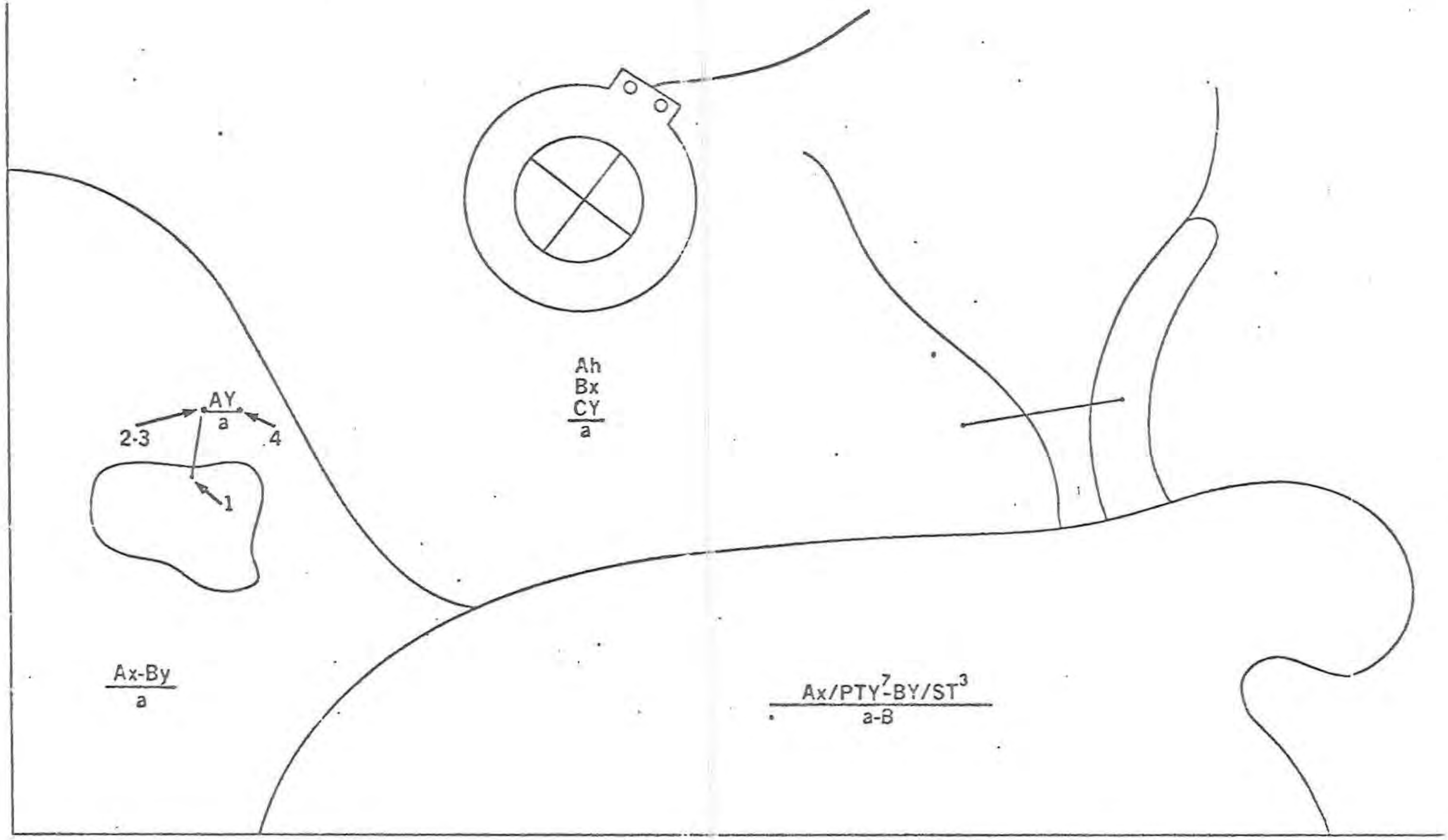

Fig. 9. Leadered symbol digitized.

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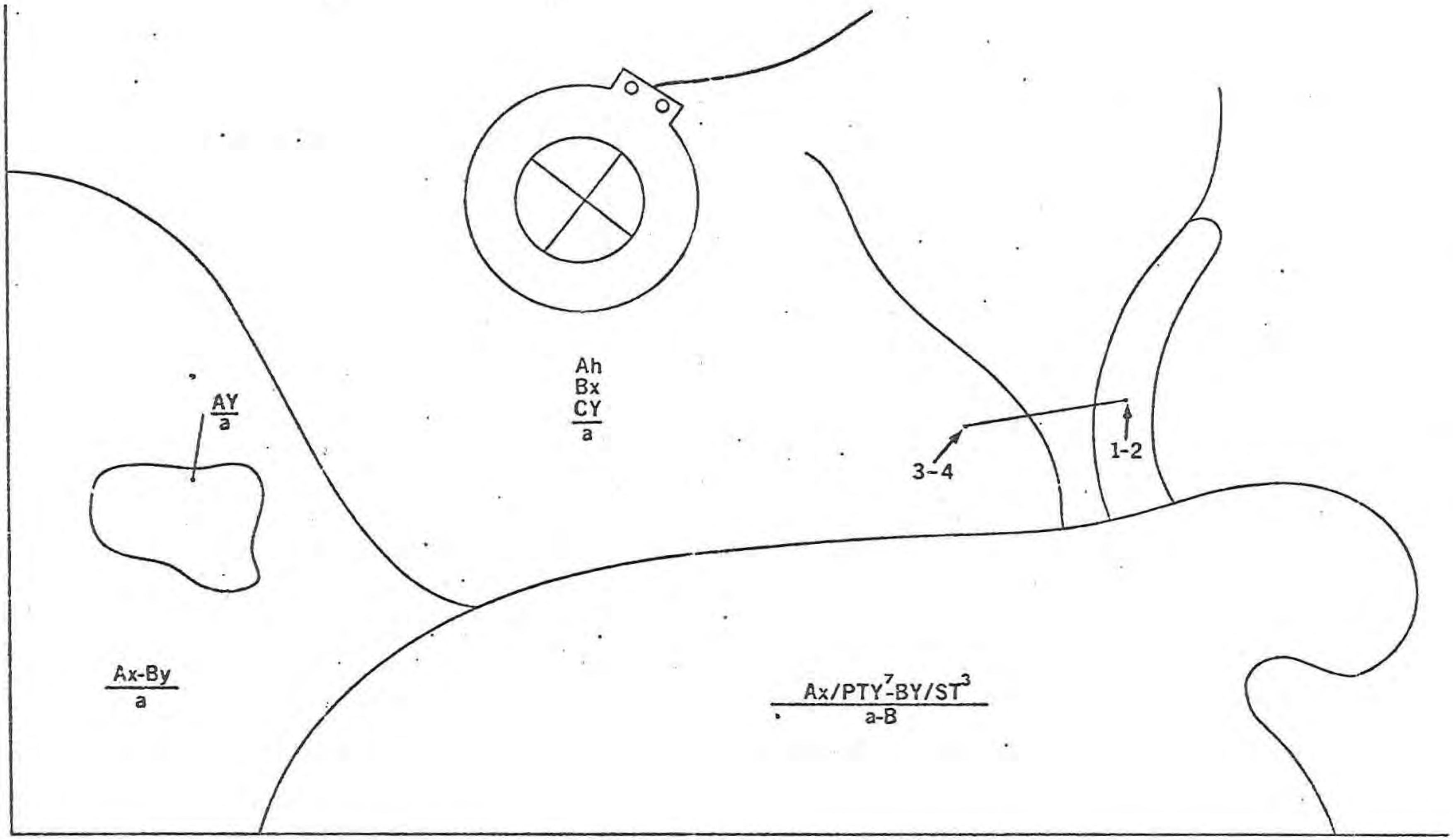

Fig. 10. Leader sharing symbol of another area.

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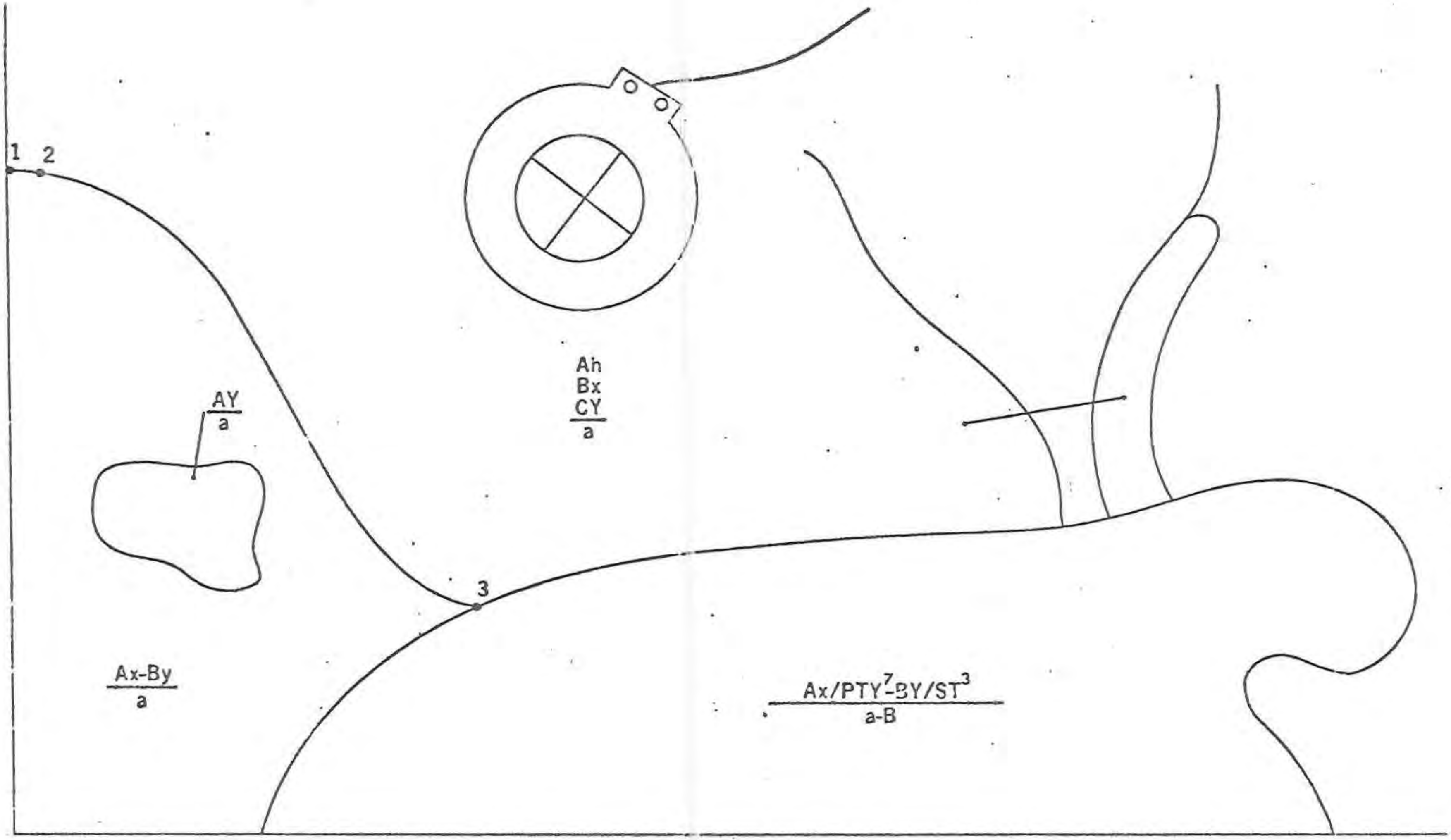

Fig. 11. 3 coordinates on one line segment are digitized clockwise around the perimeter of the soil area.

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If the area being symbolized (Figure 12) has a free standing inclusion in it, the number 1 orientation coordinate is digitized for each inclusion found.

Figure 13 illustrates the two symbol printing styles that are currently recognized. A V indicates vertical or stacked printing and an H indicates horizontal printing. This then is followed by the symbolization in the manner illustrated in Figures 14 and 15. Again the operator generally records symbol data on the map in some systematic way.

The Hinton, Edson and Chip Lake Sheets were digitized in this manner. Table 1 depicts time required to digitize each of these maps for lines and symbolization. All three maps are published at a scale of 1:126,720 and contain between 2000-3000 individually mapped areas. At a cost of $4.00 per hour the average cost to digitize these maps was $400. Since the eventual production plan is to scribe and digitize simultaneously, only part of this cost would be charged to data entry.

TABLE 1

Map	Lines (hrs)	Symbols (hrs)
Chip Lake Sheet	35	33
Hinton Map Sheet	52	42
Edson Map Sheet	72	80
TOTAL	159	155

Data Processing

Software, or program development has received the largest proportion of budgets expended on the Cartographic file. This is true for the development of all geographic information systems. After data capture, the data is processed by the computer for editing, data assembly and storage and output. Figure 16 illustrates the flow of data from the raw data stage to final data bank storage on magnetic tapes:

a) Editing

A series of computer programs have been written to edit or prepare both line and symbol data for entry into random access files. Generally speaking editing performs five basic tasks:

i) Detects errors in the data set and makes the appropriate corrections.

ii) Reduces the data set to approximately one-quarter its original size without loss of data.

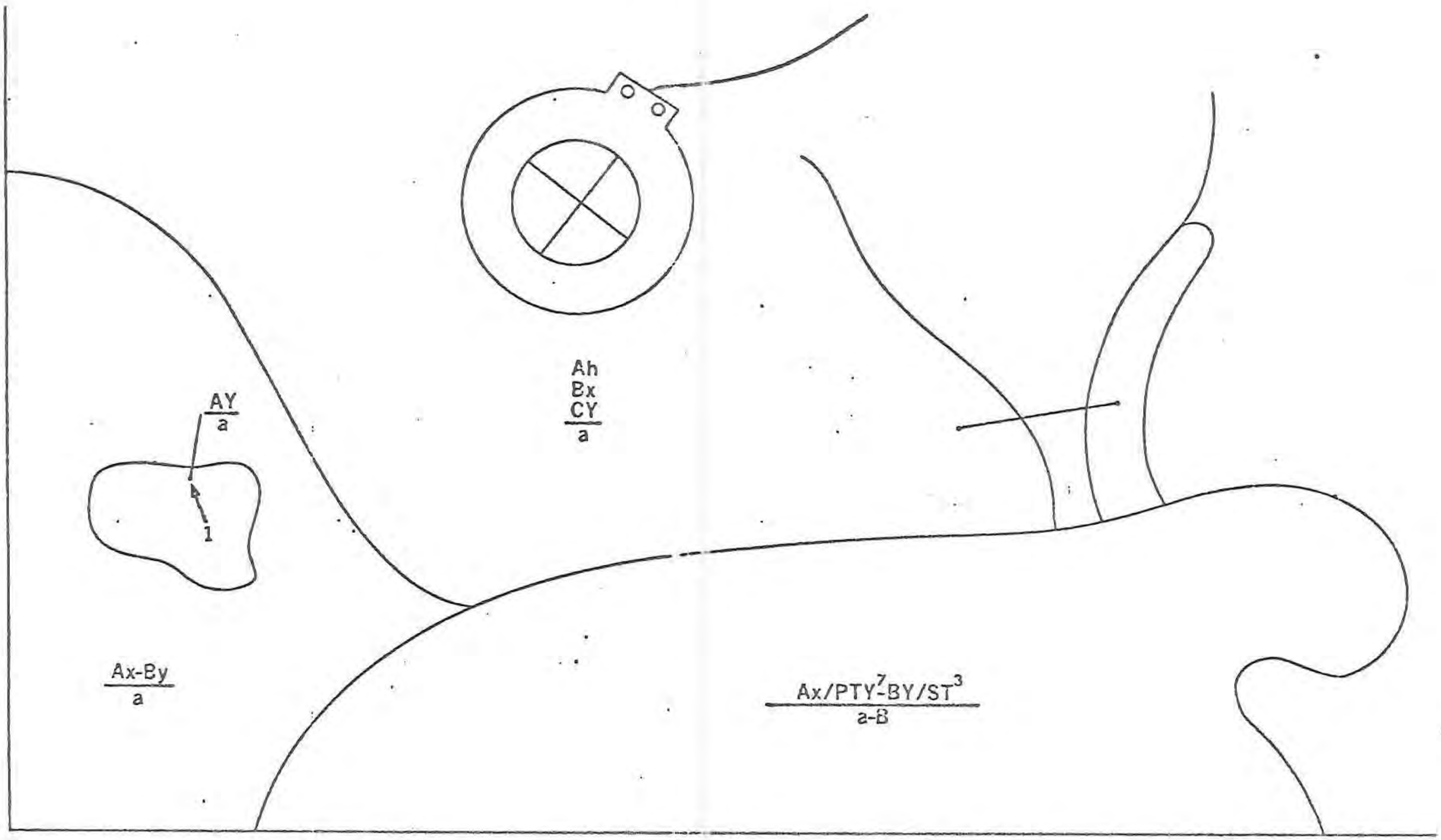

Fig. 12. The number 1 symbolization coordinate is recorded for each free standing inclusion in a soil area.

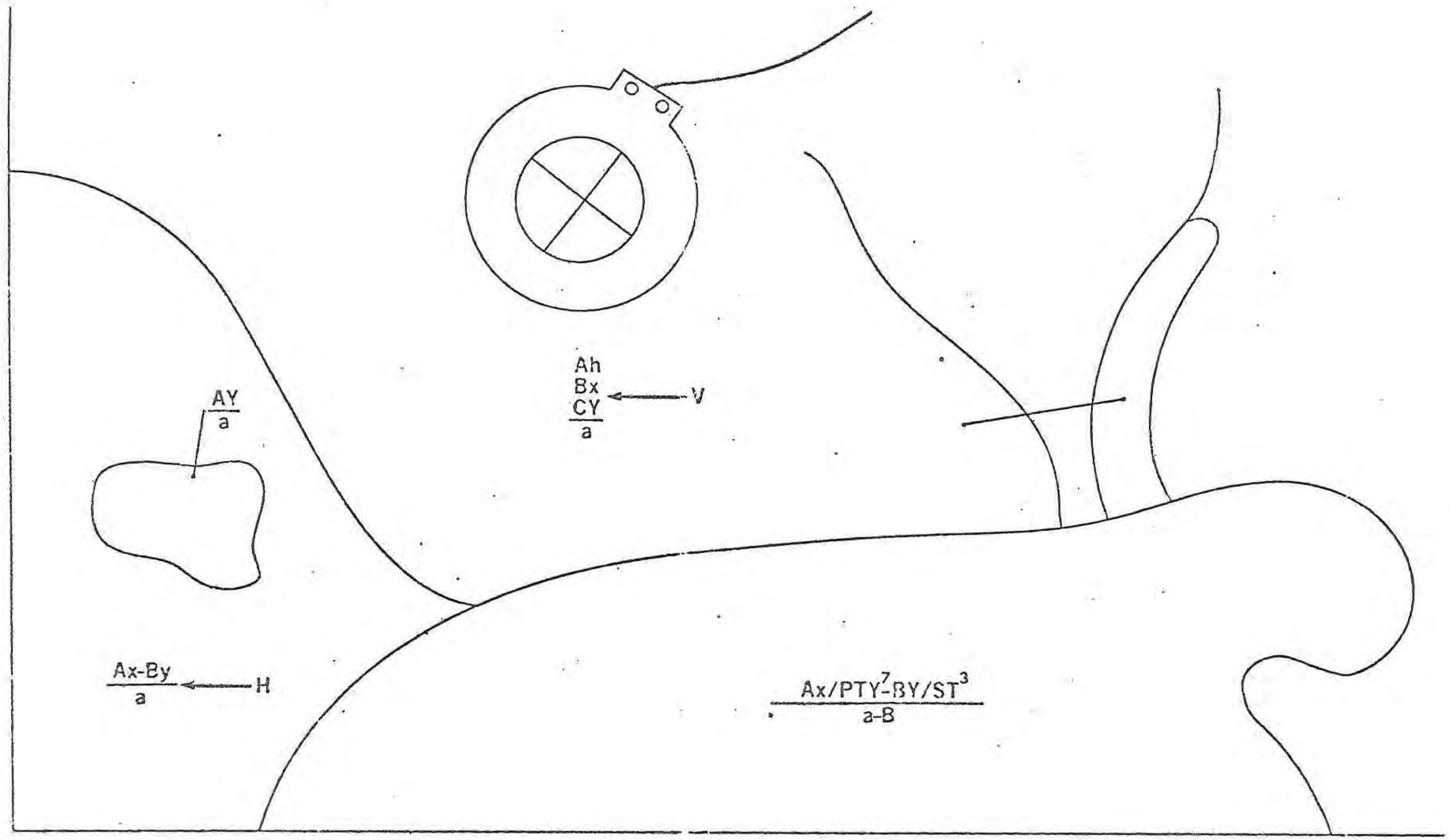

Fig. 13. Type of printing is recorded. V for vertical stacking H for horizontal placement.

SRI

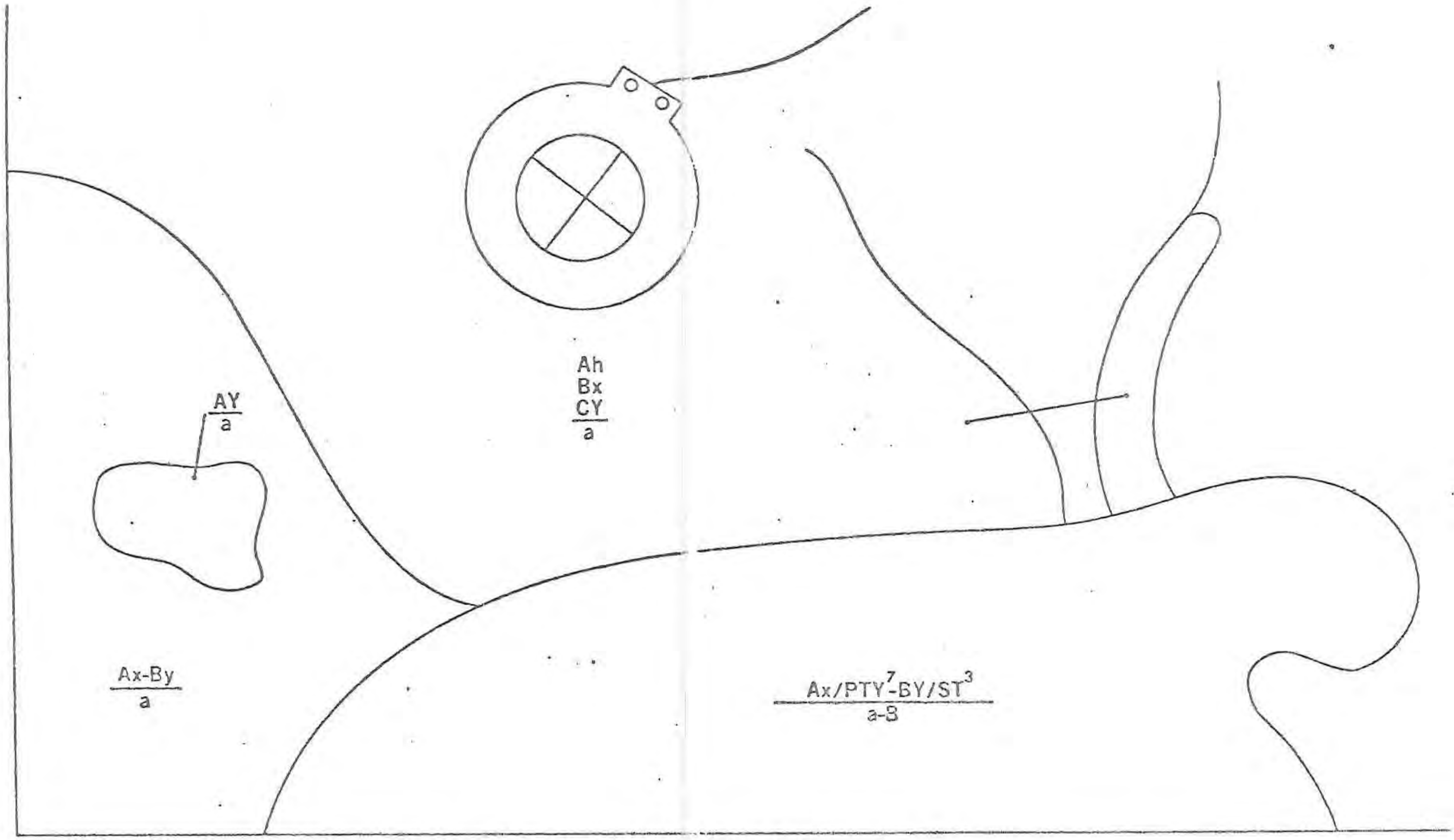

Fig. 14. The symbolization is recorded AX–BY/A.

SRI

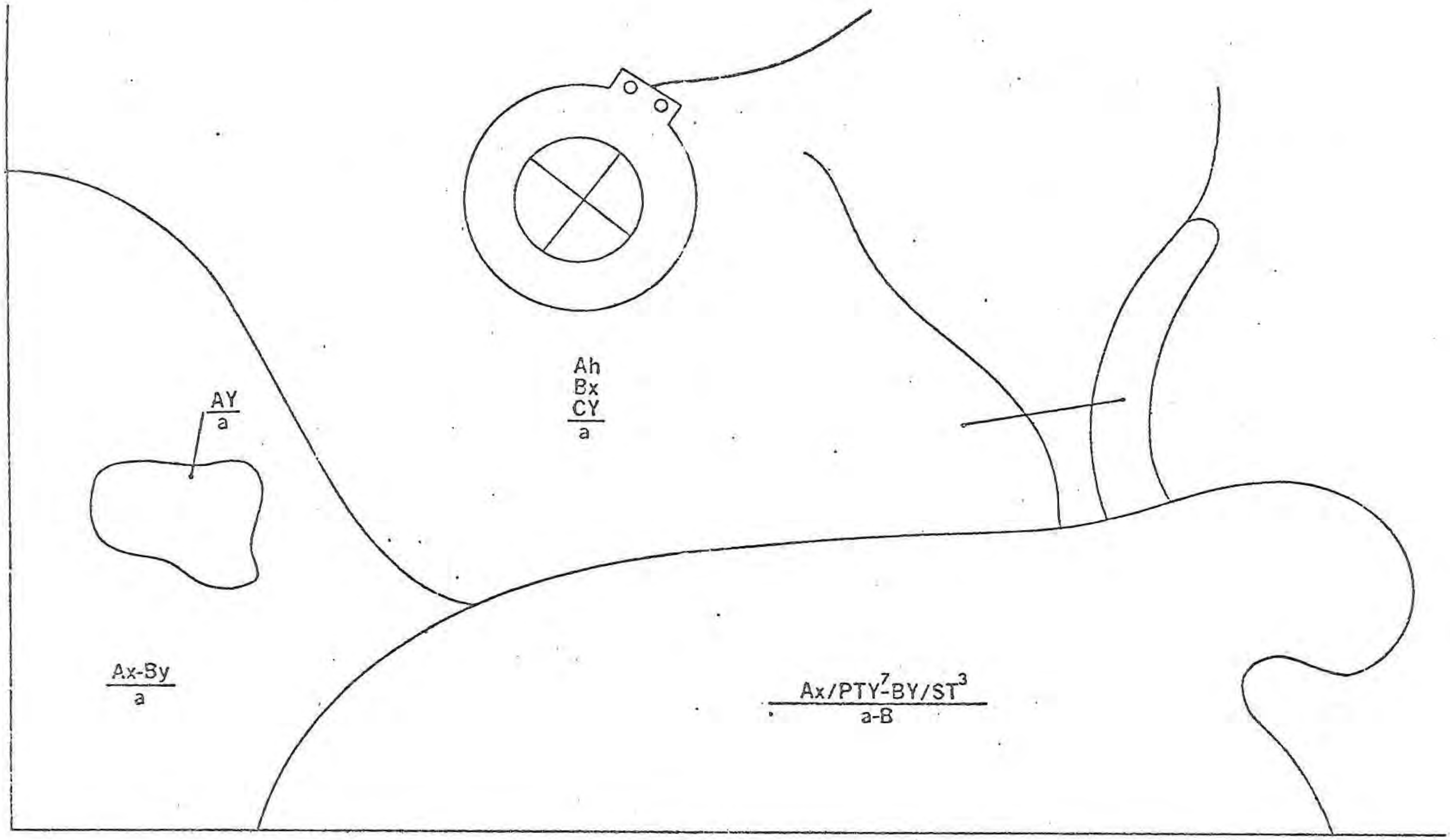

Fig. 15. Symbolization containing phases and percentages AX;PTY:7–BY;ST:3/A-B.

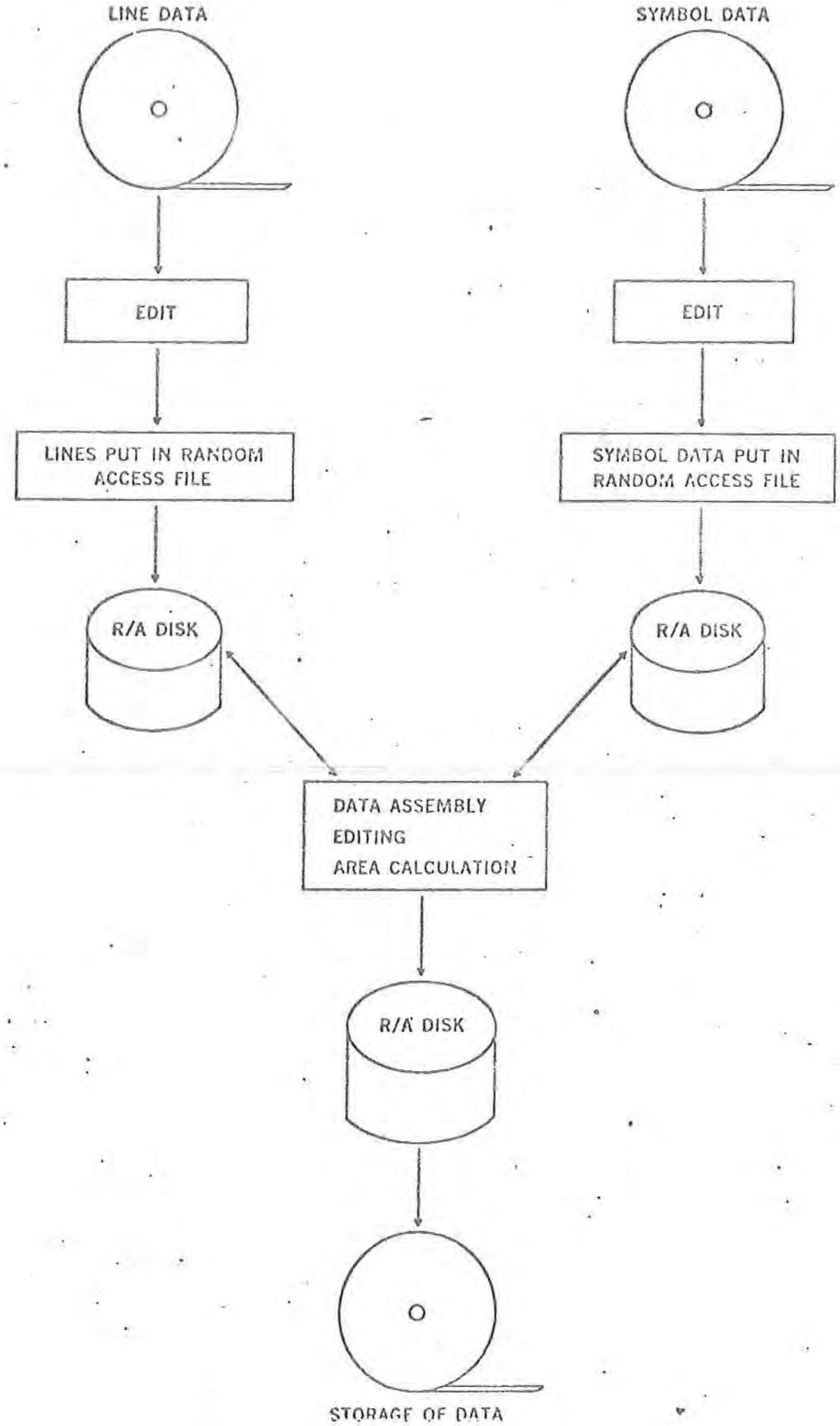

Fig. 16. Raw data is edited and organized for input to data bank. *SRI*

iii) organize data for entry into random access file.

iv) area calculation is initiated (area under the line segment calculated using Simpson's Rule).

v) write data on respective random access file up-dating the address directory so that the location of each line segment or symbol is known. The address of the line segment can be determined from its start and end points, while the address for the symbol is determined from the number 1 orientation coordinate. These addresses then are the key to organizing data for fast efficient retrieval of the data.

A number of additional programs have been written that performs such tasks as changing the scale of the maps, rotating the data to coincide with adjacent data sets and changing the format of the data if format is incompatable with the computer programs in the system, etc.

b) Data assembly and storage

A number of computer programs and subroutines have also been written to assemble the data in such a manner that any soil area can be accessed with all its pertinent information. Figure 17 illustrates graphically the final form into which the data is organized.

Each soil map will consist of a hierarchy of 3 files called Level 1 to 3. The Level 3 file contains all the line segments, Level 2 contains all the symbols on the map, while Level 1 contains a list of each unique symbol. Data assembly links all three files together in such a way that any piece of data, or any group of data can be easily obtained.

Recalling the manner in which the data was collected (summarized in Figure 19) the data assembly programs perform the following tasks:

i) It takes a symbol in the Level 2 file and from the three coordinates of the first line segment calculates in the location of that line segment in the level three file. This address is stored with the symbol.

ii) Using the coordinate found at the end of the line segment, the addresses of possible "next" line segments are found. Since there are always two or three other lines coming into the intersection of the end of the line segment, there may be three line segments at the same address.

iii) The correct line segment has to be chosen. This is illustrated in Figure 20. Knowing that the first line segment was digitized in a clockwise manner, by arcing around in an anti-clockwise direction, the first line that is hit is the correct one. Since each line may have been digitized in a clockwise or anti-clockwise manner, the program will read a line segment forwards or backwards as required. Having found the next line segment, its address is placed with the last line segment in a location which indicates either the right or left hand side of the line. Since each line is shared by two areas and it is undesirable to store the line in the file twice, each line has to be linked for the area on each side.

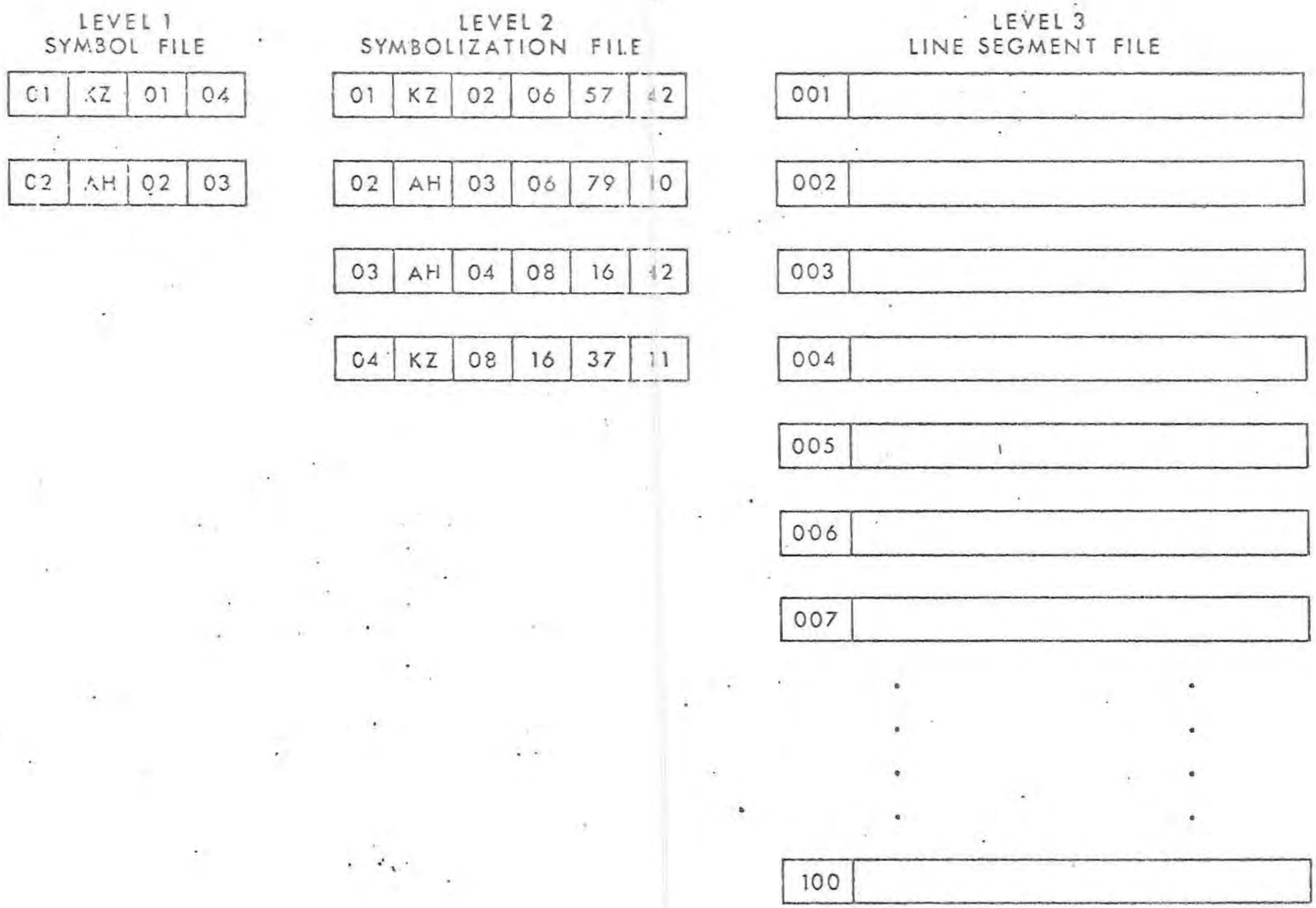

Fig. 17. Generalized presentation of cartographic file random access structure. SRI

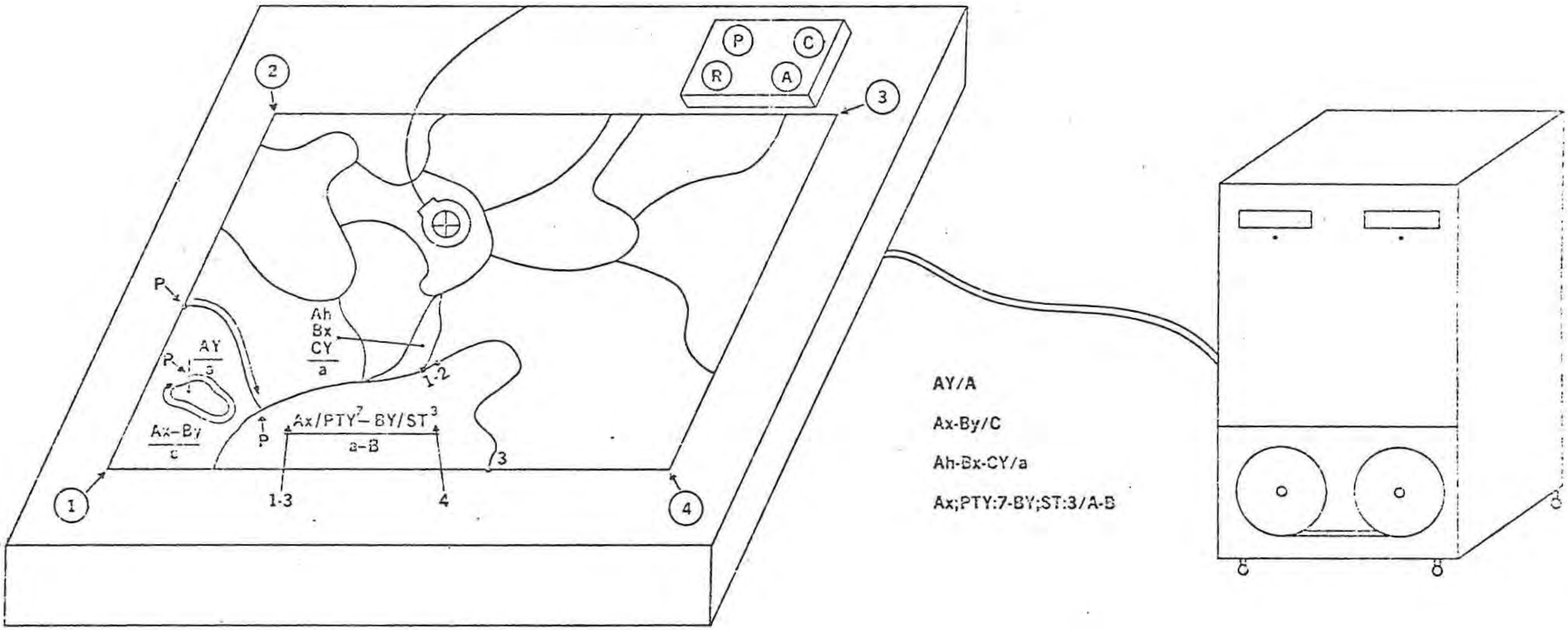

Fig. 19. Data Capture Summarization.

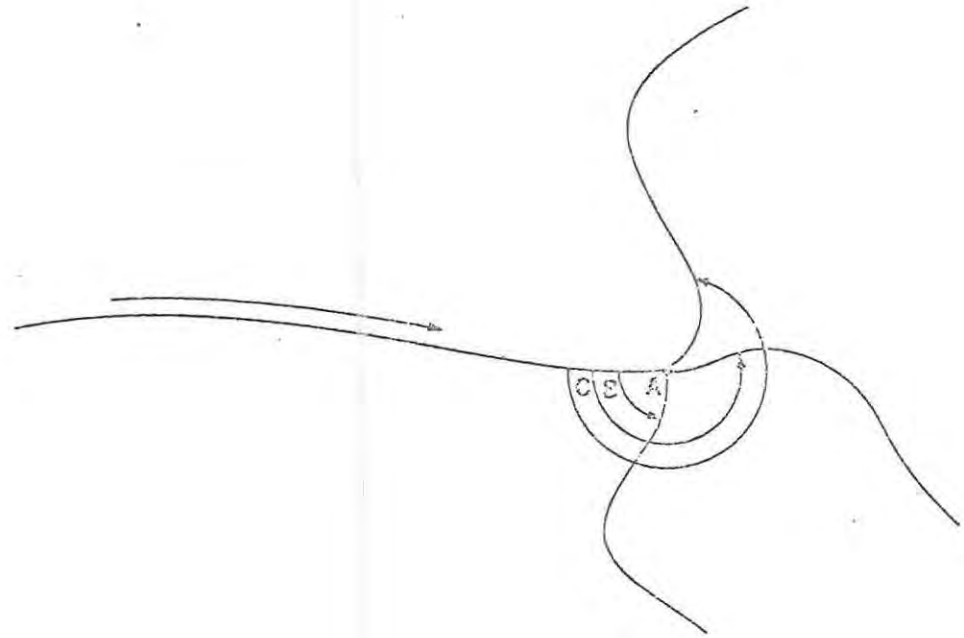

Fig. 20. The arcing algorithm where A represents the smallest angle and the correct "next" line segment.

SRI

iv) When the proper line segment has been found, the area calculation initiated in the line edit programs is accumulated for the area in question.

v) The lines are processed and linked in the level three file until the starting point is reached.

vi) The program then checks in the level one file if a symbol that is currently being considered has been processed before. If so the address of the last symbol is inserted in the symbol string of the present symbol and the address of the present symbol replaces the former in the level 1 file. The area of this unique combination of soils is accumulated as well.

vii) If the area in question has inclusions, the program keeps track of them and will link the addresses of inclusions to the appropriate areas when all the symbols in the Level 2 file have been processed. The acreage of area for a unique combination of soils is adjusted if inclusions were part of the original calculation.

viii) The programs output areas and line segments that have not been linked successfully.

Cost of development of the Cartographic file system including these programs to end of March amount to 13,000 dollars and involved 1.8 m/yrs of professional, and 1.7 m/yrs of computer expertise. To process the 1:50,000 map of part of the Edson map sheet which has   areas,   line segments cost   dollars. However, since this represents the first approximation of the software, it is apparent that processing costs can be reduced by approximately 75%. Therefore, for a soil map like the Chip Lake sheet which has 2043 symbols, and 10,000 line segments processing costs would be approximately the same as the map illustrated. Considering the high cost that has been spent to collect the data, this is a small price to pay to have the data in a form where it can be manipulated easily.

Data output

Map output from computers can be displayed on line printers, plotters or cathode ray tubes depending on the accuracy or use of the data required. Cartographic output on line printers is considered the fastest, the most inexpensive, and the crudest method, but it is useful for getting a quick look at the data. Data displayed on a CRT is used generally for a quick look at the data but if interactive facilities are available, can be used for editing and correcting the data set as well. The plotter is generally the best quality output comparable in positional accuracy of lines and points to what one might expect from a cartography unit. For reasons of time, cost of development, and accessibility to a Gerber flat-bed plotter, capabilities to present cartographic output on the flat-bed plotter were developed. Development of other output device capabilities will be dictated in the future largely by resources available and demand for alternative outputs.

A number of programs were written that would select a data set from a map, and prepare it for plotting with appropriate labelling. A number of slides will hopefully be presented to illustrate some of the possible outputs from the cartographic file.

Figure 18 summarizes the present and potential uses of the system.

To date, work on this system has been done on borrowed computers, with borrowed budgets using borrowed help. The future of the system is dependent on support. Assuming that this will eventually come, we envisage all suitable soil maps in a digitized ordered format, linked together into a filing system on the basis of the Universal Transverse Mercator Projection. How the system evolves depends on two alternatives:

a) Run system on a computer under contract with a commercial firm.

b) Run system on an in-house mini-computer.

Our rationale for favouring the second alternative is as follows:

To be viable the system requires a digitizing table for data input. A stand alone system which only records the data on magnetic tape costs $32000. A digitizing table interlaced to a PDP11 computer with a Read/Write Tape Transport system, on which a fair amount of the costly editing can be done costs $35000. Therefore for an additional $3000 a substantial savings in processing costs on the commercial computer can be incurred. With an additional outlay of approximately $34000 to purchase 2 disks, an additional tape transport and a CRT, the entire cartographic system could be run independently of a commercial computer with obvious economic benefits. Perhaps the entire CanSIS system could eventually be run on this system as well. Two of our soil survey units already have minicomputers and in the not too distant future it may be feasible for all units to have access to small computers and operate their own CanSIS sub-data files. These mini-computers would have to have a tape transport attached as a minimum and some disk capability may also be desirable.

Impact of the Cartographic File on Soil Survey

The computer is an elegant piece of electronic equipment that operates in an inefficient, laborious manner. The only reason it is used at all is that it can perform these operations at very high speeds. Although the computer is very fast it is extremely narrow. It will reject any exception to basic operations or logic that have not been accounted for in computer program development. It is for this reason that development of a computer system tends to be time consuming and expensive and when running will only accept data input prepared to narrowly defined formats.

What does this all mean in soil survey? Essentially the need for a reasonable degree of standardization in the way we map, the way we compile our maps, the way we symbolize our maps, the features we place on our maps, the legends we prepare, etc. This will require some adjustment on the part of all concerned, but we believe that this will result in the production of maps in such a way that maximum utility can be achieved. Some specific aspects illustrating the constraints and limitations that an automated geographic system may have on our activities are as follows:

1. STORAGE FACILITY FOR MAPS
2. MEASUREMENT OF SOIL AREAS
3. ASSIST IN CARTOGRAPHIC PROCESS
4. SCALE CHANGE
5. MAP GENERALIZATION
6. GROUPING OF SOILS (GEOGRAPHICALLY) FOR SPECIFIC USES (INTERPRETIVE MAPS)
7. PRODUCE SINGLE FACTOR MAPS
8. TOTAL MAP OUTPUT
9. OUTPUT SIMILAR AREAS FOR A CERTAIN REGION
10. PROVIDES AN INTERFACE WITH CGIS
11. PROVIDES A MEDIUM FOR RESEARCH OF SOIL INFORMATION PRESENTATION
12. PROVIDE DIGITAL DATA FOR OTHER AGENCIES
13. RATIONALIZES AND STANDARDIZES THE PRODUCTION OF SOIL MAPS

Fig. 18. Summary of uses of the cartographic file. *SRI*

a) Field mapping

Our methods of field mapping will reflect the uses to which the data can and will be put. Boundaries are delineated over the landscape on the basis of maximizing homogeneity and minimizing heterogeneity. This of course is a function of scale and the environment in which soils are mapped. We take representative samples of the soils which tie in somehow to the mapping units that we define. The question is one of relating the site specific data to the mapping units we define. If we define the mapping unit on the basis of series, then these can be characterized by the site specific data within known limits of confidence. If on the other hand our mapping units are not tied directly to known soil individuals we lose some predictive value. Although perhaps these questions will have very little bearing on field mapping, it is advisable to consider the presence of the cartographic file in relation to everyday mapping.

b) Symbolization of maps

The pilot project system has been set up as follows:

(1) Up to 12 symbol elements or combination of symbol elements can be accommodated. A symbol element is either a mapping symbol, phase symbol, or percentage estimate of the area of soil identified by a symbol.

(2) Three conventions can be accommodated:

i) A basic symbol can be prefixed. The computer recognizes this as a blank.

ii) A basic symbol can be suffixed by a phase. The computer recognizes this as a semi colon.

iii) A basic symbol can have a subsequent different type of suffix such as area to the nearest 10 per cent. This is recognized as a colon in the computer.

To modify a mapping symbol, one can use 1 prefix and/or 2 suffixes. This does not include elements that may be contained in the denominator of the symbol that depicts topography, stoniness, or some other feature. Figure 19 illustrates symbol complexity that can presently be accommodated. On the basis of what can readily be comprehended by a user of a map this should be adequate.

An additional problem that crops up is one of symbol uniqueness. Although it is generally assumed that map symbols for a given map sheet are unique, they may not all be necessarily unique for the computer. Most standard computers do not distinguish between upper and lower case. For this reason capital R and small b are the same as capital R capital B. Therefore, to avoid later complications it is advisable that all map symbols be alphabetically unique.

c) Hatchings

A number of soil maps published have illustrated features such as topography by hatchings of various sorts to depict slope classes. We would recommend that these features that are desireable to the represented in some special way be incorporated in the symbol and the hatching if desired would be generated on the computer. In this way the information is in a form that can be recognized and utilized by the computer to streamline the cartographic process. This should assist the soil surveyor as well since he does not have to generate the hatchings on the manuscript or as an overlay to the manuscript.

d) Map Legends

The cartographic file will allow for interpretations to be effected in three ways:

i) information can be derived from the soil data file,

ii) information can be derived from the symbol itself,

iii) information can be taken from the map legend.

For reasons of economics the cartographic file should be able to present as many independent interpretations as possible. Thus, comprehensive soil map legends will have to be designed. There appears to be a requirement to prepare a legend specific for the computer which would probably be quite independent of type of mapping. However, these will have no bearing on the published map legend since this will be produced by the pedologist.

e) Correlation between sheets

Problems often occur at the boundaries of map sheets especially if adjacent map were produced some time in the past. Since use considerations can extend beyond soil map boundaries, information will have to be correlated on the computer in order that a map can be generated that will depict the same thing for the entire map. For this reason it seems feasible that each map should be accompanied with correlation legends for adjacent map sheets where symbolization and possibly mapping scale will be different. Again if this is necessary some standard conventions will have to be developed and used.

f) Base maps

At the present time it is not the intention of CanSIS to digitize base maps. Also, it does not seem feasible that we can expect this information in machine readable form from EMR in the near future. As a result we will in all likelihood be plotting interpretive maps on positives of the base map or as a positive overly to the soil map. For this reason soil maps have to be tied to standard base map material, especially if maps from two different surveys have to be matched. In the past there have been occasions where maps have been compiled on one base map but perhaps published on another. It is imperative therefore for the soil cartographic file that soil maps be compiled on standard bases.

Conclusion

The soil cartographic file is an attempt to place soil geographic data in such a form before the pedologist that he can manipulate this data easily, on demand, to illustrate or depict soil data for the user. However, to gain maximum benefit from the cost that the survey represents, a certain additional cost will have to be incurred. One rather prominent land planner stated that we should feel justified in spending an amount representing up to 10% of the basic cost to promote our data. It is felt that since soil data is increasing in importance for many environmental applications that we must make a concerted effort to communicate our information for maximum utility.

RAPPORT SUR LES SERVICES CARTOGRAPHIQUES

J.G. Roberts et R. Norgren

Résumé

La section de la Cartographie de l'Institut de Recherche des Sols fournit l'ensemble des services graphiques que requiert le programme des Relevés des Sols. Les sept membres de son personnel produisent annuellement une douzaine de cartes de différentes échelles. En dépit d'un accroisement de la complexité, la productivité a pu être maintenue à ce niveau par l'apport d'une technologie améliorée. Cependant les cartes à être publiées s'accumulent à un rythme accéléré à cause d'une plus grande productivité sur le champ. Il est généralement admis qu'on devrait améliorer les contacts entre la Cartographie et les équipes sur le champ pour s'assurer que les cartes manuscrites soumises pour publication sont compatibles avec les techniques de reproduction.

Il est reconnu que les cartes les moins coûteuses sont celles qui sont dérivées des cartes topographiques de base auxquelles on superpose les données des relevés de sols. Il faut cependant fournir aux équipes sur le champ des cartes de base qui répondent aux exigences de la Section de la Cartographie en ce qui a trait à la reproduction. Pour que la cartographie puisse opérer efficacement, il est de la plus haute importance qu'elle soit informée des régions où on exécute des relevés pour qu'elle soit en mesure de fournir les cartes de base avec tracés en rouge ou autre méthode qui éliminerait la nécessité de recompilation lorsque ces cartes reviendraient à la Cartographie. Par ailleurs on peut étudier la méthode de cartes préparées par photographie par opposition aux cartes avec tracés de couleurs diverses et déterminer quelle méthode est la plus pratique et économique.

REPORT ON CARTOGRAPHIC SERVICES

J.G. Roberts and R. Norgren

Summary

The S.R.I. Cartography Section provides a comprehensive graphic service to the Canada Soil Survey program. With the staff of seven employees the section produces for publication approximately 12 maps per year at varying scales. Despite greater complexity productivity has been maintain at this level because of improved internal technology. However, there is an increasing backlog of maps for publication due to greater field productivity. It is generally agreed that there should be closer contact between Cartography and the Survey units to ensure that manuscript maps being submitted for publication are compatible with reproduction techniques.

It is generally agreed that derived base maps are the least expensive way of providing topographic bases on which to superimpose Soil Survey information. This does however, pose certain problems with regard to supplying surveyors with a suitable base which is consistent with the standard required in the Cartographic Section for reproduction. There is also the problem of increasing complexity in symbolization which will become very important with regard to the input for CanSIS. In order for Cartography to operate efficiently it is most important that they be informed of soil survey areas for which they can provided red line images or other suitable base material which would eliminate recompilation.

Time does not permit a lengthy historical review of soil map preparation since the inception of Canada Soil Survey, however, I would like to touch very briefly on relatively recent events leading up to the present situation.

The Central Cartographic Service was established in 1949 in the now defunct Experimental Farm Service to provide relatively simple cartographic service for the production of soil survey maps. At that early stage contact with soil survey units was minimal, reproduction services non-existent and in fact, a five or ten year backlog of maps was acceptable to the surveyor and to the Department. This situation continued through the 1950's although the staff was slightly enlarged in order to alleviate critical situations in productivity. With the amalgamation of the Experimental Farm Service and Science Service in 1959 to the present Research Branch, the function of Cartography in the Soil Research Institute was considerably enlarged and became the vital link between the soil surveyor, and the final published results of his field mapping work. At that time the staff was again increased and brought to a total of eight in order to provide a more comprehensive service. The main purpose was to provide a much broader service including an in-house photo mechanical plant. An important agreement was negotiated at that time to have soil survey maps printed at the cost of materials only by the Department of Energy, Mines and Resources to offset rising commercial map printing costs which, over a five-year period, had tripled.

Present Function

The Section's present function is still primarily to provide a photo mechanical, drafting, and reproduction service to Soil Survey. It also includes, on request, advice on data presentation, map scales, availability of base maps, aerial photography, and a variety of other cartographic information and graphic services required by soil surveyors in their day-to-day operations. This improved service, compounded by improved field technology, refinements to aerial photo interpretation, increased field staff, and easier accessibility to field operations, has resulted in an increase in the surveyors' productivity with regard to soil map production. The ARDA Program also generated a staggering input of maps to the Section for publication. Whereas ten years ago the Section could produce up to twenty maps a year, today, because of increased complexity and the requirements for better quality maps, it can only produce ten to twelve maps a year. It might be interesting for you to know that Canada Soil Survey maps are held in high regard by expert users and many of them were exhibited at the International Cartographic Association Meetings, Ottawa, 1972, and at the International Geographical Union in Montreal in that same year.

Organization

There seems to be some confusion with regard to the organization of Cartography in the Soil Research Institute and continual reference is made to the fact that it should produce more and better soil maps. The explanation of this will be short, if not so sweet, as far as Canada Soil Survey is concerned. Of the sixty people presently employed in the Section, fifty-two are supported financially under an interdepartmental agreement with Environment Canada, Lands Directorate, for the production of Canada Land Inventory Capability maps and other maps, charts and indexes, required by that Branch. One draftsman is supported in the Section by the Research Branch to provide service to Plant Research Institute, Agro-Meteorology and also Economics Branch of CDA. Seven continuing positions are established and financed by the Research Board to provide service for the coordinated Federal - Provincial Canada Soil Survey Programs. From this you can deduce that the Section is woefully understaffed to meet the requirements of Canada Soil Survey mapping operations.

Kloosterman and Norgren have touched on many facets of Cartography's operations and functions and the obvious hoped for spin-off benefits from the CanSIS Cartographic File. Additional pressure thereby has been placed on the Section, since it is the operational arm of CanSIS, with regard to digitizing of soils information for input to the Cartographic File. This will produce additional strain on the seven people presently producing soil maps and hopefully, will not have the adverse effect of offsetting the greater productivity which we hope will be a benefit of the system itself.

Cost accounting and time records indicate that we have just about reached the optimum production level per man. It is normally accepted that draftsmen work about 1900 hours a year, however, because of provisions of collective bargaining, statutory holidays, annual vacations, and sick leave, the actual working time is only somewhere between 1400 to 1500 hours per year. With the total staff of forty-five draftsmen involved in both Canada Soil Survey and Canada Land Inventory work, we lose a total of four man years per annum because of the foregoing. This is a singificant loss of time over which we have little or no control, but it is an interesting statistic that must be considered when discussing productivity.

Recent Operational Problems

Roger Norgren has explained in some detail, the two or three problems which are of utmost importance to us, and which require Federal and Provincial cooperation in the interst of efficiency and speed of map production. The red line imagery system has been difficult to sell in some provinces while others have adopted it whole-heartedly. It ensures the elimination of recompilation in Ottawa, it effectively speeds production and minimizes errors and lost time.

With regard to photo mosaic maps.the late Gus Beaudoin stated at the Sixth National Soil Survey Meetings in 1965;

> "The presentation of soil information on photo mosaic background introduces problems of both an economic and technical nature which necessitate a research program of production methods before the scheme can be fully evaluated and adopted."

Since that time, two soil surveys have been published on photo bases and Gus' statement still holds true. There are two or three more of this type of publication in progress and no concrete production costing figures are available due to a variety of recent developments such as, cost recovery by Energy, Mines and Resources for mosaic production and continually increasing cost of aerial photos over the past two years. The most important thing learned from these initial efforts is that the major value of photo maps is for detailed surveys. We have not ruled out other scales but we have found that their value diminishes greatly as the scale diminishes. Experience is proving that original criteria for photo maps was somewhat incorrect, and other than for special use maps, a scale smaller than 1:50,000 is not recommended. At smaller scales the cost and the slight increase in information presented are difficult to justify. Experimental work is being conducted into high altitude quality photography and hopefully, this will result in a suitable product for both publication and field work and reduce problems inherent in photo interpretation at smaller scales.

The first Canada Soil Survey effort at publishing photo base soil maps proved to be much more expensive than originally estimated. It required 40 mosaics at 1:20,000 to cover approximately 400 square miles. In total, 80,000 soil symbols or discrete soil areas were delineated on the 40 pages. It contained a tremendous amount of soil information, but it partially defeated the purpose of the mosaic background. However, an increase in the scale would have greatly increased publication cost. For example, if enlarged to 1:10,000, this first report would have taken 160 pages of mosaics. As Roger has indicated, it becomes a compound problem in that an increase in scale, increases detail that the soil surveyor will show, increases symbolization, increases field work, increases cartography, increases expense, ad infinitum. There is no doubt that high quality intensively used agriculture lands deserve larger scale maps, but prime considerations should be the best data at a given scale and, of course, the user. This brings up another thought. Is the product of our labours intended for ouselves or for users? In fact, it might be worthwhile to catalogue exactly who the users are in order to justify scale. Twenty-five years ago the basic user was the Ag Rep and the farmer. Today, it is much broader and a tremendous variety of disciplines use soil survey publications as basic information both in and prior to other studies.

Standard Symbolization

No doubt discussion regarding standardization of symbolization is a contentious issue to discuss with soil surveyors. It is going to be a problem which will not be readily accepted without an education program. In some cases, symbolization has become so complex that understanding for some users is exceedingly difficult. Some symbolization on recently submitted maps would pose a deciphering problem for many of you here. This problem increases as soil surveys become more detailed and if the present trend continues, symbolization may be so confusing to the user that the user demand will diminish, and this is opposite of what you want. Admittedly, maps are much more informative if you can decipher them - but we may be trying to crowd too much information into one map and it might be better if some of the interpretations which are now appearing in the symbolization were published separately. The only reason that this is mentioned is that it is a problem which continues to plague Cartography and <u>must</u> be resolved for CanSIS.

Current Status of Mapping

In the fiscal year 1972-73 we drafted for publication a total of twenty-two soil survey or miscellaneous maps to accompany soil survey publications. Earlier, it was stated that we can publish, with our present staff, ten to twelve maps a year. This does not agree exactly with the figure previously given you, but of the twenty-two, only thirteen were actual multi-colored line soil maps or photo mosaic publication. Presently in production are thirty soil map sheets which represents two to three years work. Indications are that there are another fifty to sixty maps in the provinces and these can be expected in Ottawa within the next two to three years.

In effect, you can see that within five years, we will have a ten-year backlog. Not only is this frustrating for Cartography, but it must be terribly frustrating for pedologists. There are two ways that this backlog could be handled. One is outside contract, which has been investigated and would be extremely expensive. Recent estimates indicate that the cost of compilation, drafting, symbolization, colour separation, and negative retouch would run anywhere from $10,000 to $20,000 per map sheet, depending upon complexity. To this, would have to be added the cost of outside printing. Experience has proven that minor changes to maps, which can readily be made at a very small cost in-house, become very expensive when you start adding riders to contracts. The other alternative is to have you bombard us with maps and the Department, Branch, and Institute with deadlines, and demands for service. Hopefully, sooner or later, someone will realize that Cartography must be geared to meet the increasing demands from Soil Survey.

Map Printing

One further point of information is that we have been asked by Energy, Mines and Resources to reserve press time one year in advance. We understand their problem and hopefully you will understand the problem at our end. If we reserve time for one of your maps but do not receive edited copies from you on the dates specified, that map goes to the bottom of the list, and this sets it back another year (each map sheet is scheduled for a particular press, depending upon its overall dimensions). It is very difficult to juggle our schedules and Energy, Mines and Resources is most reluctant to accommodate us in this area because of the many commitments they have. For your interest, the average soil map cost for the plating, printing, inks, and paper for 3,000 copies is around $400 per map sheet at Energy, Mines and Resources. In the past they have not charged us for labour, however, with the new cost recovery system being put into effect this may change, but as yet, no figures have been indicated.

Distribution

Finally, a few words about distribution and dissemination of soil survey information. No discipline with so much to offer is so reticent to promote its product. In fact, few do a worse job in this area. Since the decision has been made that the provinces have responsibility for distribution, I can see little improvement over what was originally being done by the federal distribution system. Unfortunately, it would appear that no two provinces have the same distribution system and in some cases difficulties in obtaining copies of soil survey maps and publications have been reported. Many requests received in Ottawa are being referred to the wrong provincial departments or addresses because of lack of communication. This is not only a reflection on the Canada Department of Agriculture, but also on Soil Survey in general. Surely it is of prime importance to this assembly that the dissemination of information relating to this discipline is well handled and looked after. I think you will agree that it is urgent that we achieve a better system and we are willing to cooperate with provincial distribution organizations and yourselves to this end.

Incidentally, it might be of interest for you to know that the new Soil Survey Index in book format is presently in production and will be available for distribution in early Fall. Also the Canada Soil Map and accompanying Climatic map are virtually cartographically complete and will be published in late 1973.

To summarize, I would like to say that, like you, we need money and manpower. If we had another ten draftsmen; accommodation for them and about $100,000 capital expenditure for badly needed equipment, we could meet your service requirements and give you reasonable turn around service.

I would now like to turn things over to you by asking if you have any solutions to the problems brought to your attention.

Cartographic Problems in Data Presentation and Techniques to Improve Turn Around Time

Cartographers have always been posed with the problem of deciding on how much base detail should be shown on a map of a given scale. Derived base maps, covering the soil survey area at scales varying from 1:63,360 to 1:126,720, are made by piecing together the 1:50,000 national topographic series maps. However, many of these topographic maps have been produced in various years and perhaps by one or more agencies whose specifications for natural and cultural detail is different. There may also be a difference in the type of detail, which is to be shown. It therefore, becomes necessary to determine a consistent standard of detail throughout the entire soil survey area. In considering which detail will be deleted, or generalized, the cartographer keeps in mind that the thematic information must take precedence over the minor topographic detail, such as houses, barns, bridges and perhaps water courses of minor size. All of this is done with the thought that more space will be required for the thematic information, or the soil symbol. This consideration is absolutely necessary today since the soil surveys are generally becoming more detailed, hence the size of the areas are becoming smaller while the symbolization has increased in size and complexity. The complexity is exemplified by the following symbolization representative of that used before 1950, in the 1960's and 1970's.

1950 P2

1960 $\dfrac{\text{FeS}}{\text{G2F2}}$

1970 $\dfrac{\text{Ht5:c-Ps3:1-Th2/T:cd-Ca3/T:ef}}{\text{G2+3:S+2-3}}$

While it is preferable to have the symbolization appear within the classified area, this is not always possible. The reduction of the type to a size, which will fit within the area is not always practical as it may become difficult to read or completely unreadable. It is generally considered that type below 4 pt. is too small for the average person to read easily.

On many occasions we find it necessary to go smaller than 4 pt. in order to accommodate the symbol somewhere within the classified area or within the immediate proximity of the area. When the type is reduced, it is often difficult to pick out the individual units of the soil symbol such as; series, texture etc. To show these various units at the reduced size of type, we have resorted to bold and medium face type so that symbols stand the reduction. This, however, requires more space, resulting in having to use condensed styles of type. This approach is by no means the answer to symbolization on very detailed soil surveys, because the symbolization is still too large for the size of the areas mapped. It is an accepted fact that as a scale becomes smaller, generalization of the base information becomes necessary. This fact should hold true for the soils information also but unfortunately does not. This makes one wonder as to whether or not mapping is too detailed in comparison to the scale of publications.

Scale of the map publication should be dictated by detail and/or complexity of the soils data. This would depart from tradition of maintaining previously established scales. Since many of the maps now being submitted are very detailed, it would result most likely in producing maps at a larger scale. This increases the number of map sheets to be printed, and would result in an even longer turn around time than is presently being provided. It would appear that we are on a merry-go-round, unless there is an alternative means of symbolization. Could this alternative be a numerics system? One such system was used in preparing the soil map of Canada, of which I am sure many of you are aware of. The use of a numerics would reduce the turn around time due to the editing, collating and type placement of symbols. Just how the legend for such an approach would be handled, however, remains to be defined.

I have dealt with the problems that the cartographer runs into in placing the symbols on a map, to this point. These problems are created by the complexity of the symbol itself. It may be worthwhile mentioning also that the "Psychological Review of March 1956" contains an article entitled "The Magical Number Seven Plus or Minus Two" (Miller, 1956) in which research was on limits in capacity of the human mind for processing information. The conclusion was we can retain and comprehend between 5 and 9 separate units of information. Many of the symbols used on our maps in the present day exceed this number. One might ask the question, "who is the user of these maps?" If it is a pedologist, perhaps there is no problem in decifering these long symbols. However, there must be many, many other users and how do they fare in interpreting the symbolization?

Bases For The Compilation Of Soils Data

Source documents are the next point that I would like to bring to your attention. I am sure many of you have wondered why we in Cartography take so long in getting your map drawn and printed. Much of the reason is compilation and editing. You may ask why must you recompile the information when it is already done in the field office? The reason is that much of this information has been prepared on paper copies on maps of scales other than the publishing scale or on a base which is different from that from which we will be working. We have, for a number of years attempted to eliminate this problem by instituting a system by which you would request a base on which to plot your soil boundaries and symbols. Your request would define the area of the survey by latitudes and longitudes also the scale with which you would want to do your compiling of the information and the publishing scale. In response, we would provide the base image on stable matte plastic. This image would be an enlargement or a reduction of the latest topographic sheet available, whether it be a provincial publication, or a federal publication. If it was a provincial publication, we would ask that you acquire the printing negatives from the province or that you provide us with the appropriate provincial authorities to whom a request for this material would be made. The purpose of requesting negatives rather than paper copies is that the base should be prepared from the printing negatives which is a stable base material. The purpose of the red line image rather than black is to make it easier for you to see the lines and symbols when they are being plotted. In addition the red line image is on the underside of the plastic which allows for changes to symbols or boundaries without obliterating the base. If you require contours they can be superimposed on the red line image as a blue image or as a separate positive and used by overlaying the red line in register with contours. The following slide shows the base image in red, your contours in blue and your soils information in black.

Using this method or approach gives dividends at both ends. The surveyor is able to request ozalid copies of his source document pending the drafting of the final map. The cartographic benefit is that the soils information has been compiled on the same base which will be used for the final drafting. In effect we could be preparing the final drafting of the base prior to receipt of the soils information with the knowledge that the source document will register with the base. The other benefit is that no compilation of boundaries is necessary and this has been achieved with no more effort on anyone's part. This document is used to photo-mechanically produce a duplicate image on our scribing material. There is no possibility of error on our part, and this is present always when the manual transfer of data is undertaken. It also reduces our editing time and of course, will have reduced the possibility of missing data. Where this procedure has not been used, we are faced often with the problem of trying to adjust soils information to the base which we are using. This can be very time consuming. In addition, if the surveyor is aware of some feature which is not on the red line image it can be added with red pencil. This added detail would then be incorporated into the final drawing. We are continually trying to improve our turn around time and this is one method by which we are sure this time can be improved. Sufficient lead time of eight weeks should be given in order that we may secure the negatives to prepare the red line base images.

Technological Advances Reduce Drafting Time

There are benefits to cartography from CanSIS. One such benefit is the preparation of colour separation guides for the cartographer. Soil maps are produced using a basic four colour system which is yellow, pink, blue and grey, or using a combination of solids and rulings a selected set of

57 colours are produced. Any map which requires all four colours and all four rulings would require eight colour masks. To colour separate the correct colour combination for each area constitues a long tedious and error prone operation. This method of providing guides virtually eliminates colour errors and reduces the tedious aspect of the operation. Utilizing data in the CanSIS file, we are able to generate plots for each of the eight masks on the Gerber plotter. Prior to the use of this technique, colour separation, with its associated operations, represented 30% of the total drafting time. Using this colour guide technique on a representative map we had a saving of 18% of the total drafting time. As an example of the effectiveness of producing colour guides the representative map contained 1,016 areas which required the removal of 1,585 pieces of peelcoat. To prove the system, the colour separations were edited by conventional methods and we were unable to detect a single colour error. This same technique can be used in preparing the topographic hatching separations, provided a topographic symbol was shown as part of the soil symbol unit. This would eliminate the necessity of you, the surveyor, having to prepare a topography manuscript showing the topography as a hatching on your source document. If standardization of symbols was possible, the CanSIS file and through the use of this data we would be able to generate the symbolization in a form ready for affixing to the map. This would increase productivity, reduce turn around time and make everyone happier.

Aerial Photography And Photo Base Maps

In mid 1972 an agreement was reached between our departmental representative on the interdepartmental Committee on Air Surveys and ourselves to improve specifications for aerial photography required for soil survey and photo map bases. This was necessary because original specifications as drawn under the ICAS agreement were primarily oriented towards stereo plotting for topographical survey mapping. There were several things that prompted this, among them were specific periods when photo interpretation for your particular needs was critical. To a large extent, this is after Spring run-off or before foliage leaf-out, in the Fall after the time foliage has dropped or before any freeze up. Your requirements for aerial photography in 1974 should actually be submitted now to allow for the preparation of specifications. If a photo base map is being considered, you should specify this in your request for photography, as it may require the preparation of a specific type of rectified print or ortho photo base and since we do not have the equipment for this work ourselves, we would have to be prepared to rely on Energy, Mines and Resources or outside contracts. Usually rectification is recommended on relatively flat terrain because it is much less expensive than ortho photo maps, however, where there is any extreme topography ortho photo is much preferred since it is far more accurate. Past experience has shown that each request should be considered individually. It is hoped that the photography which is being used for interpretation of soils can also be used for the preparation of the base. This is presently under investigation with results expected shortly. High altitude photography is considered a possible answer to many of the problems inherent in the preparation of mosaics. We are looking at the possibility of a single photo for each page of the bulletin. However, the stereo coverage will also have to be available for your use.

It is generally considered that a photo map is of most value in high growth areas where intensive soil investigations are conducted or where cultural features are few or non-existent.

RAPPORT SUR LES SOLS CRYOTURBES DU NORD CANADIEN

C. Tarnocai, W.W. Pettapiece et S.C. Zoltai

Résumé

Cette présentation faite le soir après les séances régulières a permis à plusieurs pédologues de faire connaissance avec les sols des régions froides dont les couches ont été soulevées et déplacées par l'action des gels et dégels (cryoturbation et solifluction). Les caractéristiques de ces sols ont été illustrées au moyen de diapositives, diagrammes et imprimés.

Au cours de leurs présentation, ces pédologues ont signalé que le présent système de classification ne traite pas adéquatement des sols cryoturbés. Ils ont proposé certaines modifications au système pour les y accommoder de façon plus convenable.

REPORT ON CRYOTURBED SOILS IN NORTHERN CANADA

C. Tarnocai, W.W. Pettapiece and S.C. Zoltai

Summary

This informal presentation at an evening session introduced many pedologists to soils in a cold environment that are disturbed by frost heaving (cryoturbation) and solifluction. Colored slides, diagrams and printed material were used to portray the soil characteristics.

It is stated by these pedologists that cryoturbed soils are not now adequately dealt with in the soil classification system. They have presented proposals for modification of the system to better accommodate cryoturbed soils.

INTRODUCTION

After reading the report "Classification and Some Characteristics of Cryoturbed Soils in Northern Canada", February, 1973 by C. Tarnocai, people working in the northern portion of the Mackenzie Valley and the Yukon indicated that this modified system could not handle many of the soils occurring in these areas and would, at best, provide only a temporary solution.

A two-day meeting was held in Edmonton on March 5-6, 1973 with Wayne Pettapiece, Steve Zoltai and Charles Tarnocai participating. As a result of this meeting a new Order, Cryoturbisols, was added to the modified classification. Since, based on the data collected, these soils were found to have many unique properties, a new Order was felt to be justified.

For example, the Turbic subgroups have up to a one-third disruption resulting from cryogenic processes. These soils have the basic characteristics of the Brunisolic, Regosolic and Gleysolic Orders. When soils have greater than 1/3 disruption, on the other hand, most of the properties are destroyed and hence the definitions of the above orders are not satisfied. These soils can be considered to have developed as a result of cryoturbation (cryogenic processes).

These soils can hardly be called Regosols because generally the surface soils have structure, are high in organic matter, and carbon-dating of organic matter from the subsurface horizons indicates that we are dealing with an old soil, especially in the unglaciated northern Yukon area.

In the following section is a brief review of literature relating to subarctic and arctic soils occurring in the Canadian North, Alaska and Siberia. Profile descriptions, chemical and physical analyses of profiles collected by the authors from the eastern (Keewatin area) and the western arctic (Mackenzie River and Northern Yukon areas) and the proposed classification of these soils are included.

REVIEW OF LITERATURE AS RELATED TO SUBARCTIC AND ARCTIC SOILS

Northern Canada

Leahey (1947) examined some soils in the subarctic region of Norman Wells and the arctic region of Aklavik and the western slopes of the Richardson Mountains. All of these soils were associated with permafrost as indicated by his profile description. Leahey, however, did not attach any horizon designators to the profile description and, in addition, he did not classify these soils. On the other hand, he did note some of the characteristics of these frozen soils, e.g. the presence of organic streaks and layers in the lower part of the profile. But, to quote Leahey, "No explanation can be given for the presence of organic streaks in the lower part of the subsoil other than that they may have resulted from the activities of burrowing animals".

Mackay (1958) studied the origin of the organic layers associated with perennially frozen soils in the western arctic. He theorizes that they are the result of the organic material that has accumulated in the inter-hummock depressions being progressively rolled under and smeared along the base of the active layer.

Day (1962) carried out pedogenic studies on perennially frozen soils in the Mackenzie River basin. He states that "The Brown Wooded soil with permafrost is essentially the same as the Brown Wooded in more southerly areas". Day in this study observed the subsurface organic layers in soils in the Mackenzie Delta area and explained these layers according to the theory developed by Mackay (1958). The reader, however, is left with the impression that the soil profiles examined were the most stable ones and this was also pointed out by R.E. Beschel who states in the discussion that "the paper seems to discuss mostly stable soils and it is surprising to have such a large number of these".

Day and Rice (1964) provided a detailed description of profiles sampled in the Reindeer Depot, Inuvik and Norman Wells areas. The soils were classified, according to the Canadian System of Soil Classification (1963), as Subarctic Orthic Regosol and Subarctic Gleyed Acid Brown Wooded in the Reindeer Depot area; Subarctic Brown Wooded and Subarctic Minimal Podzol in the Inuvik area; and Subarctic Brown Wooded and Subarctic Peaty Carbonated Rego Humic Gleysol in the Norman Wells area.

A soil study in conjunction with soil mapping carried out by Tedrow and Douglas (1964) on Banks Island was probably one of the first soil surveys undertaken in the Canadian Arctic. The soil mapping was done on the series level and the following genetic profile types were recognized: Arctic Brown soil was not extensive; Tundra soil (Kellet series) developed on sand to loamy sand, usually with non-sorted ice-wedge polygons; Regosols developed on talus and other coarse textured materials; Polar Desert soil (Storkerson series) developed on dry gravelly sandy loam, usually with sorted polygons; the Beaufort series developed on well-drained gravelly sandy loam, usually with sorted polygons and; the Bernard series developed under well-drained soil conditions, associated with hummocky ground and "frost-stirred" horizons. It is interesting to quote Tedrow and Douglas concerning these soils associated with hummocks: "Soils of the hummocky ground represent a condition which has been virtually unexplored from a pedologic viewpoint" and later "Although soil color sequences approximate those of Arctic Brown soil, in view of the surface configuration, erratic horizonation, salt accumulation, and probable frost displacement, it is more realistic to characterize this condition as one of a unique kind of soil".

James (1970) studied the soils of the Rankin Inlet area of Keewatin, N.W.T. The soils are classified according to the degree of disturbance by frost action and drainage. Soils relatively undisturbed by frost were classified as Half Bog, Meadow Tundra, Upland Tundra and Arctic Brown Soils (Tedrow classification system). The frost-disrupted soils were associated with patterned ground. The "frost-churned" soils associated with nonsorted circles ("mud boils") are also recognized.

Cruickshank (1971) carried out soil mapping and pedological studies around Resolute, Cornwallis Island. The terrain units for mapping were separated according to profile type, effect of frost action on soil formation, type of patterned ground or surface morphology and parent material. Although three genetic varieties - the Polar Desert, Lithosol and Tundra Gley (Tedrow classification system) - were recognized, a much greater number of soil series, soil types and soil phases were separated according to the criteria outlined above.

During the last two years work has been carried out by the authors in northern Manitoba, southern Keewatin and the Mackenzie River area. The results of this field work are summarized by Tarnocai (1972), Zoltai and Pettapiece (in press) and Tarnocai (in press).

Other Countries

A great deal of work has been done on northern soils, especially in Alaska and Siberia. The most significant work, as relates to northern soils, was carried out by Tedrow with the bulk of it relating to Alaska. The classification system developed by him has been mentioned in the previous section and, along with his concept of soil formation, is found in the papers by Tedrow (1966 and 1968), Tedrow and Cantlon (1958) and Drew and Tedrow (1962). The description of major genetic profiles occurring in northern Alaska can be found in the papers of Tedrow (1963), Tedrow, et al. (1958), Drew and Tedrow (1957) and Tedrow and Hill (1955). Research relating to frost action (cryoturbation) and subsurface organic matter can also be found in the papers of Tedrow (1965 and 1962).

More recently, the works by Brown (1967) and by Allan, Brown and Rieger (1969) deal with soils and soil formation in northern Alaska.

The U.S. soil classification (7th Approximation, 1960) provides very little information as to the classification of subarctic and arctic, cryoturbed soils. The cryoturbed northern soils are classified as Ruptic subgroups (7th Approximation, 1960, p. 22). These are multiple subgroups integrating between two given great groups. The term Ruptic indicates that "In one situation the horizons may be continuous, and in the other they may be discontinuous. Or, in one soil, properties of the two classes are mixed in a single horizon but represented by separate horizons in the other".

Little information is available from the U.S.S.R. but the information which is available indicates that there is very active research going on, especially in Siberia. The most useful sources of information available are the book "Soils of Eastern Siberia" (1969) edited by E.N. Ivanova and the papers published in the Journal of Soviet Soil Science by Ivanova (1965) and Karavayeva et al. (1965) dealing with soils and soil formation in the permafrost region of Siberia. Also interesting are the papers by Morozova (1965) and Fedorova and Yarilova (1972) which deal mainly with the morphological and other characteristics of soils in relation to cryogenesis.

It is interesting to note that soils found in the subarctic and arctic regions of Siberia are recognized as cryogenic subgroups. For example, Sokolova and Sokolov (1963) identify three subtypes of cryogenic taiga soils: 1. cryogenic taiga peaty soils; 2. cryogenic taiga peaty-humus slightly gleyed soils; and 3. cryogenic taiga humus-glei soils. They also state that "The surface of the cryogenic taiga soils always bears cryogenic forms of microrelief: stony potholes, hummocks due to swelling, and stone streams. The mineral horizon shows many traces of cryogenic mixing". Soils found in the same area but showing no indication of cryogenic processes are called simply taiga peaty soils, taiga peaty-humus slightly gleyed and taiga humus-glei soils indicating that, basically, the same soil forming processes take place in cryogenic soils as in the non-cryogenic soils but in addition, the soils in the cryogenic subgroups are affected by cryogenic processes.

DISCUSSION

Soil Development in the Subarctic and Arctic Regions

Soil development in the subarctic and arctic regions is greatly affected by cryogenic processes. In the southern portion of the Discontinuous Permafrost Zone (Boreal region) permafrost develops first in the organic soils (Brown, 1968) then, proceeding north in this zone, it is also found in the fine textured Gleysols which usually have a peaty surface layer. The permafrost begins to appear in the well-drained mineral soils in the northern portion of the Discontinuous Zone but it is sporadic on these sites and is associated mainly with fine textured soils. These mineral soils in the Discontinuous Zone have no surface microtopography resulting from cryogenic processes (see Figure 8A). Patterned ground (micro-topography caused by cryogenic processes) starts to appear in mineral soils in the southern portion of the Widespread Permafrost Zone. These soils are fine textured and have a relatively well developed hummocky topography (Figure 8B), but they show very little or no cryoturbation. The soil horizons are continuous or are disrupted only in the inter-hummock depressions. In the middle portion of the Widespread Permafrost Zone the soils show much greater effects of cryoturbation with resulting disrupted and dislocated soil horizons and the typical morphological, physical and chemical characteristics associated with soils examined in the arctic region. Finally, mineral soils examined in the Continuous Permafrost Zone (arctic region) show extremely active cryoturbation (Figure 8C).

Soils examined on alpine areas of the Franklin and Mackenzie Mountains show active cryoturbation both on the surface (patterned ground) and in the soil profile. These soils, however, have the permafrost table either below the control section (1 m depth) or developed on shallow colluvium materials over bedrock. As a result of this, these soils were not classified as cryic subgroups in spite of the fact that they show active cryoturbation.

It is well established in literature that these soils which have developed in the subarctic and arctic regions have different morphological, physical and chemical characteristics than those which have developed in the southern regions (Sokolov, 1963; Tedrow, 1963; Cruickshank, 1971). Most of the features which are related to these cryoturbed subarctic and arctic soils are shown in the profiles included in this study.

The surface organic horizons of these soils may not always be observable or may be discontinuous because, due to frost action, they are incorporated into the mineral horizons. Even in this situation, however, some build-up of organic material was found in the interhummock depressions, polygonal trenches, and the areas surrounding the circles, nets and stripes (Washburn, 1956). The surface mineral horizons of the fine textured soils usually have a granular to shotty structure although a platy structure

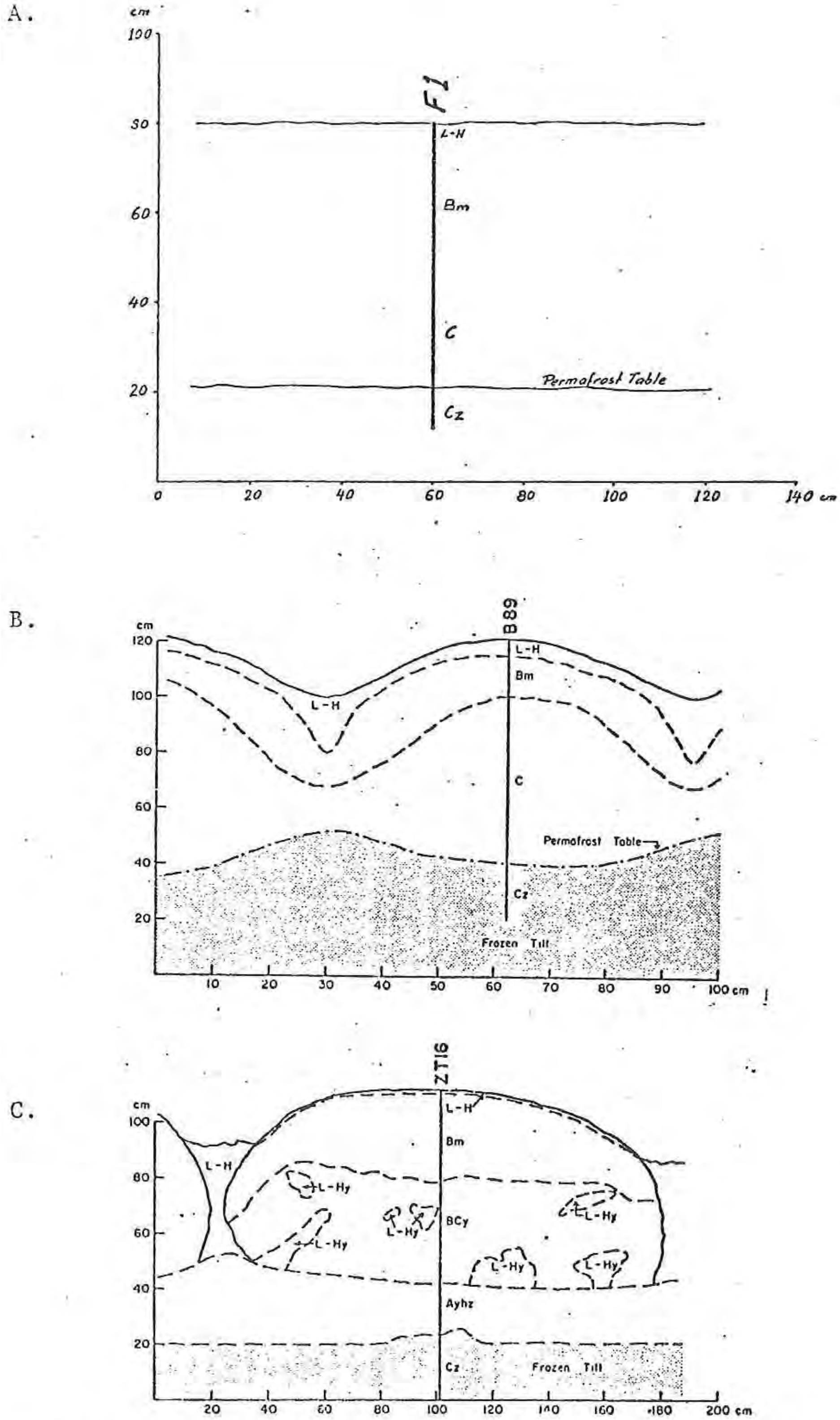

Figure 8. Perennially frozen (Cryic) mineral soils located in the Discontinuous Permafrost Zone (A), the southern portion of the Widespread Permafrost Zone (B) and the northern portion of the Widespread and Continuous Permafrost Zones (C) of the Mackenzie River area.

may also sometimes occur. This structure is probably due to soil freezing which is known to enhance aggregation (Karavaeva, 1963). Soil freezing also produces mechanical sorting of materials associated with certain forms of patterened ground. Intrusion of displacement of horizons due to cryoturbation is also one of the main characteristics of these soils.

One of the most striking features of these cryoturbed soils is the high organic matter content of the mineral horizons. The organic matter occurs in the form of organic smears, stains, intrusions and organic-rich subsurface Ah horizons developed in situ. These subsurface Ah horizons are associated with the fine textured soils which have hummocky topography. Mackay (1958), in his study of the origin of the subsurface organic layers in the Mackenzie Delta soils, theorizes that they are the result of the organic material that has accumulated in the inter-hummock depressions being progressively rolled under and smeared along the base of the active layer and on top of the permafrost table. These organic layers are very old; layers in tundra soils of Alaska range from 5,300 to 10,900 years in age (Tedrow and Douglas, 1958). Similarly, undecomposed surface wood fragments, Ledum leaves, artifacts, bones and charcoal are also rolled under, indicating that this is an on-going process including both old and recent materials. Karavaeva and Tarqul'yan (1963) suggest that there is a certain amount of migration of mobile humus substances into the deeper part of the soil, toward the frozen layer, in the spring. This is the season when the soil thaws and the level of surface water subsides. In the summer, however, migration of solutions toward the permafrost table occurs along the thermal gradient. Karavaeva (1963) suggests also that the high organic matter content of the surface mineral horizon is due to the fact that the ratio of the surface to underground biomass weights of tundra vegetation is 1:6. The bulk of the underground biomass is found in the 0 to 18 cm surface layer.

Most of the soils examined in the arctic region show very weak profile development. This is probably the result of: (1) a cold, harsh climate which provides very little opportunity for either chemical weathering or removal and addition of materials (Fedorova et al., 1972) and (2) the action of cryoturbation which tends to dislocate and intermix materials which are produced by the other pedological processes. Thus, these soil forming processes give rise to new soil types which are typical of the subarctic and arctic regions.

Justification for Creating a New Order for the Arctic and Subarctic Soils

I. If we look at the Canadian Classification it appears that Order separations are based on a) major bioclimatic zones (prairie vs. forest), b) major kinds of genetic processes (lessivage vs. podzolization) some being governed by special conditions such as by chemistry (solonetz) or drainage (gleysol), or c) lack of profile differentiation (Regosol). With these thoughts in mind, a new Order seems justified on the following:

1. The soil climate is characterized by a mean annual temperature of less than $0^{\circ}C$ and permafrost conditions. This must be considered to be a major

climatic zone. It may be noted here that traditional soil temperature - air temperature relationships do not hold. Also, soil temperature character based on a 50 cm. depth is not valid because it does not represent the temperature of the rooting zone and in fact may even be below the depth of thaw. The traditional approach to moisture regime is also difficult to apply, again because it often does not represent the zone of biological activity.

2. Principal soil fabric characteristics may be altered by cryoturbation processes, to such an extent that all elements of the soil body owe their origin to these processes. Thus, we have a unique process as a primary separation. This is analogous to the vertisol problem, another unique physical process, which is handled at the Order level in many classifications (U.S.A., FAO, French). This also involves the recognition of a cyclic component to the natural soil unit. Several of the more prominent Russian pedologists working in the north are proponents of the concept that the soils of the hillocks and hummocks should not be considered as soil individuals (Karavayeva, et al., 1965) and also that these soils are "zonal, genetically independent" soils.

3. An area consideration would also indicate that these soils warrant attention and consideration. About 50% of Canada is underlain by permafrost and probably 1/2 of this or 25% of Canada's land surface is characterized by cryoturbated soils.

4. A unique chemical feature present at least in the cryoturbated soils of the subarctic taiga is the presence of large amounts of mobile humic and fulvic acids. These soluble humic substances (often up to 3 or 4% organic C or more) may result from the breakdown of material with little or no lignin, such as lichens, in a region of low mineralizing potential. This feature is well documented in the Russian literature.

II. Assuming that the foregoing arguments justify the setting up of a new Order, let us consider some specific suggestions as to how this might be accomplished.

1. The Order should include those soils in the permafrost region which cannot be readily accommodated in other Orders, namely those formed by cryoturbic processes. This would leave very poorly drained and weakly developed non-disturbed soils in the Gleysolic and Regosolic Orders respectively, and recognize the unique physical process.

The Order definition could be:

"Soils developed through cryoturbic processes in a permafrost environment", and further, "The profile includes contiguous portions of microtopography, providing no element exceeds 2 m in lateral dimension" (simply a guide, not a hard and fast rule). These soils usually have saturated zones immediately overlying the frost table.

The following proposals may be considered:

PROPOSAL I.

Order	Great Group	Subgroup
Ia. Cryoturbisol	Cryoturbic	Orthic Miscic -/Saline -/Carbonated -/Lithic -/Separic -/Aquic -/Cryic
Ib. Cryoturbisol	Eutric	Orthic Miscic
	Dystric	Orthic Miscic -/Saline -/Carbonated -/Lithic -/Separic -/Aquic -/Cryic
Ic. Cryoturbisol	Continic Mineral profile continuous with depth	Orthic Miscic
	Separic Cryogenic organic material separates the raised mineral element from the parent material	Orthic Miscic -/Saline -/Carbonated -/Lithic -/Aquic -/Cryic

2. A second method of attack might be to consider an Order including all permafrost soils. This is justified on bioclimatic grounds, and has precedence in the Russian and French schemes (FAO, UNESCO, 1970). It might pose some conflicts in principle with our present system of classification, particularly re. Gleysols, Regosols and possibly Brunisols. The following is a possible scheme:

PROPOSAL II.

	Order	Great Group	Subgroup
IIa.	Cryosol	Regic	Orthic Cumulic -/Saline -/Carbonated -/Lithic -/Gleyed
		Brunic	Orthic Degraded -/Saline -/Carbonated -/Lithic -/Gleyed
		Gleyic	Orthic Humic Rego -/Saline -/Carbonated -/Gleyed
		Cryoturbic	Orthic Miscic -/Saline -/Carbonated -/Lithic -/Separic -/Aquic
IIb.	Cryosol	Static (noncryoturbated)	Regic Brunic Gleyic -/Saline -/Carbonated -/Separic -/Aquic
		Cryoturbic (cryoturbated)	Orthic Miscic -/Saline -/Carbonated -/Lithic -/Separic -/Aquic

The ultimate solution might lie in method 2 with some variation of the suggested proposals. However, we simply do not have enough field time in the far north (Polar Desert) to go very far now with classification. Another strong point in favour of proposal Ia is that it could very easily be converted to or molded into proposal II if this should evolve at a later date. The only difference between IIa and IIb is the level one might wish to handle the non-cryoturbic types.

PROPOSED CHANGE IN THE SOIL CLASSIFICATION

The previous section has indicated the basic proposals to modify the Canadian Soil Classification System so that these soils may be adequately accommodated.

Detailed descriptions of these proposals (Ia and IIa) are given below.

PROPOSAL Ia.

52 Eutric Brunisol

521	Orthic Eutric Brunisol
522	Degraded Eutric Brunisol
523	Alpine Eutric Brunisol
52-/7	Cryic Eutric Brunisol
52-/8	Gleyed Eutric Brunisol
52-/9	Lithic Eutric Brunisol
52-/10	Turbic Eutric Brunisol

These are Eutric Brunisol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

54 Dystric Brunisol Great Group

541	Orthic Dystric Brunisol
542	Degraded Dystric Brunisol
543	Alpine Dystric Brunisol
54-/7	Cryic Dystric Brunisol
54-/8	Gleyed Dystric Brunisol
54-/9	Lithic Dystric Brunisol
54-/10	Turbic Dystric Brunisol

These are Dystric Brunisol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

61 Regosol Great Group

611	Orthic Regosol
612	Cumulic Regosol
61-/5	Saline Regosol
61-/7	Cryic Regosol
61-/8	Gleyed Regosol
61-/9	Lithic Regosol
61-/10	Turbic Regosol

These are Regosol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

71 Humic Gleysol

711	Orthic Humic Gleysol
712	Rego Humic Gleysol
713	Fera Humic Gleysol
71-/5	Saline Humic Gleysol
71-/6	Carbonated Humic Gleysol
71-/7	Cryic Humic Gleysol
71-/9	Lithic Humic Gleysol
71-/10	Turbic Humic Gleysol

These are Humic Gleysol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

72 Gleysol Great Group

721	Orthic Gleysol
722	Rego Gleysol
723	Fera Gleysol
72-/5	Saline Gleysol
72-/6	Carbonated Gleysol
72-/7	Cryic Gleysol
72-/9	Lithic Gleysol
72-/10	Turbic Gleysol

These are Gleysol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of material from other horizons and mechanical sorting.

CRYOTURBISOL ORDER

This order consists of moderately well to imperfectly drained soils developed as a result of cryoturbation processes in a permafrost environment. These soils have disrupted sola as manifested by cryoturbation greater than 1/3 of the soil body and profile includes a contiguous portion of the microtopographic feature or a portion of the feature up to a width of 2 meters.

They may or may not have an organic surface horizon (L-H) or brownish By or BCy horizons, but they have Cy overlying a Cz or Cyz horizon. Dark randomly distributed or continuous cryoturbed Ahy or Ahyz horizons are common in the solum. As a result of cryoturbation the horizons are displaced or incorporated into other horizons and high organic matter content and patterned ground micro-topography are also characteristic.

CRYOTURBIC GREAT GROUP

Only one great group has been established; therefore, its definition is the same as that of the order.

Orthic Cryoturbisol

These are soils where the profile has horizon discontinuity in less than 1/3 of the mineral element.

Miscic Cryoturbisol

These are soils where the profile has horizon discontinuity in greater than 1/3 of the mineral element.

-/9 Saline
-/6 Carbonated
-/9 Lithic
-/11 Separic
-/13 Aquic (saturated throughout the thawed portion of the profile)

PROPOSAL IIa.

52 Eutric Brunisol

521 Orthic Eutric Brunisol
522 Degraded Eutric Brunisol
523 Alpine Eutric Brunisol
52-/7 Cryic Eutric Brunisol
52-/8 Gleyed Eutric Brunisol
52-/9 Lithic Eutric Brunisol
52-/10 Turbic Eutric Brunisol

These are Eutric Brunisol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

54 Dystric Brunisol Great Group

541 Orthic Dystric Brunisol
542 Degraded Dystric Brunisol
543 Alpine Dystric Brunisol
54-/7 Cryic Dystric Brunisol

54-/8	Gleyed Dystric Brunisol
54-/9	Lithic Dystric Brunisol
54-/10	Turbic Dystric Brunisol

These are Dystric Brunisol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

61 Regosol Great Group

611	Orthic Regosol
612	Cumulic Regosol
61-/5	Saline Regosol
61-/7	Cryic Regosol
61-/8	Gleyed Regosol
61-/9	Lithic Regosol
61-/10	Turbic Regosol

These are Regosol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

71 Humic Gleysol

711	Orthic Humic Gleysol
712	Rego Humic Gleysol
713	Fera Humic Gleysol
71-/5	Saline Humic Gleysol
71-/6	Carbonated Humic Gleysol
71-/7	Cryic Humic Gleysol
71-/9	Lithic Humic Gleysol
71-/10	Turbic Humic Gleysol

These are Humic Gleysol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

72 Gleysol Great Group

721	Orthic Gleysol
722	Rego Gleysol
723	Fera Gleysol
72-/5	Saline Gleysol
72-/6	Carbonated Gleysol
72-/7	Cryic Gleysol
72-/9	Lithic Gleysol
72-/10	Turbic Gleysol

These are Gleysol soils affected by cryoturbation as manifested by disrupted and dislocated horizons, and with less than 1/3 of the profile showing displacement and incorporation of materials from other horizons and mechanical sorting.

CRYOSOL ORDER

This order consists of well to poorly drained soils developed in a permafrost environment. They must have one or both of the following:

a) displaced or disrupted horizons greater than 1/3 of the profile or incorporated organic matter resulting from cryogenic processes.

b) a mean annual soil temperature lower than -5^{o}C [mean annual air temperature lower than -8^{o}C (17^{o}F) or mean soil temperature at a depth of zero annual amplitude of -5^{o}C (Brown, 1968)]. A mean annual soil temperature lower than -5^{o}C and a mean annual air temperature lower than -8^{o}C coincides approximately with the southern boundary of the Continuous Permafrost Zone.

REGIC GREAT GROUP

These are well and imperfectly drained perennially frozen soils, having very weak horizon development.

<u>Orthic Regic Cryosol</u>

These soils have from the surface, or below any Ah horizon, color values that are uniform with depth, or color values that increase gradually to the depth of the control section (100 cm).

<u>Cumulic Regic Cryosol</u>

These soils have from the surface, or below any Ah horizon, color values that vary by one or more units with depth in the control section. The organic matter content usually decreases irregularly with depth.

-/9 Saline
-/6 Carbonated
-/9 Lithic
-/8 Gleyed
-/10 Turbic

BRUNIC GREAT GROUP

These are well to imperfectly drained perennially frozen soils with brownish-colored sola. They may have organic surface horizons (L-H) and weakly developed Aej or strongly developed Ae horizons. All have a brownish Bm, but none have a Bt or podzolic Bf horizon.

Orthic Brunic Cryosol

These soils have organic surface horizons (L-H), overlying a brownish Bm horizon.

Degraded Brunic Cryosol

These soils have either an Aej or Ae horizon and a brownish Bm horizon.

-/8 Gleyed
-/9 Lithic
-/10 Turbic

GLEYIC GREAT GROUP

These are poorly drained perennially frozen soils with peaty surface organic horizon and dull colored mineral horizons. Mottles may not be present if the permafrost table is at the surface of the mineral horizon.

Orthic Gleyic Cryosol

These soils have a gleyed B horizon.

Humic Gleyic Cryosol

These soils have an Ah horizon more than 8 cm. thick below the peaty surface organic horizon.

Rego Gleyic Cryosol

These soils are without a B and Ah horizon, or with an Ah horizon less than 8 cm thick.

-/9 Saline
-/6 Carbonated
-/9 Lithic
-/10 Turbic

CRYOTURBIC GREAT GROUP

These are well to poorly drained perennially frozen soils developed as a result of cryoturbic processes in a permafrost environment.

Orthic Cryoturbic Cryosol

These are soils where the profile has horizon discontinuity in less than 1/3 of the mineral element.

Miscic Cryoturbic Cryosol

These are soils where the profile has horizon discontinuity in greater than 1/3 of the mineral element.

- -/9 Saline
- -/6 Carbonated
- -/9 Lithic
- -/11 Separic
- -/13 Aquic

Degree of Profile Discontinuity

I Soils not meeting definition for Cryoturbisol use whole profile.

0 1/3 2/3 1

Turbic subgroups

Regosolic Order

II Soils meeting Cryoturbisol definition use only the mineral element.

0 1/3 2/3 1

Orthic subgroup

Miscic subgroup

III If we assume that the non-mineral element makes up about 1/3 of the soil body then considering the whole profile.

0 1/3 2/3 1

Regosolic Order

Turbic subgroups of Brunisolic, Gleysolic, Regosolic Orders; Regic, Gleyic and Regic Great Groups of IIa or non-Cryoturbic Great Group of IIb

Orthic Cryoturbisols

Miscic Cryoturbisols

DEFINITIONS

The cryoturbed horizons occurring in these soils are designated by "y", a horizon affected by cryoturbation as manifested by disrupted and dislocated horizons and displacement and incorporation of materials from other horizons. It is used with A, B and C horizons, e.g. Ahy, Bmy, Bmyg, Czy, Cgy, etc. These cryoturbed horizons are not always perennially frozen and thus the "y" does not necessarily occur in conjunction with "z" (to indicate a perennially frozen horizon).

Orthic - The soil profile has horizon continuity for greater than 2/3 of the mineral element.

Miscic - (from the Latin, miscere - to mix)

- The soil profile has horizon continuity over less than 2/3 of the mineral element.

Continic - mineral profile continuous with depth.

Separic - Cryogenic organic material separates the raised mineral element from the parent material.

Aquic - An over-moistened or saturated condition throughout the thawed portion of the profile. It was felt that this is a different concept from gley.

Turbic - Disrupted horizons occur in up to 1/3 of the soil body (1/3 disrupted horizons, and not a cryoturbisol, becomes a Regosol.)

Regic - like a Regosol

Brunic - like a Brunisol

Gleyic - like a Gleysol

Some guidelines to the identification of Cryoturbisols in the field.

a) Is it located in a permafrost area?

b) Are there associated microrelief features, particularly those in which all the elements formed concurrently? An example here is earth hummock formation.

c) Are cryoturbic disruptions of horizonation apparent, often typified by inclusion of organic matter (more or less unaltered)?

On this basis, an alluvial soil which now has permafrost aggrading into it would be classed as a Cryic Cumulic Regosol if there is no other aberrant feature apart from the permafrost. If some disruption of layers (up to 1/3) was present (due to say ice-wedging) the soil might be classed as a Cryic Turbic Cumulic Regosol. If, however, the surface subsequent to deposition has been completely modified by earth hummock formation then it would become a Cryoturbisol. If the hummock itself had very mixed horizons, the soil might be classed as a Cryic Miscic Cryoturbisol (left out Great Group because is same as Order).

Profile

The profile includes a contiguous portion of the micro-topographic feature or a portion of the feature up to a width of 2 meters.

Element

Portion of the soil profile. For example, mineral element, poorly drained element, etc.

REFERENCES

Allan, R.J., J. Brown and S. Rieger. 1969. Poorly drained soils with permafrost in interior Alaska. Soil Sci. Soc. Amer. Proc. 33:559-605.

Brown, J. 1967. Tundra soils formed over ice wedges, northern Alaska. Soil Sci. Soc. Amer. Proc. 31:686-691.

Brown, R.J.E. 1968. Occurrence of permafrost in Canadian peatlands. In: Proc. Third Int. Peat Congr., Quebec, Canada, 1968, 174-181.

Cruickshank, J.G. 1971. Soils and terrain units around Resolute, Cornwallis Island. Arctic 24:195-209.

Day, J.H. 1962. Pedogenic studies on soils containing permafrost in the Mackenzie River Basin. Proc. of the First Canadian Conference of Permafrost, 1962, 37-42.

Day, J.H. and H.M. Rice. 1964. The characteristics of some permafrost soils in the Mackenzie Valley, N.W.T. Arctic 17:223-236.

Drew, J.V. and J.C.F. Tedrow. 1957. Pedology of an arctic brown profile near Point Barrow, Alaska. Soil Sci. Soc. Am. Proc. 21:336-339.

Drew, J.V. and J.C.F. Tedrow. 1962. Arctic soil classification and patterned ground. Arctic 15:109-116.

FAO/UNESCO. 1968. Approaches to soil classification. World Soil Resources Report No. 32. FAO/UNESCO, Rome.

Fedorova, N.N. and E.A. Yarilova. 1972. Morphology and genesis of prolonged seasonally frozen soils of western Siberia. Geoderma 7:1-13.

Ivanova, E.N. 1963. Soils of Eastern Siberia. Translated from Russian, Israel Program for Scientific Translations, Jerusalem, 1969.

Ivanova, E.N. 1965. Frozen taiga soils of northern Yakutia. Soviet Soil Science No. 7, 733-744.

James, P.A. 1970. The soils of the Rankin Inlet area, Keewatin, N.W.T., Canada. Arctic and Alpine Res. 2:293-302.

Karavaeva, N.A. and V.O. Tarqul'yan. 1963. Contribution to the study of soils on the tundras of northern Yakutia. Soils of Eastern Siberia, edited by E.N. Ivanova, Moskva, 1963. (Translated from Russian, 1969), 57-78.

Karavaeva, N.A. 1963. Description of arctic-tundra soils on Bol'shoi Lyakhovskii I. (Novosibirskie Islands). Soils of Eastern Siberia, edited by E.N. Ivanova, Moskva, 1963 (Translated from Russian, 1969), 123-146.

Karavaeva, N.A., I.A. Sokolov, T.A. Sokolova and V.O. Tarqul'yan. 1965. Peculiarities of soil formation in the tundra taiga frozen regions of eastern Siberia and the far East. Soviet Soil Sci. No. 7, 756-766.

Leahey, A. 1947. Characteristics of soils adjacent to the Mackenzie River in the Northwest Territories of Canada. Soil Sci. Soc. Am. Proc. 12:458-461.

Mackay, J.R. 1958. A subsurface organic layer associated with permafrost in the western Arctic. Geographical Paper No. 18, Geographical Branch, Dept. of Mines and Tech. Surveys, Ottawa.

Morozova, T.D. 1965. Micromorphological characteristics of pale yellow permafrost soils of central Yakutia in relation to cryogenesis. Soviet Soil Science, No. 11, 1333-1342.

Sokolova, T.A. and I.A. Sokolov. 1963. The Mountain-Taiga soils of Eastern Transbaikalia. Soils of Eastern Siberia, edited by E.N. Ivanova, Translated from Russian. Israel Program for Scientific Translation, Jerusalem, 1969.

Tarnocai, C. In press. Soils of the Mackenzie River area. Environmental-Social Program, Task Force on Northern Oil Development. 137 pp.

Tarnocai, C. 1972. Exploratory terrain study of northern Manitoba and southern Keewatin, N.W.T. Manitoba Soil Survey, May, 1972.

Tedrow, J.C.F. and D.E. Hill. 1955. Arctic brown soil. Soil Sci. 8:265-275.

Tedrow, J.C.F. and J.E. Cantlon. 1958. Concepts of soil formation and classification in arctic regions. Arctic 11:166-179.

Tedrow, J.C.F., J.V. Drew, D.E. Hill and L.A. Douglas. 1958. Major genetic soils of the arctic slope of Alaska. J. of Soil Sci. 9:33-45.

Tedrow, J.C.F. 1965. Concerning genesis of the buried organic matter in tundra soil. Soil Sci. Soc. Amer. Proc. 29:89-90.

__________ 1962. Morphological evidence of frost action in arctic soils. Biulet. Peryglac. No. 11, 343-352.

__________ 1968. Pedogenic gradients of the Polar Regions. J. of Soil Sci. 19:197-204.

__________ 1966. Polar desert soils. Soil Sci. Soc. Amer. Proc. 30:381-387.

__________ 1963. Arctic Soils. Proceedings Permafrost International Conference, Nov., 1963. pp. 50-55.

The System of Soil Classification for Canada. 1970. Canada Dept. of Agric. 249 p.

Washburn, A.L. 1956. Classification of patterned ground and review of suggested origins. Bulletin of the Geological Society of America. 67:823-866.

Zoltai, S.C. and W.W. Pettapiece. In Press. Studies of vegetation, landform and permafrost in the Mackenzie Valley: terrain, vegetation and permafrost relationships in the northern part of the Mackenzie Valley and Northern Yukon. Env. Soc. Prog., Northern Pipelines Task Force, Gov. of Can., 98 pp.

Summary of Comments

(Cryoturbed soils in Northern Canada)

This presentation stimulated a great deal of discussion and it was agreed that the proposed system would be studied during the next two years and then a proposal would be presented at the next Canadian Soil Survey Committee meeting. This could be done by forming a working group on northern soils. This group would also be responsible for working out a temporary solution which could be utilized during the on-going studies in this two-year period.

Appended is a report of the Northern Soils Working Group dated November, 1973 which presents a "Tentative Classification System for Cryosolic Soils".

RAPPORT DU COMITE DE LA CLASSIFICATION DES FORMES DE RELIEF

D.F. Acton, Président

Résumé

Un glossaire de la terminologie est soumis pour qu'on puisse vérifier s'il est complet, acceptable et approprié. On recommande la mise à l'essai d'un système de classification régional des formes du relief, basé surtout sur le système de Bostock et d'un système de classification local des formes du relief.

REPORT OF THE SUBCOMMITTEE ON THE CLASSIFICATION OF LANDFORMS

D.F. Acton, Chairman

Summary

A glossary of terminology is included for critical evaluation in terms of completeness, acceptability and suitability. A regional landform classification system based generally on Bostock system, and a local landform classification system, are recommended for trial.

Review:

Various attempts have been made by this subcommittee in the past to develop landform terminology and systematics with the intention being application to soil surveys in Canada. Some of these attempts have been reviewed elsewhere (1).

At the eighth meetings of the Canada Soil Survey Committee, it was recommended that membership on the landform subcommittee be broadened to include representation from the National Committee on Forest Lands and the Geological Survey of Canada. Although no formal organization or group has been established, there has been considerable co-operation with R.J. Fulton and other members of the Geological Survey of Canada.

At the second meeting of the Western Section of the Canada Soil Survey Committee, held at Kelowna in 1972, three landform classification systems were presented and discussed. These schemes presented by Fulton, Lavkulich et al. and Acton and the pertinent discussion are presented in the proceedings of these meetings (2).

Based on a recommendation from these Kelowna meetings, an additional landform description and classification system was developed and circulated to the subcommittee as well as to a number of ecologists and earth scientists (3).

It should also be reported that a NRC Committee on terrain classification met in Calgary in May, 1972 (4). At this meeting concern was expressed regarding standardization of terminology and procedure in terrain evaluation. This group felt that, although multidisciplinary uniformity of terminology and description was possible, uniformity of classification might be much more difficult to obtain. Part of one of the recommendations forthcoming from this meeting suggested that action be taken to prepare a suitable terminology for use in terrain classification. Two multidisciplinary groups were to be appointed; one to undertake the preparation of a glossary with primary concern with mineral terrain with an essential geologic-geomorphic basis and the other to be primarily concerned with a glossary of organic terrain features.

Two apparent developments were forthcoming from the above-mentioned NRC Ad Hoc committee meeting. Firstly, Prof. W.O. Kupsch, Director, Institute for Northern Studies has been charged with developing a glossary of terminology for mineral terrains. A broad selection of terms and appropriate definitions has been completed. This is currently being screened to compile a more concise second approximation. The terms in this glossary are listed in much the same manner as Dr. Kupsch's and Dr. Brown's Permafrost Glossary (5). Secondly, a group of Saskatchewan scientists interested in the development of a systematic, interdisciplinary landform classification (E.A. Christiansen, J.D. Mollard, W.O. Kupsch, B.W. Mickleborough, J.S. Rowe, D.W. Anderson, H.B. Stonehouse, L.S. Crosson and D.F. Acton) have examined problems associated with such a development through correspondence and formal discussion, as suggested by the NRC Ad Hoc Committee.

In preparation for the current meetings of the Canada Soil Survey Committee, members of the landform subcommittee were asked, in a memo dated December 7, 1972, to indicate whether the basic philosophy implied in the March 18 system mentioned above (3) was acceptable. As suggested in a further memo, dated March 9, 1973, there was a wide diversity of opinion on the whole matter of landform classification. In view of this it was suggested that more effort must be placed on terminology before real progress would be forthcoming on systematic arrangements of terminology for use in mapping. A partial glossary was developed at this time employing terminology that is in common usage in Canada. The most recent glossary of geology (6) was used as the standard reference for definition of the terms. To demonstrate how an acceptable list of well defined terms could facilitate a systematic organization for mapping purposes and for soil data banks, several hypothetical groupings were developed.

The suggestion to concentrate on terminology before devoting too much effort to systematics was generally well received. L.M. Lavkulich, A.G. Twardy, C. Tarnocai, R.J. Fulton and P. Heringa (all with reservations of one form or another) favored concentrating on terminology. John Gillespie and the group at Guelph thought the system proposed on March 8, 1972, should be put forward on trial whereas the Soil Resource Group of the Soil Research Institute generally felt (perhaps some more so than others) that a very serious attempt should be made to strive for a system that can be useful for both pedologists and geologists for mapping and for the CanSIS program as well. They consequently suggested a system be put forward for a trial period.

Proposal:

1. To develop an acceptable glossary for landform description and mapping for soil surveys in Canada.

2. To present a tentative comprehensive landform classification system for soil surveys in Canada.

Rational:

The need for clear, concise description of the landform individuals is the first and most obvious prerequisite to the development of a systematic arrangement of these individuals into some organized fashion. Some system of naming these individuals is an apparent second step. The naming process may, or may not, be dependent upon the systematic organization of knowledge pertaining to these individuals.

The proposal to develop a glossary of terminology should facilitate defining the individuals and may aid in naming these individuals. Once these steps are adequately met, the individuals or taxa may be logically grouped but perhaps new names may be desirable for the individuals, depending upon the system devised.

The proposed classification systems organize a number of widely recognized individuals using terminology that frequents the earth science literature. In so doing the omission of individuals, suitability of names for individuals, definition or description of the individuals and the organization of groups of similar individuals should all be more readily apparent.

Glossary of Terminology

1. Regional (Physiographic) Glossary

Basin - A depressed area having no surface outlet.

Borderland - According to a concept widely held in the first part of the 20th Century, and championed by Schuchert (1923), a crystalline landmass that bordered (farther out) the Phanerozoic orogenic belts near the edges of the North American continent. The borderlands were tectonically much more active than the Canadian Shield, and were subsequently lost by foundering into the oceans. The concept is now discredited; continental crust ends near the edges of the continental shelves, and it would be difficult to founder large areas of such crust into the ocean basins beyond. Most of the geological evidence adduced for these lands can be otherwise interpreted. Cf: hinterland; tectonic land. See also: Appalachia; Cascadia; Llanoria.

Coastal - Pertaining to a coast; bordering a coast, or located on or near a coast, as coastal waters or coastal lowland.

Coastal plain - (a) A low, generally broad but sometimes narrow plain that has its margin on the shore of a large body of water (especially the ocean) and its strata either horizontal or very gently sloping toward the water, and that generally represents a strip of recently emerged sea floor or continental shelf. (b) Less restrictedly, any lowland area bordering a sea or ocean, extending inland to the nearest elevated land, and sloping very gently seaward. It may result from the accumulation of material.

Delta - The low, nearly flat, alluvial tract of land deposited at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable area enclosed and crossed by many distributaries of the main river, perhaps extending beyond the general trend of the coast, and resulting from the accumulation in a wider body of water (usually a sea or lake) of sediment supplied by a river in such quantities that it is not removed by tides, waves, and currents. Most deltas are partly subaerial and partly below water. The term was introduced by Herodotus in the 5th century B.C. for the tract of land, at the mouth of the Nile River, whose outline broadly resembled the Greek capital letter "delta", Δ, with the apex pointing upstream.

Foothills - A region of relatively low, rounded hills at the base of or fringing a mountain range.

Highland - (a) A general term for a relatively large area of elevated or mountainous land standing prominently above adjacent low areas; a mountainous region. (b) A relative term denoting the higher land of a region; it may include mountains, valleys, and plains.

Hill - (a) A natural elevation of the land surface, rising rather prominently above the surrounding land, usually of limited extent and having a well-defined outline (rounded rather than peaked or rugged), and generally considered to be less than 300 m (1000 ft) from base to summit; the distinction between a hill and a mountain is arbitrary and dependent on local usage. See also: mount. (b) Any slightly elevated ground or other conspicuous elevation in a relatively flat area. (c) An eminence of inferior elevation in an area of rugged relief. (d) A range or group of hills, or a region characterized by hills or by a highland. Term usually used in the plural; e.g. the Black Hills of South Dakota.

Lowland - (a) A general term for low-lying land or an extensive region of low land, especially near the coast and including the extended plains or country lying not far above tide level. (b) The low and relatively level ground of a region, in contrast with the adjacent, higher country. (c) A low or level tract of land along a water-course; a bottom. -- The term is usually used in the plural.

Mountain - (a) Any part of the Earth's crust higher than a hill, sufficiently elevated above the surrounding land surface of which it forms a part to be considered worthy of a distinctive name, characterized by a restricted summit area (as distinguished from a plateau), and generally having comparatively steep sides and considerable bare-rock surface; it can occur as a single, isolated eminence, or in a group forming a long chain or range, and it may form by earth movements, erosion, or volcanic action. Generally, a mountain is considered to project at least 300 m (1000 ft) above the surrounding land, although older usage refers to an altitude of 600 m (2000 ft) or more above sea level. When the term is used following a proper name, it usually signifies a group of elevations, such as a range (e.g. the Adirondack Mountains) or a system (e.g. the Rocky Mountains). Abbrev: mt.; mtn. Syn: mount. (b) Any conspicuous or prominent elevation in an area of low relief, esp. one rising abruptly from the surrounding land and having a rounded base.

Plain - (a) Broadly, any flat area, large or small, at a low elevation; specif. an extensive region of comparatively flat, smooth, and level or gently undulating land, having few or no prominent surface irregularities (hills, valleys) but sometimes having a considerable slope, and usually at a low elevation with reference to surrounding areas (local relief up to 60-150 m, although some, as the Great Plains of the U.S., are as much as 1000-1800 m above sea level). A plain may be either forested or bare of trees, and may be formed by deposition or by erosion. (b) A very extensive, broad tract of level or rolling, almost treeless country with a shrubby vegetation; a prairie. In Australia, "plain" implies treelessness. The term is usually used in the plural. (c) A region underlain by low-lying horizontal strata or characterized by horizontal structure, and which may be dissected into hills and valleys by stream erosion; Davis (1885) introduced this concept of a "plain" but the term should be used without regard to the underlying geologic structure.--Cf: plateau [geomorph] .

Plateau [geomorph] (a) Broadly, any comparatively flat area of great extent and elevation; specif. an extensive land region considerably elevated (more than 150-300 m in altitude) above the adjacent country or above sea level and commonly limited on at least one side by an abrupt descent, having a flat or nearly smooth surface but often dissected by deep valleys or canyons and surmounted by ranges of high hills or mountains, and having a large part of its total surface at or near the summit level. A plateau is usually higher and has more noticeable relief than a plain (it often represents an elevated plain), and is usually higher and more extensive than a mesa; it may be tectonic, residual, or volcanic in origin. See also: tableland. (b) A flat, upland region underlain by horizontal strata or characterized by horizontal structure, and which may be highly dissected; Davis (1885) introduced this concept of a "plateau" but the term should be used without regard to the underlying geologic structure.--Etymol: French. Pl: plateaus; plateaux.

Shield - A large area of exposed basement rocks in a craton commonly with a very gently convex surface, surrounded by sediment-covered platforms.

Trench - A long, straight, relatively narrow, U-shaped valley or depression between two mountain ranges, often occupied by parts of two or more streams alternately draining the depression in opposite directions.

Upland - (a) A general term for high land or an extensive region of high land, esp. far from the coast or in the interior of a country. Sometimes used synonymously with fastland. (b) The higher ground of a region, in contrast with a valley, plain, or other low-lying land; a plateau. (c) The elevated land above the low areas along a stream or between hills; any elevated region from which rivers gather drainage. Also, an area of land above flood level, or not reached by storm tides.---Ant: lowland.

Volcanics - Those igneous rocks that have reached or nearly reached the Earth's surface before solidifying.

2. Local Form and Material Glossary - to include major form and materials with a genetic inference.

Alluvial - adj. Pertaining to or composed of alluvium, or deposited by a stream or running water; e.g. an "alluvial clay" or an "alluvial divide". Syn: alluvian; alluvious.---n. alluvium.

/Alluvium - (a) A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope; esp. such a deposit of fine-grained texture (silt or silty clay) deposited during time of flood. The term does not require permanent submergence; and it formerly included (but is not now intended to include) subaqueous deposits in seas, estuaries, lakes, and ponds. Syn: alluvial; alluvial deposit; alluvion. (b) A driller's term used "incorrectly" for the broken, earthy rock material directly below the soil layer and above the solid, unbroken bed or ledge rock (Long, 1960). (c) alluvial soil. --- Etymol: Latin alluvius, from alluere, "to wash against". Pl: alluvia; alluviums. Cf: eluvium; diluvium.

Colluvial - Pertaining to colluvium; e.g. "colluvial deposits" or "colluvial soil".

/Colluvium - (a) A general term applied to any loose, heterogeneous, and incoherent mass of soil material or rock fragments deposited chiefly by mass-wasting, usually at the base of a steep slope or cliff; e.g. talus, cliff debris, and avalanche material. (b) Alluvium deposited by unconcentrated surface runoff or sheet erosion, usually at the base of a slope. -- Cf: slope wash. Etymol: Latin colluvies, "collection of washings, dregs".

Eolian - (a) Pertaining to the wind; esp. said of rocks, soils, and deposits (such as loess, dune sand, and some volcanic tuffs) whose constituents were transported (blown) and laid down by atmospheric currents, or of landforms produced or eroded by the wind, or of sedimentary structures (such as ripple marks) made by the wind, or of geologic processes (such as erosion and deposition) accomplished by the wind. (b) Said of the active phase of a dune cycle, marked by diminished vegetal control and increased dune growth. Cf: eluvial [sed] .---Etymol: Aeolus, god of the winds. Syn: aeolian; eolic.

Fluvial - (a) Of or pertaining to a river or rivers. (b) Existing, growing, or living in or about a stream or river. (c) Produced by the action of a stream or river.---The term is used by geologists esp. in regard to river flow and river action. See also: fluviatile. Etymol: Latin fluvius, "river".

Fluvioeolian - Pertaining to the combined action of streams and wind; e.g. a fluvioeolian deposit.

Fluviolacustrine - Pertaining to sedimentation partly in lake water and partly in streams, or to sediments deposited under alternating or overlapping lacustrine and fluvial conditions.

Fluviomarine - Said of marine sediments that contain resorted and redistributed fluvial material along with the remains of marine organisms.

Glaciofluvial - Pertaining to the meltwater streams flowing from wasting glacier ice and esp. to the deposits and landforms produced by such streams, as kame terraces and outwash plains; relating to the combined action of glaciers and streams. Syn: fluvioglacial; glacioaqueous.

Glaciolacustrine - Pertaining to, derived from, or deposited in glacial lakes; esp. said of the deposits and landforms composed of suspended material brought by meltwater streams flowing into lakes bordering the glacier, as delta kames and varved sediments.

Glaciomarine - glacial marine.

Lacustrine - (a) Pertaining to, produced by, or formed in a lake or lakes; e.g. "lacustrine sands" deposited on the bottom of a lake, or a "lacustrine terrace" formed along the margin of a lake. (b) Growing in or inhabiting lakes; e.g. "lacustrine fauna". (c) Said of a region characterized by lakes; e.g. a "lacustrine desert" containing the remnants of numerous Pleistocene lakes that are now dry.---Cf: limnic. Syn: lacustral; lacustrian.

Marine* - Of the sea or ocean; inhabiting, found in, or formed by the sea.

Morainal - Of, relating to, forming, or formed by a moraine. Syn: morainic.

/Moraine - A mound, ridge, or other distinct accumulation of unsorted, unstratified glacial drift, predominantly till, deposited chiefly by direct action of glacier ice in a variety of topographic landforms that are independent of control by the surface on which the drift lies. The history of the term is confused: it was probably used originally, and is still often used, in European literature as a petrologic name for till that is being carried and deposited by a glacier, but is now more commonly used as a geomorphologic name for a landform composed mainly of till that has been deposited by either a living or an extinct glacier. Etymol: French, a term used by Alpine peasants in the 18th century for any heap of earth and stony debris; neither the exact origin of the term nor its first use in glacial geology can be traced.

Organic - Pertaining or relating to a compound containing carbon, especially as an essential component. Organic compounds usually have hydrogen bonded to the carbon atom. Cf: inorganic.

Rock [geol] - (a) Any naturally formed, consolidated or unconsolidatedmaterial (but not soil) composed of two or more minerals, or occasionally of one mineral, and having some degree of chemical and mineralogic constancy; also, a representative sample of such material. (b) Popularly, any hard, consolidated material derived from the Earth and usually of relatively small size. Partial syn: stone [geol] .

Rock [geomorph] - (a) Any notable, usually bare peak, cliff, promontory, or hill considered as one mass; e.g. the rock of Gibraltar. (b) A rocky mass lying at or near or projecting above the surface of a body of water.

3. Morphologic Expression Glossary - to include forms generally recognizable by morphology alone.

Apron - An extensive, continuous, outspread, blanket-like deposit of alluvial, glacial, eolian, marine, or other unconsolidated material derived from an identifiable source, and deposited at the base of a mountain, in front of a glacier, etc.; e.g. a bajada or an outwash plain. Syn: frontal apron.

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*Webster's New World Dictionary, College Edition.

Basin - A depressed area having no surface outlet.

Delta - The low, nearly flat, alluvial tract of land deposited at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable area enclosed and crossed by many distributaries of the main river, perhaps extending beyond the general trend of the coast, and resulting from the accumulation in a wider body of water (usually a sea or lake) of sediment supplied by a river in such quantities that it is not removed by tides, waves, and currents. Most deltas are partly subaerial and partly below water. The term was introduced by Herodotus in the 5th century B.C. for the tract of land, at the mouth of the Nile River, whose outline broadly resembled the Greek capital letter "delta", Δ, with the apex pointing upstream.

Depression - Any hollow in or relatively sunken part of the Earth's surface; esp. a low-lying area completely surrounded by higher ground and having no natural outlet for surface drainage; as an interior basin or a karstic sink.

Fan - (a) A gently sloping, fan-shaped mass of detritus forming a section of a very low cone commonly at a place where there is a notable decrease in gradient; specif. an alluvial fan. (b) A fan-shaped mass of congealed lava that formed on a steep slope by the continually changing direction of effusions.

Flat - adj. Having or marked by a continuous surface or stretch of land that is smooth, even, or horizontal, or nearly so, and that lacks any significant curvature, slope, elevations, or depressions.---n. A general term for a level or nearly level surface or small area of land marked by little or no relief, as a plain; specif: mud flat; valley flat. Also, a nearly level region that visibly displays lower relief than its surroundings.

Fluted - Abounding in large, smooth, deep gutter-like channels or furrows on the stoss side of a rocky hill obstructing the advance of a glacier. (Slopes may be several miles in length along ridge crest but generally less than 0.5 mile normal to crest. Gradient of normal slope less than 5% and relief less than 10 feet). Part included in brackets has been added to the American Geological Institute definition.

Hill Land -

/Hilly - (a) Descriptive of a region characterized by an abundance of hills. (b) Resembling the inclination or character of a hill.

/Hill - (a) A natural elevation of the land surface, rising rather prominently above the surrounding land, usually of limited extent and having a well-defined outline (rounded rather than peaked or rugged), and generally considered to be less than 300 m (1000 ft) from base to summit; the distinction between a hill and a mountain is arbitrary and dependent on local usage. See also: mount. (b) Any slightly elevated ground or other conspicuous elevation in a relatively flat area. (c) An eminence of inferior elevation in an area of rugged relief. (d) A range or group of hills, or a region characterized by hills or by a highland. Term usually used in the plural; e.g. the Black Hills of South Dakota. May be qualified by rolling, ridged and hummocky.

Hummocky - Abounding in rounded or conical knolls, mounds, or other small elevations, generally equidimensional shape and not ridge-like. (Refers to a condition of slopes less than 0.5 miles in length, local relief greater than 10 feet and dominant slope gradient greater than 5%). Part in brackets added to American Geological Institute definition.

Level - n. Any large expanse of relatively flat, usually (but not necessarily) low-lying country, unbroken by noticeable elevations or depressions; specif. any flat, alluvial tract of recent formation, such as the Bedford Level in Lincolnshire, Eng.

Mountainous - (a) Descriptive of a region characterized by mountains or mountain ranges. (b) Resembling a mountain, such as a mountainous dome that is strongly elevated and around whose flanks the strata are steeply dipping.

Pitted/Pit - A small indentation or depression left on the surface of a rock particle (esp. of a clastic particle) as a result of some eroding or corrosive process, such as etching or differential solution.

Plain - An extensive region of comparatively flat, smooth, and level or gently undulating land, having few or no prominent surface irregularities but sometimes having a considerable slope, and usually at a low elevation with reference to surrounding areas. (When unqualified infers nearly level condition with slopes of infinite length with less than 2% gradient; may be qualified by "undulating" which would include a condition of irregular slopes less than 0.5 miles in length, local relief less than 10 feet and dominant gradient less than 5%, by "fluted" which would include streamlined ridges perhaps several miles in length, local relief less than 10 feet and dominant gradient less than 5% or by "rolling" which would include irregular, smooth slopes often greater than 0.5 miles in length, local relief 10-30 feet and dominant gradient 5-20%). Part in brackets added to the American Geological Institute definition.

Ridged - A long, narrow elevation of the Earth's surface, usually sharp crested with steep sides, occurring either as an independent hill or as part of a larger hill. (As contrasted to fluted refers to a condition of parallel, sub-parallel, intersecting or circular ridges of slopes less than 0.5 miles in length, gradient greater than 5% and local relief greater than 10 feet). Part in brackets added to American Geological Institute definition.

Rolling - Abounding in irregular, smooth slopes of relatively low frequency in which slope length is often one mile or greater, relief greater than 10 feet and gradients greater than 5%. (Original definition).

Terrace - (a) Any long, narrow, relatively level or gently inclined surface, generally less broad than a plain, bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope; a large bench or step-like ledge breaking the continuity of a slope. The term is usually applied to both the lower or front slope (the riser) and the flattish surface (the tread), and it commonly denotes a valley-contained, aggradational form composed of unconsolidated material as contrasted with a bench eroded in solid rock. A terrace commonly occurs along the margin and above the level of a body of water, marking a former water level; e.g. a stream terrace. (b) A term commonly but incorrectly applied to the deposit underlying the tread and riser of a terrace, esp. the alluvium of a stream terrace; "this deposit ... should more properly be referred to as a fill, alluvial fill, or alluvial deposit, in order to differentiate it from the topographic form" (Leopold et al, 1964, p. 460). (c) structural terrace.

Undulating - Abounding in irregular, smooth slopes less than 0.5 miles in length, local relief less than 10 feet and dominant gradient less than 5%. (Original definition).

Valley [geomorph] (a) Any low-lying land bordered by higher ground; esp. an elongate, relatively large, gently sloping depression of the Earth's surface, commonly situated between two mountains or between ranges of hills or mountains, and often containing a stream with an outlet. It is usually developed by stream erosion, but may be formed by faulting. (b) A broad area of generally flat land extending inland for a considerable distance, drained or watered by a large river and its tributaries; a river basin. Example: the Mississippi Valley.--- Etymol: Latin vallis. Syn: vale; dale.

4. Modifier Glossary - to include relatively minor or current processes operative on a pre-existing form, such that the original form is not strongly altered.

Beveled/Bevel - Any surface that has or appears to have been planed off or beveled, such as the flat surface along the crest of a cuesta; esp. an inclined surface that meets another at an angle other than at right angles, such as the moderately steep and straight to convex slope produced by subaerial erosion above the vertical face of a sea cliff.

Blanketed/Blanket - A thin, widespread sedimentary body whose width/thickness ratio is greater than 1000 to 1, and may be as great as 50,000 to 1 (Krynine, 1948, p. 146). Cf: tabular. Syn: sheet [sed] .

Braided/Braid - v. To branch and rejoin repeatedly to form an intricate pattern or network, as of channels of an overloaded stream.

n. A reach of a braided stream, characterized by relatively stable branch islands and hence two or more separate channels. Cf: anabranch.

Congeliflucted/Congelifluction - The progressive and lateral flow of earth material under periglacial conditions; solifluction in a region underlain by frozen ground. Syn: gelifluction; gelisolifluction.

Congeliturbated/Congeliturbation - A collective term suggested by Bryan (1946, p. 640) to describe the stirring, churning, modification, and all other disturbances of soil, resulting from frost action; it involves frost heaving, solifluction, and differential and mass movements, and it produces patterned ground. Syn: cryoturbation; frost stirring; frost churning; geliturbation.

Dissected/Dissection - The process of erosion whereby the continuity of a relatively even topographic surface is gradually sculptured or destroyed by the formation of gullies, ravines, canyons, or other kinds of valleys; esp. the work of streams in cutting or dividing the land into hills and ridges, or into flat upland areas, separated by fairly close networks of valleys. The process is applicable esp. to surfaces, such as plains and peneplains, that have been uplifted. Adj: dissected.

Eroded/Erode - (a) To wear away the land, as by the action of streams, waves, wind, or glaciers. (b) To produce or modify a landform by the wearing away of the land.

Glaciated - Said of a formerly glacier-covered land surface, esp. one that has been modified by the action of a glacier or an ice sheet, as a glaciated rock knob. Cf: glacier-covered.

Grooved/Glacial groove - A deep, wide, usually straight furrow cut in bedrock by the abrasive action of a rock fragment embedded in the bottom of a moving glacier; it is larger and deeper than a glacial striation, ranging in size from a deep scratch to a glacial valley.

Mantled/Mantle - A general term for an outer covering of material of one kind or another, such as a regolith; specif. waste mantle.

Mass Wasted/Mass Wasting - A general term for the dislodgement and downslope transport of soil and rock material under the direct application of gravitational body stresses. In contrast to other erosion processes, the debris removed by mass wasting processes is not carried within, on, or under another medium possessing contrasting properties. The mass strength properties of the material being transported depend on the interaction of the soil and rock particles with each other. It includes slow displacements such as creep and solifluction and rapid movements such as earthflows, rockslides, avalanches, and falls. Cf: mass erosion. Syn: mass movement.

Soliflucted/Solifluction - (a) The slow (normally 0.5-5.0 cm/yr), viscous, downslope flow of waterlogged soil and other unsorted and saturated surficial material; esp. the flow occurring at high elevations in regions underlain by frozen ground (not necessarily permafrost) acting as a downward barrier to water percolation, initiated by frost action and augmented by meltwater resulting from alternate freezing and thawing of snow and ground ice. The term was proposed by Anderson (1906, p. 95-96) as "the slow flowing from higher to lower ground of masses of waste saturated with water", but as he did not state explicitly that it referred to flow over frozen ground, the term has been extended to include similar movement in temperate and tropical regions; also, it has been used as a syn. of soil creep although solifluction is generally more rapid. It is preferable to restrict the term to slow soil movement in periglacial areas. Syn: soil flow; solifluxion; soil fluction; sludging. (b) subaqueous solifluction.

Veneered/Veneer - (a) A thin but extensive layer of sediments covering an older geologic formation or surface; e.g. a veneer of alluvium covering a pediment. (b) A weathered or otherwise altered coating on a rock surface, e.g. desert varnish.

Washed/Wash [sed] - (a) Loose or eroded surface material (such as gravel, sand, silt) collected, transported, and deposited by running water, as on the lower slopes of a mountain range; esp. coarse alluvium. (b) A fan-shaped deposit, as an alluvial fan or an alluvial cone, or a mound of detritus below a cliff opening. (c) downwash.

Washed/Wash [geomorph] - (a) Erosion effected by wave action. (b) The wearing away of soil by runoff water, as in gullying or sheet erosion; rainwash.

Mapping Classification for Regional (Physiographic) Landforms

Although our greatest concern is likely to be at a more specific, local level it is always necessary in a national context to consider these local landforms in some regional framework.

Fulton (2) considered mountains, hills, uplands, midlands, lowlands and valleys as major unit terms of regional landforms. He used mountainous, hilly, rolling, hummocky and plain as relief modifier terms.

Acton (3) modified this to the extent that he deleted hills and valleys as major regional landform units but included these terms along with plain, plateau, trench and range as minor regional landform units.

In that Bostock (7) has developed a map and description of the physiographic regions of Canada, it would appear that, initially at least, an attempt should be made to follow this reference for regional landforms.

It should be clearly understood in the above that the intent is to try and follow, as closely as possible, the approach taken by Bostock. It must be recognized that he published his information at 1:5,000,000. There is every reason to expect, for instance, that people in the Great Plains may wish to separate a series of hills from the Manitoba, Saskatchewan or Alberta Plains, just as he has separated the Cypress Hills. (This has already been done in certain instances, Cf: Acton et al. (8)).

A second question involves the application of this physiographic approach to CanSIS. Each physiographic subdivision could be given a unique coding. A second alternative would involve formulating a classification from the mapping legend whereby all "Borderland Plains" would be classified as similar units, distinctly different from "Shield Plains" or "Borderland Plateaux", etc.

The regional (physiographic) glossary should provide the terminology and some of the essential definition and description for the development of a regional classification system. It is proposed that the mapping classification of Bostock be accepted on a trial basis. This classification is presented below.

Table 1. An outline of a regional landform classification system (after Bostock)

Shield	Borderlands
Highlands	Mountains
Mountains	Highlands
Uplands	Uplands
Plateaux	Hills, Foothills
Hills	Plateaux
Lowlands	Basins
Coastal Lowlands	Lowlands
Plains	Plains
	Coastal Lowlands
	Coastal Plains
	Deltas
	Trenches
	Volcanics

Mapping Classification for Local Landforms

A mapping classification for local landforms has also been developed. The system, presented below, follows many of the basic principles used by Fulton (2), as well as those employed earlier on soil survey maps in Saskatchewan (9), although it is much more comprehensive than the latter.

The system employs terms listed under the local landform and material glossary as being the major units. These major units may contain a variety of morphologic deviations, definitions of which are listed under the morphologic expression glossary. An outline of the system being proposed is presented below. It contains nine major landform-material categories, differing from Fulton (2) by: distinguishing more recent "alluvial" from the glacio-fluvial, including the unconsolidated component in "softrock" and "hardrock" forms. Several morphologic expressions have also been either added or deleted to those proposed by Fulton. An undulating plain, fluted plain, apron, mountainous and valley represent added morphologic expressions, whereas veneer represents a deleted form. (Several of these changes represent changes suggested by Fulton subsequent to the publication of his initial proposal while others represent changes that I have taken the liberty of making).

Although they have not been incorporated into the local landform classification system presented above, terms from the modifier glossary may be added to the combined name derived from the two previous local form glossaries. For instance, a veneered rolling moraine, a glaciated rock plain, or a dissected glacio-lacustrine plain may be considered.

Recommendations

1. That terminology contained in each of the individual glossaries be closely scrutinized by each unit for: a) completeness, b) acceptability of terms, and c) suitability of definitions.

2. That the four glossaries be accepted on an interim basis, pending full development of the NRC sponsored glossary.

3. That a regional classification system following the principles and general outline employed by Bostock, as presented in Table 1 and using the terminology as presented in the Regional Glossary, be adopted for trial.

4. That the local landform classification system presented in Table 2, using terminology contained in the Landform and Material Glossary and the Modifier Glossary, be adopted for trial.

5. That "adopted for trial", referred to above, should not be interpreted to mean that each and every soil survey group cease to use their present system of landform mapping. Each unit would, however, be expected to conduct or demonstrate some of their field mapping and site descriptions for soil analyses using the proposed system on an experimental basis to provide an appraisal of the system. That these appraisals be made prior to the 1974 field season.

6. That the responsibility for the continued development of a landform classification system be empowered in someone whose terms of reference are such as to permit exposure to all regions of Canada.

7. A program of geomorphological training for soil surveyors be instigated to facilitate a more comprehensive understanding of geomorphic processes and the application of geomorphologic principles to soil surveys.

Table 2. A proposed local landform classification system for Canadian soil surveys

Morphologic Expression	Landform and Materials				
	M - Morainal	L - Lacustrine*	F - Fluvial*	A - Alluvial	E - Eolian
Plain	Mp - Morainal Plain	Lp - Lacustrine Plain	Fp - Fluvial Plain	Ap - Alluvial Plain	Ep - Eolian Plain
Undulating	Mu - Undulating Morainal Plain	Lu - Undulating Lacustrine Plain	Fu - Undulating Fluvial Plain		Eu - Undulating Eolian Plain
Fluted	Mf - Fluted Morainal Plain				
Hummocky	Mh - Hummocky Morainal Hill land	gLh - Hummocky Glacio-lacustrine Hill land	gFh - Hummocky Glacio-fluvial Hill land		Eh - Hummocky Dunes
Ridged	Mr - Ridged Morainal Hill land	gLr - Ridged Glacio-lacustrine Hill land	gFr - Ridged Glacio-fluvial Hill land		Er - Ridged Dunes
Rolling	Mg - Rolling Morainal Hill land	gLg - Rolling Glacio-lacustrine Hill land	gFg - Rolling Glacio-fluvial Hill land		
Terrace		Lt - Lacustrine Terrace	gFt - Glacio-fluvial Terrace	At - Alluvial Terrace	
Fan				Af - Alluvial Fan	
Beach		Lb - Lacustrine Beach			
Mountainous	Mm - Mountainous Moraine				
Valley			Fv - Glacio-fluvial Valley		

Table 2. (continued)

Morphologic Expression	Landform and Materials				
	C - Colluvial	W - Marine	R - Consolidated Bedrock	S - Unconsolidated Bedrock	O - Organic
Plain		Wp - Marine Plain	Rp - Rock Plain	Sp - Softrock Plain	Op - Organic Plain
Undulating		Wu - Undulating Marine Plain	Ru - Undulating Rock Plain	Su - Undulating Softrock Plain	Ou - Undulating Organic Plain
Hummocky	Ch.- Hummocky Colluvial Hill land	gWh - Hummocky Glacio-marine Hill land		Sh - Hummocky Softrock land	Oh - Hummocky Organic Plain
Ridged	Cr - Ridged Colluvial Hill land	gWr - Ridged Glacio-marine Hill land			
Rolling			Rg - Rolling Rockland	Sg - Rolling Softrock land	
Terrace		Wt - Marine Terrace			
Fan	Cf - Colluvial Fan				
Beach		Wb - Marine Beach			
Apron	Ca - Colluvial Apron				
Mountainous	Cs - Mountainous Colluvial land				

*If glacial processes are also to be depicted for forms not already specified the suggested symbol could contain a lower case "g", perhaps as a prefix.

References

1. Acton, D.F. 1972. Classification of Landforms for Soil Surveys in Canada. Report on the Second Meeting of the Western Section of the Canada Soil Survey Committee. p. 22-48.

2. Anon. Report on the Second Meeting of the Western Section of the Canada Soil Survey Committee. Held at Kelowna, British Columbia, February 15-17, 1972.

3. Acton, D.F. Landform Description and Classification. Unpublished Circular. March 18, 1972.

4. Anon. Records of the Meeting of the NRC Ad Hoc Committee on Terrain Classification at Calgary. May 12, 1972. Unpublished Circular.

5. Kupsch, W.O. Personal Communication.

6. Anon. (1972) Glossary of Geology. Margaret Gary, Robert McAfee Jr., and Carol L. Wolf, editors. American Geological Institute, Washington, D.C. 805 pages with an additional 52 pages of bibliography.

7. Bostock, H.S. 1970. Physiographic Subdivision of Canada in Geology and Economic Minerals of Canada. R.J.W. Douglas, Scientific Editor. Economic Geology Report No. 1, Dept. Energy Mines and Resources, Canada. p. 11-30.

8. Acton, D.F., J.S. Clayton, J.G. Ellis, E.A. Christiansen and W.O. Kupsch. 1960. The Physiographic Divisions of Saskatchewan, Map No. 1. Saskatchewan Research Council.

9. Ellis, J.G., D.F. Acton and H.C. Moss. 1967. The Soils of the Willow Bunch Lake Map Area. Sask. Institute of Pedology, Publ. S2. pp. 97.

DISCUSSION:

Clark - stated that we have gone about as far as we can at this time with research exercises. He also observed that in soil survey operations things did not get put to work unless they were adopted for trial, use, evaluation and development.

Raad - observed that during the last four years he has found the proposed system very workable but added that the landform classification should be based on a watershed.

Zoltai - asked to know the definition of a landform, amplifying on this question by saying that some people include the form of the land and perhaps also the genesis of the landform. In his opinion this introduces a genetic bias into the classification which is an undesirable attribute. He stated that emphasis should be placed on the geomorphology of the landform. He states that the proposed system puts the onus on the observer to be very sure that the genetic statement attached to the landform is correct. Zoltai also stated that in his belief the local relief classes are entirely inadequate.

Acton - replied that his definition of landform certainly does include the requiring pattern of form and the associated material, which can be applied at any scale. He also stated that one would need to have a different definition of a hill when mapping on a county basis than when mapping on the basis of a full NTS sheet at 1:250,000 scale, therefore, the definitions have to be related to scale. He stated that it was a good thing that the terms proposed include those of Bostock because this enables a close tie-in with the soil map of Canada. He also stated that the organic landform terminology proposed by Tarnocai would be preferable.

Dumanski - stated that for the purpose of CanSIS, it would be preferable to maintain an open-ended system.

Tarnocai - stated that the organic landform terminology should include fens and bogs and should omit terms like organic plain, undulating organic plain because they do not meet anything except to satisfy the first column under morphological expression.

Sneddon - asked whose needs we are trying to satisfy. He emphasized that the needs of pedologists in the field are most important and we should attempt to satisfy them.

Acton - replied that the way to make progress and to ensure that we are satisfying the needs of users is to try a system such as this one and to improve on it over a period of time.

By a show of hands the proposal was adopted unanimously for trial.

RAPPORT DU COMITE DU REGIME DES EAUX DU SOL

E.E. MacKintosh, Président

Résumé

Une terminologie standardisée est nécessaire pour permettre de rapporter les données relatives aux régimes d'humidité du sol.

REPORT OF THE SUBCOMMITTEE ON THE SOIL WATER REGIME

E.E. MacKintosh, Chairman

Summary

Standard terminology is required for reporting data on soil moisture regimes.

The overall response to my memo of February 22, 1973 was excellent. Seventy-five percent of the people replied representing eight out of the ten provinces. It is gratifying to see such enthusiasm. I will attempt to express what appears to be the concensus of opinion, although you must realize that the opinions varied extensively and tended to show regional bias toward the problems at hand.

Response to the Questionnaire

1. Surface ponding - Although some members expressed skepticism concerning a surface water classification there was general agreement amongst most that it should be retained in some form, if only to indicate susceptibility to flooding. One or two felt that the proposed system was too detailed but no concrete suggestions were made as to changes. It was felt that the measurement was most significant when related to the snowmelt period. Some mention was made of using remote sensing as a possible aid to quantifying the class limits but in my own opinion a great deal of claims laid to remote sensing still remain to be proven.

2. Although there was no disagreement with the establishment of a watertable classification there appears to have been little progress made in testing the adequacy of the class limits proposed at the 1970 meetings (p. 11). Each province uses different limits and as a subcommittee I believe we must decide if we want national standards developed. If so, we must be prepared to test different class limits, suggest changes, and gradually evolve an acceptable system.

Further, in developing a watertable classification one presupposes that different types of watertable conditions are recognized. In fact we do not distinguish between different types of groundwater regimes e.g. groundwater gleys versus surface water gleys and this suggests that we should entertain the possibility of developing criteria for their recognition. This also relates to the question of terminology and definitions which is dealt with in a later section.

Most watertable measurements appear to be taken during the growing season. However, for many interpretations e.g. septic tank installation, year around data are necessary and where feasible should be recorded.

3. Soil moisture content - It is unfortunate that the area in which we require a major effect appears to coincide with the least amount of activity. The lack of progress in the area of quantifying soil moisture may be attributed to several factors. Firstly, I believe most institutions lack both the bodies and resources to establish the type of monitoring program that is required. Secondly, many of us are unsure as to exactly what measurements should be taken and for what reasons. This is partially reflected in the fact that most individuals saw little value in developing a soil moisture classification. I am a strong advocate of the fact that we neither have the resources nor the manpower to pursue the path taken by the Americans. We must be more selective in what measurements are taken and why they are taken. This will require a much more active role on the part of the soil physicist in our soil survey program.

   The majority of individuals felt that the soil moisture subclasses being developed by the Soil Climate Subcommittee should be tested and correlated with the soil drainage classes but allowed to develop independently. The major reasoning behind this is the fact that the soil climate moisture subclasses are applicable to regional landscapes whereas soil drainage classes are related to segments of landscapes.

4. The need for the following physical measurements was generally agreed upon:
   - hydraulic conductivity
   - moisture content - moisture tension curves
   - bulk density
   - % time soil saturated
   - redox potentials (as an aid in distinguishing aerobic from anaerobic conditions)

5. There appears to be some confusion on the section concerned with lateral water movement and I must apologize for the ambiguous way it was written. Again I believe it points to the importance of us establishing a set of standardized terminology. As someone pointed out all watertables on the landscape are dynamic and this is true. However, most of us usually restrict the usage of the term "lateral seepage" to water movement which occurs laterally along the surface of an impermeable layer, either pedogenic or stratigraphic in nature, that occurs within 4-5 feet of the soil surface. Used in this sense the importance placed on lateral seepage showed a strong regional bias. Many felt it was an important distinction to make and more effort was required in recognizing such conditions in the field.

6. Closely related to the points discussed in sections #2 and #5 is the concept of groundwater gleys versus pseudogleys. A majority of the individuals felt the distinction would be useful and should be tried out on a trail basis. Prior to proceeding to this latter step, it is important that we establish definitions of the terms to provide consistency in its testing.

7. Most individuals felt that the problem of relating soil watertable conditions to soil drainage should be tackled at the landform level using a hydrological approach. The need for closer cooperation with hydrologists was stressed by most people. It may be beneficial to our subcommittee to add a hydrologist.

8. Progress on the following projects undertaken to relate watertable levels to soil morphology and drainage classes were reported on:

   1) Manitoba - Relationship of hydrology to the occurrence of certain subgroups on the landscape. They found carbonated and saline soils occur in areas of strong discharge while orthic and leached soils occur in transitional and weak discharge areas. On the basis of this work, one should be examining an area on the basis of recharge, transitional and discharged areas and determine the "suite of soils" associated with the various hydrologic regimes.

   2) Nova Scotia - Are continuing to monitor watertable levels at 16 sites. They have obtained a good relationship between traditional morphological assessment of drainage status and the number of days in the growing season when the free water surface is within x inches from the surface.

   3) Saskatchewan - Initiated a project in conjunction with the Division of Hydrology to investigate soil moisture variations around potholes and relate this to rainfall and soil properties.

   4) Alberta - Relationship of hydrology to the genesis of Chernozemic, Solonetzic and Gleysolic soils. They are also monitoring variations in soil moisture, and electrolyte composition.

   5) Ontario - a) Monitoring of watertable levels in several soil catenas has continued and a good relation between soil morphology and watertable levels has been established. b) Modelling project has been undertaken in conjunction with a meteorologist and hydrologist to predict the relationship of rainfall events to the frequency of groundwater recharge and to the frequency of surface runoff.

   6) Quebec - Measured watertables, Eh, temperature, etc. at 5 sites on long slopes. Also recorded soil morphology and measured soil physical and chemical properties. They found a close relation between soil morphology and watertables.

Based on the data reported most people seem to have had reasonable success in correlating soil morphology to watertable levels.

General Considerations

The majority of research work underway that relates to this subcommittee is concerned with soil watertable relations. I may have developed a wrong impression from this but it is my general feeling that many people are equating soil drainage and soil watertable relations to soil water regimes, which of course is not the case. Perhaps this points to the need, as suggested by the Manitoba Group, for a clearer and most precise statement on the objectives of the subcommittee and indeed on the definition of "soil water regime". The extent to which we wish to pursue this is open to debate and for this reason, I would appreciate feedback from the individual subcommittee members. Personally, I am againt carrying it much further unless the respective agencies decide that they will commit people to acting upon the recommendations generated by the subcommittees. There is little point in developing detailed guidelines for the subcommittee, together with recommendations for future work, if these recommendations are not acted upon or tested in the intervening periods.

Also, the need for closer cooperation between agencies concerned with soil water regimes is necessary. This point was made in the 1970 Proceedings as well. The need for cooperation with hydrologists and in particular closer liason between and within the Subcommittees is stressed.

One of the major points to emerge from attempting to synthesize a general concensus of opinion from the replies is the necessity of adapting and/or developing a set of terminology. There is a lack of consistency in usage of terms across the country; yet this is a necessary prerequiste to any discussions on the subject and to developing and testing subclass limits for proposed classifications, etc.

Since the soil surveyor is still faced with the problem of mapping soil drainage classes, we should give serious consideration to ways and means of improving their definitions. One serious fault with the soil drainage classes is the lack of distinction between surface drainage and profile drainage. The B.C. Group have attempted to overcome this problem in part by developing a soil drainage classification which consists of three parts: soil moisture regime subclasses; soil drainage classes; and soil perviousness classes. A copy of their report is enclosed for your consideration in Appendix I and I would appreciate comments on it.

The close relation between soil morphology and watertable levels reported by many suggests that we may be reaching a stage where more quantitative watertable class limits could be assigned to the soil drainage classes.

Summary and Recommendations

The extent to which I forsee the subcommittee developing a detailed set of objectives for directing future efforts and indeed for setting forth recommendations is tempered by the following:

i) unless adequate time is made available at the National meetings for group discussions, I forsee a limited role that subcommittees of this nature can perform. Many points raised in reply to memos can only be clarified through open discussions.

ii) there is little point in formulating recommendations unless some action is taken upon them. I believe a more positive statement by the agencies involved in the form of delegating an individual to spend time on testing proposed classification, etc. is required. This may be impractical since there are limits to our manpower, time and a large number of subcommittees to devote our efforts to. Nevertheless we should recognize the constraints that this imposes on our subcommittee and work within these.

In view of the above it is recommended therefore that this subcommittee, in cooperation with others concerned, should:

1) adopt a standard set of terminology relating to "soil water regimes" for purposes of establishing consistency in comparison and reporting of data across the country.

2) continue to quantify the various aspects of soil water regimes wherever possible.

3) investigate the usefulness of applying the concept of groundwater gleys and pseudogleys to Canadian soils.

APPENDIX I

Soil Drainage Classification

Introduction

A national approach to the problem of classification of soil drainage is necessary for at least two reasons: firstly, soil drainage is and must remain a part of "The System of Soil Classification for Canada"; and secondly, it must fit in with the CanSIS data file.

Ideally, a quantitative classification is most desirable, however, we lack necessary data and monitoring systems to define and use such a system at present. Thus the proposed scheme is mainly qualitative but it can be used with consistency until data are collected.

The proposed scheme consists of three parts: (1) Soil Moisture Regime Subclasses; (2) Soil Drainage Classes; and (3) Soil Perviousness Classes. The first corresponds to that used on the Soil Climate Map of Canada; the second is adapted from the present Canadian system; and the U.S.D.A. Soil Survey Manual, First Edition and preliminary write-up for the Second Edition; and the third is abridged from the preliminary write-up for the Second Edition.

The proposed scheme is designed to be useful to agriculturalists, foresters, hydrologists, hydrogeologists, engineers -- everyone concerned with soil water. It is applicable to field mapping wherever quantitative measurements on moisture availability, duration, water levels, etc. are not available.

The scheme is presented in the following pages. Examples of soils-vegetation-drainage relationships are given to show how the system might work. Although British Columbia examples are given, this is intended to be a national scheme.

Why change?

1. Confusion between drainage in terms of water availability and permeability. For example, a coarse gravelly (rapidly permeable) soil may occur in a wet depression yet be classed as very poorly drained.

2. Under the present system, a rapidly drained site receives much more water, via precipitation, in a wet coastal zone than in a dry interior zone. There should be some way of differentiating these.

3. The change should be minimal as the present drainage classification has been in use for some time, hence it should fit into any new system with little difficulty.

Proposed Scheme

A Soil Climate Map of Canada has been prepared. Moisture regimes and subclasses are defined and used for the Soil Climate Map of Canada and North

America. These subclasses are based mainly on climate: a) precipitation; b) evapotranspiration; and c) varying periods and intensities of water deficits during the growing season. This provides an excellent basis within which further subdivisions can be made based primarily on soils.

Within each of these Soil Moisture Subclasses (page 4, e.g. Humic, Semiarid, etc.) there should be seven Soil Drainage Classes (pages 5 to 8) each modified at all times by one of three Soil Perviousness Classes (pages 9 and 10).

The Soil Drainage Classes are defined in terms of: a) available water storage capacity; and b) source of water.

Soil drainage, in a dynamic sense, refers to the rapidity and extent of the removal of water from the soil, in relation to additions. It is affected by a number of factors acting separately or in combination, including texture, structure, gradient, length of slope, water holding capacity, evapotranspiration. The middle drainage class (Class 4) represents the modal moisture status for a particular Moisture Subclass. Drainage Classes 3, 2 and 1 represent progressively "drier" sites and Classes 5, 6 and 7 represent progressively "wetter" sites within a Moisture Subclass.

The Soil Perviousness Classes are introduced to eliminate the confusion between drainage and permeability. Perviousness refers to the potential of a soil to transmit water internally. It is strictly qualitative and is inferred from soil characteristics such as structure, texture, porosity, cracks, and shrink-swell properties of the soil. It is related closely to measures of permeability, percolation rate, infiltration rate, etc., but these are reserved for actual measurements using standard procedures.

Perviousness is independent of field moisture and is therefore independent of climate (Moisture Regime) and Drainage Class. See the Soil Climates of Canada Map legend for moisture subclasses in the report of the Soil Climate Subcommittee.

1. Very Rapidly Drained: Water removed from the soil very rapidly in relation to supply.

   Soils: - have very low available water storage capacity, (usually <1") within the control section

   - are usually coarse textured and shallow

   - lithic subgroups

   Water Source: Precipitation.

   Excess Water: Flows downward very rapidly if underlying material is pervious (for example - fractured bedrock). There may be very rapid subsurface flow during heavy rainfall provided there is a steep gradient.

   Vegetation: Xeric.

2. Rapidly Drained: Water removed from the soil rapidly in relation to supply.

   Soils: - have low available water storage capacity (1-1.5") within the control section
   - soils are usually coarse textured and/or shallow
   - lithic and orthic subgroups

   Water Source: Precipitation.

   Excess Water: Flows downward if underlying material is pervious. Subsurface flow may occur on steep gradients during heavy rainfall.

   Vegetation: Subxeric.

3. Well Drained: Water is removed from the soil readily but not rapidly.

   Soils: - have intermediate available water storage capacity, (1.5-2") within the control section
   - generally intermediate in texture and depth
   - orthic subgroups

   Water Source: Precipitation. On slopes subsurface flow may occur for short durations but additions are equalled by losses.

   Excess Water: Flows downward readily into underlying pervious material or laterally as subsurface flow.

   Vegetation: Submesic.

4. Moderately Well Drained: Water is removed from the soil somewhat slowly in relation to supply.

   Soils: - have intermediate to high water storage capacity, (2-2.5") within the control section
   - usually medium to fine textured
   - orthic subgroups

   Water Source: Precipitation is the dominant source in fine textured soils. Precipitation and significant additions by subsurface flow are necessary in coarse textured soils.

   Excess Water: Removed somewhat slowly due to low perviousness, shallow watertable, lack of gradient, or some combination of these.

   Vegetation: Mesic.

5. Imperfectly Drained: Water is removed from the soil slowly enough in relation to supply to keep the soil wet for a significant part of the growing season.

Soils:
- considerable range in available water storage capacity
- considerable range in texture and depth
- gleyed subgroups

Water Source: Precipitation, subsurface flow, and groundwater or some combination of these. Precipitation is a dominant source if AWSC is high; contribution by subsurface and/or groundwater flow increases as AWSC decreases.

Excess Water: Moves downward slowly if precipitation is major supply. If subsurface and/or groundwater is main source, flow rate may vary but the soil remains wet for a significant part of the growing season.

Vegetation: Subhygric.

6. Poorly Drained: Water is removed so slowly in relation to supply that the soil remains wet for a comparative large part of the time.

Soils:
- considerable range in available water storage capacity
- texture varies over wide range
- gleyed subgroups, gleysols, organics

Water Source: Subsurface flow and/or groundwater flow in addition to precipitation. May also be perched water table with precipitation $>$ evapotranspiration.

Excess Water: Remains in soil for large part of the time.

Vegetation: Hygric.

7. Very Poorly Drained: Water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the time.

Soils:
- wide range in available water storage capacity
- wide range in texture and depth
- occur in level to depressional areas
- gleysols, organics

Water Source: Groundwater flow, subsurface flow. Precipitation is of lesser importance except where there is a perched water table with precipitation $>$ evapotranspiration.

Excess Water: Remains in soil the greater part of the time.

Vegetation: Subhydric.

Soil Perviousness Classes

1. Rapidly Pervious - The capacity to transmit water vertically is so great that the horizon or soil would remain wet for no more than a few hours after thorough wetting if there were no obstruction to water movement outside the body classified.
   - The horizons and soils have large and continuous or connecting pores and cracks that do not close with wetting. Many, but not all, fragmental, sandy, and sandy skeletal soil bodies provide these conditions. Some medium and fine textured horizons have extremely strong granular structure with large connecting pores.

2. Moderately Pervious - The capacity to transmit water vertically is great enough that the horizon or the soil would remain wet for no more than a few days after thorough saturation if there were no obstructions to water transmission outside the body classified.
   - Most moderately pervious soil bodies hold relatively large amounts of water against the force of gravity.
   - The horizon may be massive but porous, granular, blocky, or weakly platy if continuous conducting pores or cracks are present and do not close with wetting.
   - The class includes many soils considered good, physically, for rooting and for supplying water for plants.

3. Slowly Pervious - The potential to transmit water vertically is so slow that the horizon or the soil would remain wet (saturated) for periods of a week or more after thorough wetting whether or not there were obstructions to water movement outside the body classified.
   - The material may be massive, blocky, or platy, but connecting pores that could conduct water when the soil is wet are few, and cracks or spaces among peds that may be present when the soil is dry close with wetting.
   - Even in positions accessible to plant roots, roots are usually few or absent and if present, they are localized along cracks that close when the soil is wet.

Use of the Drainage Scheme

The Soil Moisture Regimes and Subclasses are defined and mapped at a broad scale (1:10,000,000). Future work may be directed towards mapping the above at a more detailed level.

The Perviousness Classes are rather well defined, qualitatively. These classes may be subdivided further. As presented, there should be little difficulty with correlation and variability between classes should be greater than variability within classes. Measurements of percolation, infiltration, permeability, etc., may be added wherever necessitated (as for detailed studies) or data is available.

The Drainage Classes are perhaps most difficult to identify, particularly during reconnaissance survey. Vegetation may be used as an excellent indicator of drainage class. Within each Soil Moisture Subclass, xeric (drought tolerant) species occupy the Very Rapidly and Rapidly Drained sites; mesic ("zonal") species occupy the Well and Moderately Well Drained sites, and hygric and subhydric (phreatophytic, hydrophytic) species occupy the Imperfectly, Poorly, and Very Poorly Drained sites.

To identify the middle class (Moderately Well Drained) within a Moisture Regime Subclass, select a soil site which has a high AWSC and is dependent on precipitation for water supply. Note the vegetation, particularly indicator species, and soil morphological features such as color and mottling if present. The distribution of moderately well drained sites on slopes, coarse textured soils receiving seepage water, etc., is determined by extrapolation of vegetation and "soil" indicators. Drier sites will be drained more rapidly and wetter sites will be drained more slowly. The examples presented in Tables 1 and 2 indicate the relationships between drainage, vegetation and soils for two regions on Vancouver Island. Figures 1 and 2 show possible, general relationships between soils and drainage in a coastal and interior region.

Soil nutrient status also affects vegetation composition, for example, certain species will prefer acidic sites, others more basic sites wihtin all Drainage Classes. The nutrient status will be reflected in soil analyses. Water samples should be collected for chemical analyses and redox potential should be measured for Poorly and Very Poorly Drained soils.

Runoff is not mentioned in the above system. Classification of runoff becomes mainly interpretive as it is affected by several factors including rainfall intensity and duration, antecedent soil moisture, soil drainage, soil perviousness, soil temperature, vegetative cover, cultural practice.

Table 1. Moisture Regime Subclass: Perhumid

Example: Wet Western Hemlock Biogeoclimatic Subzone (Western Vancouver Island)

	Drainage class	Soils	Vegetation*	
			Trees	Other Species
1.	Very rapidly drained	Lithic Humo-Ferric Podzols, Lithic Folisols	Pseudotsuga menziesii, Pinus contorta, Tsuga heterophylla	Pleurozium schreberi, Peltigera apthosa, Rhytidiopsis robusta, Mahonia nervosa, Arctostaphylos uva-ursi
2.	Rapidly drained	Lithic Humo-Ferric (Orstein) Podzols, Lithic Folisols	Pseudotsuga menziesii, Tsuga heterophylla	Pleuorzium schreberi, Rhytidiopsis robusta, Mahonia nervosa, Gaultheria shallon
3.	Well drained	Orthic Ferro-Humic Podzols, Orthic Humo-Ferric Podzols	Pseudotsuga menziesii, Abies amabilis, Tsuga heterophylla	Rhytidiadelphus loreus, Rhytidiopsis robusta, Plagiothecium undulatum, Vaccinium alaskaense
4.	Moderately well drained	Orthic Ferro-Humic Podzols	Pseudotsuga menziesii, Abies amabalis, Tsuga heterophylla, Thuja plicata	Rhytidiadelphus loreus, Rhytidiopsis robusta, Plagiothecium undulatum, Vaccinium alaskaense
5.	Imperfectly drained	Gleyed Ferro-Humic Podzols, Orthic Humic Podzols	Pseudotsuga menziesii, Abies amabilis, Thuja plicata, Tsuga heterophylla	Rhytidiadelphus loreus, Plagiothecium undulatum, Mnium insigne, Blechnum spicant, Vaccinium (ovalifolium and alaskaense), Polystichum munitum, Streptopus roseus
6.	Poorly drained	Gleyed Ferro-Humic and Gleyed Humic Podzols, Gleyed Regosols, Gleysols	Pseudotsuga menziesii, Abies, amabilis, Thuja plicata, Tsuga heterophylla, Picea sitchensis	Rhytidiadelphus loreus, Plagiothecium undulatum, Mnium insigne, Blechnum spicant, Vaccinium (ovalifolium and alaskaense) Polystichum munitum, Leucolepis menziesii, Rubus spectabilis
7.	Very poorly drained	Peaty Gleysols, Acidic Organic Soils	Pinus contorta, Picea sitchensis, Thuja plicata, Alnus rubra	Myrica galis, Spiraea douglasii, Lysichitum americanum

*Taken from: Krajina, V.J. and R.C. Brooke. 1969/70. Ecology of Western North America, Vol. 2. Dept. of Botany, U.B.C., Vancouver.

Table 2. Moisture Regime Subclass: Semiarid

Example: Dry Douglas-fir Subzone (East Coast of Vancouver Island)

	Drainage Class	Soils	Vegetation* Trees	Other Species
1.	Very rapidly drained	Lithic, Eutric, Dystric Melanic Brunisols	Quercus garryana, Arbutus menziesii, Pinus contorta	Dicranum, Camassia, Cladonia, Peltigera, Rhacomitrium
2.	Rapidly drained	Melanic Brunisols, Humo-Ferric Podzols, (Lithic)	Pseudotsuga menziesii, Abies Grandis, Quercus garryana, Arbutus menziesii, Pinus contorta	Camassia, Symphoricarpos mollis, Cladonia, Arctostaphylos uva-ursi
3.	Well drained	Dystric Brunisols, Humo-Ferric Podzols	Pseudotsuga menziesii, Abies grandis, Arbutus menziesii, Pinus contorta	Symphoricarpos mollis, Cladonia, Arctostaphylos uva-ursi
4.	Moderately well drained	Dystric Brunisols, Humo-Ferric Podzols	Pseudotsuga menziesii, Abies grandis	Eurhynchium oreganum, Hylocomium splendens, Mahonia nervosa, Gaultheria shallon
5.	Imperfectly drained	Gleyed Dystric Brunisols, Humo-Ferric Podzols	Pseudotsuga menziesii, Abies grandis, Thuja plicata	Eurhynchium oreganum, Rhytidiadelphus triquetrus, Mnium insigne, Polysticum munitum, Tiarella trifoliata, Achlys triphylla, Mahonia nervosa
6.	Poorly drained	Gleyed Dystric Brunisols, Gleyed Humo-Ferric Podzols, Gleyed Regosols, Gleysols	Pseudotsuga menziesii, Abies grandis, Thuja plicata	Eurhynchium, oreganum, Rhytidiadelphus Triquetrus, Mnium insigne, Polysticum munitum, Tiarella trifoliata, Achlys triphylla
7.	Very poorly drained	Acidic Organic Soils	Pinus contorta, Alnus rubra, Picea sitchensis, Thuja plicata	Sphagnum capillaceum, Ledum groenlandicum, Myrica galis, Spirea douglasii, Lysichitum americanum

*Ibid.

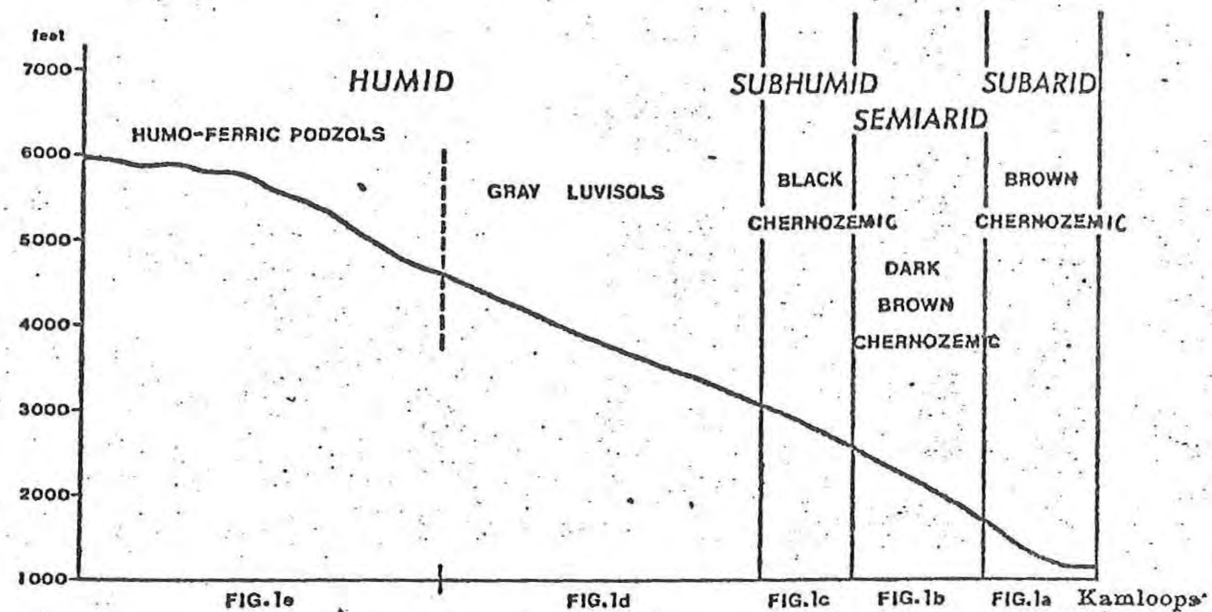

FIG. 1

Idealized relationship between Moisture Regime Subclasses and Soil Great Groups for a transect from Kamloops northward to Tranquille Plateau. Soils are loams and sandy loams developed on drift and topography is largely bedrock controlled.

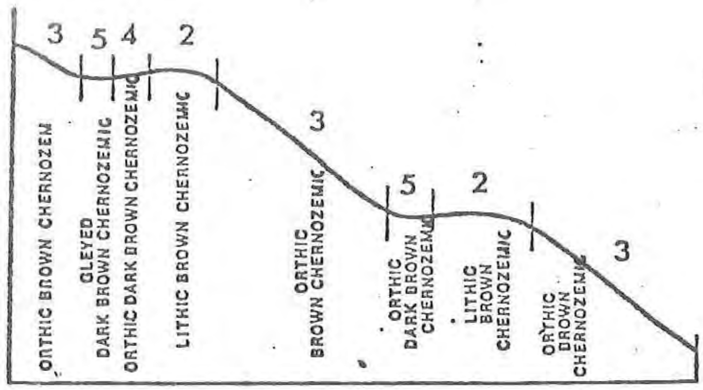

FIG. 7a

Example of relationship between Drainage Classes and Soil Subgroups in Subarid Moisture Subclass.

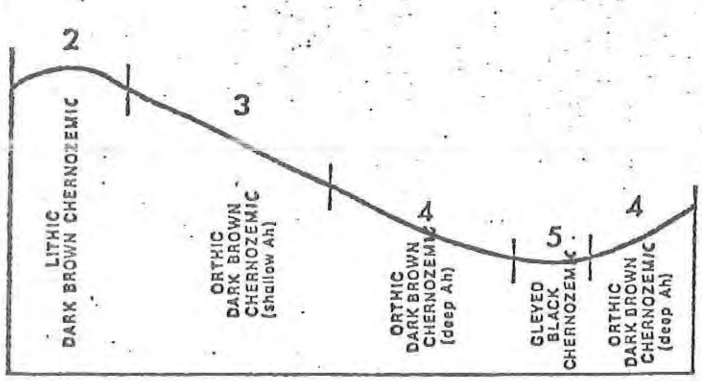

FIG. 7b

Example of relationship between Drainage Classes and Soil Subgroups in Semiarid Moisture Subclass.

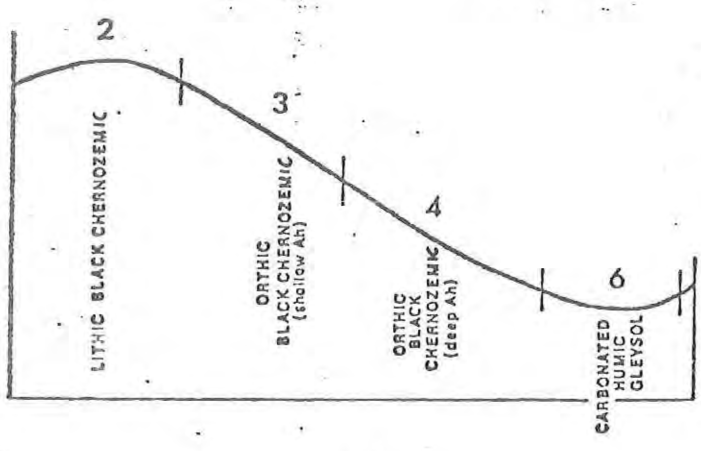

FIG. 7c

Example of relationship between Drainage Classes and Soil Subgroups in Subhumid Moisture Subclass.

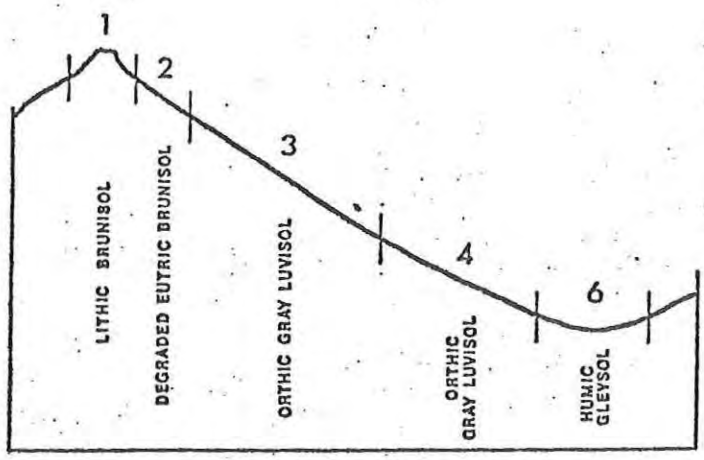

FIG. 1d

Example of relationship between Drainage Classes and Soil Subgroups in lower part of Humid Moisture Subclass.

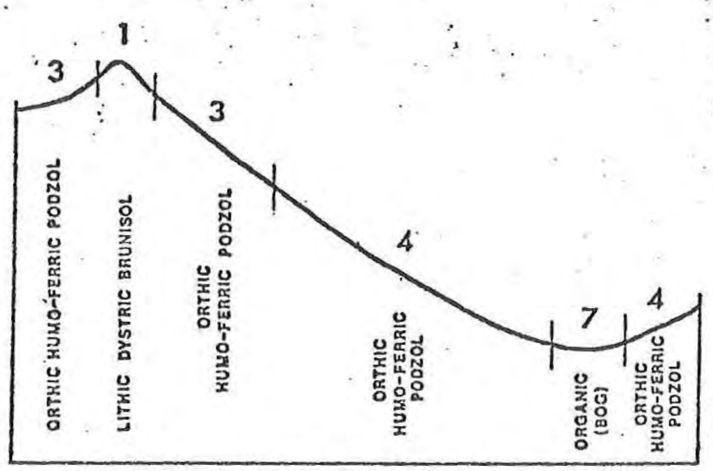

FIG. 1e

Example of relationship between Drainage Classes and Soil Subgroups in upper part of Humid Moisture Subclass.

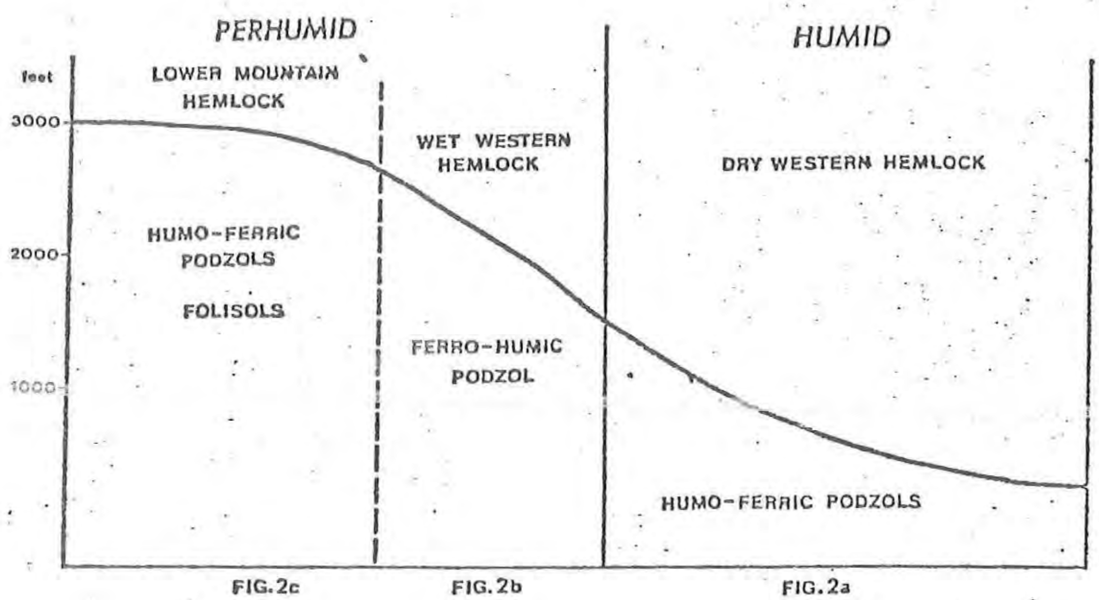

FIG. 2

Idealized relationship between Moisture Regime Subclasses, Biogeoclimatic Subzones, and Soil Great Groups for a transect on granitic bedrock in the Nimpkish Valley, northern Vancouver Island. Soils are developed on till and colluvium, overlying bedrock.

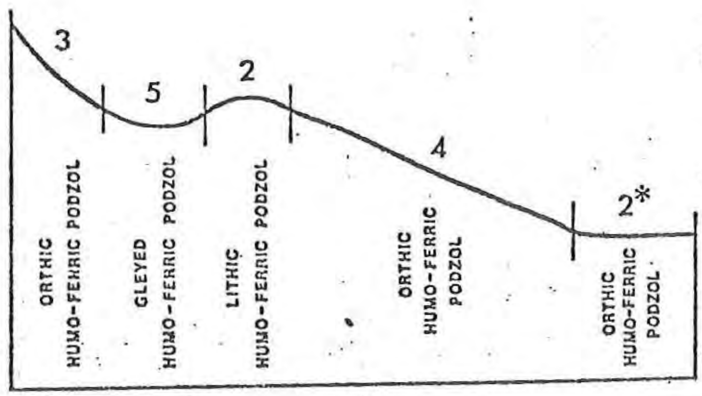

FIG 2a

Example of relationship between Drainage Classes and Soil Subgroups in Humid Moisture Subclass.

* Break in parent material, have outwash, high above water-table.

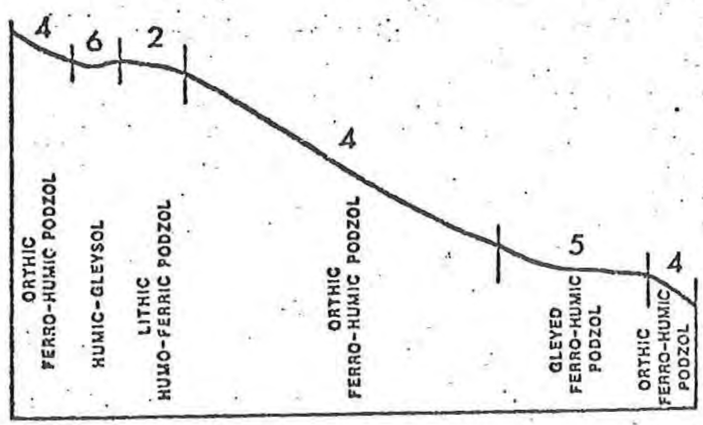

FIG 2b

Example of relationship between Drainage Classes and Soil Subgroups in lower part of Perhumid Moisture Regime.

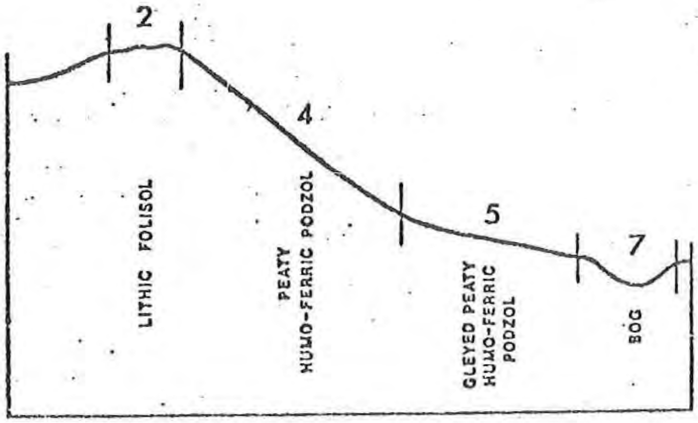

FIG. 2c

Example of relationship between Drainage Classes and Soil Subgroups in upper part of Perhumid Moisture Regime.

RAPPORT DU COMITE DE LA TELEDETECTION

C. Tarnocai, Président

Résumé

1. Evaluation de la Télédétection dans son application aux relevés de reconnaissance et détaillés.

a) Oui, il est bon d'avoir une évaluation de la télédétection dans son application aux relevés de reconnaissance et détaillés de même qu'aux relevés de terrains à petite échelle.

b) D'après les expériences en cours, la télédétection promet d'augmenter la précision et la rapidité des relevés de reconnaissance et des études de terrain à petite échelle.

c) Il faut que les unités cartographiques soient identifiables d'après les données de la télédétection, e.g. forme de terrain,pente, relief, drainage et végétation.

2. Application de la télédétection au programme de relevés de sols et type de données recommandées pour faire les cartes de sols.

a) La télédétection fournit la source primaire d'information pour faire les cartes de sols détaillées de reconnaissance ou autres cartes des terrains.

b) Une couverture stéréoscopique à grande échelle en couleur, en couleur IR et en noir et blanc est recommandée pour les relevés détaillés; pour les relevés de reconnaissance, on devrait utiliser une couverture stéréoscopique à petite échelle en couleur, en couleur IR, en noir et blanc ou l'imagerie multispectre de ERTS.

3. Demande budgétaire spéciale. Une demande budgétaire spéciale pour recherche appliquée en télédétection est justifiée, surtout les cas suivants:

a) Vérification sur le terrain, usage d'ordinateur, louage de petits avions et achat de menus articles d'équipement.

b) Achat de photographies, coût du survol pour la prise des photographies - service rendu jusqu'à maintenant par CCRS.

c) Evaluation de l'utilité de l'imagerie de ERTS pour servir de base photographique aux cartes des sols et aux relevés de reconnaissance des sols.

4. Temps et fonds à allouer à la recherche et genre de recherche à faire.

a) Le temps et les fonds à invester dans la télédétection doivent se répartir selon les besoins particuliers des diverses unités pédologiques. Pour prévenir la duplication, il faut avoir soin de bien coordonner la recherche. Le programme annuel de chaque unité devrait comprendre en moyenne 1 à 2 emplois.

b) La pédologie devrait s'intéresser d'avantage aux études de télédétection entreprises par les autres disciplines. Cet intérêt devrait d'abord se manifester par l'acquisition de données.

c) Il faudrait étudier et déterminer la meilleure façon d'utiliser l'imagerie multispectre pour dresser les cartes pédologiques de reconnaissance.

d) La recherche sur les effets électromagnétiques de sols typiques de diverses régions du Canada devrait être exécutée tant sur le champ qu'au laboratoire et s'étendre sur une large gamme de longeurs d'onde.

REPORT OF THE SUBCOMMITTEE ON REMOTE SENSING

C. Tarnocai, Chairman

Summary

1. Evaluation of remote sensing as it applies to reconnaissance and detailed soil surveys.

a) Yes, it is desirable to have an evaluation of remote sensing as it applies to reconnaissance and detailed soil surveys and to other small-scale terrain mapping.

b) Based on current experience, the use of remote sensing data shows great promise in increasing both the accuracy and speed of reconnaissance surveys and other small-scale terrain studies.

c) It is important to realize that mapping units used must be recognizable on the remotely sensed data, e.g. landform, slope, relief, drainage and vegetation.

2. Application of remote sensing to the soil survey program and the type of data recommended for soil mapping.

a) Remote sensing does provide a primary source of information for detailed and reconnaissance soil and other terrain mapping.

b) Large-scale color, color IR and black and white stereoscopic coverage is recommended for detailed soil mapping and small-scale color, color IR and black and white stereoscopic coverage and multispectral ERTS imagery are recommended for reconnaissance soil mapping.

3. Special budget request. A special budget request is justified for applied research relating remote sensing to soil survey, especially in the following areas:

a) Ground truthing, computer time, chartering of small aircraft and purchasing of small items of equipment.

b) Purchasing remote sensing imagery and covering the cost of flying, a service which has been provided by CCRS in previous years.

c) Evaluating the usefulness of ERTS imagery for photo based soil maps and for reconnaissance soil mapping.

4. Amount of time and money to be directed to research and the type of research activities to be carried out.

a) The amount of time and money directed to remote sensing depends on the needs of the individual survey units. The research must be highly co-ordinated to prevent duplication. The yearly research program would involve an average of 1 to 2 man-years at each local level.

b) There should be greater pedological input into remote sensing studies already being undertaken by other disciplines. Involvement with such studies should start with the acquisition of data.

c) Studies should be carried out to determine how best to use small-scale multispectral remote sensing imagery for reconnaissance soil mapping.

d) Research on the electromagnetic responses of typical soils in different regions of Canada over a wide range of wavelengths should be carried out both in laboratory and in situ.

INTRODUCTION

On January 9, 1973, a memorandum was sent to the members of the Subcommittee on Remote Sensing to request their opinions on remote sensing as it relates to soil survey. Specifically, answers to the following questions were requested:

1. Is it desirable and/or necessary to have an evaluation of remote sensing as it applies to the reconnaissance soil survey program?

2. Does it hold enough promise as a new technique to be used in connection with the soil survey program?

3. Is a special budget request justifiable?

4. How much time and money should be directed to studies on remote sensing as concerns the soil survey program?

Pedologists in Canada have shown a great interest in remote sensing and many are actively involved in the Canadian Remote Sensing Program. Thus, now is the time to evaluate the application of remote sensing to pedological work because, as A.J. Green pointed out,

"...in time all will be using remote sensing techniques to some degree. Certainly right now some pedologists should be getting more knowledgeable with M.S.S., filtering wavelengths and other techniques in order to ensure that the best possible material is obtained for soil survey purposes. In the past, pedologists have not had enough say in the kind of aerial photography to be done, the scale, time of year, quality, etc. Now perhaps is a good time to voice our opinions".

Based on the opinions of the members of this subcommittee, the following recommendations have been made.

1. Is it desirable and/or necessary to have an evaluation of remote sensing as it applies to the reconnaissance soil survey program?

Reconnaissance soil and terrain maps at a scale of approximately 1:250,000 or smaller are made as a first step in surveys of large areas or of inaccessible, thinly populated regions. In these areas the soil surveyor should make physiographic, landform, vegetation and surface deposit maps in which the units are described in terms of image and terrain characteristics. Soil maps can then be generated from this information (landform, vegetation and drainage) when used in conjunction with ground truth information. Reconnaissance terrain maps can be generated at a relatively fast rate by relying heavily on remotely sensed data with the use of selected ground truth information. This has been well demonstrated in the biophysical land classification and the terrain mapping carried out in the Mackenzie River Valley in 1971-72.

Because of the diversity of Canada's landscape, it is necessary to evaluate remote sensing as it applies to the reconnaissance soil survey program in several parts of Canada. In British Columbia, for instance, the main concern is with reconnaissance soil surveys in forested and mountainous terrain, while on the Prairies the concern is with surveys on level to undulating terrain. Unfortunately, very little research has been done relating remote sensing techniques to these types of survey. As was pointed out by A.J. Green we must learn what techniques are best suited to our needs.

We believe that it would be desirable to evaluate remote sensing as it applies not only to reconnaissance surveys but also to detailed surveys. Although detailed surveys generally have a greater cost per acre than reconnaissance surveys they usually cover smaller areas, so the costs are comparable. Even though acquisition of remotely sensed data is more costly than acquisition of the type of data that has been used to date, evaluation of its use for smaller areas (detailed surveys) should be considered as suggested by P.H. Crown and S. Pawluk. L.S. Crosson, on the other hand, sees very little application to detailed soil surveys but, in areas where reconnaissance surveys are to be carried out, he feels remote sensing techniques do show great promise.

We must realize, however, that remote sensing data (photographic and scanning) are already available in the large scale required for detailed soil mapping. Other advantages in the use of this large-scale data are the possibility of color enhancement and color slicing of the remotely sensed data with resulting greater tonal differences and thus more efficient extraction of information.

RECOMMENDATIONS:

a. Yes, it is desirable to have an evaluation of remote sensing as it applies to reconnaissance and detailed soil surveys and to other small-scale terrain mapping.

b. Based on current experience, the use of remote sensing data shows great promise in increasing both the accuracy and speed of reconnaissance surveys and other small-scale terrain studies.

c. It is important to realize that mapping units used must be recongizeable on the remotely sensed data, e.g. landform, slope, relief, drainage and vegetation.

2. Does it hold enough promise as a new technique to be used in connection with the soil survey program?

Although remote sensing is a rapidly expanding field, both in terms of applicability and interest, it is not essentially a new technique since by definition remote sensing (the measurement of environmental conditions at or near the surface of the earth, primarily with sensors on airborne and space vehicles) includes also aerial panchromatic photography, a technique in use for over 25 years. This long period of use has provided considerable experience which should be utilized in answering the above question.

Current and future soil survey programs are dependent on accurate and updated photographs not only of the cultivated and urbanized areas of Canada, but also of the sparsely settled forested, mountainous and tundra areas. Photographs which show clearly changes in the various physical and vegetative conditions would greatly improve the operation. Unfortunately, very few soil survey projects have been supplied with recent photography. The aerial photography used in most of our projects is at least ten years old. Thus, we have to rely on new imagery techniques to provide recent data about the terrain. This recent data is necessary because, while it is true that soil properties do not change during this period, some part of the ecosystem on which the soil interpretation is based may change (e.g. vegetation). The vegetation pattern may change due to fire or other factors and thus the use of old photographs would create difficulties during the interpretation and subsequent field work. On more settled areas cultural and management patterns change with time and thus old data could create difficulties during the course of map making. Therefore, photographs more than <u>five years</u> old should not be used for soil mapping. On more rapidly developing areas the data should not be older than <u>two years</u>.

Use of Remote Sensing Imagery for Detailed Soil Mapping

In most areas of Canada, the soil surface itself is covered by vegetation or snow for a large part of the year. When bare soils are shown, the imagery records differences related to spectral reflectance characteristics of surface soils at the time of flight. This imagery can be analyzed to produce a spectral map of bare soils. When the soil is covered with vegetation, the photo interpretation is based on the correlation of soils with surface phenomena observable on the imagery. The correlation with geomorphological and biological clues generally gives the best results and, therefore, <u>stereoscopic coverage</u> is necessary.

Thus, for detailed soil mapping, the remote sensing imagery useful as a <u>primary</u>* source of information will be sufficiently large-scale color, color IR and black and white multispectral photography with stereoscopic coverage.

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* The term "primary source" is used to denote imagery supplying direct information about the aspect of soil investigated. A secondary source is an imagery providing indirect or salient information about the phenomena of interest.

Orthophotography and radar (SLAR) should also be considered as having great potential. The cost involved, however, would probably make their general use inefficient as compared to multispectral aerial photography, especially in the case of SLAR.

Other non-stereoscopic or small-scale remote sensing data could provide a secondary source of information and should be investigated.

Use of Remote Sensing Imagery for Reconnaissance Soil Mapping

The information required for reconnaissance soil mapping was discussed under question one. Here the source of primary information is small-scale color, color IR and black and white photography with stereoscopic coverage. Recent studies indicate that ERTS imagery could provide a primary source of information on bare soil areas, especially if color composites are prepared or density slicing is carried out on this data.

Since, however, most soils are not bare, the soil photo interpretation must be based on indirect clues (landform, vegetation and drainage) present on the image. Because these clues are used integratively according to the principles of convering evidence, an ingeneous application of knowledge from several scientific disciplines is required. Therefore, it is clear that, at least in the near future, soil photo interpretation cannot be performed solely by instruments, but only by persons with an adequate knowledge of pedology, related sciences and interpretation of remotely sensed data.

RECOMMENDATIONS:

a. Remote sensing does provide a primary source of information for detailed and reconnaissance soil and other terrain mapping.

b. Large-scale color, color IR and black and white stereoscopic coverage is recommended for detailed soil mapping and small-scale color, color IR and black and white stereoscopic coverage and multispectral ERTS imagery are recommended for reconnaissance soil mapping.

3. Is a special budget request justifiable?

A special budget request can be justified for applied research relating remote sensing to soil surveys. Research programs, however, must be carefully selected and be of very high calibre. The program must be designed specifically for soil survey needs. Although working with other agencies and disciplines on remote sensing research projects can provide considerable experience and information, such projects are seldom oriented to solve mapping and interpretive problems.

Funds should be provided at the local level for such things as computer time, chartering of small aircraft, purchasing of smaller items of equipment and for ground truthing.

Funds should also be provided for purchasing remote sensing imagery. Soil survey probably does not require a great deal of multi-year data. Our requirements will generally be on a once every 2-5 year cycle, depending on the area of coverage.

A special budget would be justified to determine the value of ERTS imagery for photo based soil maps and for application to reconnaissance soil mapping.

RECOMMENDATIONS:

A special budget request is justified for applied research relating remote sensing to soil survey, especially in the following areas:

a. Ground truthing, computer time, chartering of small aircraft and purchasing of small items of equipment.

b. Purchasing remote sensing imagery and covering the cost of flying, a service which has been provided by CCRS in previous years.

c. Evaluating the usefulness of ERTS imagery for photo based maps and for reconnaissance soil mapping.

4. How much time and money should be directed to studies on remote sensing as concerns the soil survey program?

The amount of time and money directed to studies on remote sensing should be determined by the individual soil survey units. At any rate, any research must be highly co-ordinated to prevent duplication and to obtain the most return for the investment. It is likely that a yearly research program would involve an average of 1 to 2 man-years at each local level.

It has also been suggested that there should be greater pedologic input into remote sensing studies already being undertaken by forestry, engineering, ecology, geology and hydrology. Involvement with such studies should start with the acquisition of data and not later with the interpretation. For example, in B.C., a forest ecologist has requested soil maps of the Cariboo area to check soil-vegetation patterns on CF-100 and ERTS imagery. In this case, the pedologist who has the best local knowledge of the area should be working with the forest ecologist and preferably it should have been from the start of the project.

Another program, which has been suggested by J. Cihlar, involves studies on using small-scale remote sensing imagery (multiband, multispectral, multiemulsion) for reconnaissance soil mapping. Execution of this program should depend on the present and projected scope of reconnaissance soil mapping in Canada. The program could be carried out in the following phases:

Comparative studies of various imageries, their combinations and forms of enhancement, from different times of the year to single out the most effective sources of soils information. The study should be designed to produce quantitative statements about the differences among imageries and final decisions should be based on human image interpretation.

Comparative studies of the most effective imageries with those presently for reconnaissance soil mapping. As above, quantitative answers should be provided together with an evaluation of economic benefit.

The study as outlined above could be designed, co-ordinated and analyzed by one principal investigator and carried out with the participation of professional soil photo interpreters all across Canada. A proper experimental design would ensure that the interpreters work under - as much as possible - similar conditions and that a maximum of external factors can be accounted for. An instrumental approach developed by Cihlar (1971) might be used in the initial phases to decrease the number of imageries compared. Investigations by Vermeer (1969) and Orr and Quick (1971) would provide some guidelines in designing the experiment.

Since Canada operates on the assumption that "... remote sensing is not a transitory fashion, and that it should, therefore, be established on an operational basis ..." (Morley, 1971, p. 3), it is up to the soil scientists to provide information about soils which will enable a proper interpretation and utilization of both the image and digital remote sensing data. Furthermore, new sensors will be developed and the existing ones will be utilized on a broader basis; to evaluate their potential, basic soils information will be necessary. For the above reasons, it appears desirable that a research program be initiated to measure both laboratory and in situ electromagnetic responses (and their variability) of typical soils in different regions of Canada over a wide range of wavelengths (i.e. UV through microwave). The program could include measurements of the benchmark soils and thus parallel an on-going project of C.S.S.C. Initially, a lack of instrumentation could prevent more extensive measurements; however, the instrumentation could be purchased or otherwise obtained

Cihlar, J. 1971. Color aerial photography in soil mapping. M.Sc. Thesis, University of Guelph, Guelph, Ont., 195 p.

Vermeer, J. 1969. Result of an objective comparison of film-filter combinations applied to an example of photo interpretation for soil surveys. Photogrammetria 25: 87-97.

Orr, D.G. and J.R. Quick. 1971. Construction materials in delta areas. Photogrammetric Eng., 37: 337-351.

Morley, L.W. 1971. Canada's approach to remote sensing. Proc., 7th Int. Symposium on Remote Sensing of Environment, Ann Arbor, Michigan: p. 3-18.

(e.g., through S.R.I.). This program should also include investigations of electromagnetic properties of soil mapping units. The information collected could be conveniently stored in CanSIS.

The C.S.S.C. should make a determined effort to keep in touch with the latest developments in remote sensing and their potential applications to the soil survey program. For example, orthophotography and radar imagery are two tools which are of great potential but are not considered practical at present largely because of cost. The latest radar images are of excellent quality and consequently the range of potential applications has been considerably expanded, partly offsetting the relatively high cost. Another aspect of future remote sensing applications to soil survey may be acquisition of spatial and temporal data on individual soil properties.

RECOMMENDATIONS:

a. The amount of time and money directed to remote sensing depends on the needs of the individual survey units. The research must be highly co-ordinated to prevent duplication. The yearly research program would involve an average of 1 to 2 man-years at each local level.

b. There should be greater pedological input into remote sensing studies already being undertaken by other disciplines. Involvement with such studies should start with the acquisition of data.

c. Studies should be carried out to determine how best to use small-scale multispectral remote sensing imagery for reconnaissance soil mapping.

d. Research on the electromagnetic responses of typical soils in different regions of Canada over a wide range of wavelengths should be carried out both in laboratory and <u>in situ</u>.

GENERAL COMMENTS

The evaluation of remote sensing as it applies to soil survey should not be conceived of as a once-for-all effort. Remote sensing techniques are developing rapidly and clearly no conclusive statement about their applications to soil survey can be made at the present. Moreover, it should be kept in mind that remote sensing of soils involves <u>extremely</u> complex and difficult problems. Therefore, the evaluation of remote sensing tools should be made continuously as they appear and options should be kept open. Also, the evaluations should be made with practical applications in mind.

Most non-traditional interpretative techniques developed in the last ten years apply to large-scale imagery; investigators are finding

(J.C. Coiner, personal communication to J. Cihlar*) that problems with satellite imagery are of quite a different nature.

Soil scientists should not attempt to interpret all imagery that is made available to them. Unless one is interested in specific soil properties, one properly chosen image of an area will be sufficient unless time-change will bring out important information. In the latter case, a comparative interpretation must be done where the images can be looked at simultaneously and then again one image will probably be used for most of the interpretation.

It is difficult to conceive utilizing the small-scale single-coverage imagery in existing detailed soil mapping. They could be used as a secondary imagery (giving a broader view, preliminary interpretation, etc.) but this would probably happen only if they were supplied at little or no cost (i.e. not generated for that specific mapping project).

Summary of Comments

(Application of remote sensing data to soil surveys)

Under recommendation four, concerning the amount of time and money to be directed to research, 1 to 2 man-years was suggested at each local level. This would include photo-interpretation work on on-going survey projects, evaluation of small-scale multispectral remote sensing imagery for soil mapping, pedological input into remote sensing studies already undertaken by other disciplines.

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* Image interpreter, Center for Research Inc., University of Kansas, Lawrence, Kansas 66044.

RAPPORT DU COMITE DES INTERPRETATIONS DES SOLS

C. Acton, Président

Résumé

Le comité recommande la préparation d'un guide des interprétations des sols indiquant les paramètres requis pour des interprétations spécifiques et les degrés des limitations pour une utilisation donnée. Il est également recommandé de mettre à l'essai pour un an ou deux les guides élaborés aux E.U. et ailleurs.

REPORT OF THE SUBCOMMITTEE ON SOIL INTERPRETATIONS

C. Acton, Chairman

Summary

It is recommended that a soil interpretations guidebook be prepared, that the guidebook indicate the parameters required for specific interpretations, that degrees of limitations for a given use be stated, that the U.S. and other guidelines developed be tested for one or two years.

This subcommittee replaces the Subcommittee on Soil Survey Interpretations for Engineering Uses, and has expanded in scope to include interpretations for engineering, agronomic and forestry, and recreational uses of soils. The terms of reference of this subcommittee are to collect references, standards and limits from all available sources, indicate the soil paramters to be observed, measurements to be made by recommended methods, and define hazard classes in the use of soils for the purposes given above. Its ultimate objective is the preparation of a Soil Interpretation Handbook for Canadian Pedologists.

On the basis of correspondence from various subcommittee members and other interested persons, a preliminary working document on soil interpretations, entitled "Proposed Guidelines for Soil Interpretations in Canada" was prepared and circulated to members of the C.S.S.C. (Appendix A). This document refers to many interpretive guidelines already in use in the United States which are considered to have some applicability in Canada. Also, it presents guidelines which have been established and used under Canadian conditions. The intention in preparing this document was not to suggest that these guidelines be adopted by the C.S.S.C. at this time, but rather to provide a basis for discussion and evaluation by members of this subcommittee and C.S.S.C. members during the next 1-2 year period. Obviously, any document dealing with this subject must undergo considerable discussion, testing and revision before being proposed for adoption by this body.

The Soil Interpretations Subcommittee submitted the following recommendations to the C.S.S.C. for their consideration:

1. The work of this subcommittee should continue, and the preparation of a soil interpretations guidebook should be proceeded with as the major objective of this subcommittee. Such a guidebook should contain the necessary information to assist in making interpretations based on soil, landscape, climatic, geological or hydrological properties. Interpretations should be developed by pedologists in consultation with foresters, wildlife biologists, engineers, agronomists, etc. The interpretive uses for which guidelines should be established include engineering, recreation, agronomic and forestry uses of land, as well as interpretations for wildlife habitat.

2. The guidebook should indicate the parameters considered to be important for making interpretations for the specified uses. Where appropriate, the implications of a property or properties to development for a particular use also should be discussed.

3. Where possible and if applicable on a national basis, ratings for the properties should be proposed based on varying degrees of severity of the limitations for a given use. For certain uses, particularly where climatic factors are significant, guidelines must be developed in the context of regional conditions.

4. The guidelines proposed in the working document of this subcommittee, U.S.D.A. guides, etc. should be critically examined through application and testing for a trial period of 1-2 years.

5. There is an urgent need for research in soil interpretations to evaluate the significance of soil, landscape or climatic parameters for a particular use. Associated with this is the need for an in-depth review of literature and the preparation of annotated bibliographies on the subject. This could be accomplished by existing survey staff if given a block of time to complete the task, or by contractural arrangement with agencies or institutions.

6. Regional soil interpretation subcommittees should be established which include scientists from other disciplines. This C.S.S.C. subcommittee would encourage the selection of one individual in a region (province) to assume the responsibility of establishing such a multi-disciplinary committee. Its purpose would be to establish and evaluate interpretive guidelines for that particular region, and make recommendations to the Soil Interpretations Subcommittee of the C.S.S.C.

7. Pedologists should become involved at once in including soil interpretations in their soil survey reports. The form S.C.S. Soils 5, U.S.D.A. could be utilized in assisting in making these interpretations.

8. The soil interpretations module of CanSIS should be established to include interpretations related to site specific data.

These recommendations were unanimously approved by the C.S.S.C.

DISCUSSION

Coen - You have referred to the soil interpretation guidelines in the SCS handbook. We should keep in mind that these guidelines apply particularly to detailed soil maps at scales of 3 or 4 inches per mile. They would not prove too suitable if applied to broad scale reconnaissance surveys.

Acton - It is a matter of how far you can go when dealing with different intensities of surveys. Interpretations must remain fairly general when dealing with reconnaissance information but one can become more specific as the level of detail increases.

Nichols - You must talk about the probability of how much of a certain kind of soil occurs in a mapping units, and apply this in interpretations. For a detailed survey you may be able to predict for 90% of the cases, whereas this may drop to 75% for reconnaissance surveys. We must tell people the probability we are predicting for, and this isn't easy.

Mackintosh - We must know the precision or reliability of the soil maps if soil interpretation are to be meaningful. We normally think of 10-15 percent inclusions for soil series in a map unit, but we might be surprised at the precision of our maps if they were tested statistically. In Canada we don't have Soil Scientists working at the county level with planners, hence planners are using soils information to make decisions. It is therefore important to state what is the reliability of our soils information.

Raad - Referring to regional soil interpretation committees which you recommend be established, will they be involved in rating a specific soil series for all the uses you mention? The SCS in Maine has established in book form ratings for all series in the state for different uses. Is this the intention of the regional soil interpretation committees?

Acton - Not specifically. Establishing a rating for a certain series should be done by the pedologist involved with the mapping in the area in which it occurs, in consultation with people of other disciplines with expertise in the particular use for which it is being rated. The regional interpretation committees would be involved in establishing guidelines for rating soils in that area - what paramters should be considered and what limits should be applied to a certain property to establish a series at a certain suitability level.

Millette - Are you speaking about interpretations for soil maps, mapping units, or soil series?

Acton - In the first place I suggest we make interpretations for series, then apply this on a map unit basis, knowing the series which occur in the mapping unit.

Millette - If mapping has been done properly and we know the percentage of occurrence of the series in the mapping units, we can apply the interpretations with a fair amount of accuracy. The scale of the map is really not of importance if the mapping is done in this manner.

Wilson - In some interpretative uses you are more in the realm of surficial geology than pedology, e.g. septic tanks, foundations. Is it the intention that you are going to be looking at materials to a greater depth? Engineers use soil maps because they are available. They don't have surficial geology maps in many cases, however, that is going to change in Ontario.

Acton - The soil map will not replace the surficial geology map. It is recognized that we do not have soil data to a depth of 6 ft. in every case but through knowledge of soils, parent materials, glacial processes and occasional deep exposures we have a pretty good idea of sub-surface characteristics which we can make use of in making soil interpretations.

Langmaid - A distinct advantage of soil maps isthat they provide drainage information which surficial geology maps do not have. This is very important for many interpretations.

APPENDIX A: PROPOSED GUIDELINES FOR SOIL INTERPRETATIONS IN CANADA

Introduction:

Soil interpretations involved relating soil, landscape, or climatic qualities and characteristics to some defined use on the basis of their suitability or hazards for that use. Their main purpose is to present the information in a form that is more easily understandable by the potential user than is the raw data on soil or landscape properties alone.

A soil interpretations guidebook could perform two important functions. Firstly, in order to achieve some degree of consistency in soil interpretations across Canada, guidelines need to be established which specify those soil parameters considered to be important for making interpretations for a particular use. This is a logical starting point. Once this has been accomplished, limits can be developed for these properties, some of which may vary from one region to another. A further advantage of an interpretations guidebook is the convenience of having all guidance material and pertinent references in one publication.

In the proposed guidelines which follow, in addition to specifying those properties important for making interpretive decisions, the implications of a property or properties to development for a particular use will also, in some cases, be discussed. Where possible and if applicable on a national basis, ratings for the properties will be suggested based on varying degrees of severity of limitations. In most instances, ratings will reflect the experience of U.S. workers in this field; however if Canadian guidelines have been developed and are found to be satisfactory, these will be presented. All criteria are given for the purpose of further testing under local conditions and should be considered subject to modification if found to be unsuitable.

Basic Assumptions:

When dealing with the subject of soil interpretations the following assumptions apply:

1. Basic soils data are available in a readily useable form.

2. In the process of developing interpretive groupings and establishing the significance of certain properties, knowledge gaps will be identified.

3. The proposed interpretations are developed within a framework to allow the incorporation of data from other disciplines, e.g. climatology, geology, hydrology, ecology, etc.

4. Scientists from other disciplines must be actively involved with Pedologists in developing the interpretations.

5. Interpretive classifications or groupings do not eliminate the need for onsite investigations of specific sites for further information relevant to detailed design and construction purposes.

A. Engineering Uses

1. Suitability as a source of topsoil

The term "topsoil" includes soil materials used to cover barren surfaces exposed during construction, and materials used to improve soil conditions on lawns, gardens, flower beds, etc. The factors to be considered include not only the characteristics of the soil itself, but also the ease or difficulty of excavation, and where removal of topsoil is involved, accessibility to the site. The soil and landscape properties important to this use are indicated in Table 1. Suitability ratings of soils as sources of topsoil are given in Table 2, as well as in "Guide For Interpreting Engineering Uses of Soils", U.S.D.A., 1971, Guide Sheet 13.

2. Suitability as a source of fill material

Fill material for buildings or roads are included in this use. The performance of the material when removed from its original location and placed under load at the building site or road bed are to be considered. Since surface materials are generally removed during road or building construction their properties are disregarded. Aside from this layer, the whole soil to a depth of 5-6 feet should be evaluated. Those parameters of importance are indicated in Table 1. Guide sheet 11, in "Guide For Interpreting Engineering Uses of Soils", U.S.D.A., 1971, establishes classes for several soil properties.

Soil materials which are suitable for fill can be considered equally suited for road subgrade construction.

3. Suitability as a source of sand and gravel

The purpose of this interpretation is to provide guidance on the probable supply as well as quality of the sand or gravel for use as road base material andin concrete. The interpretation pertains mainly to the characteristics of the soil substratum to a dpeth of 5-6 feet, augmented by observations made in deep cuts as well as geological knowledge. The important criteria for this interpretation are given in Table 1, and suitability guidelines, based on the engineering class, in Guide sheet 12, "Guide For Interpreting Engineering Uses of Soils", U.S.D.A., 1971.

4. Suitability for septic disposal fields

The criteria used for rating soils for this use are based on their ability to absorb effluent passed through the tile field. Effluent should move through the soil at a moderate rate. Severe soil limitations exist where rapid permeability may permit contamination of water supplies, and restricted effluent movement, as a consequence of impermeable materials or high water table, result in surface overflow. Soils with slope gradients that contribute to side hill seepage of effluent also are considered to have severe limitations even though other characteristics are favourable. When evaluating the significance of water table levels to soil ratings for septic tanks, the seasonal high water table level should be considered in order to express soil suitability in the most limiting situation. Table 1 itemizes the important soil and landscape parameters to be considered for this use. Wall and Webber (1970) provide ratings for soil and site factors in terms of suitability classes. Guide sheet 3 in "Guide For Interpreting Engineering Uses of Soils", U.S.D.A., 1971, provides further guidelines for certain hazard classes.

5. Suitability for surface disposal of sewage

The renovation of liquid wastes of agricultural, municipal or industrial origin through application on the soil surface are included in this use. Rates of sewage application must be controlled so that aerobic conditions in the soil are maintained. Mineral nutrients, detergents, etc. can be removed by the processes of degradation by microorganisms in the surface horizons, chemical precipitation, ion exchange, biological transformations, etc. Many of the waste products then can be utilized as plant nutrients by an actively growing vegetative cover.

Those soil properties affecting permeability of both waste water and air, adsorption of the waste products and the ability of the site to support an actively growing vegetable cover are all of importance. These properties are indicated in Table 1. Guidelines used to evaluate soil suitability for sprinkler irrigation could likely be utilized with little modification for this use.

6. Suitability for sanitary landfill sites

The trench type sanitary landfill is considered in this use, in which dry garbage and trash is buried daily in an open trench and covered with a layer of soil material. Suitability of the site is dependent upon the potential for pollution of water sources through groundwater contact with the refuse, or leachate arising from the site. Those properties affecting ease of excavation of the site must be supplemented with geological and hydrological knowledge to provide subsurface soil and groundwater data to a depth of at least 10-15 feet, a common depth of landfills. Soil and landscape properties which are pertinent to this use are indicated in Table 1. Guide sheet 7 in "Guide For Interpreting Engineering Uses of Soils", U.S.D.A., 1971, provides ratings based on severity of limitations.

7. Suitability for foundations

These guidelines apply to the suitability for foundations for low buildings, generally less than three stories high. As foundations are placed in the substratum below the average depth of frost penetration, properties of the subsoil to a depth of at least 5-6 feet must be considered. The properties influencing foundation support are those affecting bearing strength and settlement under load. Ease of excavation is also considered as it affects cost of construction. Table 1 outlines the specific soil properties for which information is recommended in order to make interpretations for this use. Guide sheet 6, in "Guide For Interpreting Engineering Uses of Soils", U.S.D.A., 1971 may be consulted for soil suitability ratings.

8. Suitability for location of highways and roads

Soil and landscape properties that affect the design, construction and performance of highways and all-weather roads are considered here. It is not the intention to suggest that a modern soil map possesses adequate information to conduct engineering design, however, the soil map and interpretations are an invaluable aid in planning and conducting an engineering soil survey for design purposes.

Aside from the organic enriched surface horizon which is generally removed in construction, the entire soil profile in its undisturbed state should be evaluated for this use. Those properties of importance are indicated in Table 1.

9. Suitability for reservoir areas

Factors affecting the ability of undisturbed soils to impound water and prevent seepage are considered for evaluating soils on their suitability for reservoir areas. As the impounded liquids could be potential sources of contamination of nearby water supplies, e.g. sewage lagoons, the landscape position of the reservoir as it affects risk of flooding must also be considered. The important properties are presented in Table 1. Proposed ratings of criterion to be considered are given in Table 3.

10. Suitability for embankments

Soil suitability for embankment materials, including dikes and levees, is based on the ability of disturbed soil to restrain water flow when compacted. Among the soil qualities affecting evaluation for this use are shear strength, compressibility, compaction characteristics, permeability of the compacted material and susceptability to piping. The soil properties of importance to this interpretation are indicated in Table 1.

11. Suitability for shallow excavations and trenches

Soil suitability for excavations to a depth of 5 or 6 feet are considered for this use, as would be required in the installation of underground utilities, etc. Soil properties are interpreted in terms of workability of the material, resistance to sloughing and flooding hazard. Table 1 indicates the important properties to be determined. Guide sheet 5, in "Guide For Interpreting Engineering Uses of Soils", U.S.D.A., 1971, provides suitability ratings for this use.

12. Suitability of buried cables and pipelines

The properties which affect the suitability of a soil for shallow excavations and trenches, given above, also apply to its use for buried cables and pipelines, however, additional soil factors also must be taken into consideration in making the latter interpretation. These include the qualities of soil stability and corrosivity which have important implications with regard to maintenance and expected life-time of the underground installations. The properties of importance in making interpretations for this use are outlined in Table 1.

B. Recreational Uses

1. Soil suitability for playgrounds

These guidelines apply to soils that are to be used intensively for organized games such as football, baseball, etc., and as such are subject to heavy foot traffic. It should be assumed that this interpretation applies to soils in their natural condition with minimal re-shaping of the site, drainage, etc., being undertaken. Presumably, re-seeding of the site would be expected.

The most suitable sites are those with nearly level surface, good drainage, freedom from rock outcrops, and a soil texture and consistence that provides a firm surface, but not slippery or sticky when wet. Soils that present good trafficability properties are desirable in that they resist compaction with consequent development of bare patches. The ability of the soil to grow and maintain a vegetative cover is an important item to consider in the final evaluation of a site. Soil suitability classes for this use are proposed by Montgomery and Edminster (1966), and in the U.S.D.A. Guidebook For Soil Survey (1972). Table 4 presents somewhat modified guidelines which may be more pertinent to Canadian use.

2. Soil suitability for camp areas

These areas are considered to be used intensively for tenting, parking camp trailers and accompanying activity for short-term outdoor living. It is assumed that the area will require little site preparation other than levelling for tent and parking areas.

The soils should possess good trafficability properties to withstand heavy foot traffic and limited vehicular traffic. The vegetative cover should be easily maintained and the soils present no erosion hazard so that the site can be subject to prolonged use without deteriorating in quality. Guidelines for soil suitability classes for camp areas are presented in Montgomery and Edminster (1966) and U.S.D.A. Guidebook for Soil Survey (1972). Table 5 presents slightly modified guidelines for camp areas, compared to the above.

3. Soil suitability for picnic areas

Picnic areas are considered to be extensively used as park-type picnic grounds. It is assumed that most vehicular traffic would be confined to access roads and parking areas.

Soil properties that affect foot trafficability, problems of dust, surface wetness during season of use and the ability to grow and maintain a vegetative cover are very important in evaluating sites for this use.

Guidelines for soil suitability classes for picnic areas are presented in Montgomery and Edminster (1966), the U.S.D.A. Guidebook for Soil Survey (1972), and slightly modified criteria in Table 6.

4. Soil suitability for paths and trails

The limitations of soils for bridle paths or hiking trails apply to areas as they occur naturally and where little soil will be moved to provide for this recreational use.

The soils must have good trafficability for both humans and riding horses, good stability, free of coarse fragments or rock outcrops and are not subject to erosion. Where relief is sloping paths and trails should tend to follow the contour to help prevent erosion. Variability in slope gradient may add to the interest of the path or trail, but slopes should not exceed 12 percent for prolonged distances. Although the trail or path itself is generally devoid of vegetation, the vegetative potential of the soil is important in the areas through which the trail or path is developed.

Guidelines for rating soils for this use are given by Montgomery and Edminster (1966), and in the U.S.D.A. Guidebook for Soil Survey (1972). Additional guidelines are proposed in Table 7.

5. Soil suitability for ski areas

Evaluation of site suitability for ski areas involves interpretations for many uses, some covered in the "Engineering Uses" section of this report. These include interpretations for sewage disposal, foundations, roads and parking lot location, sources of building material, etc., which are all related to construction of associated facilities.

The interpretation of concern here is that of soil suitability for ski runs and trails. Ratings should evaluate the ability of the soil material to remain in place and to maintain the quality of the soil resource under this use.

Guidelines have been established by Rounsaville ( ), which probably apply mainly to the Cordillera area of Canada and the United States. He has specified three major factors (elements) which must be considered in determining site capability, including mass movement potential, onsite erosion potential and limitations for revegetation.

In different regions the significance of certain criteria used in rating soils for this use may very and it would seem more appropriate to establish details for the criteria to be used in the context of local conditions.

C. Agronomic and Forestry Interpretations

1. Soil interpretations for agriculture

Guidelines are generally well established in Canada for the interpretation of soils for agricultural use. The Soil Capability Classification System for Agriculture adopted by the Canada Land Inventory (1965) is in use nationally. Many provinces have developed regional guidelines to classify their soils within this system, based on soil and landscape limitations, regional climate and the productive capacity of common agricultural crops. A system for classifying soils on the basis of their suitability for irrigation has been developed for the prairie provinces (P.F.R.A., 1964). Agricultural capability systems also exist for classifying organic soils (Leeson, 1969). There likely are other systems in use which I have failed to mention. In most of these systems, the criteria used reflect regional needs and conditions.

Moss (1972) has outlined the physical features which affect the agricultural productivity and use of soils. This work deals specifically with Saskatchewan soils, however, the factors undoubtedly apply in a general way to other regions of Canada, although their importance may vary from one region to another. Table 8 presents, unmodified, the factors discussed in the publication. Also, the capability subclasses as defined in the Canada Land Inventory "Soil Capability Classification For Agriculture", 1967, presents those soil and landscape factors of significance to agricultural capability.

Perhaps the efforts of this subcommittee and others concerned with agronomic interpretations might be properly directed into the following areas:

a. Establish interpretive guidelines to rate soils on their capability or suitability for agriculture for a broader range of crops. The guidelines should enable one to rate the soil, landscape or climatic limitations of differing intensity as they affect productivity. Attempts are currently underway in Ontario to establish a capability system for tree crops (Mackintosh and Brown). What about vegetable crops, tobacco, etc? Guidelines appear to be required for rating soils for these uses since they generally have quite specific soil requirements.

b. Extend the capability classification system to include an additional category - a capability performance unit. This unit would consist of groups of soils that are very similar, and therefore suited to the same kinds of crops and require similar management practices. Thus, this unit is a convenient grouping of soils for management purposes.

2. Soil interpretations for forestry

A classification system exists for the interpretation of land capability for forestry on a national scale (McCormack, 1967). The national capability class descriptions have been modified for the various regions of Canada based on local experience. The capability ratings are based on the degree of soil, landscape or climatic limitations to the growth of commercial forests.

Interpretive classification systems in forestry have been developed which group soils having similar physical characteristics, are capable of producing similar kinds of tree crops, that require similar management practices and have about the same potential productivity. These units are referred to as "soil-woodland suitability groups". The S.C.S. Memorandum Soils-26 (Rev.) 1967 provides a guide for developing soil-woodland interpretations.

Soil interpretations for silvicultural and forest management uses have been proposed by the Forest Management Committee in B.C. for consideration by the Soil Interpretations subcommittee of the C.S.S.C. Interpretive classification systems for a number of forest management and forest engineering uses are given in the following pages.

A. Soil Interpretations for Silvicultural and Forest Management Uses

1. Suitability Classification for Regeneration of Logged Areas

a. Soil Parameters considered:
- soil texture
- effective rooting depth
- drainage
- elevation
- aspect

b. Suitability Classes for Regeneration:

Low - Regeneration potential with natural regeneration or planted stock is poor. The site will likely require silvicultural treatments (fill planting, re-seeding etc.) and several years before stocking will be satisfactory.

Moderate - Regeneration potential is medium. The site may require some fill planting in order to assure satisfactory stocking.

High - Regeneration potential is good and few problems should be encountered in obtaining satisfactory stocking.

c. References

Soil Cons. Serv., U. S. Dept. of Agric. 1967 Guide for developing and summarizing soil woodland interpretations. Soils Memo, SCS 26 (Rev. 2), 15 pp.

Snyder, R. V. and Wade, J. M. 1970. Mount Baker National Forest soil resource inventory. Soil Mgmt. Br., Div. of Watershed Mgmt., U.S.F.S., pp. 87-89.

2. Suitability Classification for Thinning in Forested Areas

a. Soil Parameters considered:
- soil texture
- effective rooting depth
- slope
- exposure
- drainage

b. Suitability Classes for Thinning:

Low - The site would not generally be suitable for thinning as extensive post-logging damage to the residual stand would likely occur. Soil factors considered include; steep slopes (> 30%), fine textured soils, poor drainage, exposure to wind and shallow effective rooting depth (< 18").

Moderate - The site is moderately suited for thinning treatments but have limited post-logging damage to the residual stand may occur. Slopes are shallower (15-30%), soils coarser, better drained with a greater effective rooting depth (18-36") and the stand is not directly exposed to the wind.

High - The site is highly suitable for thinning treatments and damage to the residual stand will likely be minimal. Generally, slopes are shallow (< 15%), soils are coarse, well drained and have deep effective rooting zones (> 36").

c. References

Keser, N. 1970. A mapping and interpretation system for the forested lands of B. C., B. C. Forest Service, Res. Note No. 54, p. 29.

3. Classification of Hazard Classes for Brush Revegetation of Logged Areas

a. Soil Parameters considered:
- soil texture
- effective rooting depth
- drainage
- slope
- aspect
- elevation

b. Soil Hazard Classes for Brush Revegetation

Low - Little or no brush revegetation is likely to occur and competition should not hinder initial growth of natural regeneration or planted seedlings.

Moderate - Some brush revegetation will occur and will likely retard both establishment and growth rate of seedlings but will not prevent eventual establishment of well stocked stands.

High - Brush revegetation occurs readily, occupying much of the site and thus preventing adequate natural or artificial regeneration, unless intensive site preparation and maintenance is practised.

c. References

Soil Cons. Serv., U. S. Dept. of Agric. 1967. Guide for developing and summarizing soil woodland interpretations. Soils Memo, SCS 26, (Rev. 2), 15 pp.

Snyder, R.V. and Wade, J. M. 1970. Mount Baker National Forest soil resource inventory. Soil Mgmt. Br., Div. of Watershed Mgmt., U.S.F.S., pp. 87-89.

4. Classification of Hazard Classes for Windthrow in Forested Areas

a. Soil Parameters considered:
   - effective rooting depth
   - exposure
   - soil texture
   - drainage
   - slope

b. Hazard Classes for Windthrow

Low - Generally there will be no trees blown down by wind. Soil factors considered include; deep effective rooting depth (> 36"), generally coarser textures and lack of exposed to winds.

Moderate - Some susceptability to windthrow especially during periods of soil wetness or high winds. Effective rooting depth is generally shallower (18-36"), soils are stony or finer textured and the stands are somewhat exposed to winds.

High - Windthrow is likely during periods of soil wetness or high winds. Effective rooting depth is generally shallow (< 18"), the soils may be fine textured and the stand is likely exposed to the wind.

c. References

Runka, G. G., 1972. Soil Resources of the Smithers-Hazelton Area. Soil Survey Division, B. C. Dept. of Agriculture, Kelowna, B. C., pp. 145-152.

Soil Cons. Serv., U.S. Dept. of Agriculture. 1967. Guide for developing and summarizing soil woodland interpretations. Soils Memo, SCS 26 (Rev. 2), 15pp.

Snyder, R.V. and Wade, J.M. 1970. Mount Baker National Forest soil resource inventory. Soil Mgmt. Br., Div. of Watershed Mgmt., U.S.F.S. pp. 87-89.

Sprout, P.N., Lacate, D.S. and Arlidge, J.W.C. 1966. Forest land classification and interpretations for management of a portion of the Niskonlith Provincial Forest, Kamloops District, B.C., Dept. of For. Publ. 1159, B.C.F.S. Tech. Publ. T60, 34 pp.

5. Miscellaneous items best dealt with in tabular form or mentioned in descriptions of soil units.

a. soil related insect pest and disease hazards
b. tree species best suited for the soil unit;
   - for planting
   - for natural regeneration
c. special products suited to the soil unit (such as christmas trees, hybrid poplars, etc.)

B. Soil Interpretations for Forest Engineering Uses

1. Suitability Classification for Trafficability (Equipment Limitations) in Logging Areas

   a. Soil Parameters considered:
      - slope
      - soil texture
      - drainage
      - soil structure
      - soil stability
      - soil depth

   b. Trafficability Limitation Classes

      Low - No significant soil limitations on type of equipment that can be used or what time of year it can be used. Soil factors considered include; shallow slopes ($<$15%), good drainage, coarse textures and few bedrock exposures.

      Moderate - Equipment use is moderately restricted in terms of type of equipment, or time of year used. Slopes may be steeper (15-30%), drainage poorer, texture finer and more bedrock may be exposed.

      High - Special equipment is required and its use is restricted by soil, vegetation or climatic factors. Slopes may be steep ($>$ 30%), soil drainage poor, texture fine and bedrock exposures common.

   c. References

Soil Cons. Serv., U. S. Dept. of Agriculture, 1967. Guide for developing and summarizing soil woodland interpretations. Soils Memo, SCS 26 (Rev. 2), 15 pp.

Snyder, R.V. and Wade, J.M., 1970. Mount Baker National Forest soil resource inventory. Soil Mgmt. Br., Div. of Watershed Mgmt. U.S.F.S., pp. 87-89.

Sprout, P.N., Lacata, D.S. and Arlidge, J.W.C., 1966. Forest land classification and interpretations for management of a portion of the Niskonlith Provincial Forest, Kamloops District, B. C., Dept. of For. Publ. 1159, B.C.F.S. Tech.Publ. T60, 34 pp.

2. Classification of Hazard Classes for Erosion in Logging Areas

   a. Soil Parameters considered:
      - soil texture
      - soil permeability, porosity and infiltration capacity
      - slope
      - landscape position
      - soil stability
      - soil porosity

b. Soil Hazard Classes for Erosion

Low - Problems of erosion control are relatively unimportant. The soils are generally very permeable, coarse textured, stony and slopes are shallow ($<15\%$).

Moderate - Some erosion control work will be required. Soils are generally fairly permeable, medium textured, somewhat stony and on medium slopes (15-30%).

High - Intensive erosion control, specialized equipment and operational techniques will be required to prevent erosion. Soils generally have a low permeability, fine textures, few stones and slopes may be steep ($>$ 30%).

c. References

Soil Cons. Serv., U.S. Dept. of Agric.1967. Guide for developing and summarizing soil woodland interpretations, Soils Memo SCS 26 (Rev. 2), 15 pp.

Sprout, P.N., Lacate, D.S. and Arlidge, J.W.C., 1966. Forest land classification and interpretations for management of a portion of the Niskonlith Provincial Forest, Kamloops District, B.C., Dept. of For. Publ. 1159, B.C.F.S. Tech. Publ. T60, 34 pp.

3. Miscellaneous items best dealt with in tabular form or in descriptions of soil units.

a. Recommended method of logging for each soil unit.
b. Recommended method of slash treatment and site preparation.

C. References Cited

1) Keser, N. 1970. A mapping and interpretation system for the forested lands of B. C., B. C. F. S., Res. Note No. 54, p.29

2) Runka, G. G. 1972. Soil resources of the Smithers-Hazelton area. Soil Survey Division, B. C. Dept. of Agriculture, Kelowna, B. C., pp 145-152.

3) Soil Cons. Serv., U. S. Dept. of Agriculture 1967. Guide for developing and summarizing soil woodland interpretations. Soils Memo, SCS 26 (Rev. 2), 15 pp.

4) Snyder, R.V. and Wade, J. M.1970. Mount Baker National Forest soil resource inventory. Soil Mgmt. Br., Div. of Watershed Mgmt. U.S.F.S. pp 87-89.

5) Sprout, P.N., Lacate, D.S. and Arlidge, J.W.C. 1966. Forest land classification and interpretations for management of a portion of the Niskonlith Provincial Forest, Kamloops District, B. C., Dept. of For. Publ. 1159, B.C.F.S. Tech. Publ. T60, 34 pp.

REFERENCES

Canada Land Inventory, 1965. Soil Capability Classification For Agriculture, Report No. 2.

Leeson, B., 1969. A Use Capability Classification for Organic Soils. Ontario A.R.D.A.

McCormack, R.J., 1967. Land Capability Classification for Forestry. Canada Land Inventory Report No. 4.

Montgomery, P.H. and F.C. Edminster, 1966. Use of Soil Surveys in Planning for Recreation. In Soil Surveys and Land Use Planning, Publ. by Soil Science Society of America and American Society of Agronomy.

Moss, H.C., 1972. A Revised Approach to Rating Saskatchewan Soils. Saskatchewan Institute of Pedology Publication M20.

P.F.R.A., Regina. 1964. Committee of the Canada Dept. of Agriculture Handbook for the Classification of Irrigated Land in the Prairie Provinces.

Rounsaville, H.D. Soil Interpretations for Ski Area Planning in the Rocky Mountain Region. Unpublished mimeo, U.S.D.A. - Forest Service, Rocky Mountain Region.

U.S.D.A., 1967. Soil Conservation Service Memorandum, Soils-26 (Rev.).

U.S.D.A., 1971. Guide for Interpreting Engineering Uses of Soils.

U.S.D.A., 1972. Guidebook for Soil Survey, Work Planning Conference, Hawaii.

Wall, G.J. and L.R. Webber, 1970. Soil Characteristics and Subsurface Sewage Disposal. Can. Jour. Public Health 61:47-54.

TABLE 1: SOIL AND LANDSCAPE PROPERTIES SIGNIFICANT TO INTERPRETATIONS FOR SELECTED ENGINEERING USES

Soil or Landscape Properties	SUITABILITY AS A SOURCE OF			SOIL LIMITATIONS FOR WASTE DISPOSAL					WATER RETENTION STRUCTURES			
	Topsoil	Sand & Gravel	Fill Material	Septic Tanks	Sewage	Sanitary Landfill	Foundations	Highways & Roads	Reservoirs	Embankments	Shallow Excavations & Trenches	Buried Cables & Pipelines
a) Texture or engineering class	R	R	R		R	R	R	R	R	R	R	R
b) Organic matter content	R				R				R			R
c) Thickness of surface layer	R	R						R				
d) Soil reaction	R				R							R
e) Electrical conductivity	R				R		D					D
f) Exchange capacity				D	D							
g) Soil drainage class	R		R	R	R	R	R	R			R	R
h) Field moisture content			D	D				D				
i) Depth to water table		R	R	R		R	R	R	R		R	R
j) Permeability				D	D	D			D			
k) Depth to bedrock			R	R		R		R	R		R	R
l) Type of bedrock				D		D			D		D	
m) Slope	R		R	R	R	R	R	R	R		R	R
n) Stoniness	R			R		R	R	R	R	R	R	R
o) Mineralogy			D				D	D				D
p) Liquid limit							D	D		D		D
q) Plasticity Index			R				D	D		D		D
r) Maximum dry density			D				D	D		D		
s) Optimum moisture content			D					D		D		
t) Susceptability to flooding		R	R	R	R	R	R	R	R		R	R
u) Ease of excavation	R		R			R	R	R		R		
v) Groundwater regime				D		D						D

NOTE:

R denotes information recommended on a routine basis

D denotes information that would be useful for detailed surveys conducted with engineering purposes in mind.

TABLE 2: SUITABILITY RATINGS OF SOILS AS SOURCES OF TOPSOIL.

Items Affecting Use	Degree of Soil Suitability		
	Good	Fair	Poor
Flooding	None	May flood occasionally for short periods.	Frequent flooding or constantly flooded.
Wetness	Well and moderately well drained soils not subject to ponding.	Well and moderately well drained soils subject to occasional ponding. Somewhat poorly drained soils not subject to ponding.	Poorly and very poorly drained soils. Somewhat poorly drained soils subject to ponding for periods of more than 4 weeks during construction season.
Slope	0 - 5%	>5 - 9%	>9%
Stoniness	0 - 1	2	3, 4, 5
Surface Soil Texture	SL, FSL, VFSL, L, SiL	CL, SCL, SiCL	LS, S, SC, SiC, C, organic soils
Depth of Topsoil	>6 inches	3 - 6 inches	<3 inches
Salinity of Topsoil 1/	E.C. 0 - 1	E.C. >1 - 3	E.C. >3

1/ E.C. - electrical conductivity

The soil suitability ratings of "good, fair, and poor" correspond to the limitations of "none to slight, moderate, and severe" respectively and the definitions are essentially the same. The soils may also be rated "unsuitable" as sources of topsoil.

TABLE 3: SUITABILITY RATINGS OF SOILS FOR RESERVOIR AREAS

Soil and Landscape Parameters	Degree of Limitation		
	Slight	Moderate	Severe
Depth to water table	>72 in.	48-72 in.	<48 in.
Flooding	None	None	Subject to flooding once in 50 years
Soil permeability	0-.2 in./hr.	.2-2.0 in./hr.	2.0- >20 in./hr.
Slope %	0-2	2-7	>7
Organic matter %	< 2	2-10	>10
Coarse fragments >10" in diameter, % by volume	<10	10-30	>30
Nature of bedrock*	Impermeable		Highly permeable, fractured, easily soluble
Depth to bedrock in.	>72	48-72	<48
Thickness of slowly* permeable layer (in.)	> 48	24-48	< 24
Unified soil texture classification	GC, SC, CL, and CH	GM, ML, SM, and MH	GP, GW, SW, SP, OL, OH, and PT

TABLE 4: GUIDELINES TO EVALUATE SOIL SUITABILITY FOR PLAYGROUND USE

Degree of Soil Limitation

Items Affecting Use	None to Slight	Moderate	Severe
Soil drainage	Well and moderately well drained soils.	Imperfectly drained soils.	Rapidly drained, imperfectly drained if subject to ponding. Poorly and very poorly drained soils.
Depth to water table	Below 3 feet during season of use.	Below 2 feet during season of use.	<2 feet during season of use.
Flooding	None during season of use.	May flood once in 3 years during season of use.	Floods more than once in 3 years during season of use.
Permeability	Very rapid to moderate. (20 in/hr - 0.6 in/hr)	Moderately slow (0.20 - 0.60 in/hr)	Slow and very slow. (<0.20 in/hr)
Slope	0 - 2 percent	2 - 5 percent	>5 percent
Surface soil texture	sl, fsl, vfsl, l, ls with textural B horizon	sil, cl, scl, sicl, ls.	sc, sic, c, organic soils, s and ls subject to blowing.
Depth to bedrock	3 feet	2 - 3 feet	<2 feet
Coarse fragments on surface	Relatively free of fragments.	Up to 20% coarse fragments.	>20% coarse fragments.
Stoniness	Classes 0 & 1	Class 2	Classes 3, 4, & 5
Rockiness	Class 0	Class 1	Classes 2, 3, 4 & 5

NOTE:

Perhaps guidelines also should be given for water storage capacity, bulk density, organic matter content.

TABLE 5: GUIDELINES TO EVALUATE SOIL SUITABILITY FOR CAMP AREAS

	Degree of Soil Limitation		
Items Affecting Use	None to Slight	Moderately	Severe
Soil Drainage	Well and moderately well drained soils	Imperfectly drained soils, no ponding.	Rapidly drained imperfectly drained with occasional ponding, poorly and very poorly drained soils.
Depth to water table	Below 3 feet during season of use.	Below 2 feet during season of use.	<2 feet during season of use.
Flooding	None	None during season of use.	Subject to flooding during season of use.
Permeability	Very rapid to moderate. (20.0 in/hr - 0.6 in/hr)	Moderately slow (0.20 - 0.60 in/hr)	Slow and very slow. (<0.20 in/hr)
Slope	0-9 percent	9-15 percent	>15 percent
Surface soil texture	sl, fsl, vfsl, l, ls with textural B horizon	sil, cl, scl, sicl, ls, s other than loose sand.	sc, sic, c, organic soils sand subject to blowing
Coarse fragments on surface	0-20 percent	20-50 percent	>50 percent
Stoniness	Classes 0 & 1	Class 2	Classes 3, 4 & 5
Rockiness	None	Classes 1 & 2	Classes 3, 4 & 5

NOTE:

Guidelines perhaps need to be given for organic matter content, water storage capacity and bulk density.

TABLE 6: GUIDELINES TO EVALUATE SOIL SUITABILITY FOR PICNIC AREAS

	Degree of Soil Limitation		
Items Affecting Use	None to Slight	Moderate	Severe
Soils drainage	Well and moderately well drained soils	Well and moderately well drained soils subject to occasional ponding. Imperfectly drained soils not subject to ponding.	Rapidly drained imperfectly drained subject to ponding, poorly and very poorly drained soils.
Flooding	None during season of use.	May flood 1 or 2 times during season of use.	Floods more than 2 times during season of use.
Slope	0-9 percent	9-15 percent	>15 percent
Surface soil texture	sl, fsl, vfsl, l, ls with textural B horizon	sil, cl, scl, sicl, ls, s other than loose sand.	sc, sic, c, organic soils sand subject to blowing.
Stoniness and rockiness	Classes 0, 1 & 2	Class 3	Classes 4 & 5

TABLE 7: GUIDELINES TO EVALUATE SOIL SUITABILITY FOR PATHS AND TRAILS

Item Affecting Use	Degree of Soil Limitations None to Slight	Moderate	Severe
Soil drainage	Well and moderately well drained soils.	Well and moderately well drained soils subject to seepage or ponding and imperfectly drained soils.	Rapidly drained poorly and very poorly drained soils.
Depth to seasonal water table	Below 3 feet	1-3 feet	<1 foot
Flooding	Not subject to flooding during season of use.	May flood 1 or 2 times during season of use.	Frequent flooding during season of use.
Slope	0-15 percent	15-30 percent	>30 percent
Surface texture	sl, fsl, vfsl, l	sil, sicl, scl, cl, sc, ls	sic, c, sand and soils subject to severe blowing, all very gravelly, very cherty, very cobbly, etc. soils.
Surface stoniness or rockiness	Classes 0, 1 & 2	Class 3	Classes 4 and 5

TABLE 8. PHYSICAL FEATURES
AFFECTING THE AGRICULTURAL PRODUCTIVITY AND USE OF SOILS

1. The Kind of Soil (the Soil Profile)

(a) Kind and arrangement of horizons: thickness, color, structure, consistence, total depth of profile

(b) Texture — of A or Ap first, but also including that of B, C, and D horizons; and recognition of parent material

(c) Composition — organic matter, nitrogen, phosphorus, reaction, lime carbonate, salts, exchangeable cations. (Recognition of biological activity and availability of plant nutrients)

(d) Soil moisture (internal or profile drainage) — hydraulic conductivity (permeability), moisture-holding capacity, available water, state of aeration (drainage)

2. The Soil Landscape

(a) Topography — slope, frequency (number of "rolls" or undulations per 1/2 mile or other specified distance), roughness of surface (micro-relief), aspect, pattern. (Perhaps size and shape of fields) Closely related to (b) below

(b) Drainage — type (external or local), conditions of surface drainage, liability to flooding

(c) Stoniness — affecting costs of operation or limiting land use

(d) Erosion — affecting crop production or limiting land use

(e) Wooded cover (bush or scrub) — requiring clearing on arable lands or management on forest lands

3. Climate

(a) Precipitation — annual amount, distribution, variability

(b) Temperature — annual, variations, growing season, growing-degree days

(c) P. - T relationships (moisture efficiency), evapo-transpiration ratios

RAPPORT DU COMITE DES FAMILLES DE SOLS

J.L. Nowland, Président

Résumé

Les critères pour les familles de sols ont été adoptés tant pour les sols minéraux que pour les organiques. Pour les sols minéraux ces critères se rapportent à la texture, la minéralogie, la profondeur, la réaction, la teneur en calcaire et le climat du sol. Pour les sols organiques on utilise les caractéristiques du tier de surface, la réaction, le climat du sol, la texture de la couche terrique et la nature de la couche limnique.

REPORT OF THE SUBCOMMITTEE ON SOIL FAMILIES

J.L. Nowland, Chairman

Summary

Criteria for soil family have been adopted for both mineral and organic soils. For mineral soils the criteria used to establish a soil family are particle size, mineralogy, depth, reaction, calcareousness, soil climate. For organic soils the criteria used are characteristics of surface tier, reaction, soil climate, particle size of terric layer, nature of limno layer.

A definition of the soil family appeared in the 1938 Yearbook "Soils and Man". The addition of substance to the conceptual skeleton commenced in the U.S.A. with the report of a special committee in 1945. A similar process began in Canada a decade ago at the Winnipeg Meeting of N.S.S.C., and developed under the skilled guidance of a committee chaired by Prof. Roger Baril.

Recent activity on the subject of soil family classification can be summarized as follows:

<u>March, 1971</u>

Memo from Day and Nowland containing "Guidelines to stimulate discussion, help in the naming of families and lead to subcommittee activity". This followed quite closely the contemporary United States proposals.

September, 1971

Presentation by Nowland at CSSC Eastern Meeting reviewing the state of the art and suggesting revisions to the system of Soil Classification for Canada.

February, 1972

"Some observations of soil family classification" by Cann.

May, 1972

A detailed "Report on Soil Family" by Michalyna, incorporating his presentation to the CSSC Western Meeting and subsequent amendments. Michalyna considered the concepts and philosophy of soil family in addition to proposals concerning every detail of the system. For example "At the subgroup level soils emerge as a product of climate, vegetation, drainage, topography and time; the family bridges the gap to soil series employing criteria based largely on properties of the material and the landscape". He presented the alternatives before us including adoption of the U.S. system.

After the exercise of the democratic process at Kelowna, the chief features of the scheme proposed by Michalyna were:

1) A generalized description of the control section

2) Acceptance of the U.S. particle-size classes and name, along with most of the modifications to the control section used for application of particle-size.

3) A more informative depth zonation of the control section was proposed, the existing depth classes being more suitable as series criteria.

4) Reaction and calcareous classes applied to the control section below the solum, as preferred by Western pedologists.

5) Special horizons, fragipan, ortstein be considered at the subgroup.

6) Agreed not to adopt the U.S. system, but to accept their particle size classes and terminology.

7) At this time few were prepared to make an educated vote, according to the record. Michalyna's report incorporated the ideas of many. Day pointed out that at least in the North, we need to use elements of the soil family in tailoring map legends.

8) Four recommendations for action by the soil family subcommittee went on the record.

Dr. Clark instructed the Soil Family Subcommittee to finalize the classification scheme and have recommendations ready for the May, 1973 meeting of CSSC. To this end, a provisional draft was presented at Saskatoon and adopted with the proviso that a few remaining issures be settled in subcommittee.

One or two minor changes were made by the chairman based on a sampling of opinion at the meeting, and organic soils were incorporated. Outstanding amendments proposed by Manitoba were put to a postal vote. Returns were scanty and inconclusive with two groups and two individuals in favour of the Manitoba proposals and three groups opposed. The chairman therefore takes responsibility for rejecting the proposals at present and submitting the attached draft to the chairman, CSSC for inclusion in the System of Soil Classification for Canada.

It has been judged appropriate to lean heavily on the U.S. system in order to take proper advantage of their much more copious inputs over the years. The desirability of maintaining absolute precision of correlating did not become a sacred cow; the prevailing mood was to ensure that the system satisfied our needs in Canada, with a minimum of complexity.

Briefly, in what respect does the proposed classification differ from that in the U.S. Soil Taxonomy?

1. It is half the length and less prolix.

2. It defines the basic control section for both family and series level, before stating the modifications for particle size classes. Soil Taxonomy does the opposite.

3. Particle size. Very coarse sand dropped from fragmental particle-size. Coarse (rock) fragments have an upper size limit of 25 cm rather than "horizontal dimensions less than a pedon".

   U.S. medial and medial-skeletal classes omitted.
   No exception made for podzolic B horizon

4. Control section. Not terminated by cryic horizons, lithic contact, fragipan, etc. Special treatment of podzolic B horizons omitted. Deep contrasting A horizon allowed for. Some trivial or rare cases left to common sense.

5. Strongly contrasting particle size classes. We have 10 strongly contrasting combinations which the U.S. Soil Taxonomy does not recognize. They have 4 which we do not use plus a whole suite of medial particle sizes. We do not observe qualifying conditions limiting the application of contrasting particle size classes, such as minimum percentages of sand and clay fractions.

6. Mineralogy. Twelve out of the seventeen U.S. classes proposed for Canada.

7. Soil depth. Three shallow classes recognized, compared with two in Soil Taxonomy.

8. Reaction classes. Soil Taxonomy recognizes only two classes, applied to the control section and used only in Entisols and Aquepts.

9. Calcareous classes. Soil Taxonomy recognizes only two classes, applied from 25 to 50 cm, applied only in certain subgroups.

10. Soil climate. The Canadian System is quite different, with four temperature classes covering the range of the U.S. frigid class, and defined in more detail. Soil Taxonomy does not use moisture classes.

11. Consistence. Not used in Canada; covered mostly at subgroup level.

12. Moisture equivalent. The 2% separation for coated and uncoated sands not used in Canada.

13. Slope of the soil and classes of permanent cracking are not used in Canada.

It remains for me to thank the members of the Subcommittee for their valued contributions.

SOIL FAMILY

The soil family is a taxonomic category between the subgroup and series levels that is used to group soils according to certain chemical and physical properties and environmental factors. Mineral soils within a subgroup are differentiated in families on the basis of particle-size, mineralogy, pedoclimate, reaction, calcareousness and depth. Organic soils are differentiated on the basis of kind of surface tier, reaction, pedoclimate, particle-size of terric layer and kind of limno layer. Soils in a family therefore have in common a combination of important specific properties, but treated in a broader fashion than for soil series. Families constitute a framework within which series can be established.

The criteria for mineral soil families differ considerably from those for organic soil families and they are described separately.

Distinguishing criteria are applied to the control section as defined elsewhere, or rather a segment of it of special significance for a given property.

CRITERIA AND GUIDELINES - MINERAL SOILS

1. PARTICLE-SIZE

Explanation

The terminology and class limits developed for the U.S. system have been adopted. Note that in some cases these will apply to a somewhat different segment of the control section in order to fit the needs of the Canadian system.

Particle-size

Refers to grain size distribution of the whole soil in contrast to texture, which refers to the fine earth fraction of the soil. Particle-size classes may be regarded as a compromise between engineering and pedologic classifications. The limit between sand and silt is 74 microns in the engineering classifications, and either 50 or 20 microns in pedological classifications. The engineering classifications are based on weight percentages of the fraction less than 74 mm, while textural classes are based on the less than 2 mm fraction.

The very fine sand fraction, .05 to .1mm, is split in the engineering classifications. The particle-size classes make much the same split but in a different manner. A fine sand or loamy fine sand normally has an appreciable content of very fine sand, but the very fine sand fraction is mostly coarser than 74 microns. A silty sediment, such as loess, may also have an appreciable component of very fine sand, but it is mostly finer than 74 microns. So, in particle-size classes, the very fine sand is allowed to "float". It is treated as sand if the texture is fine sand or loamy fine sand or coarser. It is treated as silt if the texture is very fine sand, loamy very fine sand, sandy loam, or silt loam or finer.

No single set of particle-size classes seems appropriate as family differentiae for all kinds of soils. The classes that follow provide for a choice of either 7 or 11 particle-size classes. This choice permits relatively fine distinctions in soils if particle-size is not susceptible to precise measurement or if use of narrowly defined classes produces undesirable groupings. Thus, in some families the term "clayey" indicates that there is 35 percent or more clay in defined horizons; but in other families the term "fine" indicates that the clay portion constitutes 35 to 60 percent of the fine earth of the horizon, and ther term "very fine" indicates 60 percent or more clay.

Particle-Size Classes for Family Groupings

1. FRAGMENTAL: Stones, cobbles and gravel, with too little fine earth to fill interstices larger than 1 mm.

2. SANDY-SKELETAL: Particles coarser than 2 mm are 35 percent or more by volume, with enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is that defined for particle-size class 5.

3. LOAMY-SKELETAL: Particles 2 mm to 25 cm are 35 percent or more by volume and enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is that defined for particle-size class 6.

4. CLAYEY-SKELETAL: Particles 2 mm to 25 cm are 35 percent or more by volume, and enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is that defined for particle-size class 7.

5. SANDY: The texture of the fine earth includes sands and loamy sands, exclusive of loamy very fine sand and very fine sand textures; and particles of 2 mm to 25 cm are less than 35 percent by volume.

6. LOAMY: The texture of the fine earth includes loamy very fine sand, very fine sand, and finer textures with less than 35 percent clay;

particles 2 mm to 25 cm are less than 35 percent by volume.

6a. Coarse-loamy: A loamy particle-size that has 15 percent or more by weight of fine sand (0.25-0.1 mm) or coarser particles, including fragments up to 7.5 cm, and has less than 18 percent clay* in the fine earth fraction.

6b. Fine-loamy: A loamy particle-size that has 15 percent or more by weight of fine sand (0.25-0.1 mm) or coarser particles, including fragments up to 7.5 cm, and has 18 to 35 percent clay* in the fine earth fraction.

6c. Coarse-silty: A loamy particle-size that has less than 15 percent of fine sand (0.25-0.1 mm) or coarser particles, including fragments up to 7.5 cm, and has less than 18 percent clay* in the fine earth fraction.

6d. Fine-silty: A loamy particle-size that has less than 15 percent of fine sand (0.25-0.1 mm) or coarser particles, including fragments up to 7.5 cm, and has between 18 and 35 percent clay* in the fine earth fraction.

7. CLAYEY*: The fine earth contains 35 percent or more clay by weight and particles 2 mm to 25 cm are less than 35 percent by volume.

7a. Fine: A clayey particle-size that has 35 to 60 percent clay in the fine earth fraction.

7b. Very fine: A clayey particle-size that has 60 percent or more clay in the fine earth fraction.

ADDITIONAL SUBSTITUTE CLASSES

Special terms are used for some soils, chiefly Brunisols, in which volcanic ash or cinders abound, and particle-size has little meaning. The terms substitute for both particle-size and mineralogy names.

Cindery: 60 percent or more of the whole soil (by weight) volcanic ash and cinders; 35 percent or more (by volume) cinders having diameter 2 mm and larger.

Ashy: 60 percent or more of the whole soil (by weight) volcanic ash and cinders; less than 35 percent (by volume) has diameter 2 mm and larger.

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* Carbonates of clay size are not considered to be clay, but are treated as silt.

Thixotropic: Less than 35 percent (by volume) has diameter 2 mm or larger; the fine-earth is thixotropic and the exchange complex is dominated by amorphous materials.

Ashy-Skeletal and Thixotropic-Skeletal: rock fragments other than cinders are 35 percent or more by volume, with matrix as above.

The substitute terms and limits listed are the same as in the U.S. system, but a "medial" class has been omitted (less than 60% ash and cinder). Subsequent reference to particle-size classes is meant to include the additional substitutes.

Application of Particle-Size Classes

To apply particle-size classes use the weighted average particle-size of the control section or segment of it listed below. The weighted average can usually be estimated, but in marginal cases it may be necessary to calculate the weighted average percentage of one or more determinant size fractions. This is done by summing the products of fraction percentage times horizon depth for the whole control section (or applicable segment of it) and dividing by total thickness.

If there are strongly contrasting particle-sizes, as shown in Table 1, both are used e.g., fine-loamy over sandy.

In applying particle sizes only a segment of the control section is commonly used, as listed below. In this way allowance is made for

a) excluding surface layers, except in the shallowest soils, partly because these are used at the soil type level, and because their characteristics may be ephemeral.

b) the special importance of Bn and Bt horizons in a profile.

1. In soils having a lithic contact within 36 cm of the surface, particle-size is assessed in the non-lithic part of the control section.

2. In other soils lacking a significant[1] Bt or Bn horizon, particle-size is assessed in the non-lithic part of the control section between 25 and 100 cm.

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(1) For this purpose a "significant" Bt or Bn horizon is 15 cm thick or more, and has an upper boundary within a depth of 50 cm.

3. In other soils that have a significant Bt or Bn horizon, extending deeper than 25 cm, particle-size is assessed

   a) in the upper 50 cm of the Bt or Bn horizons (or the entire horizon if thinner), if there are no strongly contrasting classes in or below these horizons.

   b) in that part of the control section between the top of the Bt or Bn horizons and 1 m depth, if it contains strongly contrasting classes.

NOTE: If there are no strongly contrasting classes in or below the Bt or Bn horizon, but there is a strongly contrasting A horizon more than 50 cm thick, contrasting classes are applied from 25 cm to 1 m depth.

4. If the base of a significant Bt or Bn horizon, or the control section in which it occurs, is shallower than 25 cm, particle-size is assessed on that part of the control section below the top of the Bt or Bn, or the base of the Ap, whichever is shallower.

Strongly Contrasting Particle-Size Classes identify major variations within the control section which affect properties such as water movement and retention. They emphasize features which may not have been identified at higher taxonomic levels.

The minimum significant thickness of a strongly contrasting layer is 15 cm. The particle-size classes in Table 1 are strongly contrasting if the transition is less than 12.5 cm thick. For ashy-skeletal and thixotropic-skeletal classes, enter the table at clayey-skeletal.

Where three strongly contrasting layers occur within the control section the lowest layer and the thicker of the overlying layers are used to establish contrasting classes.

Table 1. Strongly Contrasting Particle Sizes

Recognized permutations are designated by an X at the intersect.

	Over: fragmental	sandy skeletal	loamy skeletal	clayey skeletal	sandy	loamy: coarse loamy	coarse silty	fine loamy	fine silty	clayey: fine clayey	very fine clayey	cindery	ashy	thixotropic
fragmental			X	X		X	X	X	X	X	X			X
sandy skeletal				X		X	X	X	X	X	X	X		X
loamy skeletal	X									X	X			X
clayey skeletal	X	X			X									
sandy	X			X			X	X	X	X	X	X		X
loamy	X	X			X					X	X	X		X
clayey	X	X	X		X	X	X	X	X					
cindery													X	

________ if underlined indicates that the broader term be used if desired.

II. MINERALOGY

Mineralogy classes are based on the mineralogical composition of selected particle-size fractions in the control section or segment of it used for the designation of the particle-size class. If contrasting classes are recognized, the mineralogy of <u>only</u> the upper contrasting layer defines the family mineralogy.

The 12 mineralogy classes in Table 2 were taken from the 17 in Soil Taxonomy (U.S.D.A. 1973) and the sulphurous subclass abandoned in the U.S., was retained for application in Canada. The segment of the control section to which they are applied in the Canadian taxonomy differs in some cases from its U.S. counterpart. Soils are placed in the first mineralogy class in the table that accommodates them, even though they may meet the requirements of other classes.

It is recognized that in the absence of data, placement of soils will commonly depend on judgement, and that many of the classes are rare in Canada and relate to specific parent materials. Most Canadian soils have mixed mineralogy, notable exceptions being montmorillonitic clayey soils on the Prairies.

Table 2. Key to Mineralogy Classes

Class	Definition	Determinant Size Fraction
CLASSES APPLIED TO SOILS OF ANY PARTICLE-SIZE CLASS		
Carbonatic..........	More than 40 percent by weight carbonates (expressed as $CaCO_3$) plus gypsum, and the carbonates are >65 percent of the sum of carbonates and gypsum.	Whole soil, particles <2mm in diameter, or whole soil<20mm, whichever has higher percentages of carbonates plus gypsum.
Serpentinitic.......	More than 40 percent by weight serpentine minerals (antigorite, chrysotile,fibrolite and talc)	Whole soil, particles <2 mm in diameter.
CLASSES APPLIED TO SOILS OF ANY PARTICLE-SIZE CLASS		
Gypsic.........	More than 40 percent by weight of carbonates (expressed as $CaCO_3$ plus gypsum, and the gypsum is >35 percent of the sum of carbonates and gypsum.	Whole soil, particles <2mm in diameter, or whole soil <20mm, whichever has higher percentages of carbonates plus gypsum.
CLASSES APPLIED TO SOILS HAVING A SANDY, SANDY-SKELETAL, LOAMY OR LOAMY-SKELETAL PARTICLE-SIZE CLASS		
Micaceous......	More than 40 percent mica by weight (1)	0.05 to 2mm
Siliceous......	More than 90 percent by weight (1) of silica minerals (quartz, chalcedony, or opal) and other extremely durable minerals that are resistant to weathering	0.05 to 2mm
Mixed..........	All others that have <40 percent of any one mineral other than quartz or feldspars	0.05 to 2mm
CLASSES APPLIED TO SOILS HAVING A CLAYEY PARTICLE-SIZE CLASS		
Kaolinitic.....	More than half kaolinite tabular halloysite, dickite, and nacrite by weight and smaller amounts of other 1:1 or nonexpanding 2:1 layer minerals or gibbsite	<0.002mm
Montmorillonitic.	More than half montmorillonite and nontronite by weight or a mixture that has more montmorillonite than any other one clay mineral	<0.002mm

Class	Definition	Determinant Size Fraction
CLASSES APPLIED TO SOILS HAVING A CLAYEY PARTICLE-SIZE CLASS		
Illitic............	More than half illite (hydrous mica) by weight and commonly 4 percent K_2O	0.002mm
Vermiculitic.......	More than half vermiculite by weight or more vermiculite than any other one clay mineral	0.002mm
Chloritic..........	More than half chlorite by weight or more chlorite than any other clay mineral	0.002mm
Mixed..............	Other soils	0.002mm
SUBCLASS USED IN CONJUNCTION WITH MINERALOGY CLASSES		
Sulphurous.........	Soils containing either iron sulphates, commonly jarosite, if the pH after oxidation is less than 3.5; or more than 0.75% sulphur in the form of polysulphides if the soil contains less than three times as much carbonate ($CaCO_3$ equivalent) as sulphur	Whole soil less than 2mm. Organic soils and some Gleysols only.

(1) Percentages by weight are estimated from grain counts. Usually a count of one or two of the dominant size fractions of a conventional mechanical analysis is sufficient for placement of the soil.

III. SOIL DEPTH

Depth classes are applicable only in soils having a lithic or cryic contact within a depth of 1 m. In the following classes for mineral soils, depth is measured from the surface to the contact:

Extremely shallow:	18 cm deep or less
Very shallow:	18 to 50 cm deep
Shallow:	50 to 100 cm deep

IV. REACTION CLASSES

It is assumed that the range of pH in the solum is sufficiently well characterized in the subgroup classification of most soils and requires no special recognition at the family level. Important differences in reaction in subgroups of Gleysols and Gray Luvisols can be accommodated at the series level. Family reaction classes are therefore applicable only to the C horizons of mineral soils. They are used in all subgroups except where they would be redundant, as in the Chernozemic and Solonetzic Orders and Gray Brown Luvisol, Melanic Brunisol and Eutric Brunisol Great Groups.

Classes are based on the average pH in 0.01 M $CaCl_2$ of the C horizon (C, Ck, Cs, Cg) including IIC, etc., but excluding Csa and Cca. In the absence of a C horizon, the horizon overlying the lithic contact is used.

The classes are:

(a) acid - pH of 5.5 or lower
(b) neutral - pH between 5.5 and 7.4
(c) alkaline - pH of 7.4 and higher

V. CALCAREOUS CLASSES

It is assumed that $CaCO_3$ levels in the solum are sufficiently well understood from the subgroup classification of most soils and require no special recognition at the family level. Important differences in $CaCO_3$ content in subgroups of Gleysols and Gray Luvisols can be accommodated at the series level. Family calcareous classes are therefore applicable only to C horizons or the horizon overlying a lithic contact as described under IV. They are used in all soils with Ck or Cca horizons.

The classes are:

(a) weakly calcareous - 1 to 6% $CaCO_3$ equivalent
(b) strongly calcareous - 6 to 40% $CaCO_3$ equivalent
(c) extremely calcareous - over 40% $CaCO_3$ equivalent

The class extremely calcareous is redundant in soils with carbonated mineralogy.

VI. SOIL CLIMATE

Pedoclimate classes are applicable to all soils and the criteria used are those of the Soil Climatic Map of Canada. In this system soils can be grouped according to their temperatures and moisture regimes into the classes given in Tables 3 and 4.

Rather than relying upon the Map designations for a given area soil sites should be individually assessed on the basis of observations of local climatic and microclimatic variations. Extrapolation from local meteorological station data should allow for any unrepresentative site features, such as vegetation and exposure. A useful estimate of mean summer soil temperature can be obtained by averaging the three mid-monthly readings of soil temperature at 50 cm taken in July, August, and September.

Table 3. Soil Temperature Classes

EXTREMELY COLD

MAST $<$-7C ($<$20F).
Continuous permafrost usually occurs below active layer within the control section (1m).
No significant growing season $<$15 days of $\geq$5C ($\geq$41F).
Remains frozen within lower part of control section.
Cold to very cool summer. MSST $<$5C ($<$41F).
No warm thermal period $>$15C (59F).

VERY COLD

MAST -7 to 2C (20-36F)
Discontinuous permafrost may occur below active layer
Soils with Aquic regimes usually remain frozen within part of control section.
Short growing season $<$120 days $>$5C.
Degree days $>$41F are $<$1000.
Moderately cool summer. MSST 5-8C (41-47F).
No warm thermal period $>$15C.

COLD

MAST 2-8C (36-47F).
No permafrost
Undisturbed soils are usually frozen in some part of the control section for a portion of the dormant season.
Soils with Aquic regimes may remain frozen for portions of the growing season.
Moderately short to moderately long growing season.
140-220 days $>$5C.
Degree days $>$41F are 1000-2250.
Mild summer. MSST 8-15C.
An insignificant or very short warm thermal period.
0-50 days $>$15C.
Degree days $>$59F are $<$50.

COOL

MAST 5-8C (41-47F)

Undisturbed soils may or may not be frozen in part of the control section for a short portion of the dormant season.

Moderately short to moderately long growing season.

170-220 days >5C.

Degree days >41F are 2250-3100.

Mild to moderately warm summer. MSST 15-18C (59-65F).

Significant very short to short warm thermal period.

>60 days 15C.

Degree days >59F are 50-400.

MILD

MAST 8-15C (47-59F).

Undisturbed soils are rarely frozen during dormant season.

Moderately long to nearly continuous growing season.

200-365 days >5C.

Degree days >41F are 3100-5000.

Moderately warm to warm summer. MSST 15-22C (59-72F).

Short to moderately short warm thermal period.

90-180 days >15C.

Degree days >59F are 300-1200.

Table 4. Soil Moisture Subclasses

AQUIC REGIMES

Soil is saturated for significant periods of the growing season.

Peraquic

Soil saturated for very long periods

Ground water level at or within capillary reach of the surface.

Aquic

Soil saturated for moderately long periods.

Subaquic

Soil saturated for short periods

MOIST UNSATURATED REGIMES

Varying periods and intensities of water deficits during the growing season (i) United States criteria (ii) Canadian criteria (calculated).

Perhumid

(i) Soil moist all year, seldom dry
(ii) No significant water deficits in the growing season.
Water deficits $\leq$2.5 cm. Climatic Moisture Index (DMI) $>$84.

Humid

(i) Soil not dry in any part as long as 90 consecutive days in most years.
(ii) Very slight deficits in the growing season.
Water deficits 2.5-$<$6.5 cm. CMI 74-84.

Subhumid

(i) Soil dry in some parts when soil temperature is $>$5C in some years.
(ii) Significant deficits within the growing season.
Water deficits 6.5 - $<$13 cm. CMI 59-73.

Semiarid

(i) Soil dry in some parts when soil temperature is $>$5C in some years.
(ii) Moderately severe deficits in growing season.
Water deficits 13 - $<$19 cm. CMI 46-58.

Subarid

(i) Soil dry in some parts or all parts most of the time when the soil temperature is $>$5C. Some periods as long as 90 consecutive days when the soil is moist.
(ii) Severe growing season deficits. Water deficits 19 - $<$38 in Cool and Cold Regimes, 19 - $<$51 cm in Mild Regimes. CMI 25-45.

Arid

(i) Soil dry in some or all parts most of the time when soil is $>$5C.
No period as long as 90 consecutive days when soil is moist.
(ii) Very severe growing season deficits.
Water deficits $\geq$ 38 cm in Cool Regimes and $\geq$ 51 cm in Mild Regimes. CMI 25.

CRITERIA AND GUIDELINES - ORGANIC SOILS

I CHARACTERISTICS OF SURFACE TIER

Organic surface tier: fennic, silvic, sphagnic (each used only for fibric surface tiers), mesic, humic.

Mineral surface tier, 15 to 40 cm thick: sandy, coarse-loamy, coarse-silty, fine-loamy, fine-silty, clayey.

II REACTION

euic - pH $\geq$4.5 (0.01 M $CaCl_2$) in some part of the organic materials of the control section.

dysic - pH $<$4.5 (0.01 M $CaCl_2$) in all parts of the organic materials of the control section.

III SOIL CLIMATE

Pedoclimate classes are applicable to all soils and the criteria used are those of the Soil Climate Map of Canada. In this system soils can be grouped according to their temperatures and moisture regimes into the classes given in Tables 3 and 4. These classes were designed for well-drained mineral soils in temperate areas. Therefore, it is recognized that organic soils in mild regimes may have temperatures equivalent to the associated mineral soils, but that other organic soils probably are at least one temperature class colder than associated imperfectly to well-drained mineral soils.

The moisture subclasses in Table 4 are defined imprecisely on the basis of degree and duration of saturation. Table 5 gives guidelines for the selection of the appropriate moisture subclass in organic soils. These criteria apply to the surface tier for non-cryic subgroups and to the entire active layer in the case of cryic subgroups.

IV PARTICLE-SIZE CLASS OF TERRIC LAYER

The particle size classes that are to be recognized at the family level for mineral material under organic soils, in terric subgroups are fragmental, sandy, sandy-skeletal, loamy, loamy-skeletal, clayey and clayey-skeletal.

V LIMNIC MATERIALS

Limnic classes apply only to Limno subgroups: They are marl, diatomaceous, coprogenous. The definitions of these materials may be found in the section describing tiers and layers. Notice is called to the exclusion from the organic order of soils in which mineral sediment, marl or diatomaceous earth layers thicker than 40 cm occur at the surface or that have mineral sediment, marl or diatomaceous earth layers thicker than 40 cm within the upper 80 cm of the profile.

NOMENCLATURE FOR SOIL FAMILIES

A soil family becomes established after correlation procedures and is designated by the subgroup name and the sequential description:

TABLE 5 - Moisture Subclasses as Applied to Organic Soils

Moisture Regime	Aqueous	Aquic			Moist Soils	
Classification	0 Aqueous	a Peraquic	b Aquic	c Subaquic	d Perhumid	e Humid
Descriptive Condition	Free Surface water	Saturated for very long periods- Very poorly drained (6)	Saturated for mod. long periods-Poorly drained (5)	Saturated for short periods Imperfectly drained (4)	Moist with no significant seasonal deficit- Imperfectly to Mod. well drained (4) to (3)	Moist with no significant seasonal deficit Mod. well drained (3) to (2)
Suggested Criteria						
Saturation period (months)	continuous 11.5-12	very long >10	long to mod. short 4-10	short to very <4	very short <2	very short to insignificant <0.5
Moist Period (months)	insignificant <0.5	very short <2	short to mod. long 2-8	very long to long 8-11.5	very long to long 8-11.5	very long 8-11.5
Associated Native Vegetation	Hydrophytic Nymphae Potamageton Scirpus Typha, Phragmites Drepanocladus	Hydrophytic Scirpus Typha Carex Drepanocladus Feathermosses Tamarack	Meso-Hydrophytic Wet forest black spruce mixed feather-moss & Sphagnum Ericaceous shrubs	Meso-Hydrophytic wet to very moist forest black spruce Sphagnum Ericaceous shrubs	Mesophytic moist forest black spruce mixed Sphagnum & feathermosses Ericaceous shrubs lichens	Mesophytic Disturbed species Cultivated species
Associated Peat Landform	Wetlands, Marsh, Floating Fen, Collapse Scars	Flat Fens, Patterened Fens Spring Fens Swamps	Blanket Bogs Transitional Bogs	Domed Bogs, Plateaus	Frozen Plateaus Frozen Palsas, Frozen Peat Polygons	Drained Peat-lands, Folisols

Examples:

Orthic Humo-Ferric Podzol, coarse-loamy, mixed, acid, cool perhumid.

Orthic Eutric Brunisol, coarse-silty over sandy, mixed, shallow, strongly calcareous, cold humid.

Terric Mesisol, humic, dysic, cool aquic, loamy-skeletal

Limno Humisol, humic, euic, mild aquic, coprogenous.

A family thus described is a taxonomic entity within which from one to a large number of series may be established. Like the series, its suitability as a basis for pure or complex mapping units varies from region to region and according to the scale of mapping.

RAPPORT DU COMITE DES SOLS REPERES

J.A. McKeague, Président

Résumé

Le projet des sols repères a reçu des attentions mitiguées Seule la Nouvelle-Ecosse a honoré complètement ses engagements. Un programme pour la collection et la manutention d'échantillons étalons de sol a été lancé pour permettre de comparer entre elles les méthodes analytiques. Ce programme comprend aussi la collection de quelques échantillons pour le projet SRM (Standard Reference Material) du ministère de l'Energie, des Mines et des Ressources. Les membres du comité travaillent à la préparation d'un manuel de méthodes analytiques des sols.

REPORT OF SUBCOMMITTEE ON BENCHMARK SOILS

J.A. McKeague, Chairman

Summary

The benchmark soil project has received variable amounts of attention. Only Nova Scotia has completed its committment. A program of collecting and handling standard soil samples has been initiated for the purpose of comparing analytical methods. One aspect of this program is to collect certain samples to be sold as standard reference material by Dept. of E.M.R. Members of the subcommittee also are working on a manual on methods of soil analysis.

The response to the memoranda distributed on this subject has been excellent and cooperation by members of the Subcommittee and others in considering methods etc. has been most encouraging. Obviously, there exists a general feeling that we must improve our standardization of methodology and compare analytical data among laboratories in an organized way. No doubt there will be differences of opinion on the choice of methods but the prospects of improving the compatibility of data of soil analysis and of achieving a greater degree of standardization of methodology appear to be excellent. I thank all those who have been involved with this Subcommittee and especially those who undertook to obtain standard bulk samples and those who agreed to study and recommend methods for soil analysis.

Benchmark Soil Project

This project involves description, sampling and comprehensive analysis of representative pedons of the major subgroups of soils developed in medium-textured materials. It was initiated about 1968 partly because of the possibility of a meeting of the International Society of Soil Science in Canada in the 1970's and partly to supply data for a proposed monograph on the soils of Canada. The survey units across the country agreed to sample and to analyze representative pedons of certain subgroups. John Day, who undertook the overall organization of the project, sent information on proposed methods to all participants.

Some progress on the Benchmark Project, but less than had been hoped for, was reported by Ehrlich at the 1970 CSSC Meeting. At the meeting of the Western Section of CSSC in 1972, Clark outlined reasons for relegating the Project to a low priority rating. In effect, this had been done by many of the units concerned because of pressure of work and the apparent lack of urgency to complete the project. Clark proposed that the work on the Benchmark soils should be continued when possible.

Progress to date on the Benchmark Project is as follows:

B.C. (Vancouver)	- Agreed to sample 5.21, 5.31, 6.12 and 4.33
Progress	- 4.33 described sampled, monoliths taken, and most of the analysis completed.
B.C. (Kelowna)	- Agreed to sample 4.11, 4.32, 4.32/5 and 5.41
Progress	- 4.11/8 sampled and some analysis done (in place of 4.11) 4.32/5 sampled and some analysis done 4.21 sampled and some analysis done (this is an extra)
Intentions	- sample 4.32 and 5.41 in the summer of '73
Alberta	- Agreed to sample 2.11, 2.13, 2.21, 2.23, 3.21/4, 7.21
Progress	- Nil, but prospects for '73 are good.
Saskatchewan	- Agreed to sample 1.11, 1.21, 1.2/7, 1.31, 7.31, 7.32.
Progress	- All sampled and some analysis done.
Manitoba	- Agreed to sample 1.41, 3.21, 7.12, 8.11, 8.21.
Progress	- 1.41, 3.21, 8.11, and 8.21: sampled and much of the analysis done.
Ontario	- Agreed to sample 3.11, 3.12, 5.11, 7.11 (calc.)
Progress	- All sampled, thin sections prepared.
Quebec	- Agreed to sample 4.11, 4.21, 4.31, 4.31 (Fragipan), 8.21
Progress	- 4.31 and 4.31 (Fragipan) sampled and analysis nearly completed, 4.21 - some work done.
New Brunswick	- Agreed to sample 7.11, 7.12, 7.32, 8.11
Progress	- 7.12, 7.32 and 8.11 sampled and some analysis done, monolith of 8.11.
Nova Scotia	- Agreed to sample 7.21, 7.33 and 5.42
Progress	- Completed!

Several groups have sent samples of Benchmark soils to the SRI for micromorphological analysis, clay mineral analysis, minor element analysis. I have been slow in sending the results to you but the analyses are either in progress or completed and the data will be sent to you.

Standard Soil Samples

Replies to a memorandum data Nov. 17 that requested opinions on the need for bulk soil samples to be used in comparing analytical results among laboratories showed strong support. It was pointed out that the "standard" samples collected 15 or 20 years ago had served their purpose and were not used widely now possibly because they were depleted. The replies indicated that samples of certain horizons either of some of the Benchmark soils or of other established series would be appropriate.

In a memorandum dated Jan. 8, 1972 specific samples were suggested and the following samples were agreed upon:

B.C. (Green) Ah, Bm and C of 5.31
B.C. (Osborne) Bf, Bt and C of 4.3/5 in 1973
Alta. (Coen) Ah, Btna and C of 2.11
Sask. (Stonehouse) Ah, B and C of 1.21 in 1973
Man. (Eilers) A layer of 8.11 and of 8.21 in 1973
Ont. (Protz) Ah, Bt and Ck of 3.11
Quebec (Baril, DeKimpe) Ae, Bf, C of 4.31 (sandy material), 1973
N.B. (Wang) Aeg, Btg, C of 7.32 in 1973
N.S. (Nowland) Ae, Bt, C of 3.21 (red material) in 1973
S.R.I. (McKeague) C of 6.11 clay in 1973

The following procedures for handling the samples and the data have been agreed upon tentatively:

1. Bulk samples that will yield 200 pounds of dry, 2 mm soil will be taken.
2. The material will be dried and crushed to pass a 2 mm nylon or stainless steel sieve.
3. The material will be mixed thoroughly and stored by the unit that does the sampling.
4. A 1 pound subsample will be sent to all participating labs.
5. All data for the standard samples should be sent to the SRI for processing. CanSIS will aid with this. Summaries of data, "best" values etc. will sent to all participants periodically.

Since the last memorandum on this topic was sent on Feb. 20, an additional possibility for standard samples has arisen. The Department of Energy, Mines and Resources (EMR) supports a "Canada Standard Reference Materials (SRM) Project". Currently the SRM's include 5 rocks, 2 ores and 5 alloys. Dr. Gillieson, coordinator of the SRM project called the SRI a few weeks ago because he had a request for standard soil samples. I told him of the plans of this Subcommittee and he feels that the SRM's should include some soils. The advantages of this to us would be:

1. Preparation, storage and distribution of samples would be done through the SRM Project.
2. The composition of the samples would be "certified" by having them analyzed in several highly reputable labs.
3. Analytical data for the samples would be received processed and distributed through the SRM Project.
4. A less tangible advantage -- it would indicate that soils are materials as worthy of study as rocks etc. and that soil analysts are concerned with quality of data.

The only disadvantage that I know of is that the SRM Project is partially self-supporting. The charge for samples of about 200 g is $15. or so. This is not a major issue as the cost is trivial in relation to the cost of doing the analysis.

I think that SRM soils would be very useful as standards for such things as total major and minor element analysis. We would probably not use such samples for particle-size analysis, exchangeable or soluble cation analysis etc. Thus I believe that we should proceed with our own collection of standard soil samples apart from possible SRM soils.

Dr. Gillieson indicated that between 200 and 500 pounds per sample would be adequate and that up to 6 samples could be handled this year. As a basis for discussion, I suggest that we collect 300 pounds (air dry) of the following soil samples in 1973 for processing by the SRM group:

1. "Leda" clay (Rideau clay) - Ottawa
2. Podzolic B (Bf or Bhf) - Quebec
3. Chernozemic A (Ah or Ap of Black or Dark Brown) - Saskatchewan
4. A Ck horizon (10 to 30% $CaCO_3$ equivalent) - Guelph

The sources of such samples and the kind of sample can be changed if necessary. Four samples should provide a wide range of compositions and indicate whether or not such SRM's would be used. Consideration of the kinds of analyses to be done will be necessary. Suggestions before or during the meeting are welcome.

Methods of Analysis

Nearly all members of the Subcommittee agreed that:

1. A manual on methods of soil analysis recommended by CSSC would be useful and this it should have high priority.
2. The advent of CanSIS had increased the importance of uniform methods and compatible data.
3. Comparisons of data among labs should be done regularly in an organized way.

The following Subcommittee members (some of whom were added as we proceeded) agreed to study and to recommend methods for soil analysis as indicated:

Green (B.C.) - Particle-size distribution
Osborne (B.C.) - Exchangeable cations, CEC and pH
Wang (N.B.) - Extractable "free" oxides - Fe, Al, Mn, Si
Ballantyne (Sask) - Soluble salts, gypsum, SAR
McGill (Alta) - C, N, P and S
Raad (PEI) - Carbonates
Stone and Desjardins (Ottawa) - Total elemental analysis
DeKimpe (Ste-Foy) - Clay mineralogy
Eilers (Man) - Soil water characteristic, permeability etc.
Belair (Quebec) - Bulk density and shrinkage

Recommendations have been made by Osborne, Green, Wang and Raad and others are expected soon. Much work has been done in many of these areas. For example, DeKimpe has received suggestions on methods of soil clay mineral analysis from about 50 Canadians concerned with clays. The aim is to assemble a first draft of a methods manual this year. It is anticipated that, in a number of cases, several alternative methods will be given. Each will be assigned a number for convenience of CanSIS etc.

Comparison Among Labs

In 1972, Webber and I initiated a comparison of results for extractable Fe and Al by dithionite, oxalate and pyrophosphate using AA and colorimetric methods. Data obtained in 10 labs from PEI to BC have been summarized and distributed to participants. Such comparisons will be simpler to carry out and more useful when we have bulk quantities of standard soil samples.

CanSIS - Methods and Chemical, Physical and Mineralogical Modules

Dumanski asked this Subcommittee to study and to recommend changes in the above modules of the Soil Site Coding Scheme. Suggestions were made by Laflamme, Wang and McKeague and others who replied directly to Dumanski. The importance of close liason between this Subcommittee and CanSIS is recognized by all concerned.

Methods Manuals

The response to my request for compilations of methods of soil analysis used in different labs was good. Most of the soil survey labs sent copies of their manuals. In addition I have received several manuals from Canadian Forestry Service Laboratories, Soil Science Departments of Universities etc. These will be very useful when we are assembling recommended methods. Other methods manuals for soil analysis will be welcomed.

Conclusion

The Subcommittee feels that it can make a useful contribution to CSSC and to soils work in Canada generally by continuing the activities discussed in this report. It seeks the support of CSSC as a whole both for the collection of standard samples and for the preparation of a manual of recommended methods of soil analysis. Both projects will require some time of a number of pedologists. We expect to encounter difficulty in finding methods for the adequate physical characterizations of soils and we urge CSSC to promote, by whatever means possible, work on the development of convenient and adequate physical methods.

We have tried to encourage the participation of the Canadian Society of Soil Science (CSSS) in the work on standard samples and standard methods. Such participation could result in wider use of standard samples and a more comprehensive methods manual.

DISCUSSION

Day - A subcommittee on organic terrain has been established by NRC. This subcommittee will compile a manual of methods of analysis for organic materials and guidelines for interpretations. Day serves on the Subcommittee and close liason will be maintained with the CSSC Subcommittee.

The report was accepted unanimously.

RAPPORT DU COMITE DE "MISCELLANEOUS LAND TYPE"

J.G. Ellis, Président

Résumé

Le comité recommande de remplacer "Miscellaneous Land Type" par "Non Soil Feature" (Non-sols). Le non-sol est antropique (man-made) ou naturel (naturel). Il est aussi recommandé que les symboles et lettres pour représenter ces éléments du paysage sur les cartes de même que leur définition soient utilisés uniformément par les autres comités concernés.

REPORT OF THE SUBCOMMITTEE ON MISCELLANEOUS LAND TYPE

J.G. Ellis, Chairman

Summary

It is recommended that "Miscellaneous Land Type" be replaced by "non-Soil Features", "non-Soil Features" be subdivided into man-made and natural non-soil features, that symbols and letters be used to designate these features on maps, and that definitions proposed be correlated between the various affected subcommittees.

The Chairman sent out letters requesting definitions for miscellaneous land types which have been encountered in each member's region plus their reaction to changing the name from Miscellaneous Land Types to Non-soil features and then separating these features into Man-made and Natural non-soil features and finally requesting an opinion regarding the use of symbols or letters to designate non-soil features.

In their replies most members listed the miscellaneous land types which were of concern to them but rarely did they define them. Such definitions as were submitted were utilized.

A summary of replies received is recorded in Appendix I.

From the majority of replies it may be concluded that:

1. Another name rather than Miscellaneous Land Type would be acceptable.

2. The use of symbols or letters to designate these features would be acceptable.

As a result of the replies a further letter was sent to committee members in which the following proposals were put forth. Firstly that Miscellaneous Land Types consist of only those features which cannot be classified as soil using the criteria in the current Canadian system of classification or which cannot be classified as a landform feature by the landform committee. This decision was based on the conclusion that the majority of committee members indicated various kinds of miscellaneous land types on local maps. Some miscellaneous land types implied specific features, e.g. oil wells, dumps, others used miscellaneous land types as a descriptive feature, e.g. limestone rock outcrop, while others used miscellaneous land types with a landform connotation, e.g. alluvial land. It therefore becomes essential that some limits be placed on what constitutes a miscellaneous land type on a natural basis. If the first proposal is accepted by the C.S.S.C. membership the second proposal by the subcommittee would be that the term Miscellaneous Land Type be deleted and replaced by the term Non-soil features. The Non-soil features would then be separated into Man-made non-soil features and Natural non-soil features. This decision was based on the conclusion that the majority of subcommittee members favored a change of name and indicated a need to separate man-made and other non-soil features which occurred naturally. On the assumption that the second proposal might be acceptable to the C.S.S.C. membership the subcommittee concerned itself with definitions and symbols for Non-soil features. Thirdly, it was concluded that the replies from committee members that there is a need for uniformity in the definitions and depiction of non-soil features on a national basis. The source of some of the definitions included the No. 18 U.S. Handbook; the Dictionary of Geological Terms, American Geological Institute; A Dictionary of Geography by F.J. Monkhouse, University of Southampton. These definitions were compiled into a book entitled "Preliminary Definitions of Miscellaneous Land Types" which was distributed to each regional survey unit at Kelowna in 1972. Other sources, original or otherwise, are from committee members. The source of symbols or letters used to designate or identify the non-soil features are from committee members and the E.M.R. Conventions Signs as supplied by P. Lajoie.

The subcommittee submits the following definitions and symbols for Man-made and Natural non-soil features to the C.S.S.C. membership (see Appendix II) realizing the definitions will probably be amended and others submitted and that it would be preferable if the selection of the symbols and letters utilized for identification purposes were acceptable and sanctioned by the E.M.R. Paul Lajoie has kindly offered to act on our behalf to obtain E.M.R. clearance.

Suggested Future Plans

If the first and second proposals are sanctioned by the C.S.S.C. membership then the subcommittee will concern itself with the matter of definitions and symbols and hereby informs the membership that non-soil features forwarded to the chairman in the future must be accompanied by its definition and some type of identification symbols.

Recommendations

1. The name, Miscellaneous Land Type be replaced with the name Non-Soil Features.

2. Non-Soil Features be subdivided into Man-made and Natural Non-Soil Features.

3. Symbols or letters designed in co-operation with E.M.R. be utilized to identify these various Non-Soil Features.

4. That some agent or agency be designated to correlate the definitions used by various subcommittees. In the present case this could involve the Soil degradation, CanSIS, Landforms, Non-Soil Features committees, etc.

Appendix I

Summary of Comments to Letters of December 7, 1972, January 24, 1973, March 15, 1973

J. Gillespie - Guelph

1) Do not like the name Miscellaneous Land Type suggested "Special Landscape Features".

2) "Natural" and "man-made" not soil features should be separated.

3) Dune land, lava flows, salt flats, etc. are Regosols therefore are not Miscellaneous Land Types.

4) Use symbols to indicate not soil features on maps.

A. Twardy - Edmonton

1) Agree "Miscellaneous Land Types" should be replaced by "Non-Soil Features".

2) Agree on "Natural Non-Soil Features" and "Man-Made Non-Soil Features".

3) Use symbols for identification.

B. Rochefort - Quebec

1) Miscellaneous Land Type be replaced by A. Areas that are mostly soil
B. Areas with little soil

2) Do not agree that all Miscellaneous Land Types be considered "not soil features".

3) Use some kind of symbols and letter or combination.

P. Lajoie - Ottawa

1) Uses the term "Land Types" - but no objection to other terms.

2) Agree if talking exclusively "Non-Soil Features" have 2 types. Natural and Man Made.

3) Use symbols - would contact E.M.R. for the committee - which he did.

A. Dawson - Kelowna

1) Thought land types in book could be used across Canada plus a few more for British Columbia.

2) Generally agree with Natural and Man Made not-soil features.

3) Use symbols from E.M.R.

J. MacDougall - P.E.I.

1) Agree Miscellaneous Land Types include feature which cannot be classified by our system (e.g. soil classification).

2) Agree with Man-made and Natural non-soil feature and list is adequate.

3) Agree with non-soil features and use of symbols.

4) Types of subdivision e.g. pits being mine, gravel, sand, quarry, borrow, etc.

5) Use of symbols for complexes - dumps and pits - beaches and dunes.

G. Coen - Edmonton

1) Like term Miscellaneous Land Type - objects to Non-soil features.

2) Agree with standardization symbols through E.M.R.

G. Beke - Manitoba

1) Name change unimportant but would support proposal.

2) Refers to features in Portage la Prairie report as Non-soil features.

3) General slant towards agriculture in the definitions of non-soil features was found objectionable - should delete unless "non-soil features" are renamed "agricultural non-soil features".

4) Would delete marsh, swamp, marl, rough broken land, blown-out land, etc. from Natural non-soil features.

5) Criticised definition of swamp and marsh - "highly inappropriate".

L. Farstad - Vancouver

1) General agreement with majority position.

2) Replace "Miscellaneous Land Types" with "Non-Soil Feature".

3) Split "Non-Soil Features" into "Natural" and "Man-Made".

4) Use uniform symbols.

Appendix II

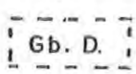
DEFINITIONS FOR MAN MADE NON-SOIL FEATURES

Cut and fill areas 

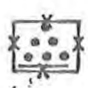
What is meant by this term - are these trenches for burying garbage etc. or are these areas that have been levelled for irrigation, etc.

Dugout 

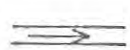
An excavation to hold water mainly from runoff of snow melt or rain from the surrounding area for domestic use.

Garbage dump 

Areas of uneven accumulations or piles of domestic or industrial non-liquid wastes.

Gravel pile  

Gravel stored in piles by private or government road authorities for utilization for highway construction and maintenance. Some gravel pile reserve areas are of a semi-permanent to permanent nature being continually replenished and are enclosed within a confined area. Often such compounds contain equipment for the preparation of asphalt.

Floodway 

A canal-like excavation to carry surface water in times of excessive run-off.

Land fill	Areas that were excavated and into which mainly solid domestic and industrial wastes are placed, packed and buried with the overburden from the excavation - thus alternate layers of waste and overburden are buried until the excavation is full.
Made land	Areas filled artificially with earth, trash or both and smoothed. It occurs most commonly in and around urban areas. Stabilized land areas with clearly developed soil characteristics or even those with young soils if definable and uniform enough to map, and especially if arable, should be classified as soils even though originally made or reworked by man.
Mine dump (× D.)	Areas of waste rock with little or no segregation that come from ore mines, coal mines, potash mines and smelters.
Mined land (× ×)	Area altered and rendered useless by mining operations.
Oil waste land (δ W.)	Areas where liquid oil waste principally salt water and oil have accumulated.
Oil field (δ δ δ)	Areas containing a proven subterranean store of petroleum of economic value.

Oil well	oil	A dug or bored well from which petroleum is obtained by pumping or by natural flow.
Pits	G.P.	Open excavations from which the overlaying material has been removed to gain access to specific material below e.g. coal pit, gravel pit, sand pit, burrow pit, mine pit.
Quarry	L	An open or surface working for the extraction of building stones e.g. limestone quarry, slate quarry, granite quarry.
Rubble land		An accumulation or piles of broken masonry, building stone or angular rock fragments usually the result of such activities of man as demolition of buildings, highway construction, quarry mining, etc.
Sewage lagoon		An excavation to hold domestic or industrial liquid wastes.
Slickens	S.s.	An accumulation of fine texured materials separated in placer - mine and ore mill operations and usually confined in especially constructed basins.
Stone piles		An accumulation or pile of stones which have generally been removed or picked from the surface of the immediate area.

Terrace T	A man made embankment or ridge constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surplus runoff in order to retard it for infiltration into the soil and so that any excess may flow slowly to prepared outlet without harm.
Terrace escarpment T.E.	The area covered by the sloping front of a man made terrace.
Urban land Toronto	Area covered by urban structures and works.
Water lagoon	An excavation to hold water for domestic or industrial use.

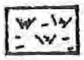
Appendix II

DEFINITIONS FOR NATURAL NON-SOIL FEATURES

Alluvial land	Av L	Consists of areas of unconsolidated alluvium, generally stratified and varying widely in texture, recently deposited by streams, and subject to frequent changes through stream overflow Subclasses - sandy, gravelly, cobbly, stony and bouldery alluvial land. Several subclasses together - mixed alluvial land.
Badland	BL	A reigon nearly devoid of vegetation where erosion, instead of carving hills and valleys of the ordinary type has cut the land into an intricate maze of narrow ravines and sharp crests and pinnacles travel across such a reigon is almost impossible, hence the name.
Beaches		Are sandy, gravelly or cobbly shores washed and rewashed by waves. The land may be partly covered with water during high tides or stormy periods. There are coastal beaches of ocean and seas, lake beaches. Beaches support little or no vegetation and have no agricultural value although they may be sources of sand and gravel.
Beaver dam	xxxxxx	A dam built by beavers.
Beaver pond		The pond formed by a beaver dam

Blown - out land	BOL	Consists of areas from which all or most of the soil material has been removed by wind - a condition resulting from an extreme degree of soil blowing or wind erosion. The areas are shallow depressions that have flat or irregular floors formed by some more resistant layers, by an accumulation of pebbles as cobbles, or by exposure of the water table. Some areas have a small proportion of hummocks or small dunes. The land is barren, or nearly so, and useless for crops. Small areas of blown - out land are often called "blow - outs".
Colluvial land	CvL	Includes area of unconsolidated recent colluvium a heterogeneous deposit of soil material, rock fragments, or mixtures of the two accumulated at the base of slopes primarily by gravity. Subclasses of colluvial land are named according to the dominant textural class or kinds of rock material. Mapping units of colluvial land commonly include small areas of soil creep and local alluvium.
Coquina land	CqL	Consists of cemented shell fragments, mainly from the conquina clam with lesser amounts from the conch, oyster, and other shell bearing mollusks and coral. This land is not useful for crops but commonly supports a few trees. The material has been used for building and for road beds.

Dune land	ΛΛ Λ	Consists of ridges and troughs that are composed of sand-sized particles that are virtually devoid of vegetation and that shift with the wind. Sand dunes that have been stabilized by vegetation should be named as a kind of soil rather than as dune land.
Eroded areas	E1-4	Areas where the land surface has been detached and transported through the action of water, wind or other geological agents.
Gullied areas	G1-4	Area where gullies and trenches are formed due to water erosion.
Glacier	Gl	A mass of ice with definite lateral limits, with motion in a definate direction, and originating from the compaction of snow by pressure.
Ice	PI	Permanent snow and ice.
Landslide	Lds	A fall of earth and rock material down a slope or mountain side, the result of gravity and rain lubrication.
Lava flows		Includes areas covered by lava rock, commonly basalt. Lava flows has no agricultural value and because of the commonly rough jagged surface and sparce vegetation it is avoided by livestock.

Marsh		Consists of wet periodically flooded areas covered dominantly with grasses, cattails, rushes or other herbaceous plants. Subclasses include tidal marsh, periodically inundated because of the tide; fresh water marsh, which is influenced by fresh water and not by the tide; and salt water marsh, which is influenced by salty water but not by the tide. Tidal marsh may be subdivided into tidal marsh (salty) and tidal marsh (fresh). Tidal marsh may be associated with tidal flats. Salt water marsh generally occurs in wet salty flats along stream valleys. Marsh is mainly covered with grasses and grass-like plants, while swamp is covered with trees.
Marl beds	MB	Include areas where marl (an earthy crumbling deposit consisting chiefly of calcium carbonate mixed with clay and other impurities) is exposed or lies a few inches below the surface. Marl is usually formed in lakes or ponds. The calcium carbonate may have originated from the calcareous remains of the chara plant (chara marl), from mollusk shells (shell marl), or from simple precipitation from solution. These beds are commonly a good source of agricultural lime.
Oil sands	O.s	Sands which are impregnated with hydrocarbons (bitumen) e.g. the tar sands in northern Canada, which cover a large area of the Athabasca Valley 100 miles north of Edmonton.

Rock outcrop	Consists of exposures of bare bedrock. Subclasses can be named according to the kind of rock materials, including: Chalk outcrop, Limestone outcrop, Sandstone outcrop, and Shale outcrop. Commonly, areas of Rock outcrop are too small to be delineated on the map and are shown by symbols.
Rough broken land R.B.L.	Consists of very steep land, ordinarily not stony, broken by numerous intermittent drainage channels. It is used for grazing and for timber. It has a cover of vegetation, as opposed to Badland, which has sparse vegetation, or complete lack of cover. Stony areas are classed as Rough broken and stony land. Rough broken land is deeply dissected by narrow V-shaped valleys and sharp torturous divides. Local relief is generally between 25 and 500 feet. Soil Slipping is often common, and the steep slopes have a succession of short vertical exposures or "cat steps". Runoff is high and geologic erosion is active.
Rubble land R.L.	Includes areas with 90 percent or more of stones and boulders. It is the extreme of Stony land, as Rock outcrop is of Rock land. Practically no soil is exposed. If some purpose will be served, Rubble land may be modified by the name of the principal rocks from which the stones are derived, as Granite rubble land.

Rough mountainous land	R.M.L.	Refers to mountainous area generally above the tree line. It includes rough mountainous areas which dominantly consist of cirques, landslides, bear rock and mountain tops.
Rock land	R.L.	Consists of areas having enough rock outcrop and very shallow soil to submerge other soil characteristics. The upper limit of rock outcrop is 90 percent of the mapped area and, unless the other features place the land in some other land type anyway, the lower limit is ordinarily 25 percent. The word "rock" may appear in the land type names if only 3 percent of the area is rock outcrop: for example, Stony rock land or Rough broken land and rock land. Where a mappable area contains more than 90percent rock outcrop, the whole is classed as Rock outcrop. Seveal kinds of Rock land are named according to the kind of rock material, including: Limestone rock land, Sandstone rock land, Lava rock land, Quartzite rock land, and Granite rock land. Usually such distinctions are not necessary.

Salt flats		A horizontal stretch of salt crust representing the bed of a former salt lake, temporarily or permanently dried up.
Scoria land	$\boxed{\text{Sc L}}$	Conists of areas of slaglike clinkers and burned shale and fine-grained sandstone characteristic of burned-out coal beds.
Swamp		A low, spongy land, generally saturated with moisture and unfit either for agricultural or pastoral purposes. The term is commonly used as synonymous with bog and morass, but a swamp may be here and there studded with trees, while bogs and marshes are destitute of trees, though frequently covered with grasses and aquatic vegetation.
Talus		A collection of fallen disintegrated material which has formed a slope at the foot of a steeper declivity.
Tidal flats		A marshy or muddy land area which is covered and uncovered by the rise and fall of the tide.
Cryoturbated land		Consists of areas of Arctic and Subarctic Soils that have been so intensely distributed by frost action that they cannot be classified in any category of S.S.C.C.

RAPPORT DU COMITE DES CLASSES DE CLIMAT DU SOL

John H. Day, Président

Résumé

Le comité a adopté un format légérement revisé pour la légende de la carte des "Climats du Sol du Canada".

REPORT OF THE SUBCOMMITTEE ON SOIL CLIMATE CLASSES

John H. Day, Chairman

Summary

A slightly revised format has been adopted for the legend to be used on the map "Soil Climates of Canada".

The map "Soil climates of Canada" is in the final stages of drafting prior to publication. This map was compiled at the SRI, Ottawa under the direction of Mr. J.S. Clayton and with the advice and cooperation of Mr. Wilber Sly and Dr. Wolfgang Baier of Agrometeorology Section of Plant Research Institute, Ottawa and of Dr. Alex Mack of SRI. Mr. Clayton consulted virtually every soil survey group at the conclusion of the project on the validity of the parameters used and on the definitions established.

In the final stage of editing the subcommittee chairman wished to clarify and add several terms in the map legend. He also wished to consult the members of the committee on these changes, and if possible to receive the blessing of the committee for the map.

Helpful responses were received from correspondents touching on three topics:

A. One of the major points raised by a number of persons was that the soil temperature criteria obviously were chosen for temperature regions, and that they are unsuitable for polar regions. It was suggested that a useful and significant value to add to the criteria would be growing season > 41 F at 10 cm depth and/or at 20 cm depth.

I therefore asked the opinion of Wilbur Sly of Agrometeorology on the feasibility of adding a supplementary statement to the legend. His response was "It is quite possible that subdivision or further descriptive characterization should be made, but at this time the lack of information prevents proper evaluation of this suggestion. As information becomes available, the subdivision of classes 1 and 2 should be considered. If information is available to some of you we suggest that you prepare suggestions for limits of such subclasses and relay the information to Agrometeorology".

In keeping with this expert opinion, I have not proposed any modification of the temperature classification.

B. One or two individuals commented on the location of class or subclass boundaries on the map, and on the use of a to j and x for moisture subclasses. In the case of the first topic, these details will be amendable to modification when we prepare the first revision of the map. In the case of the second topic, the system was established in concert with the SCS of United States for the F.A.O.-Unesco map and therefore there is nothing to be done.

C. Several individuals offered comments on the supplementary statements dealing with the distribution of permafrost, particularly in 3.1. These changes have been incorporated in the following proposal for your consideration. One person questioned the overlap in MAST and growing season between Cryoboreal and Boreal. Again, there is nothing to be done now about this. The majority of respondents endorsed the "improved" legend as more readable, etc.

Therefore it is recommended that the following legend be officially adopted for use on the map "Soil Climates of Canada", and that the map be granted the blessing of the CSSC.

Characteristics of Temperature Classes

Generalized Characteristics of Temperature Classes Used for the Soil Climate Map of Canada and North America

1. ARCTIC

Extremely Cold

** Mean annual soil temperature < 20 F (< -7 C)

** Mean summer soil temperature < 41 F (< 5 C)

* Growing season $\geq$ 41 F ($\geq$ 5 C), < 15 days

\- No Thermal period $\geq$ 59 F ($\geq$ 15 C)

Regions in this class have continuous permafrost usually within a depth of 3 ft. (1 m)

2. SUBARCTIC

Very Cold

** 'Mean annual soil temperature 20 to < 36 F (-7 to < 2 C)

** Mean summer soil temperature 41 to < 47 F (5 to < 8 C)

* Growing season $\geq$ 41 F ($\geq$ 5 C), < 120 days

* Growing season degree days $\geq$ 41 F, < 1000 ($\geq$ 5 C, < 555)

\- No Thermal period $\geq$ 59 F ($\geq$ 15 C)

Regions in this class have widespread permafrost. Some profiles do not have permafrost within a depth of 3 ft. (1 m). Alpine soils are included in this class.

** Primary classifier for Class; in accordance with criteria established for the FAO/UNESCO Soil Climate Map of North America, measured at a depth of 50 cm.

* Secondary classifier for Soil Climate Map of Canada.

\- Supplementary information.

3. CRYOBOREAL

Cold to moderately cold

** Mean annual soil temperature 36 to < 47 F (2 to < 8 C)

** Mean summer soil temperature 47 to < 59 F (8 to < 15 C)

* Growing season ≥ 41 F (≥ 5 C); 120 to 220 days

* Growing season degree days ≥ 41 F, 1000 to < 2250
(> 5 C, 555 to < 1250)

- Thermal period ≥ 59 F (≥ 15 C), no significant days

- Thermal period degree days ≥ 59 F, < 60
(≥ 15 C, < 33)

Soils with aquic regions may remain frozen for portions of the growing season. Organic soils having discontinuous or localized permafrost should be classified in 2.

3.1 Cold

* Growing season ≥ 41 F (≥ 5 C), 120 to 180 days

* Growing season degree days ≥ 41 F, 1000 to < 2000
(≥ 5 C, 555 to < 1110)

3.2 Moderately Cold

* Growing season ≥ 41 F (≥ 5 C), < 220 days

* Growing season degree days ≥ 41 F, 2000 to < 2250
(≥ 5 C, 1110 to < 1250)

4. BOREAL

Cool to moderately cool

** Mean annual soil temperature 41 to < 47 F (5 to < 8 C)

** Mean summer soil temperature 59 to < 65 F (15 to < 18 C)

* Growing season ≥ 41 F (≥ 5 C), 170 to < 220 days

* Growing season degree days ≥ 41 F, 2250 to < 3100
(≥ 5 C, 1250 to < 1720)

- Thermal period $\geq$ 59 F ($\geq$ 15 C), < 120 days
- Thermal period degree days $\geq$ 59 F, 60 to 400
  ($\geq$ 15 C, 33 to 222)

4.1 Cool

* Growing season $\geq$ 41 F ($\geq$ 5 C), > 170 days
* Growing season degree days $\geq$ 41 F, 2250 to < 2500
  ($\geq$ 5 C, 1250 to < 1388)

- Thermal period $\geq$ 59 F ($\geq$ 15 C), < 60 days

4.2 Moderately Cool

* Growing season $\geq$ 41 F ($\geq$ 5 C), < 220 days
* Growing season degree days $\geq$ 41 F, 2500 to < 3100
  ($\geq$ 5 C, 1388 to < 1720)

- Thermal period $\geq$ 59 F ($\geq$ 15 C), < 120 days

5. MESIC

Mild to moderately warm

** Mean annual soil temperature 47 to < 59 F (8 to < 15 C)
** Mean summer soil temperature 59 to < 72 F (15 to < 22 C)
* Growing season $\geq$ 41 F ($\geq$ 5 C), 200 to 365 days
* Growing season degree days $\geq$ 41 F, 3100 to 5000
  ($\geq$ 5 C, 1720 to 2775)

- Thermal period $\geq$ 59 F ($\geq$ 15 C), < 180 days
- Thermal period degree days $\geq$ 59 F, 300 to 1200
  ($\geq$ 15 C, 167 to 666)

5.1 Mild

* Growing season $\geq$ 41 F ($\geq$ 5 C), 200 to 240 days
* Growing season degree days $\geq$ 41 F, 3100 to 4000
  ($\geq$ 5 C, 1720 to 2220)

- Thermal period $\geq$ 59 F ($\geq$ 15 C) < 120 days

5.2 Moderately Warm

* Growing season $\geq$ 41 F ($\geq$ 5 C), > 240 days

* Growing season degree days $\geq$ 41 F, 4000 to 5000
($\geq$ 5 C, > 2220 to 2775)

\- Thermal period $\geq$ 59 F ($\geq$ 15 C), < 180 days

6. THERMIC

Moderately warm to warm

** Mean annual soil temperature 59 to < 72 F (15 to < 22 C)

This region does not occur in Canada

7. HYPERTHERMIC

Very warm to hot

** Mean annual soil temperature $\geq$ 72 F ($\geq$ 22 C)

This region does not occur in Canada

Characteristics of Moisture Subclasses

Generalized Characteristics of Moisture Regimes and Subclasses. Used for the Soil Climate Map of Canada and North America

AQUIC REGIME

Soil is saturated for significant periods of the growing season.

a	Peraquic	Soil saturated for very long periods. Groundwater level at or within capillary reach of the surface.
b	Aquic	Soil saturated for moderately long periods.
c	Subaquic	Soil saturated for short periods.

MOIST UNSATURATED REGIME

Varying periods and intensities of water deficits during the growing season.

d	Perhumid	** Soil moist all year, seldom dry.
		* No significant water deficits in the growing season. Water deficits 0 - < 1 inch ($\leq$ 2.5 cm) Climatic Moisture Index (CMI) > 84.
e	Humid	** Soil not dry in any part as long as 90 consecutive days in most years.
		* Very slight deficits in the growing season. Water deficits 1 - < 2.5 inches (2.5 - < 6.4 cm) CMI 74-84.
f	Subhumid	** Soil dry in some parts when soil temperature is $\geq$ 41 F ($\geq$ 5 C) in some years.
		* Significant deficits within growing season. Water deficits 2.5 - < 5.0 inches (6.4 - < 12.7 cm) CMI 59-73.
g	Semiarid	** Soil dry in some parts when soil temperature is $\geq$ 41 F ($\geq$ 5 C) in most years.
		* Moderately severe deficits in growing season. Water deficits 5.0 - < 7.5 inches (12.7 - < 19.1 cm). SMI 46-58.

h Subarid ** Soil dry in some parts or all parts most of the time when the soil temperature is $\geq$ 41 F ($\geq$ 5 C). Some periods as long as 90 consecutive days when the soil is moist.

* Severe growing season deficits. Water deficits 7.5 - < 15 inches (19.1 - 38.1 cm) in BOREAL and CRYOBOREAL classes, 7.5 - < 20 inches (19.1 - < 50.8 cm) in MESIC or warmer classes. CMI 25-45.

j Arid ** Soil dry in some or all parts of the time when soil is $\geq$ 41 F ($\geq$ 5 C). No period as long as 90 consecutive days when soil is moist.

* Very severe growing season deficits. Water deficits $\geq$ 15 inches ($\geq$ 38.1 cm) in BOREAL and $\geq$ 20 inches ($\geq$ 50.8 cm) in MESIC or warmer classes. CMI < 25.

x Xeric ** Soil dry in all parts 45 consecutive days or more within the four month period (July to October) following the summer solstice in more than 6 years out of 10.

* Soil moist in all parts for 45 consecutive days or more within the four month period (January to April) following the winter solstice in more than 6 years out of 10.

Arid and Xeric subclasses are not believed to occur extensively in Canada but may be found in local areas of microclimate.

CMI - Climatic moisture index is an expression of the percentage contribution of growing-season precipitation to the total amount of water required by a crop if lack of water is not to limit its production.

** Primary classifier for subclass; in accordance with criteria established for the FAO/UNESCO Soil Climatic Map of North America.

* Secondary classifier for Soil Climate Map of Canada.

ESTIMATED SOIL TEMPERATURES FOR SOIL CLIMATE CLASSIFICATION

W.K. Sly

Introduction

From the beginning it was recognized that available soil temperature data would be far short of that required for delineating the areas belonging to the various classes in the Soil Climate Map of Canada. At the end of 1968 there were only 47 localities recording soil temperatures and only five had records as long as nine years. Most were for less than four or five. In 1970 the number of stations reporting increased to 57 and has remained steady since then. Many more stations record climatic data and from time to time researchers have developed techniques for estimating soil temperatures from these data. If sufficient information on the thermal properties of the soil were available, classical physical formulae could be used. However, this information is generally not available and regression techniques must be employed. A literature search did not uncover techniques suitable for the purpose here, where a method of estimating soil temperatures at specified depths for the various regions throughout the country is required. Some work along these lines was carried out at the University of Calgary in 1967 and 68, supported by the Canada Land Inventory, but results were minimal. Following the CSSC meetings in 1970, where it was recommended that the Agrometeorology Section, PRI, continue the development and application of agroclimatic techniques for generating climatic data and for estimating selected parameters of the climate, and of the soil temperature and soil moisture regimes in Canada, Eugene Ouellet of this Section undertook to complete the job. The purpose of this report is to introduce the methods he used in developing the techniques for estimating soil temperatures from climatic data, and to compare some of his estimates with the observed values.

Independent variables

The objective was to estimate the mean monthly temperature at each of the standard depths for each month, for any year, from available climatic data. Although much better results should be obtained if normals were to be estimated, the scarcity of the reports made it necessary to estimate for individual years so that enough cases to develop reliable regression coefficients would be available. This procedure gave between 88 and 226 cases for each month and each depth. Data from 41 stations were used, all under short cut grass.

Table 1 shows the climatic variables that made a significant contribution to the explanation of the variation in the soil temperatures at 50 cm as determined by stepwise regression, for the months of October to May. Only the type of data used is demonstrated here, since for the 12 months and six standard depths (1,10,20,50,100, 150 cm) 72 equations in all are required.

The reasons for including the various variables can be obtained elsewhere (Ouellet 1973) and will not be discussed here. It should be pointed out that since all 41 locations from which soil temperature data were used have sandy to clayey loam soils, it was felt the significance of dividing them into groups that would be fairly similar would be lost in the regressions. In addition, the effects of climate on the group would dwarf the effects of differences within the group.

The temperature at 50 cm during the previous month has not been included for October but is included for all other months. It was found that this was a most important factor in the estimating equations. Since it was necessary to begin somewhere, and as October soil temperatures were found to be most highly correlated with climatic elements, this month's temperature was estimated from climatic data lone. The estimated temperature for the previous month is included in all other estimations. Estimated temperatures for the depth above the one being estimated have not been included as it was felt that too much error might be built in. Non-linear relationships are represented by the last six terms in the Table. The figures 35, 40 and 50 have been added as indicated so that negative values, when squared, will not have the same weight as positive values. It can be seen from the Table that the first, second, third, sixth and eighth variables are those most frequently used. This pattern continues throughout all depths, with the snow variable dropping out during the summer months. The variables listed are all generally available in climatic records.

Estimating monthly normal soil temperatures

The interest is in determining normal soil temperatures for use in soil climate classification. Once the best equations for each month have been established the temperatures for any month can be estimated for the number of years required to establish a normal (provided the climatic data are available) and the average taken. This would be a very time consuming and expensive job if undertaken for all places in Canada for which climatic data are available. Tests were made and it was found that there was very little difference from results using the above procedure if longtime averages for the climatic elements were used in the estimating equations and the normal soil temperatures estimated directly. This latter procedure has been followed.

Results

Estimated monthly normal temperatures at 50 cm are compared, in Table 2, with averages determined from 10 years of observations. In general, the estimates are within one degree Celsius of the observed. The major differences are for June, July and August at Fort Vermilion. The reason for these larger discrepencies has not yet been determined, but in general the more northerly stations have the poorest results. Data from only a few stations in the North were available for use in developing the estimating equations.

Results for the 10 cm depth are given in Table 3. As in the case of the 50 cm depth, estimates are generally within one degree of the observed, with June at Fort Vermilion being the only month with an error of over two degrees.

Table 4 gives the 50 cm data for selected localities where less than ten years of data were available for determining observed averages. Here again, except for the winter months at Swift Current the estimates are generally within a degree of the observed.

Once the monthly averages are available it is possible to interpolate and estimate daily temperatures (Brooks, 1943) and to calculate the degree days and the number of days within the various limits used for determining the soil climate classifications. Such results need to be studied and their value for classification assessed. Preliminary impressions are that they will provide indices useful in classifying areas where only climatic data are available. Estimates have been made for all stations for which the necessary climatic normals are available. This comes to about 650 stations, including 88 in the Maritimes and 13 in the Northwest Territories and Yukon. Table 5 is the computer output for a sample station showing the various depths for which estimates of the mean monthly temperatures have been made. Data for the 650 stations will be used for producing maps showing the spacial distribution of mean monthly soil temperatures in Canada for the 10 cm and 50 cm depths, for the months of January, April, July, and October.

<u>References</u>

1. Ouellet, C.E. 1973. Macroclimatic model for estimating monthly soil temperatures in Canada. Can. J. Soil Sci. in press.

2. Brooks, C.E.P. 1943. Interpolation tables for daily values of meteorological elements. Quart. J. Roy. Meteorol. Soc. 69(300) 160-162.

Table 1: Independent variables used in estimating average monthly Soil Temperatures (C) at 50 cm

Month / Variable	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Ave. temp. at 50 cm during previous month. (T50cm)		X	X	X	X	X	X	X
Ave. Max. air temp. for month.	X	X	X	X	X	X	X	X
Ave. Min air temp. for month.	X	X	X	X	X	X	X	X
Absolute Max air temp for month.	X			X		X		
Absolute Min air temp for month.	X							
No. of days with measurable rain during month.	X	X	X	X	X	X	X	X
Total Rain for month in mm.	X	X						
Total Snow for month in mm.	X	X	X	X	X	X	X	X
$(T50cm + 35)^2$					X		X	X
$(Max + 40)^2$					X		X	
$(Min + 50)^2$		X						X
(Max - Min) (Max)			X					
(Max) (Snow)				X	X	X	X	
$(Rain) (Snow)^2$		X	X					

Table 2: Estimated mean monthly normal soil temperatures at 50 cm compared with averages from 10 years of observations.

50 cm	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Ottawa CDA												
Obs (1961-70 ave)	1.9	.9	.8	3.0	9.9	15.1	18.1	18.1	15.8	11.3	6.4	3.1
Est (normal)	1.0	.4	.7	3.6	10.1	15.5	18.9	19.1	16.5	11.8	6.6	2.8
Obs - Est	.9	.5	.1	-.6	-.2	-.4	-.8	-1.0	-.7	-.5	-.2	.3
Vancouver A												
Obs (1961-70 ave) UBC	5.5	6.1	7.1	9.6	12.7	15.9	17.6	18.1	16.6	13.6	10.2	7.2
Est (normal)	5.1	5.4	6.4	10.0	13.0	15.6	17.2	17.3	16.0	12.7	9.1	6.7
Obs - Est	.4	.7	.7	-.4	-.3	.3	.4	.8	.6	.9	1.1	.5
Fort Vermilion												
Obs (1961-70 ave)	-2.7	-2.7	-2.0	-.2	5.2	12.8	15.8	16.0	11.2	5.8	1.8	-1.4
Est (normal)	-3.3	-3.9	-2.8	-.8	4.1	10.3	13.8	13.9	10.4	5.4	1.1	-1.2
Obs - Est	.6	1.2	.8	.6	1.1	2.5	2.0	2.1	.8	.4	.7	-.2

Table 2 (cont'd)

50 cm	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Harrow CDA												
Obs (1961-70 ave)	2.1	1.0	1.3	5.6	11.2	16.6	19.6	20.3	18.8	14.7	9.7	5.0
Est (Normal)	2.2	1.5	2.1	6.6	12.6	17.2	20.9	21.6	19.4	14.9	9.1	4.5
Obs - Est	-.1	-.5	-.8	-1.0	-1.4	-.6	-1.0	-1.3	-.6	-.2	.6	.5
Normandin CDA												
Obs (1961-70 ave)	.4	-.2	-.3	-.2	3.8	10.8	14.2	14.8	12.5	8.3	3.6	1.3
Est (Normal)	-.2	-.3	.0	.7	5.0	11.0	14.4	14.7	12.2	7.9	3.6	1.1
Obs - Est	.6	.1	-.3	-.9	-1.2	-.2	-.2	.1	.3	.4	.0	.2
Fredericton CDA												
Obs (1961-70 ave)	.7	.2	.4	1.7	8.6	14.5	17.8	18.0	15.3	10.9	5.6	2.3
Est (Normal)	1.3	.9	1.0	2.8	8.6	14.2	17.6	17.8	15.2	10.7	5.8	2.6
Obs - Est	-.6	-.7	-.6	-1.1	0	.3	.2	.2	.1	.2	-.2	-.3
Charlottetown CDA												
Obs (1961-70 ave)	2.1	1.3	1.1	1.7	5.8	10.9	14.6	15.6	14.0	11.4	7.5	4.1
Est (Normal)	2.3	1.5	1.3	2.4	7.1	12.2	15.4	16.4	15.2	11.3	7.1	3.9
Obs - Est	-.2	-.2	-.2	-.7	-1.3	-1.3	-.8	-.8	-.8	.1	.4	.2

Table 3: Estimated mean monthly normal soil temperatures at 10 cm compared with averages from 10 years of observations

10 cm	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Vancouver UBC												
Obs (1961-70 ave)	3.8	5.3	7.0	10.6	14.7	18.7	19.8	19.4	16.7	12.4	8.0	4.9
Est (normal)	3.8	4.6	6.3	10.9	14.8	18.0	19.9	18.2	16.2	11.9	7.6	5.0
Obs - Est	0.0	0.7	0.7	-0.3	-0.1	0.7	-0.1	1.2	0.7	0.5	0.4	-0.1
Fort Vermilion CDA												
Obs (1961-70 ave)	-6.9	-6.1	-3.8	-0.1	8.3	14.8	17.8	16.0	10.4	3.5	-1.8	-4.8
Est (normal)	-5.4	-4.4	-3.1	-0.8	9.6	16.9	18.8	17.4	10.4	3.7	-1.4	-4.8
Obs - Est	-1.5	-1.5	-0.7	0.7	-1.3	-2.1	-1.0	-1.4	0.0	-0.2	-0.4	0.0
Ottawa CDA												
Obs (1961-70 ave)	-0.4	-0.3	-0.1	3.8	11.9	17.8	20.6	19.4	15.9	10.3	4.5	1.1
Est (normal)	-1.0	-1.3	0.0	4.4	12.1	18.0	21.8	20.5	16.5	10.4	4.4	0.6
Obs - Est	0.6	1.0	-0.1	-0.6	-0.2	-0.2	-1.2	-1.1	-0.6	-0.1	0.1	0.5

Table 3 (cont'd)

10 cm	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Harrow CDA												
Obs (1961-70 ave)	0.1	-0.2	1.1	6.8	13.2	18.9	21.7	21.8	19.1	13.6	7.7	2.8
Est (normal)	0.2	0.1	1.7	7.8	14.4	19.5	23.2	22.7	19.5	13.5	6.9	2.1
Obs-Est	-0.1	-0.3	-0.6	-1.0	-1.2	-0.6	-1.5	-0.9	-0.4	0.1	0.8	0.7
Normandin CDA												
Obs (1961-70 ave)	-0.4	-0.6	-0.4	0.0	4.7	12.8	16.3	16.0	12.5	7.4	2.4	0.2
Est (normal)	-2.4	-1.7	-0.9	0.7	7.4	14.2	17.8	16.4	12.3	6.6	1.4	-1.0
Obs - Est	2.0	1.1	0.5	-0.7	-2.7	-1.4	-1.5	-0.4	0.2	0.8	1.0	1.2
Fredericton CDA												
Obs (1961-70 ave)	-0.4	-0.5	0.3	3.4	10.5	16.7	20.6	19.1	15.1	9.4	4.0	0.4
Est (normal)	-1.4	-1.1	-0.3	2.7	11.1	17.7	20.6	19.7	15.5	9.7	3.6	0.1
Obs - Est	1.0	0.6	0.6	0.7	-0.6	-1.0	0.0	-0.6	-0.4	-0.3	0.4	0.3
Charlottetown, CDA												
Obs (1961-70 ave)	0.8	0.1	0.5	2.3	8.7	14.5	18.5	18.2	15.7	10.4	5.4	1.6
Est (normal)	0.7	0.2	0.6	1.8	7.9	13.9	17.5	17.2	14.8	11.7	6.2	2.6
Obs - Est	0.1	-0.1	-0.1	0.5	0.8	0.6	1.0	1.0	0.9	-1.3	-0.8	1.0

Table 4: Estimated mean monthly normal soil temperatures at 50 cm compared with agerages from available records for representative inland localities in Western Canada

50 cm	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Summerland CDA												
Obs (1964-70)	3.0	3.2	3.6	8.3	13.6	18.4	21.4	22.5	19.2	14.2	8.7	4.2
Est (normal)	1.5	1.6	3.7	9.1	13.6	17.4	21.5	22.1	18.8	12.8	8.1	3.5
Obs-Est	1.5	1.6	-0.1	-0.8	0.0	1.0	-0.1	0.4	0.4	1.4	0.6	0.7
Lethbridge CDA												
Obs (1966-70)	-0.3	-0.8	1.0	3.8	9.3	14.4	17.9	18.3	14.8	8.9	4.3	0.9
Est (normal)	-1.0	-1.2	-0.6	3.3	9.1	13.9	17.7	17.9	14.7	10.0	4.6	0.9
Obs-Est	0.6	0.4	1.6	0.5	0.2	0.5	0.2	0.4	0.1	-1.1	-0.3	0.0
Swift Current CDA												
Obs (1963-70)	-4.8	-5.1	-2.6	1.9	7.8	13.6	17.7	18.4	14.2	8.8	3.4	-1.6
Est (normal)	-1.6	-2.4	-1.6	1.3	6.8	12.4	16.4	17.0	13.7	8.7	3.5	0.2
Obs-Est	-3.2	-2.7	-1.0	0.6	1.0	1.2	1.3	1.4	0.5	0.1	-0.1	-1.8
St. John's West CDA												
Obs (1963 - 70 ave)	2.3	1.6	1.3	1.9	5.3	9.3	12.7	14.1	12.7	10.1	7.1	4.3
Est (Normal)	2.1	1.6	1.3	2.1	5.0	9.6	12.4	13.7	12.6	9.5	6.3	3.7
Obs - Est	.2	0	0	-.2	.3	-.3	.3	.4	.1	.6	.8	.6

Table 5: Example of computer output showing normal mean monthly soil temperatures estimated from climatic data.

STATION = 8402050 LATITUDE = 4856 LONGITUDE = 5540 ELEVATION = 197 GRAND FALLS NFLD

SOIL DEPTH	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAI	JUNE	JULY	AUG.	SEPT	OCT.	NOV.	DEC.
1CM	7.3	3.7	.3	-.9	-.7	-.2	2.1	8.2	13.6	18.1	18.0	13.7	7.9	3.7	.1
10CM	8.3	4.4	1.1	-.3	-.4	.2	1.8	7.2	12.4	17.0	16.6	13.7	8.3	4.2	.5
20CM	8.5	5.0	1.7	.1	-.1	.3	1.5	6.5	11.5	15.6	15.8	13.3	8.5	4.9	1.5
50CM	9.7	6.0	3.0	1.3	.9	.9	1.8	5.5	10.3	13.8	14.7	13.2	9.4	5.9	2.9
100CM	10.8	7.9	5.1	3.1	2.5	2.3	2.7	5.1	9.2	12.9	14.1	13.1	10.6	7.5	4.7
150CM	10.9	8.7	6.4	4.5	3.6	3.2	3.1	4.7	7.6	10.2	12.2	12.3	10.8	8.4	6.0

GRANDS TRAITS DU SYSTEME DE CLASSIFICATION (A L'ESSAI)

Résumé

Suite aux décisions prises en taxonomie des sols les corrélateurs estiment qu'il est d'urgente nécessité de reviser le système de numérotage. Le système suivant est proposé pour étude et commentaires. (S.V.P. Adresser les commentaires aux corrélateurs). Les rapports des comités des divers ordres de sols ont été numérotés d'après ce nouveau système.

Le premier chiffre à gauche indique l'ordre; le second, le grand groupe; le troisième et le quatrième, le sous-groupe; le cinquième le caractère "modifiant" du sous-groupe. Si des "modifiants" additionnels sont nécessaires ils occupent la sixième et la septième position. Il est recommandable de n'avoir pas plus de deux "modifiants".

Pour les ordres de sols minéraux les "modifiants" peuvent s'ajouter à n'importe quel numéro de sous-groupe à moins qu'un tel usage soit prohibé par définition.

OUTLINE OF THE SYSTEM OF SOIL CLASSIFICATION FOR CANADA (TENTATIVE)

Summary

As a consequence of the decisions made on the soil taxonomy, it is apparent to the soil correlation staff that a revised numbering system is urgently required. The proposed system that follows is offered for study and critical comment. The reports of subcommittees on soil orders have had this number system incorporated. Please send comments to correlators.

The system of soil classification at the order, great group and subgroup levels is listed below in numerical sequence for the purposes of identification and coding.

From the left side the first number is the order, the second is the great group, the third and fourth is the subgroup, the fifth is the subgroup modifier. In the cases where more than one subgroup modifier is required the additional modifier numbers are placed in the sixth and seventh columns. However, it is strongly recommended that no more than two subgroup modifiers be used.

The subgroup modifiers in mineral soil orders may be appended to any subgroup number unless the definition of the particular subgroup stated in the chapters on soil taxonomy prohibit such use.

Order	Great Group	Subgroup	Subgroup Modifier
1 Chernozemic	11 Brown	1101 Orthic Brown	2 Grumic
		1102 Rego Brown	5 Saline
		1103 Calcareous Brown	6 Carbonated
		1104 Eluviated Brown	8 Gleyed
		1105 Solonetzic Brown	9 Lithic
		1106 Solodic Brown	
	12 Dark Brown	1201 Orthic Dark Brown	2 Grumic
		1202 Rego Dark Brown	5 Saline
		1203 Calcareous Dark Brown	6 Carbonated
		1204 Eluviated Dark Brown	8 Gleyed
		1205 Solonetzic Dark Brown	9 Lithic
		1206 Solodic Dark Brown	
	13 Black	1301 Orthic Black	2 Grumic
		1302 Rego Black	5 Saline
		1303 Calcareous Black	6 Carbonated
		1304 Eluviated Black	8 Gleyed
		1305 Solonetzic Black	9 Lithic
		1306 Solodic Black	
	14 Dark Gray	1401 Orthic Dark Gray	2 Grumic
		1402 Rego Dark Gray	5 Saline
		1403 Calcareous Dark Gray	6 Carbonated
		1405 Solonetiz Dark Gray	8 Gleyed
		1406 Solodic Dark Gray	9 Lithic
2 Solonetzic	21 Solonetz	2101 Brown Solonetz	8 Gleyed
		2102 Dark Brown Solonetz	9 Lithic
		2103 Black Solonetz	
		2104 Gray Solonetz	
		2105 Alkaline Solonetz	
	22 Solodized Solonetz	2201 Brown Solodized Solonetz	8 Gleyed
		2202 Dark Brown Solodized Solonetz	9 Lithic
		2203 Black Solodized Solonetz	
		2204 Gray Solodized Solonetz	
	23 Solod	2301 Brown Solod	8 Gleyed
		2302 Dark Brown Solod	9 Lithic
		2303 Black Solod	
		2304 Gray Solod	
3 Luvisolic	31 Gray Brown Luvisol	3101 Orthic Gray Brown Luvisol	8 Gleyed
		3102 Brunisolic Gray Brown Luvisol	9 Lithic

Order	Great Group	Subgroup	Subgroup Modifier
		3103 Podzolic Gray Brown Luvisol	
	32 Gray Luvisol	3201 Orthic Gray Luvisol	3 Turbic
		3202 Dark Gray Luvisol	7 Cryic
		3203 Brunisolic Gray Luvisol	8 Gleyed
		3204 Podzolic Gray Luvisol	9 Lithic
		3205 Solodic Gray Luvisol	
		3206 Solodic Dark Gray Luvisol	
4 Podzolic	41 Humic Podzol	4101 Orthic Humic Podzol	8 Gleyed
		4102 Ortstein Humic Podzol	9 Lithic
		4103 Placic Humic Podzol	
		4104 Duric Humic Podzol	
		4105 Fragic Humic Podzol	
	42 Ferro-Humic Podzol	4201 Orthic Ferro-Humic Podzol	8 Gleyed
		4202 Ortstein Ferro-Humic Podzol	9 Lithic
		4203 Placic Ferro-Humic Podzol	
		4204 Duric Ferro-Humic Podzol	
		4205 Fragic Ferro-Humic Podzol	
		4206 Luvisolic Ferro-Humic Podzol	
		4207 Sombric Ferro-Humic Podzol	
	43 Humo-Ferric Podzol	4301 Orthic Humo-Ferric Podzol	3 Turbic
		4302 Ortstein Humo-Ferric Podzol	7 Cryic
		4303 Placic Humo-Ferric Podzol	8 Gleyed
		4304 Duric Humo-Ferric Podzol	9 Lithic
		4305 Fragic Humo-Ferric Podzol	
		4306 Luvisolic Humo-Ferric Podzol	
		4307 Sombric Humo-Ferric Podzol	

Order	Great Group	Subgroup	Subgroup Modifier
5 Brunisolic	51 Melanic Brunisol	5101 Orthic Melanic Brunisol	1 Andic
		5102 Degraded Melanic Brunisol	3 Turbic
			7 Cryic
			8 Gleyed
			9 Lithic
	52 Eutric Brunisol	5201 Orthic Eutric Brunisol	1 Andic
		5202 Degraded Eutric Brunisol	3 Turbic
			7 Cryic
			8 Gleyed
			9 Lithic
	53 Sombric Brunisol	5301 Orthic Sombric Brunisol	1 Andic
		5302 Degraded Sombric Brunisol	3 Turbic
			7 Cryic
			8 Gleyed
			9 Lithic
	54 Dystric Brunisol	5401 Orthic Dystric Brunisol	1 Andic
		5402 Degraded Dystric Brunisol	3 Turbic
			7 Cryic
			8 Gleyed
			9 Lithic
6 Regosolic	61 Regosol	6101 Orthic Regosol	3 Turbic
		6102 Cumulic Regosol	5 Saline
			7 Cryic
			8 Gleyed
			9 Lithic
7 Gleysolic	71 Humic Gleysol	7101 Orthic Humic Gleysol	3 Turbic
		7102 Rego Humic Gleysol	4 Placic
		7103 Fera Humic Gleysol	5 Saline
			6 Carbonated
			7 Cryic
			9 Lithic
	72 Gleysol	7201 Orthic Gleysol	3 Turbic
		7202 Rego Gleysol	4 Placic
		7203 Fera Gleysol	5 Saline
			6 Carbonated
			7 Cryic
			9 Lithic

Order	Great Group	Subgroup	Subgroup Modifier
	73 Luvic Gleysol	7301 Orthic Luvic Gleysol	7 Cryic
		7302 Humic Luvic Gleysol	9 Lithic
		7303 Fera Luvic Gleysol	
8 Organic	81 Fibrisol	8101 Fenno-Fibrisol	
		8102 Silvo-Fibrisol	
		8103 Sphagno-Fibrisol	
		8104 Mesic Fibrisol	
		8105 Humic Fibrisol	
		8106 Limno Fibrisol	
		8107 Cumulo Fibrisol	
		8108 Terric Fibrisol	
		8109 Terric Mesic Fibrisol	
		8110 Terric Humic Fibrisol	
		8111 Cryic Fibrisol	
		8112 Hydric Fibrisol	
		8113 Lithic Fibrisol	
	82 Mesisol	8201 Typic Mesisol	
		8202 Fibric Mesisol	
		8203 Humic Mesisol	
		8204 Limno Mesisol	
		8205 Cumulo Mesisol	
		8206 Terric Mesisol	
		8207 Terric Fibric Mesisol	
		8208 Terric Humic Mesisol	
		8209 Cryic Mesisol	
		8210 Hydric Mesisol	
		8211 Lithic Mesisol	
	83 Humisol	8301 Typic Humisol	
		8302 Fibric Humisol	
		8303 Mesic Humisol	
		8304 Limno Humisol	
		8305 Cumulo Humisol	
		8306 Terric Humisol	
		8307 Terric Fibric Humisol	
		8308 Terric Mesic Humisol	
		8309 Cryic Humisol	
		8310 Lithic Humisol	
		8311 Lithic Humisol	
	84 Folisol	8401 Typic Folisol	
		8402 Lithic Folisol	

RAPPORT DU COMITE DES ORDRES CHERNOZEMIQUE ET ZOLONETZIQUE

T.W. Peters, Président

Résumé

Aucune changement n'a été fait dans l'ordre chernozémique. A l'ordre solonetzique, on a ajouté un grand groupe, celui des "Solonetz solodisés", de même que des sous-groupes désignés par l'appellation "Brun foncé". Les critères de couleur pour la séparation en sous-groupes sont semblables à ceux utilisés pour les sols chernozémiques.

REPORT OF THE SUBCOMMITTEE ON CHERNOZEMIC AND SOLONETZIC SOILS

T.W. Peters, Chairman

Summary

No changes have been made in the chernozemic order. A Solodized Solonetz great group and Dark Brown subgroups have been added to the order. The color criteria for the separation of the subgroups are similar as those used for chernozemic soils.

2 SOLONETZIC ORDER

Great Group		
21 Solonetz	2101	Brown Solonetz
	2102	Dark Brown Solonetz
	2103	Black Solonetz
	2104	Gray Solonetz
	2105	Alkaline Solonetz
	210-8	Gleyed Solonetz
	210-9	Lithic Solonetz
22 Solodized Solonetz	2201	Brown Solodized Solonetz
	2202	Dark Brown Solodized Solonetz
	2203	Black Solodized Solonetz
	2204	Gray Solodized Solonetz
	220-8	Gleyed Solodized Solonetz
	220-9	Lithic Solodized Solonetz
23 Solod	2301	Brown Solod
	2302	Dark Brown Solod
	2303	Black Solod
	2304	Gray Solod
	230-8	Gleyed Solod
	230-9	Lithic Solod

2 Solonetzic Order

Soils of the Solonetzic order are those having either Bn or Bnt horizons and saline C horizons. Solonetzic B horizons (Bn or Bnt) have prismatic or columnar macrostructure and the peds usually break to form blocky units. The peds have dark coatings, and their consistence when dry is hard to extremely hard. The ratio of exchangeable Ca to exchangeable Na of solonetzic B horizons is 10 or less. Solonetzic soils lack permafrost within 1 m of the surface 2 months after the summer solstice.

Solonetzic soils are thought to have originated from parent materials that were more or less uniformly salinized. The material was, and it continues to be, leached by rain. This leaching presumably caused desalinization and an increase of alkali peptized and deflocculated colloids that apparently concentrated in the B horizon. Subsequently, it is thought that alkali bases were removed and an acidic A horizon with platy structure formed. The final stage of solodization is considered to be the structural breakdown of the solonetzic B horizon.

Most Solonetzic soils in Canada have a neutral to acidic A horizon indicating that some solodization has occurred. Soils with strongly alkaline A horizons (the first stage of Solonetzic soil formation) are uncommon in Canada. As solodization proceeds the horizons of salt and of lime accumulation more downward generally from the B to the C horizon. In most Solonetzic soils the C horizon has a conductivity (saturation extract) of more than 4 mmhos/cm. Solodization is arrested where saline groundwater is within capillary reach of the solum, and a recycle of salinization may occur in groundwater discharge areas.

It is thought that most Solonetzic soils developed under a vegetative cover of grasses and forbs in regions of semiarid to subhumid climate. Although some soils of the order occur under tree cover, it is believed that the trees did not become established until solodization was well under way. Solonetzic soils are intimately associated with Chernozemic soils in some areas of the Great Plains, and to a lesser extent with Luvisolic soils.

The Solonetzic order includes three great groups: Solonetz, Solodized Solonetz, and Solod, that are separated on the basis of increasing degree of solodization.

21 Solonetz

The soils of this great group have a strongly-expressed Bnt horizon and they lack a continuous Ae horizon 2.5 cm thick or more. The boundary between the Ah or Ahe horizon and the Bnt horizon is abrupt. The Bnt horizon is usually very hard columnar with the flat or rounded tops of the peds having a thin capping of white material. Clay skins are common. The upper portion of the dark stained Bnt peds usually remains intact when the peds are removed. The Bnt horizon has a very low hydraulic conductivity and flattened roots are concentrated along cleavage planes rather than penetrating the peds. Slight graying of the Ah horizon or the presence of a very thin Ae horizon may indicate some degree of solodization. The C horizon is saline and usually calcareous.

Cultivated Solonetz soils are classified at the Subgroup level on the basis of color of the Ap horizon and other specified features.

2101 Brown Solonetz

Profile type: <u>Ah</u> or <u>Ahe</u>, (Ahe), <u>Bnt</u>, (Bts), (Btk), <u>Csa</u> or <u>Cs</u>, (Cca), (Ck).

These soils have A subhorizons with color values, when mixed, (Ap) lower than 3.5 moist and higher than 4.5 dry, and chromas usually higher than 1.5 dry. They have Bnt horizons as specified for the great group.

Brown Solonetz soils are associated with grass and forb vegetation and a semiarid climate. Areas of these soils often have patchy microrelief due to differential erosion of the A horizon. The eroded pits usually support very sparse plant growth.

2102 Dark Brown Solonetz

Profile type: <u>Ah</u> or <u>Ahe</u>, (Ae), <u>Bnt</u>, (Bts), (Btk), <u>Csa</u> or <u>Cs</u>, (Cca), (Ck)

These soils have A horizons with color values, when mixed, (Ap) lower than 3.5 moist and between 3.5 and 4.5 dry, and chromas usually higher than 1.5 dry. They have Bnt horizons as specified for the great group.

Dark Brown Solonetz soils are associated with mesophytic grasses and forbs in a semiarid to subhumid climate. Areas of these soils often have patchy microrelief due to differential erosion of the A horizon, but bare eroded pits are not as common as in areas of Brown Solonetz soils.

2103 Black Solonetz

Profile type: (S-H), Ah or Ahe, (Ae), Bnt, (Bts), (Btk), Csa or Cs, (Cca), (Ck).

These soils have A horizon with color values, when mixed (Ap) lower than 3.5 moist and dry, and chromas usually lower than 2 dry. They have a Bnt horizons as specified for the great group.

Black Solonetz soils are associated mainly with the growth of mesophytic grasses and forbs in a subhumid climate but they also occur in areas of discontinuous shrub and tree cover with a ground cover of forbs and grasses. The microrelief associated with differential erosion of the A horizon in areas of Brown Solonetz soils occurs rarely in areas of Black Solonetz soils.

2104 Gray Solonetz

Profile type: (L-H), Ahe, (Ae), Bnt, (Bts), (Btk), Csa or Cs, (Cca), (Ck).

The soils have A horizons with color values, when mixed (Ap) higher than 3.5 moist and higher than 4.5 dry, and chromas usually lower than 2. They have Bnt horizons as specified for the great group.

Gray Solonetz soils are associated with sparse shrub and tree vegetation in a subhumid climate. They are associated with Eluviated Black and Dark Gray Luvisol soils. They are distinguished from Brown and Dark Brown Solonetz soils by the associated climate, vegetation, and soils. Their occurrence is rare.

2105 Alkaline Solonetz

Profile type: Ah or Ahsa or Ahs, Bnt or Bntj (Bskg), Cskg

These soils have strongly alkaline Ah horizons (pH of 8.5 or more) with an abrupt boundary to the B horizon. The prismatic or columnar peds of the B horizon commonly have dark coatings on parts of their surfaces.

Alkaline Solonetz soils are associated with mesophytic grasses and forbs that include a significant percentage of species tolorant of alkaline conditions. The subgroup occupies a very small area of western Canada.

210-8 Gleyed Solonetz

These soils have in addition to the characteristics of one of the above subgroups evidence of gleying in the form of faint to distinct mottles in the upper 50 cm or faint to prominent mottling accompanied by matrix colors of low chroma at depths below 50 cm.

210-9 Lithic Solonetz

These soils have in addition to the characteristics of one of the above subgroups, a lithic contact between 10 and 50 cm from the mineral surface.

Both Lithic and Gleyed can be used to designate a subgroup, e.g. Gleyed Lithic Alkaline Solonetz.

22 Solodized Solonetz

The soils of this great group have a well-developed Ae horizon 2.5 cm thick or more with an abrupt boundary to a strongly expressed Bnt horizon. The Ae horizon usually has strongly developed platy structure and its reaction is neutral to acidic. The Bnt horizon is hard to extremely hard when dry and it usually has columnar macrostructure with white capped columns that remain intact when removed from the profile. The columnar peds break to blocky aggregates that usually have dark coatings. The B horizon has a low to very low hydraulic condutivity and roots tend to concentrate along cleavage plains. There are many clay skins. The C horizon is saline and commonly calcareous. Cultivated Solodized Solonetz soils are classified at the subgroup level on the basis of color of the Ap horizon and other specified features.

2201 Brown Solodized Solonetz
Profile type: Ah or Ahe ,Ae, Bnt, Csa or Cs, (Cca), (Ck)

These soils have Ah or Ahe horizons with color values, when mixed, (Ap) lower than 3.5 moist and higher than 4.5 dry, and chromas usually higher than 1.5 dry. They have Ae and Bnt horizons as specified for the great group.

Brown Solodized Solonetz soils are associated with grass and forb vegetation in a semiarid climate. Areas of this subgroup often have irregular microrelief due to differential erosion of the A horizon. The eroded pits usually support a very sparse plant cover.

2202 Dark Brown Solodized Solonetz
Profile type: Ah or Ahe, (Ae), Bnt, Cs or Csa, (Cca), (Ck).

These soils have Ah or Ahe horizons with color values, when mixed (Ap) lower than 3.5 moist and between 3.5 and 4.5 dry, and chromas usually higher than 1.5 dry. They have Ae and Bnt horizons as specified for the great group.

Dark Brown Solodized Solonetz soils are associated with mesophytic grasses and forbs in a semiarid to subhumid climate. Areas of this subgroup often have irregular microrelief due to differential erosion of the A horizon. The eroded pits usually support a fairly good grass cover.

2203 Black Solodized Solonetz

Profile type: (L-H), Ah or Ahe, Ae, Bnt, Csa or Cs (Cca), (Ck).

These soils have Ah or Ahe horizons with color values, when mixed, (Ap) lower than 3.5 moist and dry, and chromas usually lower than 2 dry. They have Ae and Bnt horizons as specified for the great group.

Black Solodized Solonetz soils are associated mainly with mesophytic grasses and forbs in a subhumid climate but they also occur in areas of discontinuous tree and shrub cover and a ground cover of forbs and grasses. The differential erosion of the A horizon, common in areas of Brown and Dark Brown Solodized Solonetz soils seldom occurs in areas of Black Solodized Solonetz soils.

2204 Gray Solodized Solonetz

Profile type: (L-H), (Ah), Ahe, Ae, Bnt, Csa or Cs, (Cca), (Ck).

These soils have Ahe horizons with color values, when mixed, (Ap) higher than 3.5 moist and higher than 4.5 dry and chromas usually lower than 2. They have Ae and Bnt horizons as specified for the great group.

Gray Solodized Solonetz soils are associated with scattered and stunted forest vegetation in a subhumid climate. They are associated with Eluviated Black and Dark Gray Luvisol soils. They are distinguished from Brown and Dark Brown Solodized Solonetz soils by the associated climate, vegetation and soils.

220-8 Gleyed Solodized Solonetz

These soils have, in addition to the characteristics of one of the above subgroups evidence of gleying in the form of faint to distinct mottles in the upper 50 cm or faint to prominent mottling accompanied by matrix colors of low chroma below 50 cm.

220-9 Lithic Solodized Solonetz

These soils have in addition to the characteristics of one of the above subgroups, a lithic contact between 10 and 50 cm from the mineral surface.

Both Lithic and Gleyed can be used to designate a subgroup, e.g. Gleyed Lithic Black Solodized Solonetz.

23 Solod

The soils of this great group have a prominent Ahe or Ae horizon or both at least 5 cm thick and an AB or BA horizon at least 5 cm thick above the Bnt horizon. The Ahe or Ae horizon is usually platy and there is a clear boundary to the AB or BA horizon. The blocky peds of the AB or BA horizon usually have white coatings and the interiors of the peds have the darker color of the B horizon. The boundary to the Bnt horizon is gradual. The Bnt horizon may be priamatic or blocky; the peds have dark coatings and are hard to very hard when dry. The B horizon usually has a moderate hydraulic conductivity and roots penetrate the peds as well as following cleavage planes. Clay skins are common. The Cs or Csa horizon commonly occurs below a Cca or Ck horizon.

The combined A horizons are thicker in relation to the B horizon than in the Solonetz and Solodized Solonetz soils. The relic structure of the former Bnt horizon commonly may be seen in the A horizons. Cultivated Solods are distinguished from other Solonetzic great groups by the nature of the AB or BA horizons. The subgroups of cultivated Solods are distinguished by the color of the Ap horizon.

2301 Brown Solod
Profile type: Ah or Ahe, Ae, AB or BA, Bnt, (Cca), (Ck), Csa or Cs

These soils have Ah or Ahe horizons with color values, when mixed (Ap), lower than 3.5 moist and higher than 4.5 dry, and chromas usually higher than 1.5 dry. They have the Ae, AB or BA and the Bnt horizons as specified for the great group.

Brown Solods are associated with grass and forb vegetation in a semiarid climate. In areas of these soils there is commonly some evidence of formerly eroded pits but they are usually shallow and grass covered.

2302 Dark Brown Solod
Profile type: Ah or Ahe, Ae, AB or BA, Bnt, (Cca), (Ck), Csa or Cs

These soils have Ah or Ahe horizons with color values, when mixed, (Ap) lower than 3.5 moist and 4.5 to 5.5 dry, and chromas usually higher than 1.5 dry. They have Ae, AB or BA and Bnt horizons as specified for the great group.

Dark Brown Solods are associated with mesophytic grasses and forbs in a semiarid to subhumid climate There is commonly some evidence of previously eroded pits but they are usually shallow and well covered with grass.

2303 Black Solod
Profile type: (L-H), Ah or Ahe, Ae, AB or BA, Bnt, (Cca), (Ck), Csa or Cs

These soils have Ah or Ahe horizons with color values, when mixed (Ap) lower than 3.5 moist and dry, and chromas usually lower than 2 dry. They have the Ae, AB or BA and Bnt horizons as specified for the great group.

Black Solods are associated mainly with mesophytic grasses and forbs in a subhumid climate but they also occur in areas of thin or discontinuous tree and shrub cover.

2304 Gray Solod
Profile type: (L-H), (Ah), Ahe, Ae, AB or BA, Bnt, (Cca), (Ck), Csa or Cs

These soils have Ahe horizons with color values, when mixed (Ap) higher than 3.5 moist and higher than 4.5 dry, and chromas usually lower than 2 dry.

They have Ae, AB or BA and Bnt horizons as specified for the great group.

Gray Solods are associated with forest vegetation in a subhumid climate. They are associated with Eluviated Black and Dark Gray Luvisol soils. They are distinguished from Brown Solod and Dark Brown Solod by the associated climate, vegetation and soils.

230-8 Gleyed Solod

These soils have in addition to the characteristics of one of the above subgroups evidence of gleying in the form of faint to distinct mottling in the upper 50 cm or faint to prominent mottling accompanied by matrix colors of low chroma below 50 cm.

230-9 Lithic Solod

These soils have in addition to the characteristics of one of the above subgroups, a lithic contact between 10 and 50 cm from the mineral surface. Both Lithic and Gleyed can be used to designate a subgroup, e.g. Gleyed Lithic Gray Solod.

RAPPORT DU COMITE DE L'ORDRE LUVISOLIQUE

J.A. Shields et J.A. McKeague, Présidents

Résumé

Les changements à l'ordre luvisolique concernent surtout l'addition des sous-groupes 'cryique' et 'turbique' au grand groupe des Luvisols gris de même que quelques modifications mineures des sous-groupes 'bisequa', 'brunisolique' et 'solodique'.

Le 'bisequa' a été enlevé de l'ordre luvisolique et le sous-groupe concerné s'appele maintenant Luvisol gris podzolique. Ce sol doit avoir un Bf d'au moins 5 cm surplombant la limite supérieure du Bt qui se trouve à moins de 75 cm de la surface. Si le Bt est faiblement exprimé (forte structure et pellicules argileuses évidentes toutes deux manquantes et teneur en argile augmentant juste assez pour un Bt) sa limite supérieure peut se trouver à 50 cm de la surface minérale.

Le 'brunisolique' a un Bm brunatre (chroma$>$3) de plus de 5 cm d'épaisseur au dessus du Bt. Il peut avoir un Bf de moins de 5 cm ou un Ae (chroma$<$3) au dessus ou en-dessous du Bm ou du Bf. L'intensité de la couleur est un bon guide pour différencier entre un Bm (chroma$>$3) et un Ae (chroma$>$3).

Le Luvisol gris solodique a été séparé en 'gris' et 'gris foncé' d'après l'épaisseur du Ah. Le 'gris foncé' a un Ah ou un Ahe de plus de 5 cm au-dessus des Ae et Btnj, par comparaison avec le Luvisol gris Solodique dont le Ah est mince ou absent.

Il faut noter que le 12 mai 1972 John Day a informé les membres d'un changement d'appellation de "Sol Gris boisé" pour "Luvisol gris". Une forte majorité des membres avaient supporté un tel changement.

REPORT OF THE SUBCOMMITTEE ON LUVISOLIC SOILS

J.A. Shields and J.A. McKeague, Co-Chairman

Summary

Changes in the Luvisolic Order were centered around the addition of Cryic and Turbic subgroups to the Gray Luvisol Great Group and with minor modifications within the Bisequa, Brunisolic and Solodic subgroups.

The term Bisequa was retired from the Luvisolic Order and the subgroup was renamed Podzolic Gray Luvisol., This subgroup must

have a Bf horizon at least 5 cm thick overlying the upper boundary of the Bt horizon which occurs within 75 cm of the surface. If the Bt horizon is weakly expressed (lacks both strong structures and obvious clay films and just meets the clay increase specified for a Bt horizon) its upper boundary may occur within 50 cm of the mineral surface.

Brunisolic subgroups have a brownish colored Bm horizon (chroma >3) greater than 5 cm thick in the upper sola overlying the Bt horizon. They may also have a thin Bf horizon less than 5 cm thick or a bleached Ae horizon (chroma <3) which may occur above or below the Bm or Bf horizons. It was generally agreed that color served as a useful guideline in the differentiation of a Bm horizon (chroma >3) from an Ae horizon (chroma <3).

The Solodic Gray Luvisol was separated into the Solodic Gray Luvisol and Solodic Dark Gray Luvisol subgroups according to the thickness of the Ah horizon. Solodic Dark Gray Luvisols have an Ah or Ahe horizon greater than 5 cm thick overlying the Ae and Btnj horizons. In contrast, the Ah horizon of Solodic Gray Luvisols is thin or absent.

It is noteworthy that a memo by John Day (May 12, 1972) was sent to members of the CSSC inregard to changing the Great Group name from Gray Wooded to Gray Luvisol. The vote on this topic strongly favored deleting the term Gray Wooded and using the term Gray Luvisol.

3 LUVISOLIC ORDER

Great Group		Subgroup
31 Gray Brown Luvisol	3101	Orthic Gray Brown Luvisol
	3102	Brunisolic Gray Brown Luvisol
	3103	Podzolic Gray Brown Luvisol
	310-9	Lithic Gray Brown Luvisol
	310-8	Gleyed Gray Brown Luvisol
32 Gray Luvisol	3201	Orthic Gray Luvisol
	3202	Dark Gray Luvisol
	3203	Brunisolic Gray Luvisol
	3204	Podzolic Gray Luvisol
	3205	Solodic Gray Luvisol
	3206	Solodic Dark Gray Luvisol
	320-7	Cryic Gray Luvisol
	320-3	Turbic Gray Luvisol
	320-9	Lithic Gray Luvisol
	320-8	Gleyed Gray Luvisol

Soils of the Luvisolic Order have an illuvial B horizon in which silicate clay is the main accumulation product and which meets the requirements of a Bt horizon as defined. They have either no Ah horizon or an Ah horizon less than 5 cm thick overlying the Ae or Bm horizon, or a dark colored chernozemic-like Ah more than 5 cm thick over an Ae thicker than 6 cm with a lower boundary below 15 cm or a dark colored forest-mull Ah more than 5 cm thick overlying an Ae or Bm horizon.

These soils have developed under deciduous, mixed deciduous-coniferous, or boreal forests, or under mixed forest in the forest-grassland transition zones. They occur under soil climatic conditions ranging from mild humic to very cold humid. The parent materials are generally neutral to alkaline in reaction.

Under cultivated conditions, the Ap horizon 15 cm thick, may vary considerably in organic matter and color (dry values 3 or higher) depending on whether the Ap consists of Ah, Ae, or a mixture of these in combination with the Bt horizon. In general, the Ap does not meet the requirements of a Chernozemic Ap horizon. Where it does meet these requirements, it is underlain by a light colored Ae horizon. In some cases where the Ah and Ae are thin, the Ap is underlain by the Bt horizon.

The Luvisolic order is divided into Gray Brown Luvisol and Gray Luvisol Great Groups.

31 Gray Brown Luvisol

The Gray Brown Luvisols have developed under deciduous or mixed forest vegetation and in a mild mesic climate, generally having a mean annual soil temperature of 8 to 15C at 50 cm depth. These soils have dark colored forest-mull surface horizons (Ah) more than 5 cm thick and illuvial horizons in which clay is the main product of accumulation (Bt). The soils have developed on basic or calcareous parent materials and the solum has a high degree of base saturation (by neutral salt extraction).

Under undisturbed conditions, the soils may have thin L, F and H layers, but because of high biological activity and the abundance of earthworms the leaf litter is usually quickly incorporated into the soil and humified. A transition AB or BA horizon having gray coatings on structural aggregates is generally present, particularly in medium and fine-textured soils. Although the Bt horizon is generally immediately underlain by calcareous materials, a transition BC horizon, may be present. These transition horizons are not diagnostic for the group. An increase in dithionite-extractable Fe and small increases of organic matter are usually associated with the accumulation of clay, but, the horizons do not meet the limits specified for a podzolic B.

Under cultivated conditions, the Ah and often part of the Ae are mixed to form an Ap, but the Bt and part of the Ae usually remain intact under the Ap, unless cultivation greatly exceeds 15 cm in depth.

Soils of this great group differ from the Degraded Melanic Brunisols in which the Ae and B development is weak and the B horizon does not meet the requirements of Bt. They differ from Dark Gray Luvisols which have developed in a cooler climate, mainly in the nature of the Ah horizons. Whereas the Gray Brown Luvisols have a forest-mull type of Ah with well developed granular structure (texture permitting), the Dark Gray Luvisols have a degraded chernozemic-like Ah, as evidenced by gray streaks and splotches which lack strongly developed granular structure and may be platy. They are differentiated from Chernozemic soils primarily on the basis of soil climate since Chernozemic soils are found mainly in areas with a cool to moderately cool climate (mean annual soil temperature of less than 8C).

The subgroups of the Gray Brown Luvisol Great Group are established on the basis of the profile development above the Bt horizon and on the evidence of gleying in the solum.

3101 Orthic Gray Brown Luvisol
Profile type: (L-H), <u>Ah</u>, <u>Ae</u>, (AB), (BA), <u>Bt</u>, (BC), (Ck), (C)

These soils have well developed Ah, Ae and Bt horizons and the other general charactertistics of the great group. The upper Ae is light colored with moist values of 4.5 or higher and with chromas of 3 or less; the difference in chroma between the upper and lower portion of the Ae is less than 1. The Ae is underlain directly by a blocky Bt with clay skins or by a BA horizon in which the blocky aggregates have gray coatings and tend to disintegrate. Faint mottlings may occur just above the Bt or in the lower part of the B horizon.

3102 Brunisolic Gray Brown Luvisol
Profile type: L-H, <u>Ah</u>, <u>Bm</u>, (Ae), (AB), <u>Bt</u>, (Ck), (C)
L-H, <u>Ah</u>, <u>Ae</u>, (Bf), <u>Bm</u>, (Ae), (AB), <u>Bt</u>, (Ck), (C)

These soils have the general characteristics of the great group. They also have in the upper solum either a Bm horizon at least 5 cm thick with a chroma of 3 or more, or a Bf horizon less than 5 cm thick that does not extend below the Ap horizon in cultivated soils, or both a Bf and a Bm. An Ae may or may not be present and when present it may occur above or below the Bf or Bm. The chroma of the Ae is usually less than 3.

The Bm horizon is generally granular and friable when moist. The upper Ae horizon is generally platy and friable when moist, but may be hard and often vesicular when dry. When present, the lower Ae horizon may have an irregular diffuse boundary with the underlying AB or BA horizon which often has gray coatings on the structural aggregates. Faint mottling may occur in the lower Ae horizon.

3103 Podzolic Gray Brown Luvisol

Profile type: L-H, Ah, (Ae), Bf, (Ae), Bt, (BC), (Ck), (C)

These soils have the general characteristics of the great group. In the upper sola they also have a Bf horizon at least 5 cm thick overlying a Bt horizon in the lower sola. In cultivated soils part of the Bf horizon must occur below the Ap. The upper boundary of a Bt horizon must be at a depth shallower than 75 cm. If the Bt horizon is weakly expressed (lacks both strong structures and obvious clay films and just meets the clay increase specified for a Bt horizon) its upper boundary must be at a depth shallower than 50 cm. Where a Bf horizon more than 5 cm thick occurs in the upper solum and either part of a weakly expressed Bt horizon occurs between depths of 50 and 75 cm or a strongly expressed Bt occurs below a depth of 75 cm, the soil is classified as a Luvisolic Humo-Ferric Podzol.

These soils differ from the Podzolic Gray Luvisols which either lack a mull Ah or have such an Ah less than 5 cm thick.

310-9 Lithic Gray Brown Luvisol

These soils have a lithic contact at a depth between 10 and 50 cm of the mineral surface in addition to the other general characteristics of the major subgroups.

310-8 Gleyed Gray Brown Luvisol

Profile type: Ah, Aegj, Btgj, (Ck), (C)
Ah, Bmgj, or Bfgj, (ABgj), Btgj, (Ck), (C)

These soils have in addition to the characteristics of the major subgroups distinct mottles indicative of gleying within 50 cm of the mineral surface or prominent mottles at depths between 50 and 100 cm. Commonly the matrix colors are of lower chroma than the associated well drained soils.

The Gleyed Gray Brown Luvisols generally have thicker and darker Ah horizons than the well-drained subgroups on similar parent materials. The color and textural differences between the Ae and Bt are generally less marked in the gleyed than in the well-drained subgroups.

Peaty or mucky phases having less than 40 cm of mixed peat or up to 60 cm of fibric moss peat over the Ah horizon, may occur in the gleyed subgroups.

Under cultivated conditions the Ap of the gleyed subgroups is generally darker (dry values may be as low as 2) than that of the orthic subgroups. The Ap is generally underlain by a gleyed Ae or Bt horizon, or both.

32 Gray Luvisol

The Gray Luvisols have developed under boreal forest or mixed forest in the grassland-forest transition zone within climatic areas under a wide range of climates. These soils usually have organic layer (L-H), and have illuvial horizons in which clay is the main accumulation product (Bt). These soils may have a degraded chernozemic-like Ah or an Ahe horizon as evidenced by gray streaks and splotches and often by a platy structure. An AB or BA horizon having gray coatings on the structural aggregates is often present. The solum is generally slightly to moderately acid, but the degree of base saturation based on neutral salt extraction is generally high. The parent materials are usually neutral to slightly alkaline and they are commonly calcareous.

Under cultivated conditions, the Ap may consist largely of Ah material, Ae material, or mixed Ah and Ae material. Occasionally it may also contain Bt material. The organic matter content and the color of the Ap may therefore vary considerably. When dry, the color value of an Ap may range from 3.5 to 5.5 or more. The Ap is underlain by remnants of Ae or by Bt.

3201 Orthic Gray Luvisol
Profile type: L-H, (Ah or Ahe), Ae, (AB), Bt, (Cca), (Ck), (C)

These soils have prominent light colored Ae, and Bt horizons and other general characteristics of the great group. An Ah, if present, is less than 5 cm thick. The lower part of the Ae may be slightly mottled and often overlies an AB or BA horizon.

The Ae has a dry color value of 5.5 or higher and a chroma of usually less than 3 although higher chromas may be associated with some parent materials.

When cultivated the mixed surface, or Ap horizons have a dry color value of 5.0 or higher and are underlain by remnants of Ae or by Bt. Where the total thickness of Ah and Ae is less than 6 inches (15 cm) and substantial amounts of the Bt have been incorporated into the Ap, the Ap may be slightly darker in value than 5.0 dry because of the darker color of the Bt. In such cases, fragments of the Bt should be clearly identifiable in the Ap.

3202 Dark Gray Luvisol
Profile type: (L-H), Ah or Ahe, Ae, Bt, (Cca), (Ck), (C)

These soils have Ah or Ahe horizons, or both whose combined thickness is more than 5 cm, prominent Ae horizons more than 6 cm thick, Bt horizons and other general characteristics of the great group. The total thickness of the Ah, Ahe, and Ae is greater than 15 cm and it extends below the plow layer.

The Ah or Ahe horizons show definite signs of degradation as evidenced by gray streaks or splotches when the soil is dry. They may be platy or weak, fine granular structure and resemble a degraded chernozemic Ah horizon. They differ from the forest-mull type of Ah, which generally has a well developed granular structure (texture permitting) with more intimate association of organic and mineral constituents.

Under cultivated conditions, the Ap has a dry color value lighter than 3.5 and darker than 5.0, but may be darker than 3.5 when moist. The range of color value in the Dark Gray Luvisol is the same as in the Dark Gray Chernozemic but the Ap of the latter is not underlain by a distinct Ae. The Ae of the Dark Gray Luvisol extends below the plow layer.

These soils represent an intergrade between the Dark Gray Chernozemic and the Orthic Gray Luvisol soils and lie in the transition forest-grassland zone.

3203 Brunisolic Gray Luvisol

Profile type: <u>L-H</u>, (Ah), <u>Ae</u>, (Bf), <u>Bm</u>, (Ae), (AB), <u>Bt</u>, (Ck), (C)
<u>L-H</u>, (Ah), <u>Bm</u>, (Ae), (AB), <u>Bt</u>, (Ck), (C)

These soils have the general characteristics of the great group. They also have in the upper solum either a Bm horizon at least 5 cm thick with a chroma of 3 or more, or a Bf horizon less than 5 cm thick that does not extend below the Ap horizon in cultivated soils, or both a Bm and Bf. An Ae may or may not be present and when present it may occur above or below the Bf or Bm.

The cultivated surface usually has color values similar to those of the Orthic Gray Luvisol or the Dark Gray Luvisol subgroups, but the chroma may be slightly higher on similar materials. The Ap is underlain by a Bm horizon.

The Brunisolic subgroup may be intergraded with the Orthic Gray Luvisol or with the Dark Gray Luvisol.

3204 Podzolic Gray Luvisol

Profile type: <u>L-H</u>, (Ah), <u>Ae</u>, <u>Bf</u>, (Ae), (AB), <u>Bt</u>, (Ck), (C)

These soils have the general characteristics of the great group. They also have in the upper sola a Bf horizon at least 5 cm thick. In cultivated soils part of the Bf must occur below the Ap. The upper boundary of the Bt horizon occurs either above 50 cm if it is weakly expressed (lacks both strong structure and obvious clay films and just meets the clay increase specified for a Bt horizon) or above 75 cm if it is strongly expressed. If the Bf horizon is more than 5 cm thick and either a weakly expressed Bt occurs between depths of 50 - 75 cm or a strongly expressed Bt occurs below a depth of 75 cm the soil is classified as a Luvisolic Humo-Ferric Podzol.

Under cultivated conditions, the Ap usually has color values similar to those of the Orthic Gray Luvisol or Dark Gray Luvisol subgroups, but the chroma may be slightly higher on similar materials.

3205 Solodic Gray Luvisol
Profile type: L-H, (Ah) or (Ahe), Ae, (AB), Btnj, (Cca), (Csk), (C)

These soils have hard, prismatic, or blocky structural Btnj horizons with pronounced dark coatings instead of the Bt horizon characteristic of the Great Group. Overlying the Btnj horizon is a pronounced Ae horizon with strong, fine, platy structure. An Ah is present is less than 5 cm thick. They have the other general properties charactertistic of the great group.

These soils resemble the Solod structurally, but they contain less exchangeable Na than is required for Bn horizons of Solonetz soils.

3206 Solodic Dark Gray Luvisol
Profile type: L-H, Ah or Ahe, Ae, (AB), Btnj, (Cca), (Csk), (C)

These soils have hard, prismatic, or blocky structural Btnj horizons with pronounced dark coatings instead of the Bt horizon characteristic of the Great Group. Overlying the Btnj horizon is a pronounced Ae horizon with strong, fine, platy structure. The Ah horizon must be more than 5 cm thick. They have the other general properties characteristic of the great group.

These soils resemble the Solod structurally but they contain less exchangeable Na than is required of Solonetz soils. They are distinguished from the Solodic Gray Luvisol which have Ah horizons less than 5 cm thick.

320-8 Gleyed Gray Luvisol
Profile type: L-H, (Ah), Aegj, (ABgj), Btgj, (BCg), (Cg), (Ck), (C)
L-H, Ah or Ahe, Ae or Bmgj, (ABgj), Btgj, (Ck), (C)

These soils have in addition to the characteristics of the major subgroups distinct mottles indicative of gleying within 50 cm of the mineral surface or prominent mottles at depths between 50 and 100 cm. Commonly the matrix colors are of lower chroma than the associated well-drained soils.

The Gleyed Gray Luvisols generally have thicker L-H layers than the well drained subgroups. Peaty or mucky phases with less than 40 cm of mixed peat or up to 60 cm of fibric moss peat on the surface of the mineral soil, may occur. When developed on reasonably permeable materials they often have thicker Ae and better-developed Bt horizons in depressions than in the associated well-drained soils particularly within the forest-grassland transition zone. However, in more humid regions on level land and less-permeable materials, the gleyed members may have weaker developed Ae and Bt horizons than the associated well-drained soils. They differ from the Orthic Luvic Gleysols in that the latter have developed under greater extremes of wetness and have matrix colors of lower chroma, or more prominent mottling in the upper 50 cm or both.

Specific profiles may be designated as 32018, 32038, etc.

320-7 Cryic Gray Luvisol

These soils have Ae horizons and Bt horizons and a cryic horizon within 100 cm of the mineral surface. A cryic horizon is permanently frozen or its temperature is $0^{o}C$ or lower 2 months after the summer solstice (Aug. 21). These soils occur in areas of subarctic or arctic temperature class within the region of continuous permafrost.

They may or may not be affected by cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons and mechanical sorting.

320-3 Turbic Gray Luvisol

These soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups, they have within 1 m of the mineral surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons and mechanical sorting.

320-9 Lithic Gray Luvisol

These soils have a lithic contact between 10 and 25 cm of the mineral surface and have the other general characteristics of the major subgroups.

DISCUSSION

A healthy discussion focussed on the occurrence and depth of Bt horizons in the Podzolic subgroups of the Luvisolic Order and the Luvisolic subgroups of the Podzolic Order. Here are a few of the pertinent exerpts from the tape.

Stonehouse: I would like to ask why it is necessary to have depth criteria for the occurrence of the Bt horizon in the Podzolic Gray Luvisol subgroups? Our group would prefer that a Bt take precedence over a Bf horizon. Thereby a soil having a Bt is placed in the Luvisolic Order regardless of the depth at which it occurs.

Shields: I was hoping this question would come up during the discussion on the Podzolic Order because the depth criteria at which the Bt is encountered in the subgroups of these two Orders has been meshed. Therefore, it is rather awkward to make any changes in the criteria within the Luvisolic Order without making corresponding adjustments in the Podzolic Order whose recommendation have already been accepted. In any case you do agree that we should have a Podzolic Gray Luvisol subgroup.

Stonehouse: Yes, but just because the Bt occurs at a greater depth in the soil, that is not enough reason for splitting the soil into a different Order.

Shields: We experienced considerable controversy on this depth criteria and on whether or not a Bt should take precedence over a Bf I'm sure that many people feel that the occurrence of a Bt within the control section places the soil into the Luvisolic Order. However, there are other people who would say that the presence of a Bf horizon would place it in the Podzolic Order.

Stonehouse: But you have got it both ways.

Shields: Yes, this was a compromising situation that we tried to work out the best we could depending on the degree of expression of the Bt and the depth at which it occurred. This is no doubt contentions but we felt that we had come up with some sort of a compromise.

DeKimpe: We must remember the sequence of soil formation because when the Podzolic B develops in the Bt we have to keep in mind that the last process involved is that of Podzolization. So from that, we are to keep the Luvisolic Humo-Ferric Podzol regardless of the depth at which the Bt horizon occurs.

McKeague: Yes, during the initial stages of this committee we suggested that because of inputs from Baril and a number of others that if the soils had a Podzolic B, it would be classified as a Podzol and we would then have a Luvic Podzol. Well, that's one way of looking at it as Chris DeKimpe has already pointed out. So we tried that on the first round which drew rather violent reaction from other areas. Bernie Stonehouse has already expressed a completely opposite viewpoint that if a soil has a Bt, then it has to be a Luvisol and it doesn't matter if it has a Podzolic B or not. Since there are two completely opposite points of view, you can't really resolve it.

C. Acton: We have soils with highly undulating B horizons where the Bt may be 18 inches from the surface at one point and 2 or 3 feet away, it may be down to 36 inches. This gives rise to the situation where according to the proposed criteria, you actually have two Orders standing side by side. You have a Luvisolic Humo-Ferric Podzol and a Podzolic Gray Brown Luvisol just on the basis of the depth of the Bt.

Shields: Yes, I fully realize your problems with those soils. In this particular case, the pedologist must use his discretion where this type of criteria has to be used with a grain of salt.

Day: Tsk, Tsk; Now, that's not quality control.

Shields: Nevertheless, John, it's a judgement that has to be used in the field every once in a while. You have to make up your mind to classify those kinds of soils either one way or the other.

Langmaid: I would suggest that we strike the Podzolic Gray Luvisol from the Order.

Shields: Where would you suggest putting them.

Langmaid: Put them in with the Luvisolic Humo-Ferric Podzols.

Shields: You're implying that a Bf takes precedence over a Bt.

Langmaid: Yes, this eliminates these kinds of separations based on the depth of Bt from the surface.

Shields: I'm happy with this type of open discussion because I'm sure it makes people aware of what the chairmen of these committees have to deal with. We certainly have explored both ends of the spectrum since the western groups would have a Bt take precedence over a Bf while Quebec, New Brunswick and the Maritimes would prefer it vice versa.

Personally, I don't like these depth criteria any better than you do because I realize it becomes a frustration in the field. But we have to use them as guidelines. Quite frankly, I would be happy if someone would suggest an alternative which would be agreeable to all. What is expressed in the present proposal is a compromising situation.

Dumanski: I would like to request that some type of systematics be incorporated into the entire system regarding these rather controversial points. Take a simple thing like thickness of horizons, we have 2 inches, 2 1/2 inches, 6 inches. Systematics are important, particularly in view of the fact we don't have a soil unless we have 4 inches of material. Without keying in particular to the Luvisolic Order, these comments could well apply to all Orders within the system.

Shields: Yes, depth criteria tend to be a frustration, they are scattered all throughout our system and to come to grips with it we are going to have to some coordinating body to sort it out. It can't simply be sorted out in one Order without having reprecussions on another.

In summary, I recommend that this report be accepted subject to minor modifications required to mesh with the Podzolic, Brunisolic and Chernozemic Orders.

A show of hands indicated that this report was accepted unanimously by the voting members of the CSSC.

RAPPORT DU COMITE DE L'ORDRE PODZOLIQUE

J.A. McKeague et J.A. Shields, Présidents

Résumé

Les principaux changements aux sols de l'ordre podsolique sont: a) l'insertion de critères morphologiques pour l'horizon B podsolique; b) le changement des critères chimiques pour l'horizon B podsolique, soit: un extrait au pyrophosphate Al+Fe $>$ 0.6% pour les sols plus fins que les sables et un extrait $\geq$ 0.4% dans le cas des sables (grossiers, moyens, fins et très fins), un rapport d'extrait au pyrophosphate Al+Fe à l'argile ($<$2mm) de $>$0.05 et une teneur en C organique $>$0.5%; c) l'addition des sous-groupes durique, fragique et à ortstein; d) l'élimination des "mini" sous-groupes.

REPORT OF THE SUBCOMMITTEE ON PODZOLIC SOILS

J.A. McKeague and J.A. Shields, Co-chairman

Summary

The principal changes instituted in the Podzolic soils are a) insertion of morphological criteria for podzolic B horizons, b) change of chemical criteria for podzolic B horizon e.g. pyrophosphate-extractable Al+Fe$>$0.6% in textures finer than sand and $\geq$0.4% in sands (CoS, S, FS, VFS), has a ratio of pyrophosphate-extractable Al+Fe to clay ($<$2mm) of $>$0.05 and has an organic C content $>$0.5%; c) addition of ortstein, duric and fragic subgroups; d) elimination of mini subgroup.

Before presenting our proposal for the classification of Podzolic soils we will outline briefly the recent history concerning the Podzolic order.

1. In 1965 at Quebec, the CSSC adopted specific chemical criteria for Podzolic soils. These were tested in succeeding years and it was found that the criteria resulted in the elimination from the order of a number of soils considered to be Podzolic and the inclusion of some soils not considered to be Podzolic.

2. At the 1970 CSSC meeting in Ottawa, a case was presented for altering the criteria of Podzolic soils so as to include once again certain sandy soils with well developed Ae horizons overlying B horizons of high chroma. No change was made at the time but a field trip was organized to bring together a number of the pedologists involved to study these soils in the field.

3. The field trip through parts of Sask., Alta. and B.C. in the fall of 1971 had several useful results.

   a) Data, both for many of the sandy soils and for other Brunisolic and Podzolic soils were accumulated and recorded in guidebooks in all of the 4 western provinces.

   b) A number of pedologists had an opportunity to broaden their perspective of the soils of Canada.

   c) Differences in concepts of soil classification were brought clearly into focus.

4. At a meeting in Hinton during the tour, it was decided that a committee composed of pedologists from the 4 western provinces should study the data in the tour guidebooks and develop proposals for amending the Podzolic order. The proposals would be considered at the meeting of the western section of CSSC in 1972.

5. At the eastern meeting of CSSC at Fredericton in Sept. 1971, Cann proposed several changes in the Podzolic order. These included, in addition to changes in wording:

   a) Greater emphasis on morphological criteria and less on chemical criteria at the order level.

   b) Combination of Ferro-Humic and Humo-Ferric as one great group.

   c) Elimination of Mini Subgroups.

   After discussion, these changes were accepted by the meeting.

6. At the western meeting of CSSC at Kelowna in Feb. 1972, Sprout, who chaired the committee on Podzolic soils, outlined the problems encountered during the western Podzolic tour in 1971, considered the proposals for changes adopted at the eastern meeting, and outlined some other possible changes, specifically:

   a) Introduction of a new great group, Ferric Podzols, for the sandy soils with Ae and color B horizons. This seemed to be favored generally by Saskatchewan and Alberta, but opposed by British Columbia.

   b) Changing the present chemical criteria for podzolic B horizon to criteria involving the relationships among organic matter, Fe, Al and clay, and similar to those for the spodic horizon.

   c) Consideration of subgroups of Podzolic great groups both for soils having indurated pans and for soils strongly influenced by volcanic ash.

   In addition, Sprout reported acceptance by the Western group of recommendations a) and c) of the Eastern group, but rejection of b).

7. It was decided at Kelowna that a correlator in Ottawa should undertake to develop improved criteria for the classification of Podzolic soils to be presented at the 1973 meeting. Rennie considered that an immediate decision should be made on the classification of the sandy

prairie soils. Clark recommended that criteria be developed to include sandy Podzol-like soils in the Podzolic order and that opinions be polled on this matter by the correlator and a working group. The recommendation passed after some opposition. Clark designated Shields and McKeague to poll opinions and develop improved criteria for Podzolic soils.

8. We sent a memorandum dated April 5, 1972 to soil survey heads and many others concerned with Podzolic soils asking for opinions, definitions and supporting data on the classification of Podzolic soils. The response has been good, although several pedologists with strong convictions on the subject have not replied. We also sent several memos on specific matters such as the question of Ferro-Humic and Humo-Ferric great groups, Fragic subgroups, etc.

9. During the summer of 1972, Shields studied Podzolic and associated soils in the field with the local pedologists in P.E.I., Nova Scotia, Quebec, Ontario (a bit), Sask., Alta. and B.C. Both Shields and McKeague studied soils with pans and volcanic ash affected soils in B.C. with the B.C. pedologists. McKeague studied soils with fragipans with Quebec pedologists.

10. After studying descriptions and data sent in '8', studying our data and field notes and considering opinion expressed in a thick file of letters, we prepared a memorandum dated Oct. 25 on "Proposed changes in classification of the Podzolic order". The proposal did not include "Ferric Podzols" because your comments, collectively, and our observations persuaded us that they did not belong logically in the Podzolic order.

11. Replies from all groups and many individuals showed that our Oct. 25 proposal was acceptable to many but not to all groups. Many suggestions were made for improvements. The Saskatchewan group objected strongly to the exclusion of sandy "Podzol-like" soils from the order. Stonehouse sent a detailed report on the concepts and definition of a great group "Ferric Podzol" based on color of Ae and B horizons.

12. We studied all the comments and prepared 2 proposals for the definition and classification of Podzolic soils in a memorandum dated Feb. 12. Proposal 1 insisted on both morphological and chemical criteria. Proposal 2 involved morphological (color) criteria alone for one great group, "Ferric Podzols".

    This brings the story up to date. The following material includes our final proposal for the May meeting.

First we want to thank all who replied to our memorandum of Feb. 12. Your replies were helpful both in revealing the variety of opinions on soil taxonomy and in pointing out ambiguities in our proposals. Choices between Proposals I and II as outlined were as follows:

Proposal I	Proposal II
P.E.I.	Nfld.
N.S.	N.B.
Quebec	Ont.
Manitoba	Sask.
Alberta	
B.C. (Both groups)	

In addition, we received a number of replies from individuals some of whom opted for I, others for II. Several of the survey group choices were split decisions, e.g. Ontario and Alberta, and all groups except Saskatchewan indicated that they could use either system. The Vancouver group favored making no changes now. The Saskatchewan group wanted less rigorous color criteria than those specified in Proposal II.

I suppose that Mr. Trudeau would be happy with the kind of clear majority preference expressed for Proposal I, but as several of you pointed out, scientific matters are not decided by votes. We are inclined to agree and would add that neither are matters of religious faith, which may be closely comparable to concepts of soil taxonomy.

The proposal presented here is based both upon your replies and upon many discussions here with pedologists who hold differing views on taxonomy. We will attempt to explain the overall logic upon which the proposal is based as well as the reasoning behind some of the details after presenting the proposal.

4 PODZOLIC ORDER

Great Group		Subgroup	
41	Humic Podzol	4101	Orthic Humic Podzol
		4102	Ortstein Humic Podzol
		4103	Placic Humic Podzol
		4104	Duric Humic Podzol
		4105	Fragic Humic Podzol
		410-9	Lithic Humic Podzol
		410-8	Gleyed Humic Podzol
42	Ferro-Humic Podzol	4201	Orthic Ferro-Humic Podzol
		4202	Ortstein Ferro-Humic Podzol
		4203	Placic Ferro-Humic Podzol
		4204	Duric Ferro-Humic Podzol
		4205	Fragic Ferro-Humic Podzol
		4206	Luvisolic Ferro-Humic Podzol
		4207	Sombric Ferro-Humic Podzol
		420-9	Lithic Ferro-Humic Podzol
		420-8	Gleyed Ferro-Humic Podzol
43	Humo-Ferric Podzol	4301	Orthic Humo-Ferric Podzol
		4302	Ortstein Humo-Ferric Podzol
		4303	Placic Humo-Ferric Podzol
		4304	Duric Humo-Ferric Podzol
		4305	Fragic Humo-Ferric Podzol
		4306	Luvisolic Humo-Ferric Podzol
		4307	Sombric Humo-Ferric Podzol
		430-7	Cryic Humo-Ferric Podzol
		430-3	Turbic Humo-Ferric Podzol
		430-9	Lithic Humo-Ferric Podzol
		430-8	Gleyed Humo-Ferric Podzol

4 Soils of the Podzolic order have B horizons (podzolic B) in which the dominant accumulation products are organic matter (mainly fulvic acid) combined in varying degrees with Al and Fe. These amorphous materials occur in sufficient quantity to have a major influence on the properties of the podzolic B horizon and many soil properties are associated with their occurrence. In general, the development of podzolic B horizons is associated with certain kinds of vegetation, climates and parent materials. However, the soils cannot be defined on the basis of these environmental factors. Podzolic soils can generally be recognized by their morphology but no combination of morphological criteria have been developed that will define this order unambigously. Podzolic soils might be defined on the basis of the amount of amorphous materials accumulated in the B horizons but no absolute method is known for the determination of these materials. Furthermore, a definition based solely upon a property that is measured in the laboratory is not acceptable to many pedologists. Thus, the order is defined on the basis of a combination of morphological and chemical criteria.

Soils of the Podzolic order meet the following limits:

A. Morphological

1. The B horizon, at least 5 cm thick, has moist crushed colors as follows:

   a) The hue is 7.5 YR or redder, or it is 10 YR near the upper boundary and becomes yellower with depth, and

   b) The chroma is higher than 3 or the value is 3 or less, and

2. Accumulation of amorphous material in a B horizon at least 5 cm thick is indicated by:

   a) Brown to black coatings on some mineral grains or brown to black microaggregates, and

   b) A silty feel when rubbed wet unless the material is cemented.

3. The texture of the podzolic B horizon is coarser than clay.

4. The soil either has no Bt horizon, or the Bt horizon occurs below 75 cm, or a weakly-expressed Bt horizon occurs below 50 cm. (A weakly-expressed Bt horizon lacks both strong structure and obvious clay films and just meets the clay increase specified for a Bt horizon).

B. Chemical

Either 1. They have a B subhorizon (Bh) at least 10 cm thick that contains:

a) More than 1% organic C, and

b) Less than 0.3% pyrophosphate-extractable Fe, and

c) That has a ratio of organic C to pyrophosphate-extractable Fe of 20 or more.

Or 2. They have a B subhorizon (Bf or Bhf) at least 5 cm thick that:

a) Contains 0.6% or more pyrophosphate-extractable Al+Fe in textures finer than sand and 0.4% or more in sands (coarse sand, sand, fine sand and very fine sand).

b) Has a ratio of pyrophosphate-extractable Al+Fe to clay ($\langle$2mm) of more than 0.05, and

c) Has an organic C content of more than 0.5%.

The Bf and Bhf horizons referred to in '2' are distinguished on the basis or organic C content as follows: Bf contains 0.5% to 5% organic C. Bhf contains more than 5% organic C.

As a field test, a 2% suspension of soil in 1M NaF gives a pH of 10.3 or more for most podzolic B horizons. Volcanic ash samples also commonly give a high pH with this test.

Many soils that are not Podzolic will satisfy the minimum morphological limits specified. However these limits are thought to be useful to exclude from the order some soils having horizons that satisfy the chemical limits specified but that otherwise do not resemble Podzolic soils. To be classified as Podzolic, a borderline soil must meet both the morphological and the chemical limits specified.

A podzolic B horizon takes precedence over gley features. Thus a soil having both a podzolic B horizon and gley colors as specified for soils of the Gleysolic order is classified as a Gleyed subgroup of the Podzolic order.

Some associated properties of podzolic B horizons

In addition to the properties specified as diagnostic, podzolic B horizons have a number of associated properties that may be useful in distinguishing them from other B horizons. Some of these associated properties are:

1. They have a high pH-dependent cation exchange capacity (CEC). The difference (ΔCEC) between CEC measured at pH 7 and at the pH of the soil is usually 8 me per 100 g or more.

2. Usually they are acid and base saturation, as determined by an unbuffered salt, is nearly always below 80% and commonly less than 50%.

3. Unless cemented, they have a high water holding capacity in relation to their texture.

4. They have a high capacity to fix phosphate.

5. Although they commonly contain appreciably more clay than the overlying Ae horizon (if present) usually very little of the clay occurs as oriented coatings on particles or peds.

General Morphology of Podzolic Soils

Well developed Podzolic soils can usually be recognized in the field. Typically a light gray Ae horizon contrasts sharply both with an overlying organic layer and with an underlying podzolic B horizon, the reddest hues, highest chromas or lowest values of which usually occur at the top and grade to yellower hues, higher values and lower chromas with depth. Under virgin conditions, they commonly have mor or moder surface layers, but they may have a peat layer, an Ah horizon, an Ae horizon or a podzolic B horizon at the surface. Commonly they have an eluviated, light colored Ae horizon with an abrupt lower boundary but this horizon may be discontinuous or absent. They have podzolic B horizons (Bh, Bhf, Bf) that are dominated by amorphous materials occurring as coatings on mineral grains, as microaggregates, or as brownish to black material dispersed rather uniformly throughout the matrix. Hues of moist podzolic B horizons usually grade from redder than 7.5 YR at the upper boundary to yellower with depth but this does not apply in reddish parent materials. Some common values and chromas of these horizons are:

Bh - 2/1, 2/2; Bhf - 3/2, 3/4; Bf - 4/4, 5/6.

However, colors of Bh, Bhf, Bf and Bm, horizons overlap and they are influenced by parent materials.

Podzolic B horizons are usually friable unless they are cemented. They are nonsticky.

Cultivated Podzolic soils are recognized by properties of the B horizon below the plow layer.

Vegetation Climates and Parent Materials Associated with Podzolic Soils

Most Podzolic soils occur under coniferous or mixed forest vegetation or under heath in areas of cryoboreal to mesic temperature class and subaquic to humic moisture subclass. However, many soils under these climatic and vegetative conditions are not Podzolic soils. Some Podzolic soils occur under deciduous forest vegetation, others under peat and still others in areas where the natural vegetation has been removed. In addition, some Podzolic soils are found in areas of subarctic and even of arctic temperature-class, and others in areas of subhumid, aquic and even peraquic moisture subclass.

Most Podzolic soils develop in materials that fall within either the sandy or the coarse loamy family particle size classes. However, some develop in coarse silty, fine loamy or fine silty materials. Most Podzolic soils developed in materials that contained very little or no free lime but some apparently developed in material from which appreciable lime was removed during soil development.

The Podzolic order is divided into Humic, Ferro-Humic and Humo-Ferric great groups on the basis of the organic matter content and the organic C to pyrophosphate-extractable Fe ratio of the podzolic B horizon.

41 Humic Podzol

These soils have dark colored (moist values and chromas usually less than 3) Bh horizons at least 10 cm thick. The Bh horizon, which usually occurs at the top of the B horizon, contains more than 1% organic C and less than 0.3% pyrophosphate-extractable Fe, has a ratio or organic C to pyrophosphate-extractable Fe of 20 or more, and generally does not turn redder on ignition.

Under virgin conditions, these soils usually have thick L-H or O layers underlain by a light colored eluviated horizon (Ae), or by an eluviated horizon darkened by infiltrated humic materials, or by a podzolic B horizon - usually Bh. The podzolic B horizon may include

Bhf and Bf subhorizons in addition to the very dark colored Bh subhorizon in any position or combination. These B subhorizons may be loose to very firm in consistence or cemented (ortstein) and they may be mottled. One or more thin (commonly about 5 mm), hard, impervious, dark reddish-brown to black pans (placic horizons) may occur in the solum or in the C horizon. The material below the podzolic B horizon may be cemented (duric) or compact and brittle (fragic).

Under disturbed conditions and in cases where the Bh horizon directly underlies the organic surface layer, the Bh may be confused with an Ah horizon. Two guidelines that aid in making this distinction are: (1) more than 50% of the organic C of Bh horizon is extractable by $NaOH-Na_4P_2O_7$ and (2) more than 50% of the extractable C of Bh horizons is fulvic acid C. Cultivated Humic Podzols are identified by properties of the B horizon below the cultivated layer.

Humic Podzols occur generally under heath, under forest with heath, under sphagnum, or under western coastal forest vegetation. The soils occur mainly in areas of cryoboreal to mesic temperature classes and peraquic to perhumid moisture subclasses in the following kinds of environments: maritime fringe, high elevations inland, locally in peaty depressions. Generally they form in materials of low Fe content or in materials that have been strongly leached of Fe, in some cases under reducing conditions. Some Bh horizons are thought to have developed by decomposition of humic material within a former Ae horizon. In some cases Bh horizons are thought to result from deposition of humic materials moving downslope at some depth within the solum.

The sola of Humic Podzols are generally strongly acid and are usually less than 50% base saturated (neutral salt). The Δ CEC value of the Bh horizon is usually well above 8 me per 100 grams.

4101 Orthic Humic Podzol
Profile type: (LFH) or (O) (Ae) <u>Bh</u> (Bhf) (Bf) (C)

These soils have a Bh horizon at least 10 cm thick. They do not have either a lithic contact within 50 cm or ortstein, placic, duric or fragic horizons, or evidence of gleying as specified for gleyed subgroups. Usually, Orthic Humic Podzols have L-H, or O layers and Ae horizons, and commonly they have Bhf or Bf horizons but none of these horizons is essential. The vegetation and climates associated with this subgroup are those indicated for Humic Podzols generally.

4102 Ortstein Humic Podzol
Profile type: (LFH) or (O), (Ae), <u>Bh</u>, <u>Bhfc</u> or <u>Bfc</u> (Bg) (C)

These soils have both a Bh horizon at least 10 cm thick and an ortstein horizon at least 2.5 cm thick. They do not have a lithic contact or evidence of gleying as specified for gleyed subgroups but they may have placic, duric, or fragic horizons. An ortstein horizon is a Bhf or Bf horizon that is strongly cemented and that occurs over at least 1/3 of the exposure. The ortstein horizon is designated as Bhfc or Bfc depending upon the organic carbon content. Usually, Ortstein Humic Podzols have L-H or O layers and Ae horizons. The vegetation and climates associated with this subgroup are those indicated for Humic Podzols generally.

4103 Placic Humic Podzol

Profile type: (LFH) or (O), (Ae), Bh, Bhfc or Bfc or Bgfc, (Bg), (C)

These soils have both a Bh horizon at least 10 cm thick and a placic horizon. They do not have either a lithic contact or an ortstein horizon or evidence of gleying as specified for gleyed subgroups but they may have duric or fragic horizons. The placic horizon, Bhfc, Bfc, Bgfc, consists of a single thin band (commonly about 5 mm) or a series of bands that are irregular or involute, hard, impervious, often vitreous and dark reddish brown to black. These thin horizons are apparently cemented either by dithionite-extractable Fe or by dithionite-extractable Fe and Mn, or by organic matter (mainly fulvic acid)-Fe complexes. In placic horizons studied, the C content is 1 to 15%, dithionite-extractable Fe, 3 to 20%, and dithionite-extractable Mn, 0 to 15%. The pan may occur in any part of the B horizon, except the Bh, and commonly it extends into a BC horizon.

Placic Humic Podzols usually have L-H or O layers and Ae horizons. They occur most commonly in perhumid or wetter maritime regions, and frequently the surface is peaty.

4104 Duric Humic Podzol

Profile type: (LFH) or (O), (Ae), Bh, (Bhf), (Bf), Bc or Btc or BCc, (C)

These soils have both a Bh horizon at least 10 cm thick and a duric horizon. They do not have either a lithic contact, or ortstein or placic horizons, or evidence of gleying as specified for gleyed subgroups. The duric horizon (Bc) is a strongly cemented horizon that does not satisfy the criteria of a podzolic B horizon. Usually it has an abrupt upper boundary to an overlying podzolic B horizon and a diffuse lower boundary several feet below. Cementation is usually strongest near the upper boundary. The color of duric horizons usually differs little from that of the parent material and the structure is usually massive or very coarse platy. Air-dry clods of the material do not slake when immersed in water. Duric horizons may meet the criteria of a Bt horizon (Btc).

Duric Humic Podzols usually have L-H or O layers and Ae horizons. No specific association with climate or vegetation is known other than that specified for Humic Podzols generally.

4105 Fragic Humic Podzol

Profile type: (LFH) or (O), (Ae), Bh, (Bhf), (Bf), Bx or Btx or BCx (C)

These soils have both a Bh horizon at least 10 cm thick and a fragic horizon. They do not have either a lithic contact, or ortstein, placic or duric horizons or evidence of gleying as specified for gleyed subgroups. A fragic horizon (Bx or BCx) is a subsurface horizon of high bulk density, firm and brittle consistence when moist and hard to extremely hard when dry. Commonly it has bleached fracture planes separating very coarse prismatic units, and frequently the secondary structure is platy. Usually, the color of a fragic horizon is similar to that of the parent material but it differs from the parent material in structure, consistence or bulk density. Air-dry clods of fragic horizons slake in water. The upper boundary is usually abrupt or clear but the lower boundary is diffuse. Fragic horizons, which are usually of medium texture, do not satisfy the criteria of podzolic B horizons but they meet the limits of a Bt (Btx).

Fragic Humic Podzols usually have L-H or O layers and Ae horizons. No specific association with climate or vegetation is known other than that specified for the great group.

410-9 Lithic Humic Podzol

These soils have a lithic contact at a depth between 10 and 50 cm from the mineral surface in addition to the characteristics of the above subgroups. The names of these subgroups are:

41019 Lithic Humic Podzol
41029 Lithic Ortstein Humic Podzol
41039 Lithic Placic Humic Podzol
41049 Lithic Duric Humic Podzol
41059 Lithic Fragic Humic Podzol

410-8 Gleyed Humic Podzol

These soils have in addition to the characteristics of the major subgroups, evidence of gleying within 100 cm of the mineral surface as follows:

a) Mottling (faint to prominent) within 50 cm of the mineral surface, or

b) Distinct or prominent mottling within 100 cm of the mineral surface, or

c) Patchy black and gray colored Bh horizons.

The subgroups are named as follows:

41018 Gleyed Humic Podzol
410189 Gleyed Lithic Humic Podzol
41028 Gleyed Ortstein Humic Podzol, etc.

Some of the possible combinations may not be necessary.

42 Ferro-Humic Podzol

These soils have dark colored (moist color value usually less than 4) Bhf horizons at least 10 cm thick and they lack a Bh horizon 10 cm or more thick. The Bhf horizon contains 5% or more organic C, 0.6% or more pyrophosphate-extractable Al+Fe, and either has a ratio of organic C to pyrophosphate-extractable Fe or less than 20, or contains more than 0.3% pyrophosphate-extractable Fe, or both.

Under virgin conditions, these soils usually have thick L-H or O layers. They may have Ah horizons and commonly they have light colored Ae horizons overlying the podzolic B horizon which may include a Bf horizon as well as the Bhf. Parts of the podzolic B horizon may be cemented (ortstein), one or more thin, cemented pans may occur within or below the podzolic B horizon (placic), and the material below the podzolic B horizon may be cemented (duric) or compact and brittle (fragic). A weakly expressed Bt horizon may occur 50 cm or more below the surface and a well-expressed Bt horizon may occur 75 cm below the surface. In general, the Bhf horizon of Ferro-Humic Podzols, although dark colored, have higher chromas (commonly 2, 3 or 4) than those typical of Humic Podzols. Cultivated Ferro-Humic Podzols are identified by properties of the B horizon below the cultivated layer.

Ferro-Humic Podzols occur generally under forest vegetation or under forest with heath or moss groundcover. They occur mainly in areas of cryoboreal to mesic temperature classes and aquic to perhumid moisture subclasses within maritime fringe regions and at high elevations inland.

The sola of Ferro-Humic Podzols are generally both strongly acid and less than 50% base saturated (neutral salt). The ΔCEC value of the Bhf horizon is usually well above 8 me per 100 grams. The Bhf horizons of these soils usually have a markedly silty feel when rubbed moist, presumably due to their high content of amorphous material.

4201 Orthic Ferro-Humic Podzol
Profile type: (LFH) or (O), (Ah), (Ae), (Bh), <u>Bhf</u>, (Bf), (C)

These soils have a Bhf horizon at least 10 cm thick. They do not have either a Bh horizon that is 10 cm or more thick or an Ah horizon more than 7.5 cm thick or a lithic contact within 50 cm of the mineral surface or ortstein, placic, duric, fragic or Bt horizons, or evidence of gleying as specified for gleyed subgroups. Usually, Orthic Ferro-Humic Podzols have L-H or O layers and Ae horizons above the Bhf horizon and Bf horizons below, but none of these horizons, except the Bhf, is essential. Typically the Bhf horizon is dark reddish brown to dark brown in color and has a high content of amorphous material. The vegetation and climates associated with this subgroup are those specified for Ferro-Humic Podzols generally.

4202 Ortstein Ferro-Humic Podzol
Profile type: (LFH) or (O), (Ah), (Ae), (Bh), <u>Bhf</u> and <u>Bhfc</u>, or <u>Bhf</u> and <u>Bfc</u>, (C)

These soils have both a Bhf horizon at least 10 cm thick and an ortstein horizon at least 2.5 cm thick. They do not have either a Bh horizon that is 10 cm or more thick or a lithic contact within 50 cm of the mineral surface or evidence of gleying as specified for gleyed subgroups but they may have placic, duric, fragic, Ah or Bt horizons. An ortstein is a Bhf or Bf horizon that is strongly cemented and that occurs over at least 1/3 of the exposure. It is designated as Bhfc or Bfc depending upon the organic carbon content.

Usually Ortstein Ferro-Humic Podzols have L-H or O layers and Ae horizons. The vegetation and climate associated with this subgroup are those indicated for Ferro-Humic Podzols generally.

4203 Placic Ferro-Humic Podzol
Profile type: (LFH) or (O), (Ah), (Ae), (Bh), Bhf, Bhfc or Bfc or Bgfc, (C)

These soils have both a Bhf horizon at least 10 cm thick and a placic horizon. They do not have either a lithic contact within 50 cm of the mineral surface or an ortstein horizon, or a Bh horizon 10 cm or more thick or evidence of gleying as specified for gleyed subgroups. They may have duric, fragic, Ah or Bt horizons. The placic horizon, Bhfc, Bfc, Bgfc, consists of a single thin band (commonly about 5 mm thick) or a series of bands that are dark colored, hard and impervious. They may occur either within or below the podzolic B horizon.

Placic Ferro-Humic Podzols usually have thick L-H or O layers and Ae horizons. They occur most commonly in perhumid or wetter maritime regions, and frequently the surface is peaty.

4204 Duric Ferro-Humic Podzol
Profile type: (LFH) or (O), (Ah), (Ae), (Bh), Bhf, (Bf), Bc or BCc or Btc, (C)

These soils have both a Bhf horizon at least 10 cm thick and a duric horizon. They do not have either a lithic contact within 50 cm of the mineral surface, or a Bh horizon 10 cm or more thick, or ortstein or placic horizons, or evidence of gleying as specified for gleyed subgroups. The duric horizon, Bc or BCc is a strongly cemented horizon that does not satisfy the criteria of a podzolic B horizon. Usually it has an abrupt upper boundary to an overlying podzolic B horizon and a diffuse lower boundary several feet below. The color of duric horizons usually differs little from that of the parent material and the structure is usually amorphous or very coarse platy. Air-dry clods of the material do not slake when immersed in water. Duric horizons may meet the criteria of Bt horizons (Btc).

Duric Ferro-Humic Podzols usually have L-H or O layers and Ae horizons and they may have Ah horizons. No specific association with climate or vegetation is known other than that specified for Ferro-Humic Podzols generally.

4205 Fragic Ferro-Humic Podzol
Profile type: (LFH) or (O), (Ah), (Ae), (Bh), Bhf, (Bf), Bx or BCx or Btx. (C)

These soils have both a Bhf horizon at least 10 cm thick and a fragic horizon. They do not have either a Bh horizon 10 cm or more thick, or a lithic, or a lithic contact within 50 cm of the mineral, or ortstein, placic or duric horizons, or evidence of gleying as specified for gleyed subgroups. A fragic horizon (Bx or BCx) is a subsurface horizon of high bulk density, firm and brittle consistence when moist, and hard to extremely hard when dry. Commonly it has bleached fracture planes separating very coarse prismatic units, and frequently the secondary structure is platy. Usually the color of a fragic horizon is similar to that of the parent material but it differs from the parent material in structure, consistence or bulk density. Fragic horizons are usually of medium texture. Air-dry clods of fragic horizons slake in water. Fragic horizons do not satisfy the criteria of podzolic B horizons but they may meet the limits of a Bt (Btx).

Fragic Ferro-Humic Podzols usually have L-H or O layers and Ae horizons and they may have Ah horizons. They are known to occur mainly under forest vegetation in areas of cryoboreal temperature class and perhumid moisture subclass.

4206 Luvisolic Ferro-Humic Podzol
Profile type: (LFH), or (O), (Ae), (Bh), Bhf, (Bf), Bt, (C)

These soils have both a Bhf horizon at least 10 cm thick and a Bt horizon that occurs 50 cm or more below the mineral surface if it is weakly expressed, and 75 cm or more if it is strongly expressed. They do not have either a Bh horizon 10 cm or more thick, or a lithic contact within 50 cm of the mineral surface, or ortstein, placic, duric or fragic horizons, or evidence of gleying as specified for gleyed subgroups.

Luvisolic Podzols usually have L-H surface layers and Ae horizons and they may have Ah horizons. They occur mainly under forest vegetation in areas of cryoboreal temperature class and perhumid moisture subclass.

4207 Sombric Ferro-Humic Podzol
Profile type: (LFH), Ah, (Ae), Bhf, (Bf), (C)

These soils have Bhf horizons at least 10 cm thick and Ah horizons more than 7.5 cm thick. They do not have either Bh horizons 10 cm or more thick, or a lithic contact within 50 cm of the mineral surface, or ortstein, placic, duric, fragic, or Bt horizons, or evidence of gleying as specified for gleyed subgroups.

Sombric Ferro-Humic Podzols usually have L-H layers and they commonly have Ae horizons. They occur mainly under forest vegetation in areas of cryoboreal to mesic temperature class and perhumid moisture subclass.

420-9 Lithic Ferro-Humic Podzol

These soils have a lithic contact at a depth between 4 and 20 cm from the mineral surface in addition to the general charactertistics of the major subgroups. These subgroups are named as follows:

42019 Lithic Ferro-Humic Podzol
42029 Lithic Ortstein Ferro-Humic Podzol etc.

420-8 Gleyed Ferro-Humic Podzol

These soils have, in addition to the characteristics of the major subgroups, evidence of gleying within 1 m of the mineral surface as follows:

a) Mottling (faint to prominent) within 50 cm of the mineral surface, or

b) Distinct or prominent mottling within 1 m of the mineral surface.

The subgroups are named as follows:

42018 Gleyed Ferro-Humic Podzol
420189 Gleyed Lithic Ferro-Humic Podzol
42028 Gleyed Ortstein Ferro-Humic Podzol etc.

43 Humo-Ferric Podzol

These soils have brownish colored (hue usually 7.5 YR or redder and chroma usually greater than 3) podzolic B horizons, usually Bf, at least 5 cm thick. They do not have either a Bh horizon 10 cm or more thick or a Bhf horizon 10 cm or more thick. The Bf horizon contains between 0.5% and 5% organic C, 0.6% or more pyrophosphate-extractable Al+Fe (0.4% for sands), and has a pyrophosphate-extractable Fe to organic C ratio of less than 20.

Under virgin conditions, these soils usually have an L-H layer and they may have an Ah horizon. They usually have a light colored Ae horizon with an abrupt lower boundary to a podzolic B horizon in which the reddest hues or highest chromas and lowest values occur near the top of the horizon and fade with depth. Parts of the podzolic B horizon may be cemented (ortstein), one or more thin cemented pans may occur within or below the podzolic B horizon (placic), and the material below the podzolic B horizon may be cemented (duric) or compact and brittle(fragic). A weakly-expressed Bt may occur 50 cm or more below the surface and a well-expressed Bt horizon may occur 75 cm or more below the surface. In general, the Bf horizon of Humo-Ferric Podzols have higher color values and chromas than those typical of Humic and Ferro-Humic Podzols. Cultivated Humo-Ferric Podzols are identified by properties of the B horizon below the cultivated layer.

Humo-Ferric Podzols occur generally under forest vegetation in areas of cryoboreal to mesic temperature class and perhumid to humic moisture subclass.

The sola of Humo-Ferric Podzols are generally strongly acid and frequently less than 50% base saturated (neutral salt). The ΔCEC value of the Bf horizon is usually 8 me per 100 grams or more. Typically the podzolic B horizon of Humo-Ferric Podzols contains less amorphous material than is characteristic of the podzolic B of Ferro-Humic Podzols.

4301 Orthic Humo-Ferric Podzol
Profile type: (LFH), (Ah), (Ae), (Bhf), <u>Bf</u>, (BC), (C)

These soils have a podzolic B horizon at least 5 cm thick. They do not have either a Bh horizon that is 10 cm or more thick, or a Bhf horizon that is 10 cm or more thick, or an Ah horizon more than 7.5 cm thick, or a lithic contact within 50 cm of the mineral surface or a turbic or a cryic horizon within 1 m of the mineral surface, or ortstein, placic, duric, fragic or Bt horizons, or evidence of gleying as specified for gleyed subgroups.

Usually Orthic Humo-Ferric Podzols have an L-H layer and an Ae horizon with an abrupt lower boundary to the podzolic B horizon. Typically, the podzolic B horizon is reddish brown to dark brown near the top and the color fades with depth. However, the color is influenced by the parent material and probably by other factors. The vegetation and climates associated with this subgroup are those specified for Humo-Ferric Podzols generally.

4302 Ortstein Humo-Ferric Podzol
Profile type: (LFH), (Ah), (Ae), (Bhf), Bf, Bfc, (BC), (C)

These soils have both a podzolic B horizon at least 5 cm thick and an ortstein horizon at least 2.5 cm thick. They do not have either a Bh horizon that is 10 cm or more thick, or a Bhf horizon that is 10 cm or more thick or a lithic contact within 50 cm of the mineral surface, or a turbic or a cryic horizon within 1 m of the mineral surface or evidence of gleying as specified for gleyed subgroups but they may have placic, duric, fragic, Ah or Bt horizons. The ortstein horizon in these soils is a Bfc horizon that is strongly cemented and that occurs over at least 1/3 of the exposure. Usually Ortstein Humo-Ferric Podzols have both L-H layers and Ae horizons. The vegetation and climate associated with this subgroup are generally those of the wetter part of the range specified for Humo-Ferric Podzols.

4303 Placic Humo-Ferric Podzol
Profile type: (LFH), (Ah), (Ae), (Bhf), Bf, Bfc, (BC), (C)

These soils have both a podzolic B horizon at least 5 cm thick and a placic horizon. They do not have either a Bh horizon 10 cm or more thick, or a Bhf horizon 10 cm or more thick, or a lithic contact within 50 cm of the mineral surface, or a cryic horizon within 1 m of the mineral surface or a turbic horizon, or an ortstein horizon or evidence of gleying as specified for gleyed subgroups. They may have duric, fragic, Ah or Bt horizons. The placic horizon consists of a single thin band (commonly about 5 mm thick) or a series of such bands that are dark colored, hard and impervious. They may occur either within or below the podzolic B horizon.

Placic Humo-Ferric Podzols usually have thick L-H or O layers and Ae horizons. They occur most commonly in perhumid maritime regions and frequently the surface is peaty.

4304 Duric Humo-Ferric Podzol
Profile type: (LFH), (Ah), (Ae), (Bhf), Bf, Bc or Btc or BCc, (C)

These soils have both a podzolic B horizon at least 5 cm thick and a duric horizon. They do not have either a Bh horizon 10 cm or more thick, or a Bhf horizon 10 cm or more thick, or a lithic contact within 50 cm of the mineral surface or a cryic horizon within 1 m of the mineral surface or a turbic horizon, or ortstein or placic horizons, or evidence of gleying as specified for gleyed subgroups.

The duric horizon, Bc or BCc is a strongly cemented horizon that does not satisfy the criteria of a podzolic B horizon. Usually it has an abrupt upper boundary to an overlying podzolic B horizon and a diffuse lower boundary several feet below. The color of duric horizons usually differs little from that of the parent material and the structure is usually amorphous or very coarse platy. Air dry clods of the material do not slake when immersed in water. Duric horizons may meet the criteria of Bt horizons (Btc).

Duric Humo-Ferric Podzols usually have both L-H or O layers and Ae horizons, and they may have Ah horizons. The vegetation and climate associated with this subgroup are generally those of the wetter part of the range specified for Humo-Ferric Podzols.

4305 Fragic Humo-Ferric Podzol
Profile type: (LFH), (Ah), (Ae), (Bhf), <u>Bf</u>, <u>Bx</u> or <u>BCx</u> or <u>Btx</u>, (C)

These soils have both a podzolic B horizon at least 5 cm thick and a fragic horizon. They do not have either a Bh horizon 10 cm or more thick, or a Bhf horizon 10 cm or more thick, or a lithic contact within 50 cm of the mineral surface, or a cryic horizon within 1 m of the mineral surface or a turbic horizon or ortstein, placic or duric horizons, or evidence of gleying as specified for gleyed subgroups. A fragic horizon is a subsurface horizon of high bulk density, firm and brittle consistence when moist, and hard to extremely hard when dry. Commonly, it has bleached fracture planes separating very coarse prismatic units, and frequently the secondary structure is platy. Usually the color of a fragic horizon is similar to that of the parent material but it differs from the parent material in structure, consistence or bulk density. Fragic horizons are usually of medium texture and air-dry clods of these horizons slake in water. Fragic horizons do not satisfy the criteria of podzolic B horizons but they may meet the limits of a Bt (Btx).

Fragic Humo-Ferric Podzols usually have both L-H layers and Ae horizons, and they may have Ah horizons. They are known to occur mainly under forest vegetation in areas of cryoboreal temperature class and perhumid moisture subclass.

4306 Luvisolic Humo-Ferric Podzol
Profile type: (LFH), (Ah), (Ae), (Bhf), <u>Bf</u>, (Ae), <u>Bt</u>, (BC), (C)

These soils have both a podzolic B horizon at least 5 cm thick and a Bt horizon that is either weakly expressed and between 50 and 75 cm below the mineral surface or more than 75 cm below the mineral surface. They do not have either a Bh horizon 10 cm or more thick, or a Bhf horizon 10 cm or more thick, or a lithic contact within 50 cm of the mineral surface, or a cryic horizon within 1 m of the mineral surface or a turbic horizon, or ortstein, placic, duric or fragic horizons or evidence of gleying as specified for gleyed subgroups.

Luvisolic Humo-Ferric Podzols usually have both L-H layers and Ae horizons, and they may have Ah horizons. They are known to occur mainly in areas of cryoboreal temperatures class and perhumid moisture subclass.

4307 Sombric Humo-Ferric Podzols
Profile type: (LFH), Ah, (Ae), Bf, (BC), (C)

These soils have podzolic B horizons at least 5 cm thick and Ah horizons more than 7.5 cm thick. They do not have either Bh horizons 10 cm or more thick, or Bhf horizons 10 cm or more thick, or a lithic contact within 50 cm of the mineral surface, or a cryic horizon within 1 m of the mineral surface, or a turbic horizon or ortstein, placic, duric, fragic or Bt horizons, or evidence of gleying as specified for gleyed subgroups.

Sombric Humo-Ferric Podzols usually have L-H layers and they commonly have Ae horizons. They occur mainly under forest vegetation in areas of cryoboreal to mesic temperature class and perhumid to humid moisture subclass.

430-7 Cryic Humo-Ferric Podzols*

These soils have a cryic horizon within 1 m of the mineral surface in addition to the general characteristics of the major subgroups. A cryic horizon is permanently frozen or has a temperature of 0 C or lower 2 months after the summer solstice (Aug. 21).

Cryic Humo-Ferric Podzols occur in areas of subarctic or arctic temperature class.

These subgroups are named as follows:

43017 Cryic Humo-Ferric Podzol
43027 Cryic Ortstein Humo-Ferric Podzol (if they exist) etc.

430-3 Turbic Humo-Ferric Podzol*

The soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups they have, within 1 m of the mineral surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons and mechanical sorting.

These subgroups are named as follows:

43017 Turbic Humo-Ferric Podzol
43077 Turbic Sombric Humo-Ferric Podzol etc.

430-9 Lithic Humo-Ferric Podzol

These soils have a lithic contact between 10 and 50 cm from the mineral surface in addition to the characteristics of the major subgroups.

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* Cryic and Turbic subgroups of Humic and Ferro-Humic Podzols are not defined because none are known to exist.

These subgroups are named as follows:

43019	Lithic Humo-Ferric Podzol
430179	Cryic Lithic Humo-Ferric Podzol
43029	Lithic Ortstein Humo-Ferric Podzol etc.

430-8 Gleyed Humo-Ferric Podzol

These soils have, in addition to the characteristics of the major subgroups, evidence of gleying within 1 m of the mineral surface as follows:

a) Mottling (faint to prominent) within 50 cm of the mineral surface, or

b) Distinct or prominent mottling within 1 m of the mineral surface.

These subgroups are named as follows:

43018	Gleyed Humo-Ferric Podzol
430183	Gleyed Turbic Humo-Ferric Podzol
43028	Gleyed Ortstein Humo-Ferric Podzol etc.

Reasoning Involved in this proposal

1. Both chemical and morphological criteria are specified for all soils of the Podzolic order for a number of reasons.

a) The idea that Podzolic soils have an accumulation of amorphous material in the B horizon has been accepted widely. Thus, it did not satisfy the concepts of logic of many of you or of us to waive the chemical criteria for sandy soils with well developed Ae and color B horizons. However, several felt that a given amount of amorphous material affects the properties of sand more than of loamy soils and this is reasonable. Thus, we suggested that pyrophosphate Fe+Al may be as low as 0.4% in the podzolic B horizon of sands. This is based upon limited data, but the limit could not be much lower if we intend to retain the concept of a podzolic B as a horizon of accumulation of amorphous material composed mainly of Fe, Al and organic matter.

b) Manitoba, Alberta and B.C. have been classifying sandy soils with Ae and color B horizons as Degraded Dystric or Eutric Brunisols and they favored maintaining chemical criteria. The change involved in proposal II would alter the classification of soils in at least these 3 provinces and hence cause far more disruption that would the present proposal.

c) We accept limits of clay accumulation (3% more than the Ae etc.) for the Bt horizon of Luvisolic soils, and of Na for Solonetzic soils. Thus, it is certainly consistent with the system to have criteria beyond color for Podzolic soils.

d) Specific criteria seem to be necessary if we are to have a taxonomic system that can be used uniformly.

2. The great group names were changed back to the 1968, 1970 version because of a clear majority opinion on a matter of preference not principle

3. The subgroup setup proposed must be flexible as it must be consistent with the division of subgroups in other orders. Most favored leaving Gleyed Lithic and Cryic as subgroup modifiers and this has been done. The major subgroups proposed all have unique combinations of genetic horizons. For example, a Luvisolic Humo-Ferric Podzol has a Bt horizon in addition to a podzolic B. Several of you thought that subgroups should not be based upon parent material factors such as lithic, but on genetic horizons.

A Turbic subgroup was added to Humo-Ferric Podzols because there are apparently such soils and because Turbic subgroups are likely to be added to other orders. Probably some of you can suggest a better definition of this subgroup.

4. The thickness of Bh horizon required for Humic Podzols was changed back to 10 cm (as in 1970) from 5 because of protests from a few and because it seems more reasonable to require 10 cm when the thickness limit for the Bhf of Ferro-Humic Podzols is 10 cm. Several wanted to have the thickness requirement for all podzolic B's uniform 10 cm or more. Others wanted the thickness limit for a Bf dropped entirely or reduced to 2 cm. There is some logic in allowing a thinner diagnostic horizon in Humo-Ferric Podzols than in the other two great groups because the Humo-Ferric are, broadly speaking, the Podzolic soils of the drier end of the Podzol region. Thus their development is expected to be weaker, or shallower or both. The two inch limit will probably cause less trouble than a few of you expect. The reason for stating "podzolic B" instead of 'Bf' in the definition of Humo-Ferric Podzols is that a soil could have 2 cm of B that qualifies as Bhf and only 2 cm that qualifies as Bf. If we stated 5 cm of "Bf" in the definition, such a soil would be defined out of the Podzolic order.

5. All of the recommendations made at both the Eastern and Western meetings were considered thoroughly and many have been followed at least in part: more emphais on morphology, deletion of mini subgroups, revised order definition, including clay and organic C in the criteria of a podzolic B, defining subgroups with fragipans and "duric" horizons.

Recommendation 6 at the Western Meeting was recorded as follows: "That criteria be established to include Podzol-like soils on sandy or coarser textured soils within the Podzolic order of the Canadian System. We can poll your opinion on this and pursue it through a working group under an Ottawa correlator."

We followed the recommendation in the sense that we polled opinions on criteria that included such soils (Proposal II) and, in the present proposal, somewhat relaxed chemical criteria are stated for sandy Podzol-like soils.

DISCUSSION

The discussion is not included because of failure of the recording equipment during this part of the meeting. Some of the points raised were:

1. The effect of the proposed criteria on the classification of borderline Podzolic soils.

2. The change in concepts of Podzolic soils in recent years. At one time an Ae horizon was the essential feature; now a Podzolic soil might have no Ae.

3. It would have been better to have presented an alternative (Proposal II) for consideration at the meeting.

The report was accepted with 3 votes against.

NOTE: A few changes have been made since the report was presented at Saskatoon.

1. Metric units only are given as decided at the meeting.

2. The definition of Turbic Humo-Ferric Podzols has been changed slightly.

3. The suffix 'd' for duric horizons has been deleted. Duric horizons are cemented horizons so 'c' is appropriate. No special suffix is used for ortstein and placic horizons so it seems illogical to use one for duric.

RAPPORT DU COMITE DE L'ORDRE BRUNISOLIQUE

J.A. McKeague, Président

Résumé

Les quelques changements mineurs effectués dans l'ordre brunisolique sont les suivants: a) élimination du sous-groupe "alpin", b) précision des critères du sous-groupe "gleyifié", c) introduction du sous-groupe "andique", d) introduction du sous-groupe "turbique".

REPORT OF THE SUBCOMMITTEE ON BRUNISOLIC SOILS

J.A. McKeague, Chairman

Summary

A number of minor changes made are a) alpine subgroups eliminated, b) improved criteria for gleyed subgroups, c) andic subgroup introduced, d) turbic subgroup introduced.

As you know Jack Shields and I were appointed as co-chairmen for the Podzolic, Luvisolic and Brunisolic Orders for the CSSC meeting. Jack has worked on the Luvisolic order, I have worked on the Brunisolic, and both of us have worked on the Podzolic order. We have criticized each others memoranda on these subjects. The first memo on Brunisolic soils dated Nov. 3 proposed 3 new great groups: Regic, Luvic and Podzic. Several individuals and a few groups of pedologists liked the new scheme but others were strongly opposed to it. Some pointed out that we had no mandate to make major changes in the Brunisolic order. Many suggestions of minor changes were made but there was no approach to a concensus of opinion on the desired changes.

The second memorandum dated Feb. 19 outlined several proposals based upon the suggestions received and asked you to state your preferences. Although no clear cut choice was evident, the replies overall conveyed the message that although the definition of the order required a change and that some changes were needed in subgroups, the general scheme should remain unchanged. Thus, in spite of a strong preference by some for our proposal of Nov. 3, I am attempting to improve the precision of definitions but to leave the order intact.

5 BRUNISOLIC ORDER

51	Melanic Brunisol	5101	Orthic Melanic Brunisol
		5102	Degraded Melanic Brunisol
		510-1	Andic Melanic Brunisol
		510-9	Lithic Melanic Brunisol
		510-8	Gleyed Melanic Brunisol
		510-3	Turbic Melanic Brunisol
		510-7	Cryic Melanic Brunisol
52	Eutric Brunisol	5201	Orthic Eutric Brunisol
		5202	Degraded Eutric Brunisol
		520-1	Andic Eutric Brunisol
		520-9	Lithic Eutric Brunisol
		520-8	Gleyed Eutric Brunisol
		520-3	Turbic Eutric Brunisol
		520-7	Cryic Eutric Brunisol
53	Sombric Brunisol	5301	Orthic Sombric Brunisol
		5302	Degraded Sombric Brunisol
		530-1	Andic Sombric Brunisol
		530-9	Lithic Sombric Brunisol
		530-8	Gleyed Sombric Brunisol
		530-3	Turbic Sombric Brunisol
		530-7	Cryic Sombric Brunisol
54	Dystric Brunisol	5401	Orthic Dystric Brunisol
		5402	Degraded Dystric Brunisol
		540-1	Andic Dystric Brunisol
		540-9	Lithic Dystric Brunisol
		540-8	Gleyed Dystric Brunisol
		540-3	Turbic Dystric Brunisol
		540-7	Cryic Dystric Brunisol

5 Soils of the Brunisolic order are those having sufficient development to exclude them from the Regosolic order, but lacking the degrees or kinds of horizon development specified for soils of other orders. The order includes soils in which several different dominant processes are thought to be involved in the development of horizons. Although the central concept of the order is that of soils having brownish-colored Bm horizons, the order includes soils of various colors having both Ae horizons and weakly-expressed horizons of accumulation of either clay or sesquioxides. These soils occur in a wide range of climatic and vegetative environments including mixed forest and grass, Boreal forest, heath and tundra.

Brunisolic soils are usually recognized in the field by the presence of a Bm horizon and the lack of horizons that have either sufficient clay accumulation to satisfy the limits of Bt horizons or sufficient organic matter Al, Fe complex materials to satisfy the limits of a podzolic B horizon. Usually they have brownish-colored sola except for Ae horizons that may occur, but they may have gray, black or red sola depending both upon the parent material and upon the kind of B horizon development. The Bm horizon as presently defined includes horizons with evidence of alteration or illuviation as follows:

a) Stronger chromas the redder hues than the underlying material.

b) Evidence of removal of carbonates.

c) Evidence of slight illuviation either of clay or of amorphous material composed largely of organic matter, Fe and Al.

d) A change in structure from that of the original material.

A consideration of the various kinds of Bm horizons developed in parent materials that may be gray, brown, black, red, etc., that may or may not contain carbonates; that vary in texture from gravel to clay, shows clearly that Bm horizons may and do range widely in color, structure and other properties.

Brunisolic soils include some that are calcareous to the surface and very slightly weathered, and others that are strongly acid and apparently weathered to about the same extent as the associated Podzolic soils. Most Brunisolic soils are well to imperfectly drained but some, especially those affected by seepage water are moderately poorly to poorly drained. However, they lack the gley features specified for Gleysolic soils. The order is divided among four great groups: Melanic Brunisols, Eutric Brunisols, Sombric Brunisols and Dystric Brunisols based both upon acidity and presence or absence of an Ah horizon.

51 Melanic Brunisol

These soils have either an Ah horizon more than 5 cm thick or an Ap horizon with a color value (moist) of less than 4, and either a Bm or a Btj horizon 5 cm thick or more. The pH ($CaCl_2$) within some part of the control section is 5.5 or more. These soils may have L-H layers and Ae or Aej horizons but they lack both podzolic B and Bt horizons. The Ah horizon commonly has the characteristics specified for a chermozemic A but the soils are excluded from the Chernozemic order on the basis of environmental factors (climate and vegetation).

Melanic Brunisols occur typically under deciduous or mixed forest vegetation on calcareous parent materials in areas of boreal to mesic temperature class and humid moisture subclass, but they are not restricted to such environments.

5101 Orthic Melanic Brunisol

Profile type: (L-H), <u>Ah</u> or <u>Ap</u>, <u>Bm</u>, (Ck), (C)

These soils have either an Ah horizon 5 cm or more thick or an Ap horizon with a color value (moist) of less than 4. In addition, they have a Bm horizon at least 5 cm thick below the Ah or Ap horizon. The pH ($CaCl_2$) within some part of the control section is 5.5 or more. These soils may have L-H layers but they lack Ae, Bt and podzolic B horizons, andic properties as specified for Andic subgroups, evidence of gleying as specified for gleyed subgroups, a lithic contact within 50 cm of the mineral surface, and cryic and turbic horizons as specified for Cryic and Turbic subgroups.

5102 Degraded Melanic Brunisols

Profile type: (L-H), Ah or Ap, Ae or Aej and Btj or Bm, (Ck), (C)

These soils have either an Ah horizon 5 cm or more thick or an Ap horizon with a color value (moist) of less than 4. In addition, they have either an Ae or an Aej horizon and a Btj or Bm horizon, or both. The pH ($CaCl_2$) within som part of the control section is 5.5 or more. These soils may have L-H layers but they lack Bt and podzolic B horizons, andic properties as specified for Andic subgroups, evidence of gleying as specified for gleyed subgroups, a lithic contact within 50 cm of the mineral surface, and cryic and turbic horizons as specified for Cryic and Turbic subgroups.

510-1 Andic Melanic Brunisols

These soils have, in addition to the properties specified for the major subgroups, andic properties as indicated. They have to a depth of 35 cm or to a lithic contact shallower than 35 cm one or both of:

a) A bulk density (at 1/3 bar water retention) of the fine earth fraction of the soil of less than 0.85 g/cc, and an exchange complex dominated by amorphous material.

b) Sixty percent or more vitric pyroclastic material in the silt, sand or gravel fractions.

Soils containing volcanic ash that havepodzolic B horizons that satisfy the requirements of a great group of the Podzolic order are classified as Podzolic soils.

510-9 Lithic Melanic Brunisols

These soils have, in addition to the properties specified for the major subgroups, a lithic contact at a depth between 10 and 50 cm from the mineral surface.

510-8 Gleyed Melanic Brunisols

These soils have, in addition to the properties specified for the major subgroups, evidence of gleying within 1 m of the mineral surface as follows:

a) Faint to distinct mottling within 50 cm of the mineral surface.

b) Distinct or prominent mottling at depths between 50 and 100 cm from the mineral surface.

510-3 Turbic Melanic Brunisol

These soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups they have, within 1 m of the mineral surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons, and mechanical sorting.

510-7 Cryic Melanic Brunisol

These soils have, in addition to the properties specified for the major subgroups, a cryic horizon within 1 m of the mineral surface. A cryic horizon is permanently frozen or has a temperature of 0^oC or lower 2 months after the summer solstice (Aug. 21).

The subgroups are designated and named as follows:

51011 Andic Melanic Brunisol
51021 Andic Degraded Melanic Brunisol
510139 Turbic Lithic Melanic Brunisol

52 Eutric Brunisol

These soils have either a Bm or a Btj horizon at least 5 cm thick, and a pH ($CaCl_2$) within some part of the control section of 5.5 or more. They may have L-H layers, Ae or Aej horizons, or Ah horizons less than 5 cm thick but they lack both Bt and podzolic B horizons. If cultivated, these soils are classified as Eutric Brunisols if part of the Bm horizon remains below the Ap. They are classified as Regosols if the Ap includes all of the Bm horizon.

5201 Orthic Eutric Brunisols
Profile type: (L-H), (Ah), <u>Bm</u>, (C), (Ck)

These soils have both a Bm horizon at least 5 cm thick and a pH ($CaCl_2$) within some part of the control section of 5.5 or more. They may have L-H layers and Ah horizons less than 5 cm thick. They lack Ae, Aej, Bt and podzolic B horizons, andic properties as specified for Andic subgroups, a lithic contact within 50 cm of the mineral surface, evidence of gleying as specified for Gleyed subgroups, and turbic and cryic horizons as specified by Turbic and Cryic subgroups.

5202 Degraded Eutric Brunisol
Profile type: (L-H), (Ah), <u>Ae</u> or <u>Aej</u> and/or <u>Btj</u> or <u>Bm</u>, (C), (Ck)

These soils have either Ae or Aej horizons or Btj horizons at least 5 cm thick, or both. The pH ($CaCl_2$) within some part of the control section is 5.5 or more. They may have L-H layers and Ah horizons less than 5 cm thick. They lack Bt and podzolic B horizons, andic properties as specified for Andic subgroups, a lithic contact within 50 cm of the mineral surface, evidence of gleying as specified for gleyed subgroups, and turbic and cryic horizons as specified for Turbic and Cryic subgroups.

520-1 Andic Eutric Brunisols

These soils have, in addition to the properties specified for the major subgroups, andic properties as indicated. They have to a depth of 35 cm or to a lithic contact shallower than 35 cm one or both of:

a) A bulk density (at 1/3 bar water retention) of the fine earth fraction of the soil of less than 0.85 g/cc, and an exchange complex dominated by amorphous material.

b) Sixty percent or more vitric pyroclastic material in the silt, sand or gravel fractions.

Soils containing volcanic ash that have podzolic B horizons that satisfy the requirements of a great group of the Podzolic order are classified as Podzolic soils.

520-9 Lithic Eutric Brunisol

These soils have in addition to the properties specified for the major subgroups, a lithic contact at a depth between 10 and 50 cm from the mineral surface.

520-8 Gleyed Eutric Brunisol

These soils have, in addition to the properties specified for the major subgroups, evidence of gleying within 1m of the mineral surface as follows:

a) Faint to distinct mottling within 50 cm of the mineral surface.

b) Distinct or prominent mottling at depths between 50 and 100 cm from the mineral surface.

520-3 Turbic Eutric Brunisol

These soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups they have, within 1m of the mineral surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons, and mechanical sorting.

520-7 Cryic Eutric Brunisol

These soils have, in addition to the properties specified for the major subgroups, a cryic horizon within 1m of the mineral surface. A cryic horizon is permanently frozen or has a temperature of $0^{\circ}C$ or lower 2 months after the summer solstice (Aug. 21).

The subgroups are designated and named as follows:

52011	Andic Eutric Brunisol
52021	Andic Degraded Eutric Brunisol
520289	Gleyed Lithic Degraded Eutric Brunisol

53 Sombric Brunisol

These soils have either an Ah horizon 5 cm or more thick or an Ap horizon with a color value (moist) of less than 4. In addition they have either a Bm or a Btj horizon at least 5 cm thick and a pH ($CaCl_2$) of less than 5.5 throughout the control section. They may have L-H layers and Ae or Aej horizons but they lack Bt and podzolic B horizons.

5301 Orthic Sombric Brunisol
Profile type: (L-H), Ah or Ap, Bm, (C)

These soils have either an Ah horizon 5 cm or more thick or an Ap horizon with a color value (moist) of less than 4. In addition they have a Bm horizon at least 5cm thick and a pH ($CaCl_2$) of less than 5.5 throughout the control section. They may have L-H layers but they lack Ae, Bt and podzolic B horizons, andic properties as specified for Andic subgroups, a lithic contact within 50 cm of the mineral surface, evidence of gleying as specified for gleyed subgroups, and turbic and cryic horizons as specified for Turbic and Cryic subgroups.

5302 Degraded Sombric Brunisol
Profile type: (L-H), Ah, Ae or Aej and/or Btj or Bm, (C)

These soils have either an Ah horizon 5 cm thick or more or an Ap horizon with a color value (moist) of less than 4. In addition they have either an Ae or an Aej horizon or a Btj horizon or both. The pH ($CaCl_2$) is less than 5.5 throughout the control section.

These soils may have L-H layers but they lack Bt and podzolic B horizons, andic properties as specified for Andic subgroups, a lithic contact within 50 cm of the mineral surface, evidence of gleying as specified for gleyed subgroups, and turbic and cryic horizons as specified for Turbic and Cryic subgroups.

530-1 Andic Sombric Brunisol

These soils have, in addition to the properties specified for the major subgroups, andic properties as indicated. They have to a depth of 35 cm or to a lithic contact shallower than 35 cm one or both of:

a) A bulk density (at 1/3 bar water retention) of the fine earth fraction of the soil of less than 0.85 g/cc, and an exchange complex dominated by amorphous material.

b) Sixty percent or more vitric pyroclastic material in the silt, sand or gravel fractions.

Soils containing volcanic ash that have podzolic B horizons that satisfy the requirements of a great group of the Podzolic order are classified as Podzolic soils.

530-9 Lithic Sombric Brunisol

These soils have, in addition to the properties specified for the major subgroups, a lithic contact at a depth between 10 and 50 cm from the mineral surface.

530-8 Gleyed Sombric Brunisol

These soils have, in addition to the properties specified for the major subgroups, evidence of gleying within 1m of the mineral surface as follows:

a) Faint to distinct mottling within 50 cm of the mineral surface.

b) Distinct or prominent mottling at depths between 50 and 100 cm from the mineral surface.

530-3 Turbic Sombric Brunisol

These soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups they have, within 1m of the mineral surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons, and mechanical sorting.

530-7 Cryic Sombric Brunisol

These soils have, in addition to the properties specified for the major subgroups, a cryic horizon within 1m of the mineral surface. A cryic horizon is permanently frozen or has a temperature of $0^{o}C$ or lower 2 months after the summer solstice (Aug. 21).

The subgroups are designated and named as follows:

53019	Lithic Sombric Brunisol
53029	Lithic Degraded Sombric Brunisol
530181	Gleyed Andic Sombric Brunisol

54 Dystric Brunisol

These soils have either a Bm or a Btj horizon at least 5 cm thick, and a pH ($CaCl_2$) of less than 5.5 throughout the control section. They may have L-H layers Ae or Aej horizons, or Ah horizons less than 5 cm thick but they lack both Bt and podzolic B horizons.

If cultivated, these soils are classified as Dystric Brunisols if part of the Bm horizon remains below the Ap. They are classified as Regosols if the Ap includes all of the Bm horizon.

5401 Orthic Dystric Brunisol
Profile type: (L-H), (Ah), Bm, (C)

These soils have both a Bm horizon at least 5 cm thick and a pH ($CaCl_2$) less than 5.5 throughout the control section. They may have L-H layers and Ah horizons less than 5 cm thick. They lack Ae, Aej, Bt and podzolic B horizons, andic properties as specified for Andic subgroups, a lithic contact within 50 cm of the mineral surface, evidence of gleying as specified for Gleyed subgroups, and turbic and cryic horizons as specified for Turbic and Cryic Subgroups.

5402 Degraded Dystric Brunisol
Profile type: (L-H), (Ah), Ae, or Aej and Btj or Bm, (C)

These soils have either Ae or Aej horizons, and Btj or Bm horizons at least 5 cm thick. The pH ($CaCl_2$) is less than 5.5 throughout the control section. They may have L-H layers and Ah horizons less than 5 cm thick. They lack Bt and podzolic B horizons, andic properties as specified for Andic subgroups, a lithic contact within 50 cm of the mineral surface, evidence of gleying as specified for gleying subgroups, and turbic and cryic horizons as specified for Turbic and Cryic subgroups.

540-1 Andic Dystric Brunisol

These soils have, in addition to the properties specified for the major subgroups, andic properties as indicated. They have to a depth of 35 cm or to a lithic contact shallower than 35 cm one or both of:

a) A bulk density (at 1/3 bar water retention) of the fine earth fraction of the soil of less than 0.85 g/cc, and an exchange complex dominanted by amorphous material.

b) Sixty percent or more vitric pyroclastic material in the silt, sand or gravel fractions.

Soils containing volcanic ash that have podzolic B horizons that satisfy the requirements of a great group of the Podzolic order are classified as Podzolic soils.

540-9 Lithic Dystric Brunisol

These soils have, in addition to the properties specified for the major subgroups, a lithic contact at a depth between 10 and 50 cm from the mineral surface.

540-8 Gleyed Dystric Brunisol

These soils have, in addition to the properties specified for the major subgroups, evidence of gleying within 1 m of the mineral surface as follows:

a) Faint to distinct mottling within 50 cm of the mineral surface.

b) Distinct or prominent mottling at depths between 50 and 100 cm from the mineral surface.

540-3 Turbic Dystric Brunisol

These soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups they have, within 1m of the mineral surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons, and mechanical sorting.

540-7 Cryic Dystric Brunisol

These soils have, in addition to the properties specified for the major subgroups, a cryic horizon within 1m of the mineral surface. A cryic horizon is permanently frozen or has a temperature of $0^{o}C$ or lower 2 months after the summer solstice (Aug. 21).

These subgroups are designated and named as follows:

54017	Cryic Dystric Brunisol
54027	Cryic Degraded Dystric Brunisol
540191	Lithic Andic Dystric Brunisol

Some comments on these definitions.

1. Alpine subgroups were deleted as several of you pointed out that Subalpine, Arctic etc. subgroups could be justified equally well and that Alpine etc. could be taken care of at the family level. Thus, the former Alpine subgroups would be included with the appropriate subgroups of 51 and 53 in the proposed scheme. It should be noted that 51 no longer specifies a mull Ah.

2. Turbic and Andic subgroups are included because of the recommendations of pedologists who have worked with such soils. The definition of both subgroups could be improved and suggestions are welcome. The criteria listed for Andic are those from the U.S. system as suggested by two respondents to the previous memorandum.

3. The 5 subgroup modifiers allow the possibility of some unduly long class names unless some guidelines are agreed upon. For example, I suppose that a Cryic Turbic Gleyed Lithic Andic Degraded Sombric Brunisol could occur but the name is unmanageable. Perhaps Turbic Lithic Degraded Sombric Brunisol would be adequate. I would suggest a maximum of 2 modifiers with the order of precedence as follows: Turbic or Cryic $\rangle$ Lithic $\rangle$ Andic $\rangle$ Gleyed. This may not be the most reasonable order of precedence. If you agree on the general idea, please suggest better alternatives.

4. There is not complete agreement either on the pH split for Dystric vs Eutric or on the control section for pH. The initial pH split of 5.5 was based on data of Clark and others for a wide range of samples. No exchangeable Al was found in soils having pH values ($CaCl_2$) of 5.5 or higher. It is also true that very little exchangeable Al was found in

soils with pH's of 5 or more but some had a detectable amount. The Alberta group agrees with this but prefers pH5. Most who stated a preference chose 5.5 and thus 5.5 is stated here.

The control section for pH is a bigger issue. Some prefer the "solum" but where 2 or 3 are gathered together the lower limit of the solum commonly is put at 2 or 3 depths. The majority who stated a preference chose the control section stated here.

DISCUSSION

There was some discussion on the changes in concepts of Brunisolic soils in recent years. This is not included because of failure of the recording equipment during this part of the meeting.

The report was accepted with 2 votes against.

NOTE: The report fails to specify guidelines for the distinction of Eutric from Melanic and Dystric from Sombric subgroups in the case of cultivated soils. The following guidelines are proposed for trial:

If the Ap horizon has:

1. A rubbed color value (moist) of 3.5 or less that is lower by at least one unit than the value of the underlying horizon, and

2. An organic carbon content of at least 2%, the cultivated soil is classified as either Melanic or Sombric. If the Ap horizon fails to meet these limits, the soil is classified as Eutric or Dystric.

RAPPORT DU COMITE DE L'ORDRE REGOSOLIQUE

B. Rochefort, Président

Résumé

Un nouveau sous-groupe, appelé turbique s'ajoute maintenant à la classification des sols régosoliques. Les définitions de toutes les catégories, à l'exception de celle du grand groupe, sont modifiées. Les changements les plus significatifs regardent les définitions de l'ordre, ainsi que celles des deux sous-groupes orthique et cumulique.

La définition de l'ordre, proposée ici, comporte l'addition de deux phrases, insérées entre la premiére et la derniére phrase de la définition actuelle (1970). Dans cette définition modifiée, le premier de ces deux éconcés nouveaux précise le concept général des régosols et le second, les dimensions de la coupe de référence (control section), auparavant mentionnées de facon incompléte dans la définition du sous-groupe orthique.

La derniére phrase: "Les sols n'ont ni sels solubles, ni gley...", qui se répéte dans les définitions actuelles des deux sous-groupes majeurs: orthique et cumulique, ne figure plus dans les nouvelles définitions de ces deux sous-groupes. L'emploi de cette phrase est superflu, sinon restrictif, eu égard au mode d'emploi de ces sous-groupes avec d'autres sous-groupes, dits mineurs, qui leur servent en quelque sorte de qualificatifs, dans la désignation de certains sols régosoliques, e.g., régosols cumuliques gléifiés.

La description de la couche cryique, qui apparait dans la nouvelle définition du sous-groupe cryique, se veut plus compléte et plus précise que celle qui figure dans la définition actuelle de ce même sous-groupe. Aucun changement significatif n'est apporté sux définitions des autres sous-groupes mineurs si ce n'est l'addition, à chacune de leurs définitions, de l'énoncé suivant: "En plus des caractéristiques générales propres aux sous-groupes majeurs." Cet énoncé exprime bien la nature des sous-groupes mineurs, ainsi que leur fonction complétive ou d'adjectifs, vis-à-vis des sous-groupes majeurs, dans la désignation de certains sols régosoliques.

REPORT OF THE SUBCOMMITTEE ON REGOSOLIC SOILS

B. Rochefort, Chairman

Summary

Besides the addition of a Turbic subgroup, the only changes proposed consist in more or less important modifications made in the definitions of the Order, of the Orthic and Cumulic subgroups and in those of the subgroup modifiers.

6 REGOSOLIC ORDER

Great Group		Subgroup
61 Regosol	6101	Orthic Regosol
	6102	Cumulic Regosol
	610-5	Saline Regosol
	610-7	Cryic Regosol
	610-3	Turbic Regosol
	610-8	Gleyed Regosol
	610-9	Lithic Regosol

6 Regosolic Order

These are rapidly to imperfectly drained mineral soils with good to moderate oxidizing conditions, having horizon development too weak to meet the requirements of soils in any other order. Regosolic soils being essentially parent materials are characterized by the lack of soil horizons except when thin, usually darker, surface horizons occur. Soils with nonchernozemic[1] Ah horizons may be included.

61

Only one great group has been established, therefore its definition is the same as that of the order.

6101 Orthic Regosol
Profile type: (L-H), (Ah), Ck or C

These soils have from the surface, or below any nonchernozemic Ah horizon, color values that are uniform with depth, or color values that increase

[1] See definition of Chernozemic A horizon, page 43 of SSCC manual.

gradually to the depth of the control section. The organic matter content usually decreases regularly with depth.

6102 Cumulic Regosol
Profile type: C, Ahb, C or Ck; Ah, C, Ahb, C or Ck

These soils have from the surface, or below any nonchernozemic Ah horizons, color values that vary by one or more units with depth in the control section. The organic matter content usually decreases irregularly with depth. Often these soils are the result of intermittent flooding, erosion and weak soil development as indicated by buried layered or stratified deposits which occur on past or current flood plains. The color values and organic matter content within the control section are irregular.

610-5 Saline Regosol

In addition to the characteristics of the major subgroups, these soils have salinity exceeding 4 mmhos/cm in a horizon(s) within 60 cm of the surface, or salinity exceeding 6 mmhos/cm between 60 and 100 cm from the surface if the soil above is nonsaline ($<$4 mmhos/cm).

610-7 Cryic Regosol

These soils have a cryic horizon within 1m of the mineral surface, in addition to the general characteristics of the major subgroups. A cryic horizon is permanently frozen or has a temperature is 0^{o}C or lower 2 months after the summer solstice (August 21).

610-3 Turbic Regosol

These soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups they have, within 1m of the mineral surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons, and mechanical sorting.

610-8 Gleyed Regosol

These soils have mottling and dull colors within 50 cm of the surface, in addition to the characteristics of the major subgroups.

610-9 Lithic Regosol

These soils have a lithic contact at a depth greater than 10 cm but less than 50 cm below the mineral soil surface, in addition to the characteristics specified for the major subgroups.

RAPPORT DU COMITE DE L'ORDRE GLEYSOLIQUE

R.E. Smith, Président

Résumé

Les questions et propositions de modifications laissées en plan à la réunion de 1970 ont servi de base au travail du comité qui a conduit à l'adoption de certaines modifications.

Les échanges de vues par correspondance ont clairement fait voir que, bien qu'imparfaite, la présente formule est assez adéquate. Québec avec un certain appui de l'Alberta, a proposé de diviser l'ordre gleysolique en deux grands groupes, en se basant sur la présence ou l'absence d'horizon Ah, soit les Gleysols humiques et les Gleysols. On a reproché l'inconsistance dans l'importance accordée à l'horizon Ah dans les définitions des grands groupes et sous-groupes. Cependant l'opinion que l'application de critères uniformes de différentiation à un niveau donné du système résulterait en un meilleur groupement des sols n'a pas été partagée par la majorité des pédologues canadiens.

Les modifications adoptées à la réunion comprennent:

a) des changements mineurs dans le préambule de la définition de l'ordre gleysolique.

b) une meilleur définition de l'horizon Bg.

c) un changement de nom du grand groupe Gleysol éluvié à celui de Gleysol luvique.

d) l'incorporation des sous-groupes "turbique" et "placique".

e) la recommendation que les corrélateurs (Ottawa) 1) évaluent les méthodes illustratives de la Commission pour voir si elles sont adéquates, 2) voient à trouver une définition adéquate du sol tel que conçu par la Commission, 3) étudient le conflit crée par l'utilisation de 'cryique' au Canada par opposition à 'pergélique' aux E.U.

REPORT OF THE SUBCOMMITTEE ON GLEYSOLIC SOILS

R.E. Smith, Chairman

Summary

The questions and proposals for modification of the classification of Gleysolic soils raised but not disposed of at the 1970 national meetings of C.S.S.C. formed the basis for discussion by the present subcommittee. These discussions led to the adoption of a number of modifications.

It also became very clear during discussion by correspondence that the classification of Gleysolic soils, while not without fault, is reasonably adequate in its present form. The Quebec group, supported to some degree by Alberta, proposed grouping all soils in the Gleysolic Order into two great groups, Humic Gleysols and Gleysols, based on the presence or absence of significant Ah horizons. They objected to the inconsistent importance given to the Ah horizon in defining great groups and subgroups in the Order. However, the concept that uniform differentiae at a given level in the system will result in the best grouping of soils was not supported by the majority of pedologists in Canada.

The modifications adopted by plenary session of C.S.S.C. included:

a) Minor changes in the preamble of the definition of the Gleysolic Order.

b) A more adequate definition of the Bg horizon.

c) Changing the name of the Eluviated Gleysol Great Group to Luvic Gleysol.

d) Immediate incorporation into SSCC of a Turbic Subgroup and a Placic subgroup.

e) Recommendations to the Ottawa Correlation Group to (1) evaluate the adequacy of illustrative material employed in SSCC; (2) look into the matter of an adequate definition of soil as classified in SSCC; and (3) look into the international correlation problem that is raised through use of Cryic in SSCC, as opposed to Pergelic in USDA Soil Taxonomy.

The proposals discussed by correspondence and the recommendations resulting therefrom are the following:

Proposal 1. To add a Pseudogleysol Great Group to S.S.C.C. Proposed by J. Nowland, Nova Scotia, 1970.

The concensus (including J. Nowland) was that this proposal be dropped. The major arguement against adoption was that it would be extremely difficult if not impossible to establish differentiae separating such soils from gleyed subgroupos in other orders and from other great groups within the Gleysolic Order.

Proposal 2. To add a Humic Maxi Ferra Eluviated Gleysol to S.S.C.C. to accommodate soils with sola low in free and total Fe. Proposed by R. Baril, Quebec, 1970.

It was unanimously agreed that this proposal also be dropped. Comments received suggest that these soils can be accommodated at the series level within the Orthic Humic Gleysol Subgroup.

Proposal 3. To change the Great Group name "Eluviated Gleysol" to "Luvic Gleysol". Proposed by J. Clayton, Ottawa, 1970.

All units except for strong objection by Saskatchewan, supported the change. Those arguing in favor agreed with J. Clayton that this would result in shorter names for the great group and its subgroups and would avoid some confusion due to the term "Eluviated". "Eluviated" referred to Gleysolic soils having Btg horizons not to those that do not have Btg horizons. Most Canadian pedologists would, it seems, associate the term "Luvic" with clay translocation and accumulation rather than with forest ecosystems, which may or may not lead to formation of Bt horizons in soils, as Saskatchewan suggests. The Subcommittee recommends the change in name.

Proposal 4. Differentiae for distinguishing Gleysolic soils should be based on regionally developed criteria.

Most agreed in principal that regional guidelines for distinguishing gleyed subgroups from Gleysolics should be developed, but on the other hand, would not want to see such specific criteria incorporated in definitions of taxa. This, it was argued, would tend to break down the national basis for classification. The Subcommittee recommends dropping this proposal.

Proposal 5. To (a) substitute straight lines for those used in current diagrams of Gleysols and other soils; (b) horizons not diagnostic of subgroups be deleted from diagrams.

Reaction to this proposal by C. Acton was mixed, ranging from full agreement to disagreement. What seems to be emerging is the need to re-evaluate illustrative material (diagrams, photographs, etc.) utilized in S.S.C.C., not just those used in the Gleysolic Order. The Subcommittee, therefore, recommends a review of figures, diagrams and photographs employed in S.S.C.C. to determine their adequacy and that this review be undertaken by the correlation group in Ottawa.

Proposal 6. The phrase "a horizon or horizons at least 4 inches (10 cm) thick" be deleted from the fourth sentence in the definition of Gleysolic soils. Proposed by B. Cann, Nova Scotia, 1970.

The sentence as presently written suggests that the whole horizon must be within 50 cm of the surface. The Subcommittee recommends that the sentence be changed to read: "They have, within 50 cm of the surface, the upper boundary of a horizon or horizons of significant thickness with dominant colors as follows:" A minority of members of the Subcommittee felt that it would be desirable to be as explicit as possible and would prefer the phrase "of significant thickness" to read "at least 10 cm thick".

Proposal 7. To establish a more meaningful definition of Bg. Proposed by D. Lindsay, Alberta, 1970.

The subcommittee agreed unanimously and recommends the following change in the definition of the Bg horizon on Page 29 of S.S.C.C. to read:

"Bg - These horizons are analogous to Bm horizons but they have colors indicative of poor drainage and periodic reduction. They include horizons occurring between A and C horizons in which the main features are 1. Colors of low chroma, that is, chromas of 1 or less, without mottles on ped surfaces or in the matrix if peds are lacking; or chromas of 2 or less, in hues of 10YR or redder, on ped surfaces or in the matrix if peds are lacking, accompanied by more prominent mottles than those in the C horizon; or hues bluer than 10Y, with or without mottles, on ped surfaces or in the matrix if peds are lacking. 2. A change in structure from that of the C horizon and colors indicated in 1. 3. Illuviation of clay too slight to meet the requirement of Bt; or accumulation of iron oxide too slight to meet the limits of Bgf and colors indicated in 1. 4. Removal of carbonates and colors indicated in 1. Bg horizons occur in some Orthic Humic Gleysols and some Orthic Gleysols".

The above includes all positive suggestions for improvement of definition and satisfies most who feel that not sufficient guidelines have been provided in the past to identify important diagnostic horizons with some degree of consistency. It is also apparent that little, if anything, would have been gained by attempting to draft regional guidelines for interpretation.

Proposal 8. Introduce a Turbic Subgroup for Gleysolic soils affected by Cryoturbation. Proposed by C. Tarnocai, Manitoba, 1973.

Considerable discussion was generated and opinion varied from enthusiastic support to outright rejection. The majority of opinion favors some recognition of cryoturbation, the question is how and at what category in the System.

Arctic pedologists believe that cryoturbation is a major soil forming process, equal in importance to processes leading to the development of dark colored A horizons, Bm or Btj horizons commonly found in soils in arctic regions. Very often the manifestation of cryoturbation is much more dominant than are the processes leading to the development of Gleysolic, Brunisolic and Regosolic soils. In fact, differentiation of these soils in Tundra environment is often very difficult. They suggest that stop gap measures such as the introduction of Turbic Subgroups in affected orders is not the solution and that we should consider more drastic steps to accommodate these soils such as establishing a new order of soils (Turbisolic), somewhat analogous to Vertisols in USDA Soil Taxonomy.

Frankly, I think we need to focus more research on this problem and more time to establish better perspective before a suitable solution is worked out. In the interim (next 2 to 3 years) I also think it would be very useful to flag affected soils at the Subgroup level within S.S.C.C. Introduction of such taxa at this level would draw attention to the unique character of these soils and would not seriously affect the current order of established taxa. I would therefore, recommend for immediate incoporation in S.S.C.C. a Turbic Subgroup forGleysolic soils affected by cryoturbation. This subgroup would only apply to Humic Gleysol and Gleysol great groups, since cryoturbation is not presently known to affect Luvic Gleysols.

Turbic Humic Gleysol and Turbic Gleysol: These soils are affected by cryoturbation as manifested by disrupted and dislocated horizons, displacement and incorporation of materials from other horizons and by mechanical sorting of the parent material. Such horizons occur in regions of discontinuous or continuous permafrost.

Proposal 9. To introduce a Placic Subgroup that would include Gleysolic soils having placic horizons that would meet the limits of Bgf (Bgfc) but not podzolic B horizons thick enough to meet the requirements of the Podzolic Order. Proposed by A. McKeague, Ottawa, 1973.

I do not know these soils, but accept his views. Apparently a significant acreage of these soils occur in Newfoundland. Their inclusion, as he suggests, would not involve much of a change. I would, therefore, recommend introduction of the following Subgroup.

Placic Humic Gleysol and Placic Gleysol: These soils have placic horizons that meet the limits of Bgf (Bgfc). The placic horizon consists of a thin band (commonly about 5 cm thick) or a series of such bands that are dark colored, hard and impervious. These horizons may occur within or below the Bgf horizon.

A number of additional comments and suggestions have emerged that require disposition.

1. Pettapiece points out:

   a) At present there are problems in the identification of Cryic taxa. Disturbance (thermal erosion) will cause variable depth of active layer in frozen soils. Presumably, in undisturbed sites, ice or frost will occur within 40 inches (100 cm) of the surface, while in disturbed sites, such conditions might exceed the 100 cm depth limit. Should such criteria as depth to permafrost be employed at Subgroup level?

   b) Canadian Use of Cryic is equivalent to Pergelic as employed in U.S.D.A. Soil Taxonomy. Since such ambivalent terminology exists, it presents obvious problems in national and international correlation.

Reactions to these comments are:

a) Cryic subgroups have been found to be very useful in the past. There is not reason why such subgroups cannot continue to be useful, despite some obvious problems.

b) Whether or not Pergelic as opposed to Cryic is a more suitable name for such subgroups is a correlation problem and I would recommend that our correlation group in Ottawa look into the matter.

Professor Isabel Bayly, Biology Department of the University of Carleton, Ottawa, suggests that the preamble to the Gleysolic Order should include the following sentence: "Some of these soils may even be continuously overlain by water, as in marshes". Apparently, some ecologists are hesitant to apply S.S.C.C. classification to marsh or wetland soils. The extra sentence would, in her view, do much to overcome this problem.

The point is well taken since it illustrates the need for an adequate definition of soil as it is classified in S.S.C.C. It would be a simple matter to include the sentence proposed in the definition of the Gleysolic Order. However, I believe the problem exists in other Orders as well as in the Gleysolic Order, and would, therefore, recommend that our Ottawa correlation group look into the matter of an adequate definition of soil as classified in S.S.C.C.

Hopefully, this definition would include some statement on boundaries and limits of soil that would accommodate the problem indicated by Prof. Bayly. Personally, I like the statement found in U.S.D.A. Soil Taxonomy.

In summary, it is recommended that the Gleysolic Order be left unchanged except for the positive proposals and suggestions agreed upon in this report, as well as any others that might be presented at the plenary session.

While I've not acknowledged individual replies, I do wish to thank all who have participated in our discussions.

7 GLEYSOLIC ORDER

Great Group		Subgroup
71 Humic Gleysol	7101	Orthic Humic Gleysol
	7102	Rego Humic Gleysol
	7103	Fera Humic Gleysol
	710-4	Placic Humic Gleysol
	710-5	Saline Humic Gleysol
	710-6	Carbonated Humic Gleysol
	710-7	Cryic Humic Gleysol
	710-9	Lithic Humic Gleysol
	710-3	Turbic Humic Gleysol
72 Gleysol	7201	Orthic Gleysol
	7202	Rego Gleysol
	7203	Fera Gleysol
	720-4	Placic Gleysol
	720-5	Saline Gleysol
	720-6	Carbonated Gleysol
	720-7	Cryic Gleysol
	720-9	Lithic Gleysol
	720-3	Turbic Gleysol
73 Luvic Gleysol	7301	Orthic Luvic Gleysol
	7302	Humic Luvic Gleysol
	7303	Fera Luvic Gleysol
	730-7	Cryic Luvic Gleysol
	730-9	Lithic Luvic Gleysol

These soils are saturated with water and are under reducing conditions continuously or during some period of the year, unless they are artificially drained. Some of these soils may be continuously overlain by shallow water. As a result of the reducing conditions they have matrix colors of low chroma within 50 cm of the mineral surface. They may have distinct or prominent mottles of high chroma, presumably as a result of localized oxidation of ferrous iron and the deposition of hydrated ferric oxides. They have, within 50 cm of the mineral surface, the upper boundary of a horizon or horizons of significant thickness with dominant moist colors as follows:

a) Chromas of 1 or less, without mottles, on ped surfaces or in the matrix if peds are lacking; or

b) Chromas of 2 or less, in hues of 10YR or redder, on ped surfaces or in the matrix if peds are lacking, accompanied by prominent mottles; or

c) Chromas of 3 or less, in hues yellower than 10YR, on ped surfaces or in the matrix if peds are lacking, accompanied by prominent mottles; or

d) Hues bluer than 10Y, with or without mottles, on ped surfaces or in the matrix if peds are lacking.

These soils have developed under hydrophytic vegetation and they may be expected to support hydrophytic vegetation if left undisturbed. They may have an organic surface layer of less than 40 cm of mixed peat (bulk density greater than 0.1) or up to 60 cm of fibric moss peat (bulk density less than 0.1). They may have A and B horizons.

The color criteria listed are tentative because they have not been checked on enough soils. However, color is the most useful indicator of the oxidation-reduction status of a soil. Some accessory properties that may help to identify some of these soils are:

1) Saturation to the surface for a month or more while the soil is not frozen
2) Organic surface layers
3) Hydrophytic vegetation
4) Position in the landscape -- undrained depressions in subhumid regions and level areas in humid regions.

An Eh of less than 100 mv within the upper 50 cm for a period of a week or more is a possible chemical criterion for these soils, but little information is available.

The inclusion of "under reducing conditions" in the definition of the order is necessary because some soils that are saturated with water for a month or more each year are not gleyed. Two examples are soils on slopes that are saturated with aerated water, and some soils in depressions that are flooded only in the spring when the temperature is only a few degrees above freezing. Temperatures high enough (above about $5^{\circ}C$) to permit microbial activity and hence depletion of oxygen are thought to be essential to the gley process. Some Podzols and Humic Podzols are saturated with water for several months each year, yet they are not considered to be Gleysolic soils.

71 Humic Gleysol

These are Gleysolic soils that, when virgin, have an Ah horizon more than 8 cm thick. When cultivated to a depth of 15 cm, they have an Ap horizon with more than 2% organic carbon and a rubbed color value as follows:

a) 3.5 or lower moist, or 5.0 or lower dry; and
b) at least 1.5 units of value (moist) lower than that of the next underlying horizon, either B or C, if the value of the underlying horizon is 4 or more; or
c) at least 1 unit (moist) lower than that of the next underlying horizon if the value of the underlying horizon is less than 4. Examples of color values of cultivated soils:

$$\frac{\text{Ap}}{\text{B or C}} \qquad \frac{3.5 \text{ or less}}{5.0} \quad \text{or} \quad \frac{2.0 \text{ or less}}{3.0}$$

All the subgroups may have organic surface layers, up to 40 cm of mixed peat with bulk density greater than 0.1, or up to 60 cm of fibric moss peat with bulk density less than 0.1.

7101 Orthic Humic Gleysol

These are Humic Gleysol soils with a noneffervescent[1] Ah or Ap horizon and a gleyed B (Bg or Btjg) horizon. They do not have Bgf or Bgfc horizons, or placic, saline, carbonated, cryic or turbic horizons or a lithic contact. The C horizon may be strongly gleyed.

7102 Rego Humic Gleysol

These are Humic Gleysol soils with a noneffervescent Ah or Ap horizon and without a B horizon. They lack placic, saline, carbonated, cryic and turbic horizons, and a lithic contact.

7103 Fera Humic Gleysol

These are Humic Gleysol soils with a noneffervescent Ah or Ap horizon. They also have Bgf horizon with many prominent mottles of high chroma. They lack placic, saline, cryic, turbic horizons and a lithic contact.

710-4 Placic Humic Gleysol

These are Humic Gleysol soils having placic horizons but not podzolic B horizons thick enough to meet the requirements of the Podzolic Order. The placic horizon consists of a thin band (commonly about 5 mm thick) or a series of such bands that are dark colored, hard and impervious. These horizons may occur within or below the Bgf horizon. They do not have Btjg horizons nor saline, carbonated, cryic, or turbic horizons, or a lithic contact.

710-5 Saline Humic Gleysol

These are Humic Gleysol soils having in addition to the properties specified for major subgroups, saline horizons as specified:

a) The conductivity of the saturation extract of a horizon within 60 cm of the surface exceeds 4 mmhos/cm; or

b) The conductivity of the saturation extract of a horizon between 60 and 120 cm from the surface exceeds 6 mmhos/cm, if the soil above is nonsaline (<4 mmhos/cm). They may also have effervescent Ah or Ap horizons.

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[1] No effervescence with 3N HCl.

710-6 Carbonated Humic Gleysol

These are Humic Gleysol soils having in addition to the properties specified for major subgroups, an effervescent (carbonate) Ah or Ap horizon. They do not have placic, saline, cryic, or turbic horizons or a lithic contact.

NOTE: As defined, 710-6 includes Humic Gleysol soils having effervescent Ah or Ap horizons due to either primary or secondary carbonates. In these wet soils, any A horizon containing primary carbonates is thought to contain at least some secondary carbonates, and a distinction is not practical.

710-7 Cryic Humic Gleysol

These are Humic Gleysol soils having in addition to the properties specified for major subgroups, permafrost (z) within 1m of the mineral soil surface. They also may have placic, saline and carbonated horizons. They do not have turbic horizons or a lithic contact.

710-9 Lithic Humic Gleysol

These are Humic Gleysol soils having in addition to the properties specified for major subgroups, a lithic contact between 10 and 50 cm of the mineral surface. They may also have placic, saline or carbonated horizons.

710-3 Turbic Humic Gleysol

These soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups they have, within 1m of the mineral surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons (y), displacement and incorporation of materials from other horizons and mechanical sorting.

72 Gleysol

These are Gleysolic soils that, when virgin, have either no Ah horizon or an Ah horizon up to 8 cm thick. When cultivated to a depth of 15 cm they have an Ap horizon with either less than 2% organic carbon or rubbed color values (moist) as follows:

a) Higher than 3.5; or

b) Less than 1.5 units of value lower than that of the next underlying horizon (Aej, B, or C) if the value of the underlying horizon is 4 or more; or

c) Less than 1 unit of value lower than that of the next underlying horizon if the value of the underlying horizon is less than 4.

Examples of color values of cultivated soils:

$$\frac{\text{Ap}}{\text{Aej, B, or C}} \qquad \frac{\text{higher than } 2.5}{4} \qquad \text{or} \qquad \frac{\text{higher than } 2.0}{3.0}$$

All the subgroups may have organic surface layers as specified for 71.

7201 Orthic Gleysol

These are Gleysol soils with a gleyed B (Bg or Bgtj) horizon. They do not have Bgf or Bgfc horizon. They lack an effervescent surface horizon and placic, saline, cryic, and turbic horizons and a lithic contact.

7202 Rego Gleysol

These are Gleysol soils without a B horizon. They lack an effervescent surface horizon and placic, saline, cryic, and turbic horizons and a lithic contact.

7203 Fera Gleysol

These are Gleysol soils having a Bgf horizon with many prominent mottles of high chroma. They lack effervescent surface horizons and placic, saline, cryic, and turbic horizons and a lithic contact.

720-4 Placic Gleysol

These are Gleysol soils having placic horizons but not podzolic B horizons thick enough to meet the requirements of the Podzolic Order. The Placic horizon consists of a thin band (commonly about 5 mm thick) or a series of such bands that are dark colored, hard and impervious. These horizons may occur within or below the Bgf horizon. They do not have Btjg horizons nor saline, carbonated, cryic, or turbic horizons or a lithic contact.

720-5 Saline Gleysol

These are Gleysol soils having in addition to the properties specified for major subgroups, a saline horizon as specified:

a) The conductivity of the saturation extract of a horizon within 60 cm of the surface exceeds 4 mmhos/cm; or

b) The conductivity of the saturation extract of a horizon between 60 and 120 cm from the surface exceeds 6 mmhos/cm, if the soil above is nonsaline (<4 mmhos/cm). They may also have effervescent Ah or Ap horizons.

720-6 Carbonated Gleysol

These are Gleysol soils having in addition to the properties specified for major subgroups, an effervescent (carbonate) Ah or Ap horizon. They do not have placic, saline, cryic or turbic horizons or a lithic contact. See note for 710-6.

720-7 Cryic Gleysol

These are Gleysol soils having in addition to the properties specified for major subgroups, permafrost (z) within 1m of the mineral surface. They may have placic, saline and carbonated horizons. They do not have turbic horizon or a lithic contact.

720-9 Lithic Gleysol

These are Gleysol soils having in addition to the properties specified for major subgroups, a lithic contact between 10 and 50 cm of the mineral surface. They also may have placic, saline or carbonated horizons.

720-3 Turbic Gleysol

These soils occur in areas of continuous or discontinuous permafrost. In addition to the properties specified for the major subgroups they have within 1m of the surface, properties due to cryoturbation as manifested by disrupted and dislocated horizons (y) displacement and incorporation of materials from other horizons and mechanical sorting.

73 Luvic Gleysol

These are Gleysolic soils with Aeg and Btg horizons. All the subgroups may have organic surface layers as specified for 71 and they may have an Ah horizon.

7301 Orthic Luvic Gleysol

These are Luvic Gleysol soils without an Ah horizon or with an Ah or Ap horizon as specified for 72, and with Aeg and Btg horizons. They lack a cryic horizon and a lithic contact.

7302 Humic Luvic Gleysol

These are Luvic Gleysol soils with an Ah horizon as specified for 71 and with Aeg and Btg horizons. They lack placic and cryic horizons and a lithic contact.

7303 Fera Luvic Gleysol

These are Luvic Gleysol soils having either Btg and Bgf horizons or a Btgf horizon with many prominent mottles of high chroma. They lack cryic horizon and a lithic contact.

730-7 Cryic Luvic Gleysol

These are Luvic Gleysol soils having properties specified for major subgroups with permafrost (z) within 1m of the mineral surface. They may have placic, saline or carbonated horizons. They do not have a turbic horizon or a lithic contact.

730-9 Lithic Luvic Gleysol

These are Luvic Gleysol soils with a lithic contact between 10 and 50 cm of a mineral surface.

NOTE: Peaty phases

As specified, Gleysolic soils may have up to 60 cm of fibric moss peat or 40 cm of mixed peat at the surface. Peaty soils are no longer separated from other soils at the subgroup level. Gleysolic soils having 15 to 40 cm of mixed peat or 15 to 60 of fibric moss peat may be designated as peaty phases of the appropriate subgroups.

RAPPORT DU COMITE DE L'ORDRE ORGANIQUE

J.H. Day, Président

Résumé

Certains changements de définitions sont proposeés. La plus importante à être mise à l'essai est celle d'une coupe de référence unique (single control section) de 160 cm, dont le tier de surface est de 40 cm, le moyen, de 80 cm et celui du fond, de 40 cm. Les définitions de 'fibrique', 'mésique' et 'humique' seront à titre d'essai basées sur la teneur en fibres frottées. Les critères de familles et de séries ont été adoptés.

REPORT OF THE SUBCOMMITTEE ON ORGANIC SOILS

J.H. Day, Chairman

Summary

A number of changes in the definitions are proposed. The most important of these to be tested is the single control section of 160 cm, with surface tier thickness 40 cm, middle tier 80 cm and bottom tier 40 cm. The definitions of fibric, mesic and humic are tentatively to be based on rubbed fiber content. The criteria for soil family and for soil series were adopted.

Report of the Subcommittee on Organic Soils

J.H. Day, Chairman

The additions and changes accepted for immediate use or for testing over a two-year period are as follows:

Proposal 1.

Adopt immediately for trial over the next two-year period the use of one control section of 160 cm thickness.

Definition of Control Section

The control section refers to the part of the soil that is considered in the classification of organic soils. It is 160 cm thick for all organic soils.

Proposal 2. Definition of tiers

Adopt for trial over 2 years

Surface tier

The surface tier, exclusive of loose litter, crowns of sedges and reeds or living mosses, is 40 cm thick.

Mineral soil on the surface of profile is part of the surface tier.

Middle tier

The middle tier is 80 cm thick. This tier establishes the great group classification if no terric, lithic or hydric substratum is present. If any of these substrata are present the dominant kind of organic material in this and the surface tier establishes the great group classification. The nature of the substratum and of the subdominant kind of organic material in any tier assists in establishing the subgroup classification.

Bottom tier

The bottom tier is 40 cm thick. The material in this tier establishes or assists in establishing the subgroup classification.

Proposal 3. Revised definition of organic order for immediate incorporation and use

Only a) and b) are new and these have been accepted at eastern and western regional meetings.

These are soils that have developed dominantly from organic deposits. The majority of them are saturated for most of the year, or artificially drained, but some of them are not usually saturated for more than a few days. They contain 30% by weight or more of organic matter and must meet the following specifications:

a) if the surface layer consists of fibric organic material having a bulk density of less than 0.1 g/cc (with or without mesic or humic Op thinner than 15 cm), the organic material must extend to a depth of at least 60 cm.

b) if the surface layer consists of organic material having a bulk density of 0.1 g/cc or more, the organic material must extend to a depth of at least 40 cm.

c) if a lithic contact occurs at a depth shallower than in a) or b) above, the organic material must extend to a depth of at least 10 cm. Mineral material less than 10 cm thick may overlie the lithic contact, but the organic materials must be more than twice the thickness of the mineral layer.

d) the organic soil may have a mineral layer thinner than 40 cm on the surface. If covered with less than 40 cm of mineral soil the organic layer or layers taken singly or cumulatively must be at least 40 cm thick.

e) mineral layers thinner than 40 cm, beginning within a depth of 40 cm from the surface, may occur within the organic soil. A mineral layer, or layers taken cumulatively, thinner than 40 cm may occur within the upper 80 cm.

Proposal 4. for immediate incorporation and use

Revision of particle size classes for underlying mineral (terric) layers. This proposal is changed from that adopted at eastern and western regional meetings in that the names of the classes used are those proposed in the family subcommittee report.

The particle size classes that are to be recognized at the family level for mineral material under organic soils in terric subgroups are fragmental, sandy, sandy-skeletal, loamy, loamy-skeletal, clayey and clayey-skeletal.

Proposal 5. for testing and study

New definitions of fibric, mesic and humic based on rubbed fiber content. The reason to test this is because unrubbed fiber is misleading in most cases because "ghost fibers" give an impression of less decomposition than is actually the case.

Please note that physical parameters mentioned ("usually") are not limits and are intended only as explanatory observations.

p. 2 Fibric - The fibric layer is the least decomposed of all the organic soil materials. It has large amounts of well-preserved fiber that are readily identifiable as to botanical origin.

A fibric layer has 40% or more of rubbed fiber by volume and a pyrophosphate index[1] of 5 or more. If the rubbed fiber volume is 75% or more, the pyrophosphate criterion does not apply.

Fibric material usually has physical properties as follows[2]:

bulk density	(g/cc)	< 0.075
total porosity	(% v)	> 90
water yield coefficient	(% v)	> 42
0.1 bar H_2O content	(% v)	< 48
hydraulic conductivity	(10^{-5} cm/sec)	> 180
	(cm/day)	> 154

The fibric subgroup name is used alone or in combination only with Terric. Terric Fibric is given precedence over Cumulo.

Mesic - The mesic layer is the intermediate stage of decomposition with intermediate amounts of fiber, bulk density and water-holding capacity. The material is partly altered both physically and biochemically.

A mesic layer is one that fails to meet the requirements of fibric or of humic. The mesic subgroup name is used alone or in combination only with Terric. Terric Mesic is given precedence over Cumulo.

Humic - The humic layer is the most highly decomposed of the organic soil materials. It has the least amount of fiber, the highest bulk density, and the lowest saturated water-holding capacity.

A humic layer has less than 10% rubbed fiber by volume and a pyrophosphate index[1] of 3 or less.

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1 Pyrophosphate index is obtained by subtracting the chroma from the value of the Munsell color notation derived from the pyrophosphate solubility test.

2 Boelter, D.H. Proc. 3rd Int. Peat Cong. Montreal, 1968. p. 150-154. Nat. Res. Coun. of Canada.

Humic material usually has physical properties as follows[2]:

bulk density	(g/cc)	> 0.195
total porosity	(% v)	< 85
water yield coefficient	(% v)	< 15
0.1 bar H_2O content	(% v)	> 70
hydraulic conductivity	(10^{-5} cm/sec)	< 2.1
	(cm/day)	< 1.8

The humic subgroup name is used alone or in combination only with Terric. Terric Humic is given precedence over Cumulo.

Proposal 6. for immediate adoption

Delete clastic family, add clastic as a series criterium.

Proposal 7. for testing

Recognize as soil series those soils having significant content of logs and stumps within the control section. Logs and stumps are defined as coarse fragments greater than 10 cm in diameter. Three frequency classes should be tested: 0-5%, 5 to 25% and > 25% by volume.

The 5% level is taken from the Ontario ARDA classification and the 25% from correspondence of the U.S. Task Force on organic soils.

Proposal 8. for immediate adoption and incorporations

Revise first paragraph top of page 14 SSCC revised chapter Organic soils by adding the words "This includes mineral sediment, marl and diatomaceous earth".

Additional suitable restrictions should be added to the definitions of marl and of diatomaceous earth on p. 4 SSCC organic chapter revised.

Proposal 9. adopt immediately the following criteria for use in soil family taxum

9-1. Characteristics of organic surface tiers:

fennic, silvic, sphagnic (each used only for fibric surface tiers), mesic, humic.

Characteristics of mineral surface tiers of between 15 and 40 cm thick: sandy, coarse loamy, coarse silty, fine loamy, fine silty, clayey.

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[2] Boelter, D.H. Proc. 3rd Int. Peat Cong. Montreal, 1968. p. 150-154. Nat. Res. Coun. of Canada.

9-2. Reaction

euic - $pH \geq 4.5$ (0.01 M $CaCl_2$) in some part of the organic materials of the control section.

dysic - $pH < 4.5$ (0.01 M $CaCl_2$) in all parts of the organic materials of the control section.

9-3. Temperature class names suggested are taken from the soil climate map of Canada legend.

extremely cold
very cold
cold
cool
mild

However, in the application of soil temperature classes it should be recognized that organics in mild regimes may have temperature equivalent to the associated mineral soils, but that other organics probably are at least one temperature class colder than associated imperfectly to well-drained mineral soils.

9-4. Moisture subclass names suggested are the same as those used on the soil climate map of Canada.

peraquic
aquic
subaquic
perhumid
humid

These subclasses are defined on the basis of degrees and duration of saturation, albeit not with much precision. Appropriate guidelines have to be developed to recognize the range of moisture regimes that exist in various peat landforms, and for the depths to which moisture subclass criteria apply.

The following guidelines for subclasses are proposed for trial by the Manitoba group, and the criteria should apply to the surface tier for non-cryic organic soils and to the entire active layer in the case of cryic organic soils.

Moisture Subclasses as Applied to Organic Soils

Moisture Regime	Aqueous	Aquic			Moist Soils	
Classification	0 Aqueous	a Peraquic	b Aquic	c Subaquic	d Perhumid	e Humid
Descriptive Condition	Free surface water	Saturated for very long periods - Very poorly drained (6)	Saturated for moderately long periods - Poorly drained (5)	Saturated for short periods - Imperfectly drained (4)	Moist with no significant seasonal deficit - Imperfectly to Moderately well drained (4) to (3)	Moist with no significant seasonal deficit - Moderately well drained (3) to (2)
Suggested Criteria	continuous	very long	long to moderately short	short to very short	very short	very short to insignificant
Saturation period (months)	11.5-12	> 10 months	4-10	< 4	< 2	< 0.5
Moist Period (months)	Insignificant	Very short	Short to moderately long	Very long to long	Very long to long	Very long
	< 0.5	< 2	2-8	8-11.5	8-11.5	8-11.5
Moisture deficit	None	None	None	None	None to insignificant	None to insignificant
Associated Native Vegetation	Hydrophytic Nymphae Potamageton Scirpus Typha, Phragmites Drepanocladus	Hydrophytic Scirpus Typha Carex Drepanocladus Feathermosses Tamarack	Meso-Hydrophytic Wet forest black spruce mixed feathermoss & Sphagnum Ericaceous shrubs	Meso-Hydrophytic wet to very moist forest black spruce Sphagnum Ericaceous shrubs	Mesophytic moist forest black spruce mixed Sphagnum & feathermosses Ericaceous shrubs lichens	Mesophytic Disturbed species Cultivated species
Associated Peat Landform	Wetlands, Marsh, Floating Fen, Collapse Scars	Flat Fens, Patterned Fens, Spring Fens, Swamps	Blanket Bogs, Transitional Bogs	Domed Bogs, Plateaus	Frozen Plateaus, Frozen Palsas, Frozen Peat Polygons	Drained Peatlands, Folisols

9-5. Particle size class of terric layer. See Proposal 4. Fragmental, sandy, sandy-skeletal, loamy, loamy-skeletal, clayey, clayey-skeletal.

9-6. Limnic classes apply only to Limno subgroups: They are: marl, diatomaceous, coprogeneous. The definitions of these materials may be found in the section describing tiers and layers. Notice is called to the exclusion from the organic order of soils in which marl layers thicker than 40 cm at the surface or that have a marl layer thicker than 40 cm within the upper 80 cm of the profile.

<u>Proposal 10.</u> <u>adopt immediately the use of the following criteria for describing soil series. Some of these should be tested for two years.</u>

10-1. Parent material - the botanical origin of the fibers and particle size class of terric layer or rock type.
examples - fen peat, forest peat, sphagnum peat
- mesic fen peat over sandy lacustrine deposits, fibric forest peat over limestone, fibric sphagnum peat over loamy skeletal glacial till.

10-2. Logs and stumps (or coarse particles). Those soils having 0-5%, 5-25%, and > 25% by volume of logs, stumps or wood of size larger than 10 cm in diameter. See also Proposal 7 for testing.

10-3. Calcareousness
weakly, 1-6% $CaCO_3$ equivalent
moderately to very strongly, 6-40% $CaCO_3$
extremely calcareous, > 40% $CaCO_3$

10-4. Bulk Density. Some Humisols have quite high bulk density (> 0.5 g/cc). These could be separated from other Humisols.

10-5. Depth classes to the contact (lithic, cryic, terric, hydric, etc.)
very shallow: lithic or cryic at < 40 cm
shallow : any contact between 40-120 cm
deep : any contact between 120-160 cm

10-6. Mineral content of organic material in the middle and bottom tiers, or of the organic material above any terric, lithic, hydric or cryic contact that occurs in the middle tier.

Sulfurous - These soils are affected by sulfer compounds. Sulfidic materials are undrained, black, nearly neutral in reaction. Sulfuric materials are drained, may have straw-colored jarosite mottles within 50 cm of the surface, and are extremely acid and toxic to most plants. Most have appreciable amounts of mineral material within the control section.

Ferrihumic (bog iron) - consists of authigenic deposits of hydrated iron oxide mixed with organic materials. It may be cemented or soft. Colors are usually dark reddish brown mixed with black and change little on drying. FeO content should exceed 10% (Fe > 7%) and there is at least 1% OM. There should be more than 2% concretions by weight which may range in size from < 5 mm to 1 m or more in the largest lateral dimension.

Clastic - these soils have 55% to < 70% of ash or of mineral particles intimately mixed with organic material.

10-7. Content of ice particles and lenses in the control section of cryic soils based on moisture content by volume
Low ice content - < 70 by volume
Moderate ice content - 70-90 by volume
High ice content - > 90 by volume

10-8. Soil development (great group?) in the terric layer.

10-9. Reaction of terric layer
euic - pH $\geq$ 5.5 (0.01 M $CaCl_2$)
dysic - pH < 5.5 (0.01 M $CaCl_2$)

10-10. Mineralogy of terric or cumulo layers.

10-11. Texture of cumulo layers in middle or bottom tiers.

10-12. Presence of luvic (illuvial) layer in middle or bottom tier.

These proposals were adopted for either immediate use, or for testing, as stated.

RAPPORT DU COMITE DES HORIZONS ET COUCHES DU SOL

J.D. Lindsay, Président

Résumé

Le rapport comprend des changements mineurs aux définitions des horizons Bf, Bfh, Bg, Bc, y, et des couches Of, Om, Oh et Oco de même que des énoncés plus simples pour définir les horizons et les couches.

REPORT OF THE SUBCOMMITTEE ON SOIL HORIZONS AND LAYERS

J.D. Lindsay, Chairman

Summary

Minor changes in the definitions of horizons Bf, Bfh, Bg, Bc, y, and layers Of, Om, Oh, Oco, and simplified statements that define horizons and layers are included.

A soil profile is a vertical section of the soil through all its horizons and layers into the parent material. Soil horizons may be thick or thin but generally they merge with one another and lack sharp boundaries. A soil horizon is defined as a layer of soil or soil material approximately parallel to the land surface; it differs from adjacent genetically related horizons in properties such as color, structure, consistence, and chemical, biological and mineralogical composition.

A layer as used in this manual refers primarily to organic strata (layers) that may be found in organic soils, at the surface of mineral soils, or at any depth beneath the surface in buried soils, or overlying geological deposits. The pedogenic processes normally associated with mineral soils are inoperative in organic layers and the main development is associated with microbiological activity. Layer is also applied in mineral soils to underlying strata of consolidated bedrock.

The Use of Designations

The uppercase letters A and B for horizons and the letter O for layer may not be used singly in profile descriptions, but must be accompanied by a lowercase suffix (for example, Ah, Bf, Bt or Om) indicating the estimated modification from the parent material. The capital letter C may be used alone except when the material is affected by reducing conditions, cementation, salinity or calcium carbonate.

Unless otherwise specified, additional lowercase suffixes indicate a secondary or subordinate feature or features, in addition to those characteristic of the defined main horizon. The symbol Btg, for example, indicates that in addition to the dominance of illuvial clay in the B horizon, there is also evidence of strong gleying. Some combinations are redundant or impractical in the light of present knowledge and definitions, and their use should be avoided, for example, Bmj. In some cases, such as Bgf and Bhf, the combination of suffixes has a specific meaning which differs from that of the sum of the two suffixes used singly.

All horizons except A and B, and B and A may be vertically subdivided by consecutive Arabic numeral suffixes. The uppermost subdivision is indicated by the numeral 1; each successive subdivision with depth is indicated by the sequential numeral, using as many as desired. This convention is followed regardless of whether or not the horizon subdivisions are interrupted by a horizon of different character. For example, an acceptable subdivision of horizons would be: Ae1, Bf, Ae2, Bt1, Bt2, C1, C2. In some instances it may be useful, for sampling purposes, to subdivide a single horizon, for example as Bm1-1, Bm1-2, Bm1-3, etc.

Roman numerals are prefixed to horizon designations to indicate unconsolidated lithologic discontinuities in the profile. Roman numeral I is understood for the uppermost material, and therefore, is not written. Subsequent contrasting materials are numbered consecutively in the order in which they are encountered downward, that is, II, III, and so on.

Organic Layers

Organic layers are found in organic soils, and usually at the surface of the mineral soils. They may occur at any depth beneath the surface in buried soils, or overlying geologic deposits. They contain more than 17% organic carbon by weight. Two groups of these layers are recognized:

O - This is an organic layer developed mainly from mosses, rushes, and woody materials.

Of - The fibric layer is the least decomposed of all the organic soil materials. It has large amounts of well-preserved fibre that are readily identifiable as to botanical origin. A fibric layer has 40% or more of rubbed fibre by volume and a pyrophosphate index of 5 or more. If the rubbed fibre volume is 75% or more, the pyrophosphate criterion does not apply. For a definition of pyrophosphate index see the chapter on organic soils.

Om - The mesic layer is the intermediate stage of decomposition with intermediate amounts of fibre, bulk density and water-holding capacity. The material is partly altered both physically and biochemically. A mesic layer is one that fails to meet the requirements of fibric or of humic.

Oh - The humic layer is the most highly decomposed of the organic soil materials. It has the least amount of fibre, the highest bulk density, and the lowest saturated water-holding capacity. It is very stable and changes very little physically or chemically with time unless it is drained. A humic layer has less than 10% rubbed fibre by volume and a pyrophosphate index of 3 or less.

Oco - Coprogenous Earth (terre coprogene) - A material in some organic soils that contains at least 50% by volume of fecal pellets less than 0.5 mm in diameter.

L-F-H - These organic layers develop primarily from leaves, twigs, woody materials and a minor component of mosses.

L - This is an organic layer characterized by an accumulation of organic matter in which the original structures are easily discernible.

F - This is an organic layer characterized by an accumulation of partly decomposed organic matter. The original structures in part are difficult to recognize. The layer may be partly comminuted by soil fauna, as in moder[1], or it may be a partly decomposed mat permeated by fungal hyphae, as in mor.[1]

H - This is an organic layer characterized by an accumulation of decomposed organic matter in which the original structures are indiscernible. This material differs from the F layer by its greater humification chiefly through the action of organisms. This layer is a zoogenous humus form consisting mainly of spherical or cylindrical droppings of microarthropods. It is frequently intermixed with mineral grains, especially near the junction with a mineral layer.

Mineral Horizons and Layers

Mineral horizons are those that contain less organic carbon that that specified for organic layers.

A - This is a mineral horizon formed at or near the surface, in the zone of the removal of materials in solution or suspension or of maximum <u>in situ</u> accumulation of organic carbon or both.

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1 B. Bernier. 1968. Soils under forest. Proceedings of the Seventh Meeting of the National Soil Survey Committee of Canada. p. 145 and 147.

The accumulation of organic carbon is expressed morphologically by a darkening of the surface soil color (Ah) and conversely the removal of organic carbon is expressed by a lightening of the soil color usually in the upper part of the solum (Ae). The removal of clay from the upper part of the solum (Ae) is expressed by a coarser soil texture relative to the underlying subsoil layers. The removal of sesquioxides is denoted usually by paler or less red soil color in the upper part of the solum (Ae) relative to the lower part of the subsoil. Each of these morphological expressions is supported by chemical criteria explained in another section.

B - This is a mineral horizon characterized by enrichment in organic carbon, sesquioxides, or clay, or by the development of soil structure or by a change of color denoting hydrolysis, reduction or oxidation.

The accumulation in B horizons of organic carbon is evidenced usually by dark colors relative to the C horizon (Bh). Clay accumulation is expressed by finer soil textures and by cutans lining peds and pores (Bt). The development of soil structure in B horizons includes prismatic or columnar units with coatings or stainings and significant amounts of exchangeable sodium (Bn), and by soil structure or soil colors different from the C horizons (Bm, Bg).

Each of these morphological expressions is supported by chemical criteria explained in another section.

C - This is a mineral horizon comparatively unaffected by the pedogenic processes operative in A and B, excepting (i) the process of gleying, and (ii) the accumulation of calcium and magnesium carbonates and more soluble salts (Cca, Csa, Cg, and C). Marl and diatomaceous earth are considered to be C horizons.

R - This is a consolidated bedrock layer that is too hard to break with the hands (>3 on Mohs scale) or to dig with a spade when moist, and that does not meet the requirements of a C horizon. The boundary between the R layer and any overlying unconsolidated material is called a lithic contact.

Lowercase Suffixes

b - A buried soil horizon.

c - A cemented (irreversible) pedogenic horizon. Ortstein, placic and duric horizons of Podzolic soils and a layer cemented by calcium carbonate are examples.

ca - A horizon of secondary carbonate enrichment in which the concentration of lime exceeds that in the unenriched parent material.

It is more than 10 cm (4 in.) thick, and if it has a $CaCO_3$ equivalent of less than 15%, it should have at least 5% more $CaCO_3$ equivalent than the parent material (IC). If it has more than 15% $CaCO_3$ equivalent, it should have 1/3 more $CaCO_3$ equivalent than IC. If no IC is present, this horizon is more than 10 cm thick and contains more than 5% (by volume) of secondary carbonates in concretions or in soft, powdery forms.

cc - Cemented (irreversible) pedogenic concretions.

e - A horizon characterized by the removal of clay, iron, aluminum, or organic matter alone or in combination. When dry, it is usually higher in color value by 1 or more units than an underlying B horizon. It is used with A (Ae).

f - A horizon enriched with amorphous material, principally Al+Fe combined with organic matter. It usually has a hue of 7.5YR or redder or it is 10YR near the upper boundary and becomes yellower with depth. When moist, the chroma is higher than 3 or the value is 3 or less. It contains 0.6% or more pyrophosphate - extractable Al+Fe in textures finer than sand and 0.4% or more in sands (coarse sand, sand, fine sand, and very fine sand). The ratio of pyrophosphate - extractable Al+Fe to clay ($<$.002 mm) is more than 0.05 and organic C exceeds 0.5%. It is used with B alone (Bf), with B and h (Bhf), with B and g (Bfg), and with other suffixes. The criteria for "f" do not apply to Bgf horizons.

The following horizons are differentiated on the basis of organic carbon content:

Bf - 0.5% to 5% organic carbon

Bhf - more than 5% organic carbon

g - A horizon characterized by gray colors, or prominent mottling, or both, indicative of permanent or periodic intense reduction. Chromas of the matrix are generally 1 or less. It is used with A and e (Aeg), with B alone (Bg), with B and f (Bfg), with B, h, and f (Bhfg), with B and t (Btg), with C alone (Cg), with C and k (Ckg), and several others. In some reddish parent materials, matrix colors of reddish hues and high chromas may persist despite long periods of reduction. In these soils, horizons are designated as g if there is gray mottling or if there is marked bleaching on ped faces or along cracks.

Aeg - This horizon must meet the definitions of A, e, and g.

Bg - These horizons are analogous to Bm horizons but they have colors indicative of poor drainage and periodic reduction. They include horizons occurring between A and C horizons in which the main features are (i) colors of low chroma, that is, chromas of 1 or less, without mottles on ped surfaces or in the matrix if peds are lacking; or chromas of 2 or less in hues of 10YR or redder, on ped surfaces or in the matrix if peds are lacking, accompanied by more prominent mottles than those in the C horizon; or hues bluer than 10Y, with or without mottles on ped surfaces or in the matrix if peds are lacking, (ii) colors indicated in (i) and a change in structure from that of the C horizons, (iii) colors indicated in (i) and illuviation of clay too slight to meet the requirements of Bt; or accumulation of iron oxide too slight to meet the limits of Bgf, (iv) colors indicated in (i) and removal of carbonates. Bg horizons occur in some Orthic Humic Gleysols and some Orthic Gleysols.

Bfg, Bhfg, Btg, and others - When used in any of these combinations the limits set for f, hf, t, and others must be met.

Bgf - The dithionite-extractable Fe of this horizon exceeds that of the IC by 1% or more, and the dithionite-extractable Al does not exceed that of the IC by more than 0.5%. This horizon occurs in Fera Gleysols and Fera Humic Gleysols, and possibly below the Bfg horizons of gleyed Podzols. It is distinguished from the Bfg horizon of Podzols on the basis of the extractability of the Fe and Al. The Fe in the Bgf horizon is thought to have accumulated as a result of the oxidation of ferrous iron. The iron oxide formed is not associated intimately with organic matter or with Al, and it is sometimes crystalline. The Bgf horizons are usually prominently mottled, with more than half of the soil material occurring as mottles of high chroma.

Cg, Ckg, Ccag, Csg, Csag - When g is used with C alone, or with C and one of the lowercase suffixes k, ca, s, or sa, it must meet the definition for C and for the particular suffix.

h - A horizon enriched with organic matter. It is used with A alone (Ah); or with A and e (Ahe); or with B alone (Bh); or with B and f (Bhf).

Ah - A horizon enriched with organic matter that either has a color value at least one unit lower than the underlying horizon or contains 0.5% more organic carbon than the IC, or both. It contains less than 17% organic carbon by weight.

Ahe - An Ah horizon that has been degraded as evidenced, under natural conditions, by streaks and splotches and often by platy structure. It may be overlain by a darker-colored Ah and underlain by a higher-colored Ae.

Bh - This horizon contains more than 1% organic carbon, less than 0.3% pyrophosphate-extractable Fe, and has a ratio of organic carbon to pyrophosphate-extractable Fe of 20 or more. Generally the color value and chroma are less than 3 when moist.

j - Used as a modifier of suffixes e., g, n, and t to denote an expression of, but failure to meet, the specified limits of the suffix it modifies. It must be placed to the right and adjacent to the suffix it modifies.

Aej - It denotes an eluvial horizon that is thin, discontinuous, or slightly discernible.

Btj - It is a horizon with some illuviation of clay, but not enough to meet the limits of Bt.

Btgj, Bmgj - Horizons that are mottled but do not meet the criteria of g.

Btnj - j may be used with n to indicate secondary enrichment of Na insufficient to meet the limits for n.

k - Denotes the presence of carbonate, as indicated by visible effervescence when dilute HCl is added. Most often it is used with B and m (Bmk) or C (Ck), and occasionally with Ah (Ahk).

m[1] - A horizon slightly altered by hydrolysis, oxidation, or solution or all three, to give a change in color or structure, or both. It has:

(1) Soil structure rather than rock structure comprising more than half the volume of all subhorizons.

(2) Some weatherable minerals.

(3) Evidence of alteration in one of the following forms:

(a) Higher chromas and redder hues than the underlying horizons.

(b) Evidence of removal of carbonates.

(4) Illuviation, if evident, is too slight to meet the requirements of a textural B or a podzolic B.

(5) No cementation or induration and lacks a brittle consistence when moist.

This suffix can be used as Bm, Bmgj, Bmk, and Bms.

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[1] The Bm is similar to the cambic horizon described in the U.S. and World soil classification systems except for the following:
(1) Its lower boundary must be 5 cm or more from the surface compared with 25 cm in the other systems.

n - A horizon in which the ratio of exchangeable Ca to exchangeable Na is 10 or less. When used with B it must also have the following distinctive morphological characteristics: prismatic or columnar structure, dark coatings on ped surfaces, and hard to very hard consistence when dry.

p - A horizon or layer disturbed by man's activities, that is, by cultivation, or pasturing, or both. It is used with A or O.

s - A horizon with salts, including gypsum, which may be detected as crystals or veins, as surface cruts of salt crystals, by distressed crop growth, or by the presence of salt-tolerant plants. It is commonly used with C and k (Csk), but can be used with any horizon or combination of horizon and lowercase suffix.

sa - A horizon with secondary enrichment of salts more soluble than calcium and magnesium carbonates, where the concentration of salts exceeds that present in the unenriched parent material. The horizon is 10 cm or more thick. The conductivity of the saturation extract must be at least 4 mmhos/cm and must exceed that of the C horizon by at least one-third.

t - A horizon enriched with silicate clay. It is used with B alone (Bt), with B and g (Btg), and with others.

Bt - A Bt horizon is one that contains illuvial layer-lattice clays. It forms below an eluvial horizon, but may occur at the surface of a soil that has been partially truncated. It usually has a higher ratio of fine clay to total clay than IC. It has the following properties:

(1) If any part of an eluvial horizon remains and there is no lithologic discontinuity between it and the Bt horizon, the Bt horizon contains more total and fine clay than the eluvial horizon, as follows:

(a) If any part of the eluvial horizon has less than 15% total clay in the fine earth fraction, the Bt horizon must contain at least 3% more clay, e.g., Ae 10% clay - Bt minimum 13% clay.

(b) If the eluvial horizon has more than 15% and less than 40% total clay in the fine earth fraction, the ratio of the clay in the Bt horizon to that in the eluvial horizon must be 1.2 or more, e.g., 20% clay increase in the Bt over Ae.

(c) If the eluvial horizon has more than 40% total clay in the fine earth fraction, the Bt horizon must contain at least 8% more clay than the eluvial horizon.

(2) A Bt horizon must be at least 5 cm thick. In some sandy soils where clay accumulation occurs in the

lamellae, the total thickness of the lamellae should be more than 10 cm in the upper 150 cm of the profile.

(3) In massive soils the Bt horizon should have oriented clays in some pores and also as bridges between the sand grains.

(4) If peds are present, a Bt horizon shows clay skins on some of the vertical and horizontal ped surfaces and in the fine pores, or shows oriented clays in 1% or more of the cross section.

(5) If a soil shows a lithologic discontinuity between the eluvial horizon and the Bt horizon, or if only a plow layer overlies the Bt horizon, the Bt horizon need show only clay skins in some part, either in some fine pores or on some vertical and horizontal ped surfaces. Thin sections should show that some part of the horizon has about 1% or more of oriented clay bodies.

Btj and Btg are defined under j and g.

x - A horizon of fragipan character. A fragipan is a loamy subsurface horizon of high bulk density. It is very low in organic matter and when dry it has a hard consistence and is seemingly cemented. When moist, it has a moderate to weak brittleness. It has few or many bleached fracture planes and has an overlying friable B horizon. Air dry clods of fragic horizons slake in water.

z - A permanently frozen layer.

y - A horizon affected by cryoturbation as manifested by disrupted and broken horizons and by incorporation of materials from other horizons and mechanical sorting. It is used with A, B, and C, alone or in combination with other subscripts, e.g. Ahy, Ahgy, Bmy, Cy, Cgy, Cyg2, etc.

NOTES:

(1) Transitional horizons need capitals only:

(a) If the transition is gradual, use, e.g., AB or BC.

(b) If the transition is interfingered, use, e.g., A and B, or B and C.

(c) If desired, dominance can be shown by order, e.g., AB and BA.

(2) The designations for diagnostic horizons must be given in the same sequence as shown for the definition, e.g., Ahe not Aeh.

(3) Although definitions have been given for all horizon symbols, all possible combinations of horizon designations have not been covered. It is still necessary to write profile descriptions.

(4) Some diagnostic horizons are not defined here but in the chapter on the order concerned, e.g., chernozemic A, podzolic B, duric horizon, placic horizon, ortstein.

RESOLUTION

P.K. Heringa and L.M. Lavkulich

Attendu que à la réunion précédente de la Commission à Ottawa il avait été décidé que la Commission considère les avantages et désavantages du système de classification des E.U., il est résolu qu'une personne familière avec notre système et celui des E.U. soit nommée pour faire rapport sur les mérites de chacun et recommander l'attitude à prendre.

RESOLUTION

P.K. Heringa and L.M. Lavkulich

Whereas at the previous CSSC meeting held in Ottawa it was resolved that a committee consider the advantages and disadvantages of the U.S.D.A. soil classification system.

Be it resolved that a person familiar with our and the USDA system be forthwith appointed to report on their merits and recommend future action.

Liste des membres officiels (avec droit de vote)

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RAPPORT DE L'ATELIER SUR LES SOLS NORDIQUES

"CLASSIFICATION PROVISOIRE POUR LES SOLS CRYOSOLIQUES"

La classification proposée à Saskatoon (p.96) a été prise en considération et a subi des revisions basées sur des discussions et de nouvelles observations faites sur le champ. Un mémorandum adressé en septembre aux pédologues canadiens, aux collègues des U.S.A. et aux spécialistes du Nord dans les autres disciplines, exposait deux alternatives de classification. D'après les réponses reçues, d'autres modifications ont de nouveau été apportées.

Les sols cryosoliques sont définis comme étant les sols minéraux et organiques dont le matériel demeure gelé de façon permanente (permagel) à moins d'un mètre de la surface dans quelque partie que ce soit du sol proprement dit (pédon). On reconnaît trois principaux genres de sols cryosoliques:

1) les Cryosols turbiques - sols minéraux exhibant une évidente cryoturbation et généralement associés à des terrains marqués de réseaux géométriques;
2) les Cryosols statiques - sols minéraux sans marques évidentes de cryoturbation;
3) les Organo-cryosols - pergelisols organiques.

REPORT OF THE WORKING GROUP ON NORTHERN SOILS

The system of classification proposed at Saskatoon (p.96) was taken under consideration and underwent revisions based on further field observation and discussions. In September, a memorandum outlining two possible alternatives for classifying Cryosolic soils was sent to Canadian pedologists,colleagues in the U.S.A., and northern specialists in other disciplines. Further modifications were made based on the replies received. Following are:

1) A brief outline of the rationale behind the Cryosolic Order.
2) A tentative classification system, to be used for a two year trial period.

Rationale of the Cryosolic Order

The basic criterion used in distinguishing Cryosolic soils from soils of other orders is the presence of permafrost within 1m of the surface in some part of the pedon. Although this criterion seems to trace an arbitrary line through a continuum of soils, it implies many associated soil properties having genetic implications. Some of these associated properties are:

1) Cryosolic soils are cold soils associated with an extremely cold environment in which vegetative growth is slow. Much of the region of Cryosolic soils is beyond the treeline. Roots of mature plants exploit only the uppermost few cm of most Cryosolic soils and commonly they are restricted to organic surface layers. This is presumably due to the fact that, in general, only the uppermost part of the active layer warms up appreciably above $0^{\circ}C$.

2) Evidence of cryoturbation (frost heaving or churning) is a common, though not a universal feature of these soils. The evidence is of different forms which include:

   a) Hummocky microrelief consisting of rounded or elongated hummocks, commonly 0.5 to 1.5 m in diameter, separated by troughs, usually partly filled with peat, whose mineral surfaces are commonly 20 to 50 cm below the crest of the hummock.

   b) Other kinds of patterned ground such as stone stripes and stone nets that arise from sorting of particles of different sizes by frost action.

   c) Discontinuous and disrupted horizons and irregular inclusions of material from other soil horizons within horizons of parts of the pedon.

   d) "Frost boils" - bare spots resulting apparently from the upward thrust of fine soil materials by frost action. The surface is disturbed frequently enough to prevent the establishment of plants.

3) Excessive wetness in the active layer immediately above the frozen front in all Cryosolic mineral soils except those having dry permafrost. The excessive wetness is due to melting of ice within the soil as well as to precipitation in some instances. The frozen layer acts as a completely impermeable barrier to water - much more so than a lithic contact, as bedrock usually has some fissures through which water may move. The wetness commonly gives rise to mottling or to reduced colors in soils that would be well drained if permafrost were not present.

4) Weakly-developed structure or no structure in sub-surface horizons. This is probably associated with excessive wetness of much of the active layer of many soils and with frost churning. The surface and near-surface horizons of some Cryosolic soils have well-developed granular structure.

5) Cryosolic soils frequently contain appreciable volumes of ice below the permafrost table. Commonly, the ice content is particularly high at the surface of the permafrost table. Any disturbance of the soil that results in the melting of significant quantities of this ice may have catastrophic effects upon the soil. In general, subsidence occurs and the active layer becomes a supersaturated, fluid mass.

6) Many Cryosolic soils contain sensitive material some of which is thixotropic and some which has a high void rate and may be subject to flow.

The extreme sensitivity of many Cryosolic soils, due partly to properties mentioned in 5 and 6, is an important characteristic.

Clearly, these properties and processes associated with the occurrence of permafrost within 1 m of the surface of some part of the pedon are all consequences of cold temperatures. Climate, particularly temperature, is a major factor governing the pedogenic development of Cryosolic soils. Permafrost at shallow depths is a better basic criterion than air temperature <u>per se</u> because soils in regions having mean annual temperatures of 0° C may or may not have permafrost. Mean summer soil temperatures at some depth might be a suitable criterion but very few temperature data are available for soils of northern Canada.

The depth to permafrost criterion appears deceptively simple Because most observations of soils with permafrost are made at times other than that of the date of maximum depth of thawing, and as maximum depth of thawing varies somewhat from year to year it is commonly necessary to estimate the position of the permafrost table. In many cases, especially at high latitudes and altitudes this estimate can be made with confidence. However, in transition zones between Cryosolic and other soils the degree of certainly is much less. The following facts are of use in deciding whether or not permafrost occurs within 1 m.

1) Thawing of the uppermost part of the active layer proceeds relatively rapidly. As the active layer becomes deeper, further thawing becomes progressively slower. Thus, in most soils, by mid July the active layer is approaching its maximum depth (80% or more).

2) Even a thin organic surface horizon greatly retards the rate of thawing especially when the organic material is dry.

3) Commonly, a layer of high ice content occurs at the permafrost table. Thus, the depth at which such a layer occurs is likely to be the depth of maximum thawing.

4) In hummocky terrain, inclusions of organic matter as black streaks or continuous horizons commonly occur at the permafrost table below the hummock.

5) As with the application of other diagnostic criteria, much extrapolation can be done safely from basic data for a few kinds of sites in each of several regions. The basic data required would be measurements of depth to the frozen layer at various times throughout the summer at well selected sites.

TENTATIVE CLASSIFICATION SYSTEM FOR CRYOSOLIC SOILS

November, 1973.

Cryosolic soils are those mineral and organic soils that have perenially frozen material (permafrost) within 1 meter of the surface in some part of the soil body (pedon). The mean annual soil temperature is less than 0^{o} C. They are the dominant soils in the zone of continuous permafrost and become less widespread to the south in the discontinuous permafrost zone with their maximum extension being found in organic and poorly-drained, fine-textured mineral materials. The vegetation associated with Cryosolic soils varies from the sparse plant cover of the high arctic, through tundra, to subarctic and northern boreal forests. The active layer of these soils is frequently saturated with water, especially near the frozen layers and colors associated with gleying are therefore common in mineral soils, even in those occurring on well drained portions of the landscape. They may or may not be markedly affected by croturbation.

The classification of Cryosolic soils assumes the use of the pedon concept and is based on a control section which extends from the surface to a depth of 1 meter or to a lithic contact whichever is shallower. An exception is made for the Organo Cryosols where a depth of 130 cm is allowed, if required, to establish Terric and Glacic subgroups. Three major kinds of Cryosolic soils are recognized at the Great Group level. These are:

1) Mineral soils displaying marked cryoturbation and generally occurring on patterned ground.

2) Mineral soils without marked cryoturbation.

3) Organic soils.

Many of the Cryosolic mineral soils have structurally unstable horizons resulting from thixotropy, high void ratios, saturated soil, or some combination of these conditions. This feature should be recognized as a phase of the respective subgroups.

Order	Great Group	Subgroup	Subgroup modifier
9 Cryosolic	91 Turbic Cryosol	9101 Brunisolic Turbic Cryosol	5 Saline
		9102 Regosolic Turbic Cryosol	9 Lithic
		9103 Gleysolic Turbic Cryosol	

92 Static Cryosol	9201 Brunisolic Static Cryosol 9202 Regosolic Static Cryosol 9203 Gleysolic Static Cryosol	5 Saline 9 Lithic
93 Organo Cryosol	9301 Fibric Organo Cryosol 9302 Mesic Organo Cryosol 9304 Humic Organo Cryosol	9 Lithic 10 Glacic 11 Terric

91 Turbic Cryosols

These Cryosolic mineral soils generally occur on patterned ground and have marked evidence of cryoturbation as indicated by broken horizons and displaced material in more than one third of the pedon or by microrelief.elevations greater than one third of the pedon diameter. Patterned ground includes such cryogenic forms as sorted and nonsorted circles, nets, polygons, stripes and steps in stony or coarse textured material and nonsorted units such as earth hummocks in medium and fine textured materials. Microrelief is generally greater than 10 cm and the pedon includes all elements of the microtopography in cycles less than 7 m in width. Processes include sorting of different sized particles and mixing of both mineral and organic material from different horizons.

Organic (Oy) or organic-rich mineral horizons (Ahy) are characteristically present in the region of the permafrost table and there is generally a Buildup of ice in the upper part of the permafrost layer.

9101 Brunisolic Turbic Cryosol

These Turbic Cryosols have a Bm horizon greater than 10 cm thick which covers more than two-thirds of the mineral element of the pedon. They are generally imperfectly to moderately well drained within the rooting zone but usually show evidence of gleization in the lower part of the active layer. Peaty surface horizons may range up to 20 cm or more in thickness,particularly in the forested area.

9102 Regosolic Turbic Cryosol

These Turbic Cryosols lack a Bm horizon as defined for Brunic. Mixing and disruption is usually strongly expressed. The soils are generally imperfectly to moderately well drained within the rooting zone but may have a gleyed horizon immediately above the frozen layer. Peaty surface horizons may range up to 20 cm or more in thickness, particularly in the forested area.

9103 Gleysolic Turbic Cryosol

These Turbic Cryosols have a Cg or Bg horizon at the mineral surface. They are poorly drained and have low chroma or weak mottling in the surface horizons. They may have up to 40 cm of peat.

910 -- 5 Saline

S or Sa horizons occur within 50 cm of the surface (conductivity of saturation extracts exceed 4 mmhos/cm)

910 -- 9 Lithic

A consolidated mineral layer (bedrock) occurs within the control section (10 to 100 cm).

92 Static Cryosol

These Cryosolic mineral soils show no evidence of cryoturbation or display cryoturbic features in less than one third of the pedon. These soils are most common in coarse textured materials and in the high arctic where stone pavements and salt crusts may be present. Some patterned ground features may be associated.

9201 Brunisolic Static Cryosol

These Static Cryosols have a Bm horizon greater than 10 cm thick. Ah (moder) horizons may be present. They are imperfectly to rapidly drained within the rooting zone but may exhibit gley features immediately above the permafrost table.

9202 Regosolic Static Cryosol

These Static Cryosols have Bm horizon development too weak to meet the requirements for Brunic. Ah (moder) horizons may be present and gley features below the imperfectly to rapidly drained surface are included.

9203 Gleysolic Static Cryosol

These Static Cryosols have low chromas or weak mottling (Bg or Cg horizons) at the surface. Peaty surfaces are common but do not exceed 40 cm in depth.

920 -- 5 Saline - as for 910

920 -- 9 Lithic - as for 910

93 Organo Cryosol

These are Cryosolic soils developed principally from organic materials. They have a surface organic layer (more than 30% organic matter) greater than 40 cm thick or greater than 10 cm thick over a lithic contact or greater than 10 cm thick over an ice layer which is at least 30 cm thick. Associated landforms include palsas, peat plateaus and peat polygons.

The subgroup separations are based on the fibre content of the dominant organic layer below 40 cm or above a Terric, Glacic or Lithic contact if these occur in the control section. Only one subgroup modifier may be used based on the following order of precedence: Lithic before Glacic before Terric. The fibre content of the active layer may be recognized as a phase of a subgroup (analagous to a textural phase of a mineral subgroup).

9301 Fibric Organo Cryosol

These Organo Cryosols are composed of dominantly fibric material in the control section below 40 cm if no Lithic, Clacic or Terric contact is present or in the entire organic profile above such a contact.

9302 Mesic Organo Cryosol

These Organo Cryosols are composed of dominantly Mesic material in the control section below 40 cm if no Lithic, Glacic or Terric contact is present or in the entire organic profile above such a contact.

9303 Humic Organo Cryosol

These Organo Cryosols are composed of dominantly humic material in the control section below 40 cm if no Lithic, Glacic or Terric contact is present or in the entire organic profile above such a contact.

930 -- 11 Terric

Unconsolidated mineral material, greater than 30 cm thick, occurs within the control section (40-100 cm).

930 -- 9 Lithic

A consolidated mineral layer (bedrock) occurs within the control section (10-100 cm).

930 -- 10 Glacic

A ground ice layer greater than 95% ice by volume and more than 30 cm thick, occurs within the control section (10 to 100 cm)

APPENDIX

The Pedon

The pedon is the smallest 3 dimensional unit at the surface of the earth that is considered as a soil. It is the basic unit of soil that is classified and sampled. The pedon concept was developed and the term defined by the Soil Conservation Service Staff, U.S.D.A. The definition given here follows that given in Soil Taxonomy, the U.S. system of soil classification. The pedon, as defined, is the entity of soil classified in the Cryosolic order. It is of particular importance in this order as many Cryosolic soils have cyclic variation; for example, soils in hummocky terrain in the Mackenzie Valley.

A pedon is a 3 dimensional unit of soil. Its lateral dimensions are 1 m if ordered variation in genetic horizons can be sampled within that distance, or if such horizons are few and faintly expressed. If horizons are cyclical or intermittent and they are repeated within a lateral distance of 7 m, the lateral dimensions of the pedon are half the cycle (from 1 to 3.5 m depending upon the span of the cycle). A pedon has vertical dimensions of 2 m or less. In the case of Cryosolic soils, the control section is 1 m (130 cm for some Terric and Glacic subgroups) and thus these are the vertical dimensions that apply.

It may be useful to apply the pedon concept in classifying specific Cryosolic soils. Consider the Brunisolic Turbic Cryosol depicted in Fig. 1. Here, the full cycle from trough to trough is less than 2 m. Thus the pedon includes the full cycle, and all the variability throughout that cycle to a depth of 1 m is considered a single soil. If the basic unit of soil were considered to be a narrow profile, at least 2 soils would be identified in Fig. 1. The trough unit might be classified as a Gleysolic soil and the hummock element as a Brunisolic soil. Application of the pedon concept involves classifying the whole unit recording to the dominant element in the pedon, in this case the Brunisolic Turbic element. If the trough element had been the major one, the soil would be classified as a Gleyic Turbic Cryosol.

In the case of the Regic Static Cryosol depicted in Fig. 2, the dimensions of the pedon would be 1 cubic meter.

In cases where cyclic variation occurs and the cycle is repeated over a lateral dimension of more than 7 m, the pedon does not include all elements of the cyclic variation. For example, suppose a sorted polygonal network had units 8 m in diameter and separated by troughs 1 m across. One pedon would represent the trough element.and other pedons would represent the hummock element. The sizes of the pedons involved would depend upon whether or not there was cyclic variation within the trough or the hummock. The mapping unit in such terrain would be a complex named in terms of at least 2 taxonomic units.

Additional Nomenclature

y - Denotes a horizon which has been affected or formed by cryoturbation as manifested by disrupted and dislocated horizons and displacement and incorporation of materials from other horizons. These horizons are not necessarily perennially frozen and therefore "y" does not always occur in conjunction with "z" (a frozen layer). In addition, these cryoturbated horizons differ from burried soil horizons (designated "b"), which are formed by the deposition of new material on top of older horizons and involve little or no disruption, dislocation, displacement or incorporation. The "y" may be used with O, A, B or C, or combinations of these and other lower case modifiers. It will always be the last symbol in a designation. Examples are: Omy, Ahy, Bmy, Cy and BCy.

W - A master layer indicating greater than 95% by volume of water.
When used with z (Wz) it indicates a layer of ice.

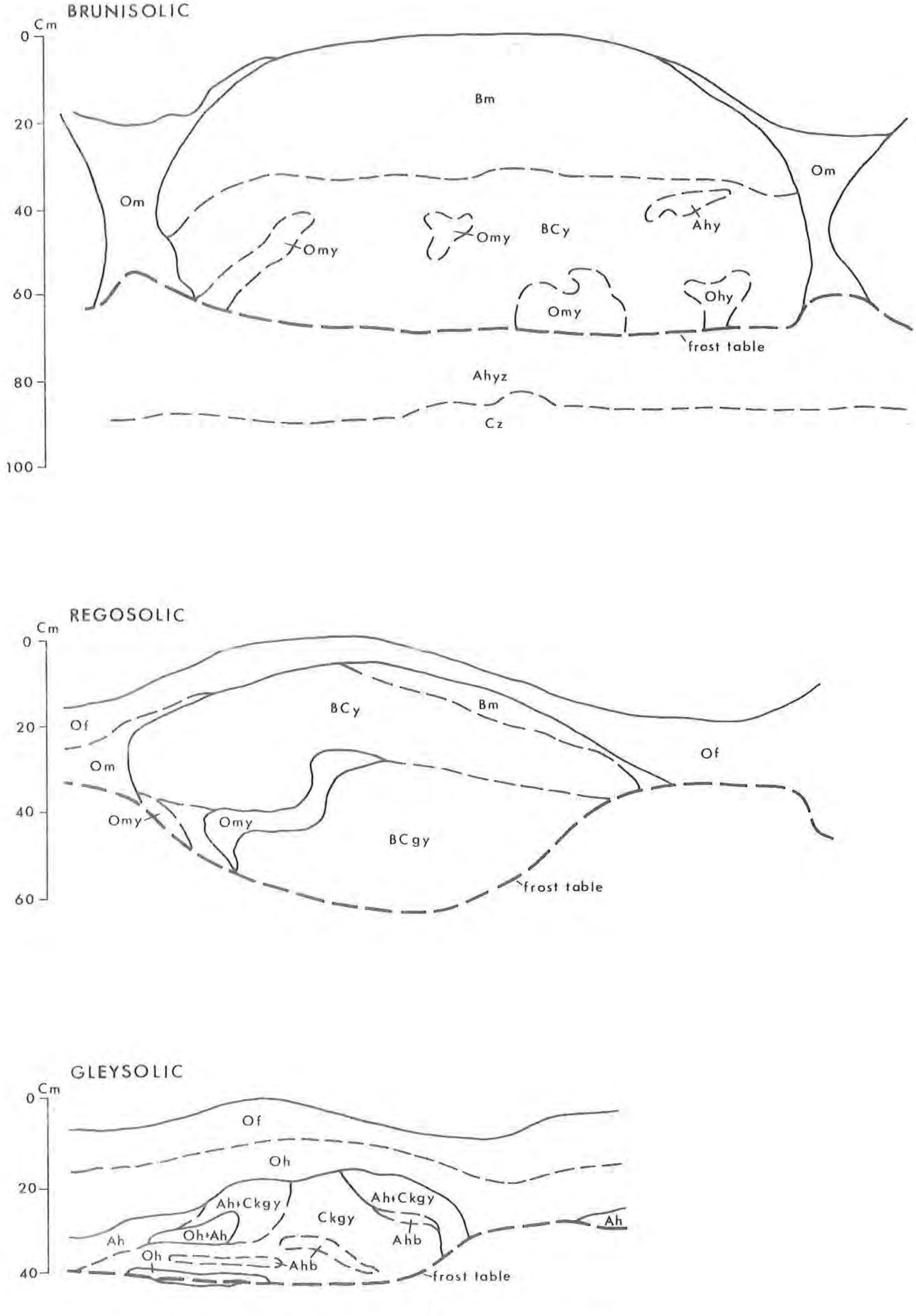

Fig.1 Diagrams of specific examples of Turbic Cryosols. *SRI*

STATIC CRYOSOLS

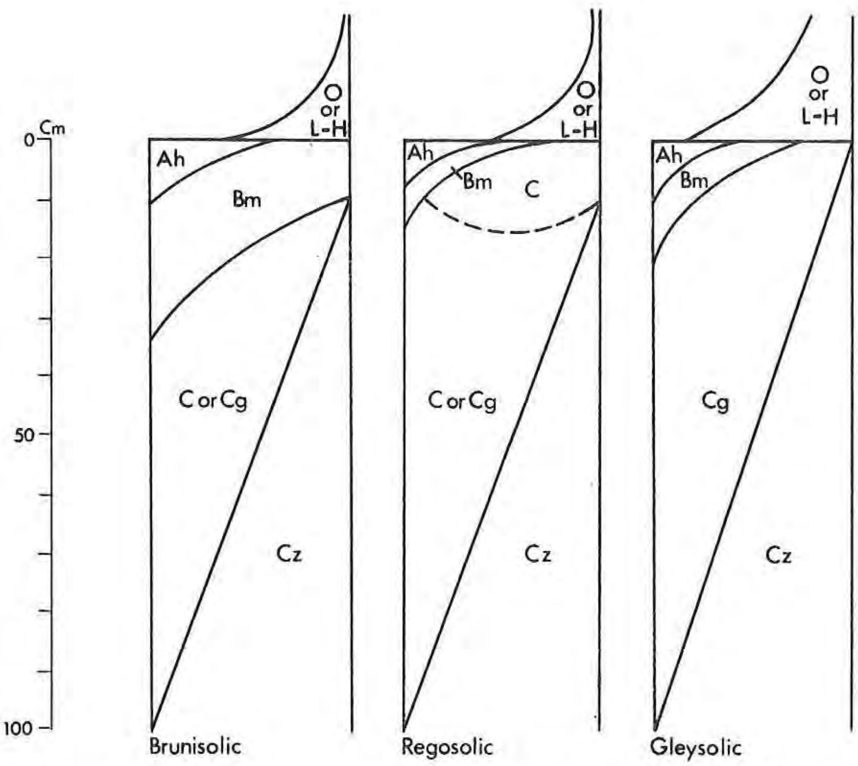

Fig. 2 A diagrammatic representation of the horizon depth relationships of the Static Cryosols.
Perennially frozen ground occurs within 1m. of the surface.

SRI

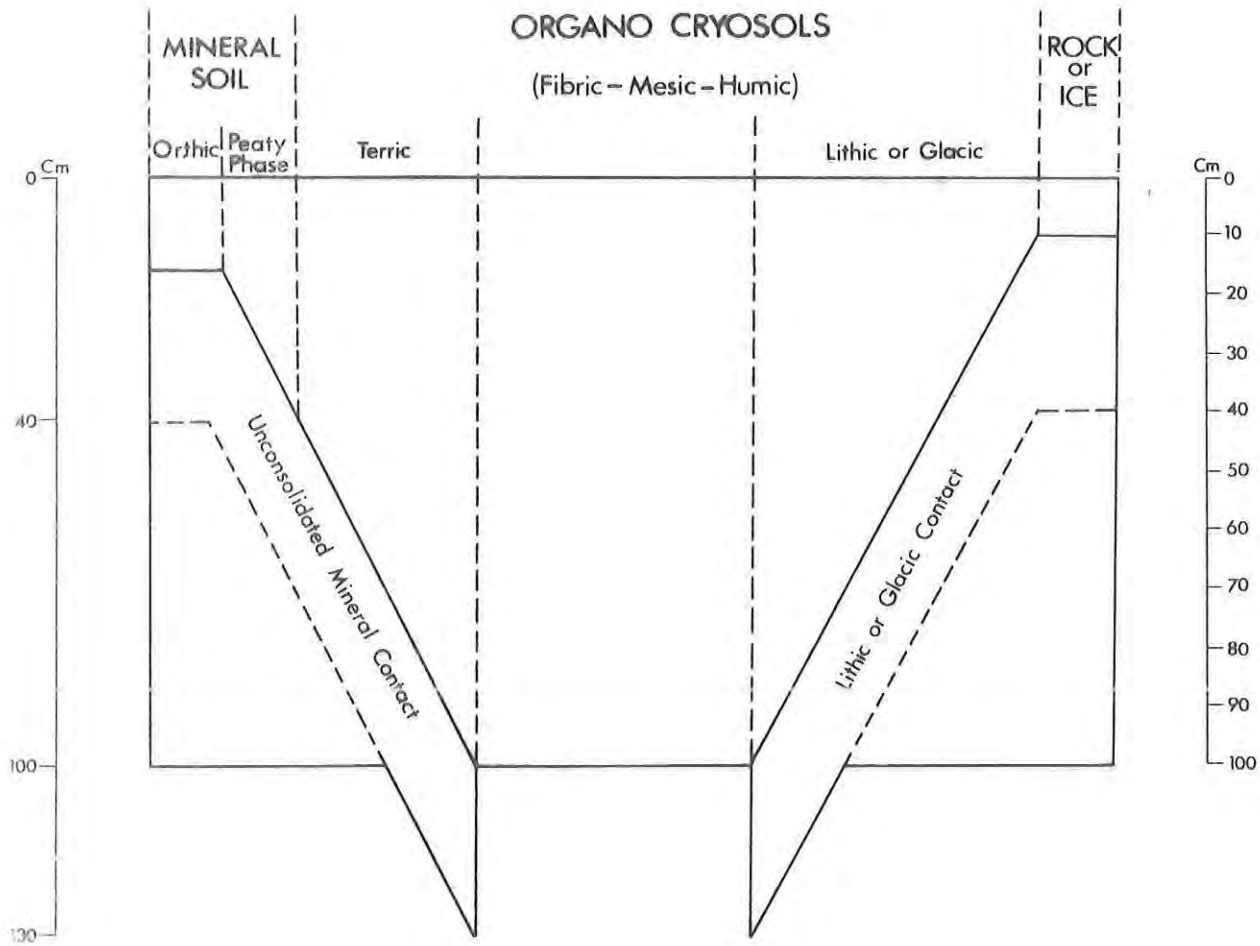

Fig. 3 A diagrammatic representation of the depth relationships pertinent to the use of subgroup modifiers. Perennially frozen ground occurs within 1m. of the surface.

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