Science Language, Parsing and Querying: The Surficial Side of Things*

By Andrée M. Bolduc[1], Andrew Moore[2],
Kaz Shimamura[3], Matt Pyne[3], and Ron DiLabio[3]

[1]Geological Survey of Canada
GSC-Québec
490 de la Couronne
Québec, Canada G1K 9A9
Telephone: (418) 654-2635
Fax: (418) 654-2615

[2]Natural Resources Canada, ESS Info
[3]Geological Survey of Canada

e-mail: {abolduc, amoore, kshimamu, mapyne, rdilabio}@nrcan.gc.ca

ABSTRACT

Communicating geological concepts amongst geologists as well as from geologists to the general public requires that a well established and documented science language be available. This task is tackled by various groups that have an interest in making available geological data to a broad community. This paper focuses on science language needed to adequately represent geological concepts portrayed on surficial geology maps in Canada. Words necessary to describe glacial and ice-contact deposits, environments, landforms, etc., have been extracted from map legends. They have been organized hierarchically under high level concepts such as earth materials, physical characteristics, and genesis. The science language will be an evolving tool used by geologists and the general public. Therefore, it needs to have the flexibility to accommodate modifications under the supervision of an expert committee to insure that such modifications are made according to the accepted philosophy.

INTRODUCTION

Words are a powerful tool for communication, if the definition of the word is agreed upon by all users. Too many times do we hear: "in this context, we use the word (*insert your choice*) to mean (*a definition of the word*)." With the advent of digital mapping, it has become more and more important to develop common terminologies in order to facilitate the querying of maps by knowledgeable and lay users of geological information. The Science Language Technical Teams of the North America Data Model Steering Committee (http://nadm-geo.org) have undertaken this very task. We will refer to reports by the Science Language Technical Team on Sedimentary Materials (North American Geologic Map Data Model Science Language Technical Team, 2003 and their paper in this volume) as needed, using the acronym "SLTTS_1.0".

Traditionally, surficial geology has been regarded as a completely separate geological topic, especially in Canada where it is largely equivalent to Quaternary glacial geology. This is not rigidly enforced, and one could rightly argue that recently erupted lavas are surficial materials. There remain problematic issues (pyroclastic materials are a good example) that will not be resolved here. Rather, we will treat this subject from a Canadian surficial geological map point of view, recognizing that it is incomplete. The main objective of this paper is to present the science language that is being used with the parsing and querying tools currently under development at the Geological Survey of Canada (GSC).

Recently, the point has been made that surficial geology describes unconsolidated earth material of sedimentary origin. Glacial geology is thus a subset of sedimentary geology where the sedimentation agent is ice, rather than water or wind, although both (water and wind) are involved in forming the materials and landscape of the ice contact environment. This clarification comes at a time when the GSC is developing web-based tools (http://cgkn.net/) to help a variety of geological data users to sort through the information available on maps (Moore and

*GSC contribution 2004057

others, 2003). The challenge remains: providing a coherent science language adapted to surficial geology. Specialized terminology needed to adequately describe glacial deposits, especially landforms, had not yet been developed under SLTTS_1.0. We hope to contribute to science language development in North America by providing such terminology and a coherent classification scheme. The reader should keep in mind that the rest of this paper is focused on the ultimate GSC goal, parsing map legends (by the geologist) and querying the data (by any user).

THE SCIENCE LANGUAGE

The goal of the GSC is to develop a science language to be used in the parsing and querying of surficial geology maps, supported by a glossary of all terms used. The science language needs to adhere to a coherent classification scheme. It also should be intuitively simple enough for non-expert users (novice geologist-users as well as the general public), and complete enough for experienced users. For bedrock geology, the problem was tackled using NADM-C1 (2004) as a starting point (Davenport and others, 2002; Struik and others, 2002).

The group working on the science language for surficial geology adopted a "*legend to science language*" approach, similar to the one described in Thorleifson and Pyne (2003). As a starting point, we identified the science words most commonly used in surficial geology map legends, rather than using an already existing classification. The rationale behind this approach was to quickly provide users with a working science language that would cover most of the terminology used on maps. Following two pan-Canadian workshops, the results of this exercise were organised into a flat table, the heading of each column representing first order concepts such as depositional environment or sedimentary material. Quickly, it became clear that this simple schema was not satisfying if it was to be incorporated into SLTTS_1.0.

The next step was to look at the results of the legend analysis exercise and to compare it with SLTTS_1.0. A large proportion of the words readily found a niche in SLTTS_1.0. Words for earth materials, sedimentary structures, and, to a certain extent, depositional environments already existed. We put together a series of tables, each representing a high level concept (e.g., earth materials (Figure 1), physical characteristics (Figure 2), genesis (Figure 3)). Each of the tables then proposes a hierarchical classification of terminology into lower level concepts until the words resulting from the map legend analysis exercise were reached. In most cases, words from the legends were introduced on the 4th level or lower.

Earth Material

Earth material ("*a naturally occurring substance formed in or on the Earth by physical, chemical, or biogenic processes that produce solid particles or crystals of mineral and (or) rock*"; SLTTS_1.0 (NADM, unpublished document) is the starting point for all map unit descriptions. As shown in Figure 1, following SLTTS_1.0 philosophy, this first level concept is divided at level two according to the primary genetic process, into igneous, composite-genesis (includes metamorphic rocks), and sedimentary earth material. Sedimentary earth materials are further subdivided into consolidated sedimentary materials and unconsolidated sedimentary materials (level 3). Terminology for Quaternary glacial geology resides underneath the latter. Any older consolidated glacial deposits such as tillites would reside under consolidated sedimentary earth material. There is no need to introduce additional terminology for earth material, since sand is sand whether deposited by water, wind or ice. Therefore, for surficial geology science language needs, we extract from SLTTS_1.0 the subset of terms needed to adequately describe map units on surficial geology maps.

However, a "miscellaneous" category was required to accommodate polygons that are identified as "bedrock" without further description, or ice, in areas where icefields and/or glaciers are large enough to be mapped. In the case of bedrock, we would suggest that the polygon, whenever possible, be identified at least to its 2nd level (sedimentary, igneous, or composite genesis) or 3rd level (general rock name) concept, and where possible, a link to the appropriate bedrock geology map (if web-available) should be included with the description of the polygon.

Because map units are rarely composed of a unique earth material, we suggest the use of a table of relative abundance (as proposed in NADM-C1, http://nadm-geo.org/) in conjunction with earth materials. The combination of the two tables would yield the information necessary to answer a data user query such as "*Show me, in this region, places where the surficial deposits are mostly sand*".

Physical Characteristics

SLTTS_1.0 has proposed language to describe map unit characteristics. As shown in Figure 2, we have chosen to group under the first level concept of "physical characteristics" second level concepts such as outcrop characteristics, map-unit thickness, sedimentary fabric, and sedimentary structures. Descriptions of map units are usually qualitative, but there may be some quantitative information where there exists, for example, grain size analysis or others. Therefore, we offer the parser the choice between using qualitative terminology or quantitative terminology at the same level.

Sedimentary structures are an important aspect of all sedimentary materials, but perhaps because surficial geology is partly done via air-photo interpretation,

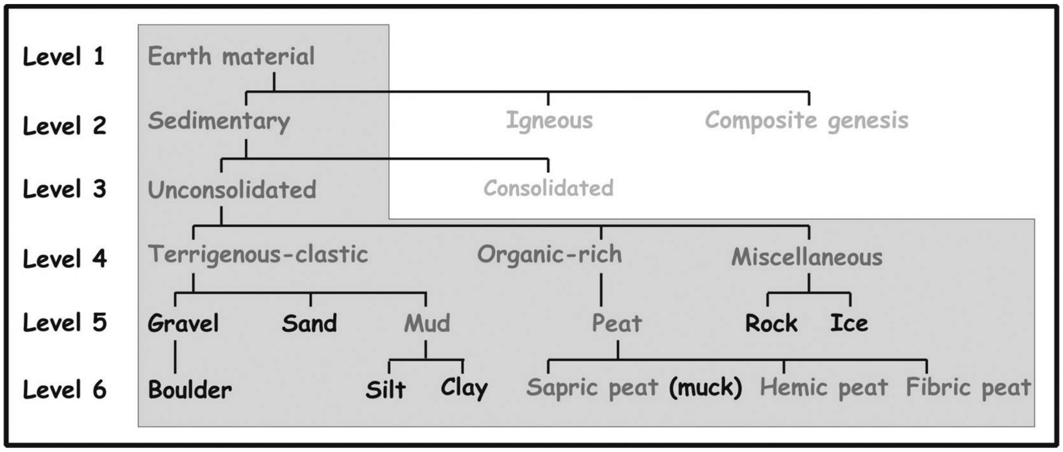

Figure 1. Classification of earth materials for surficial geology. The subset of words in the greyed area represents surficial glacial materials. Words in bold were either already in SLTTS_1.0 and in map legends, or they were added by the legend analysis exercise.

descriptions of sedimentary structures are rarely included, or briefly mentioned, in surficial geology map legends. When this information is provided in the map legend, it can be captured using SLTTS_1.0 proposed hierarchy, following the path: sedimentary structures → primary → inorganic → syngenetic (or penecontemporaneous) and depositional (or erosional) structures (Figure 2B). Again, because this paper provides science language derived from the analysis of map legends, Figure 2 only shows a very restricted number of words, but all the terminology proposed in SLTTS_1.0 is available as needed.

There are a number of features that may be grouped under secondary sedimentary structures, like those produced by the growth of ground ice. Because the development of such features is normally of a scale large enough to allow mapping of individual features, we suggest that these may be better classified as landforms. Micro-landforms such as striation could also be argued to be secondary sedimentary structures imposed on bedrock surfaces. We prefer, however, to include these in glacial landforms, where they more intuitively belong.

Genesis

Considerable attention in SLTTS_1.0 has been given to the high level concept of genesis. Depositional processes, environments, and products are three interrelated second level concepts; in Figure 3 the hierarchy of glacial processes and environments are shown. We would like to introduce a fourth concept, landforms, in order to address the needs of surficial geologists (Figure 4). The rationale is as follows.

We believe that depositional products (the map unit itself) and the landform (of which there may be one or more within a map unit) are both the direct results of a depositional process taking place in an environment. In the most simple case, the landform is a flat plain that does not contribute very much to the description of the map unit or the interpretation of the map. In the most complex case, a map unit would host many landforms that result from interrelated processes, such as the association of recessional moraines with kames and kettles (ridges, mounds and depressions to speak in non-genetic terms).

In devising the hierarchy for depositional processes and environments related to a glacial setting, we were inspired by the comprehensive work produced by the Commission on Genesis and Lithology of Glacial Quaternary Deposits of the International Union for Quaternary Research [INQUA] (in Goldthwait and Matsch, 1988), specifically those papers by Dreimanis (1988), Goldthwait and others (1988), and Lundqvist (1988). We subdivide ice flow processes and environments into "glacial" (*requiring the direct action of glacial ice*; Lundqvist, 1988) and "ice-contact" rather than "glacigenic" (*processes, depositional environments, deposits or landforms that require glacial ice, but not necessarily directly related to it*; Lundqvist, 1988). We prefer the term "ice-contact" because it is in common usage amongst glacial mappers. Under "ice-contact", we find concepts such as glaciofluvial, glaciolacustrine and glaciomarine. We also introduce the concept of "periglacial" processes and environments for those regions where extreme cold conditions result in unique depositional products and landforms.

Clearly, the dividing line between glacio (fluvial-lacustrine-marine) and strictly fluvial-lacustrine-marine terminology requires some thought. It has been argued amongst members of the SLTTS working group that processes and environments outside of a glacier already have terminology and descriptions. Fluvial processes are the same whether the water comes from direct precipitation or from the melting of glacier ice. Similarly, lacustrine and marine processes/environments exist whether in con-

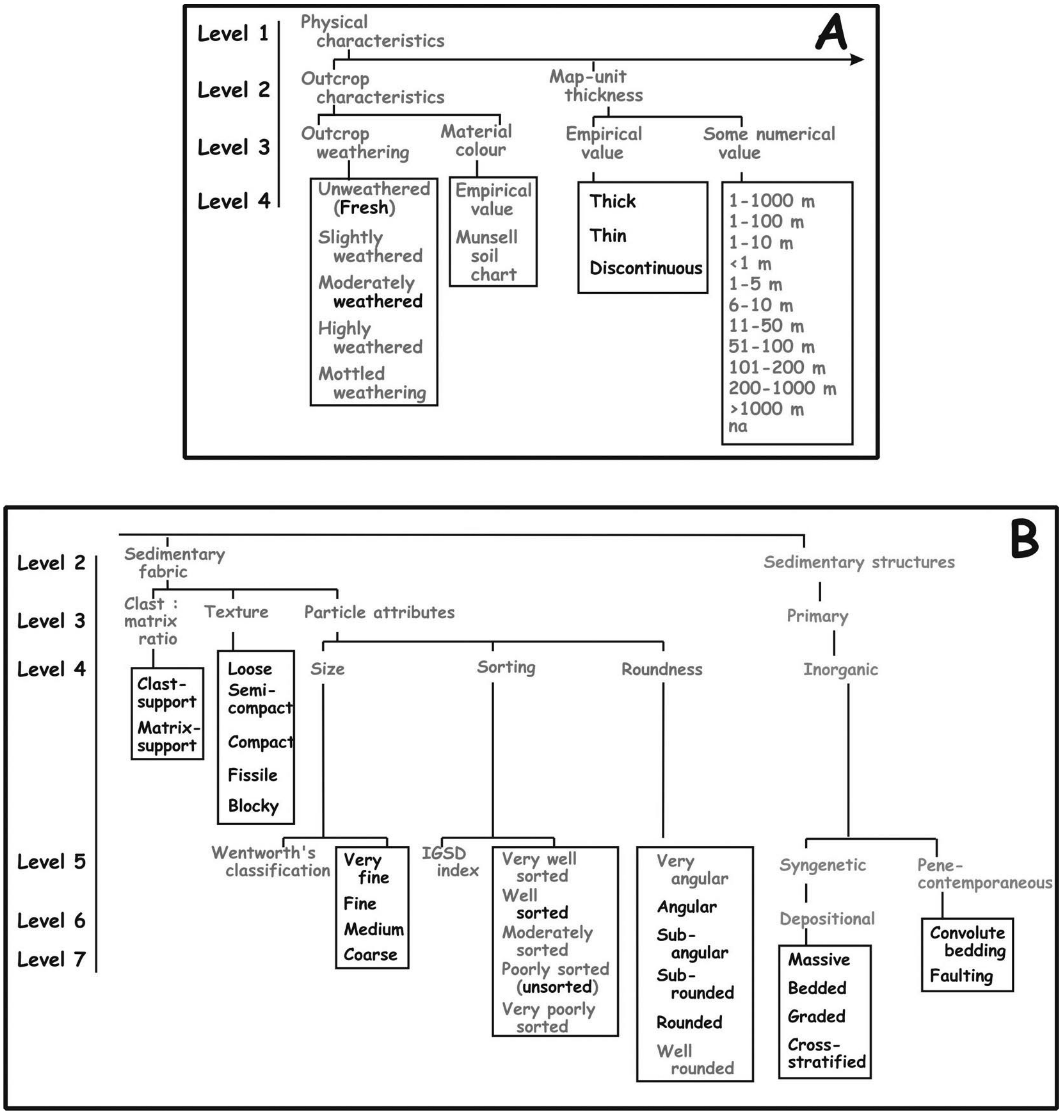

Figure 2. Classification of physical characteristics for surficial geology: A) Outcrop characteristics and map-unit thickness; B) Sedimentary fabric and sedimentary structures. Words in bold were either already in SLTTS_1.0 and in map legends, or they were added by the legend analysis exercise. It is possible to provide some choices for “material colour” such as grey(ish), yellow(ish), red(dish), etc. if the Munsell chart is not used. The distinction between map-unit thickness values “thick” and “thin” will need to be decided by the CGKN stewardship committee. Although “thin” is usually associated with “discontinuous”, i.e. with numerous bedrock outcrops found in the deposit, it may actually be continuous and range from less than 1m to 5 m depending on the map maker.

tact with a glacier or not. Therefore, these should not be duplicated under “ice flow processes”, or “glacial-related settings”. Perhaps a multihierarchical classification, such as proposed in Struik and others (2002) would better serve this complex concept of genesis.

We believe there is a logical reason to address glaciofluvial, glaciolacustrine and glaciomarine processes/environments separately, because there are some unique features associated with them. For example, landforms such as eskers and kames are not formed without the presence of glacial ice. Similarly, deposits such as varves and glaciomarine diamictons will not be formed in non-glacial lacustrine/marine environments. We thus use in Figure 4 some specialized terminology related to those transitional environments, where the “glacio-” component is critical in the development of deposits and landforms. Because there is a continuous evolution between the glacially-influenced and the non-glacially influenced, the distinction is seldom evident in surficial geology map legends. This paper will not address the non-glacial fluvial, lacustrine and marine processes/environments that are present on surficial geology maps,

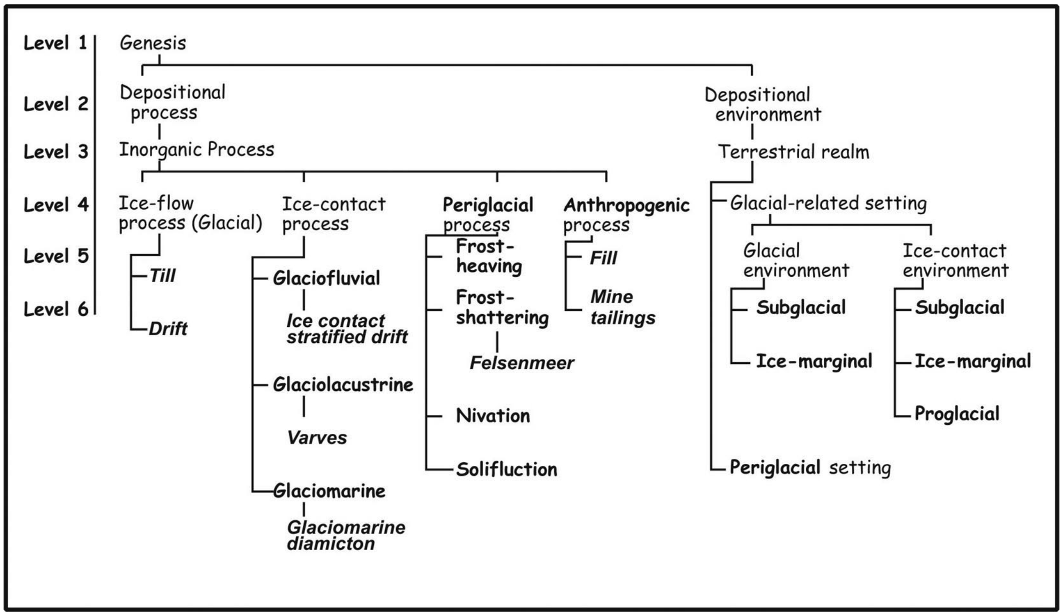

Figure 3. The high-level concept of "genesis" and its constituents, processes and environments. Words in bold-italics represent depositional products, and words in bold were either already in SLTTS_1.0 and in map legends, or they were added by the legend analysis exercise.

as we recognize that the terminology and hierarchy provided by SLTTS_1.0 satisfies our needs.

Two more concepts need to be introduced to adequately capture the information on surficial geology map legends: periglacial and anthropogenic. We use Lundqvist's (1988) definition of the term periglacial. It encompasses processes, depositional environments, deposits or landforms "*caused by cold climate and thus often occurring outside a glacier but not requiring its presence*".

From the Glossary of Geology (Jackson, 1997), periglacial is more narrowly defined as "*said of the processes, conditions, areas, climates, and topographic features at the immediate margins of former and existing glaciers and ice sheets, and influenced by the cold temperature of the ice*". This definition is extended to include "*an environment in which frost action is an important factor, or of phenomena induced by a periglacial climate beyond the periphery of the ice*" (Jackson, 1997). This extension of the term "periglacial" might include features that do not require perennially frozen ground, but that do require extreme cold temperatures.

We believe that the heading "cryogenic" (processes, depositional environments, deposits or landforms that are related to extreme cold conditions including but not restricted to perennially frozen grounds) should be the higher-level concept under which periglacial (requiring perennially frozen grounds) and extreme cold climate would reside. Whether this distinction is needed is open to discussion. This is why Figures 3 and 4 do not reflect this thinking. Similarly, how we choose the cut-off percentage for the volume of ground ice required before a process, depositional environment, deposit, or landform is classified under periglacial needs to be fine-tuned. We offer language to at least cover the terminology found in map legends. We will need to address this issue with expert references such as those available at the Frozen Ground Data center web site (http://nsidc.org/fgdc/glossary/description.html), and specifically Everdingen (1998).

Finally, a concept that also requires some thought is the action of man on its environment. Anthropogenic processes result in such deposits as fill or mine tailings, which are important mappable units, especially where they conceal the underlying geology.

CONCLUSIONS

Science language development is not a minor task. Those involved in this effort each have a different view of the hierarchy and organisation of the terminology depending on their professional background. A carefully considered philosophy brings together ideas and concepts into a largely accepted consensus from which the science language is built. This is by no means a static issue. Users will need to work with the proposed science language and offer suggestions to improve its usefulness. Discussions will result in modifications, minor and perhaps major, which will lead to a new release of the science language. In order to facilitate this process, the GSC has established a stewardship policy (http://cgkn.net/2002/working/surficial_e.htm;

	GLACIAL PROCESS		ICE-CONTACT PROCESS		PERIGLACIAL PROCESS	
	Subglacial	**Ice-marginal**	**Subglacial**	**Ice-marginal**	**Perennially frozen**	**Extreme cold temperatures**
Plain	Cover moraine, veneer			Outwash plain		
	Cover moraine, blanket			Kame terrace		
	Cover moraine, undulating			Apron		
Ridge (stream-lined drift)	Flute		Flute			
	Drumlinoid		Drumlinoid			
	Drumlin		Drumlin			
	Crag-and-tail		Streamlined drift			
	Till ramp					
Ridge (stream-lined bedrock)	Rock drumlin (whaleback)					
	Roche moutonnée					
	Rat-tails					
Ridges (drift, not stream-lined)	Ribbed (Rogen) moraine	Terminal moraine	Crevasse filling		Ice-wedge polygons	
	DeGeer moraines	Frontal moraine	Esker			
	Thrust moraine	Recessional moraine Lateral moraine Interlobate moraine				
Mound	Hummocky moraine		Kame	Outwash fan	Pingo	Solifluction lobe
				Subwash	Palsa	Sorted circles
Depression	Cirque			Channel		
	Glacial furrow			Kettle		
	U-shaped trough					
	Fjord					
	Glacial-lake basin					
	Striation					

Figure 4. Glacial, ice-contact, and periglacial landforms. All the words found in this table were added by the map legend analysis exercise.

see Appendix for the description of the CGKN working group on surficial materials).

The progress report that we present here shows the situation at the GSC regarding surficial geology. Future versions of this science language will most likely include more specialized terminology, and perhaps change the classification scheme somewhat in order to better comply to SLTTS_1.0. We welcome discussion and comments on this proposition. We also believe that we need to publicly discuss our thought processes and science language so that potential users can critically comment on it. We think the approach we have taken will satisfy users' needs and allow the geologists to find the terminology they want to use. It will take some time before we are all comfortable with the science language and its use, but it is a powerful tool for earth scientists and for decision-making authorities, planners, and the general public.

ACKNOWLEDGMENTS

This work is being carried out by the authors under, and financially supported by, project GK4350 "Integrated Information System for Bedrock, Surficial, Geochronological, Stratigraphic and Paleontological Data" of the program "Consolidating Canada's Geoscience Knowledge" of the Earth Science Sector, Natural Resources Canada. We wish to acknowledge the numerous discussions we have had with our colleagues, as well as Dr. Alain Plouffe for critically reviewing this manuscript. The first author has nagged repeatedly some specific individuals, Éric Boisvert of GSC-Québec, Peter Davenport of GSC-Calgary, and Jonathan Matti of the USGS. Thank you all!

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APPENDIX

Roles and responsibilities of the Canadian Geoscience Knowledge Network's Working Group on Surficial Geology.

MANDATE

To provide, through the Internet, coherent visualizations of the nation's surficial geology from the map collections of Canada's geological survey agencies. This will be done from distributed databases maintained by individual agencies that are based on a common data model, including science language, which makes the information from mapping published at different scales and to different standards both interoperable and scalable.

PRINCIPLES

- Each geological map database will remain under the control of the source agency, which would be responsible for maintaining and updating it.
- The Subgroup will cooperate to ensure a stable and robust science language and glossary.
- The Subgroup will communicate regularly with geologists and information managers to ensure that this model addresses concerns and requirements.
- The data model will support both national «standards» for a common CGKN portal, and allow flexibility so that individual agencies can provide information to their own «standards» directly from their web portals.
- The data model should respect the well-established geological principles of geologic time, superposition, and correlation and conventions such as the North American Stratigraphic Code.
- The data model will accommodate both the original geological information from the source maps, and common science language and high-level classifications that would follow international standards and protocols where available.
- Source information, including original citations, must be explicitly linked to all information in the databases.

MEMBERSHIP

All Territorial, Provincial and Federal agencies who are actively involved in the mapping of surficial geology will be represented on the subgroup to guide the development of the data model, its science language, and to populate the geological map databases. Members must be able to effectively communicate the decisions and concerns of the Subgroup to their own organizations and to represent fairly to the Subgroup the views of their organizations. Each Agency will:

- Nominate a member for a period of one year and this individual will:
  a) Have a background in the Earth Sciences
  b) Have published at least one surficial geology map for the agency they represent
  c) Participate in technical teams when needed
  d) Be available to co-chair the subgroup if elected for this role

- Provide their representative with sufficient time and resources to participate on htis subgroup
- Recognize the contribution of the representative in their annual performance appraisal so that participation in this subgroup will not be detrimental to career progression
- Make available, where possible, additional expertise to technical teams struck by this subgroup

CHARGE AND ROLES

1. Overall guidance. The Subgroup specifies the scope of activities for development and implementation of the data model. The Subgroup provides authoritative statements of the model's purpose, its intended use and users, and its relationships with other specifications such as the Canadian Geospatial Data Infrastructure (CGDI), the Open GIS Consortium (OGC), the USGS National Geologic Map Database (NGMDB), and the North American Data Model (NADM) Steering Committee.
2. Coordination of technical teams. The Subgroup identifies functional goals for the data model in sufficient detail that a technical team working towards each goal can accomplish clearly specified tasks within one year. For each

functional goal, the Subgroup will identify the technical need, state the immediate goals of the team, identify people who can work on the team, and facilitate, evaluate, and disseminate the work of the team. Examples of technical teams may include: conceptual data model design; scientific terminology; software tool development; and policy evolution.

3. Publicity and organizational liaison. The Subgroup works to publicize the model and its supporting products in appropriate conventions, meetings, workshops, and publications. The Subgroup provides information on its progress to related groups such as the Bedrock Subgroup (and others through the Data Infrastructure Working Group meetings), the NADM Steering Committee, and the NADM Surficial Science Language Technical Team.
4. Communication and Support. The Steering Committee facilitates public discussion and individual guidance regarding both broad issues and technical details of concern in the data model. These discussions and guidance are supported by technical information exchange at the CGKN web site. Members will actively solicit comments and guidance from the technical experts whose interests they represent to the Committee, and will respond regularly to that constituency.

STEWARDSHIP

Two co-leaders, one representing Federal agencies and the other the Provincial and Territorial agencies will lead the Subgroup. GSC management and the Committee of Provincial Geologists will appoint the co-leaders, respectively. These leaders will act as the Stewards for this data model and will:

- Lead Subgroup meetings
- Work with Subgroup members to develop meeting agendas
- Compile minutes for each Subgroup meeting
- Oversee the work of contracts let by the Subgroup
- Coordinate technical team activities
- Serve as the official point of contact between the Subgroup and the public

FUNDING

Each agency will be responsible for maintaining its own database, including the provision of the necessary computer systems to support it and personnel to populate it. Funding will be sought from national programs such as GeoConnections for support in developing common software and documentation, and to support travel to regular subgroup meetings (two per year). Travel support will also be required so that subgroup members can actively participate in international activities related to data model development, especially science language.

PROJECTS

The subgroup will establish annual and longer-term (3 year) plans to estimate funding requirements from member agencies and from national programs.

COORDINATION

The subgroup will meet via conference call regularly (6-10 times per year), and face-to-face twice annually. The subgroup will submit its annual plan to the CGKN secretariat for approval, and will prepare a written report to the secretariat annually. At least one member of the Data Infrastructure Coordination subgroup will be a member of the surficial subgroup.

TECHNICAL TEAMS

Technical teams are formed by the Subgroup to develop: detailed functional specifications of the data model; software tools and test-data meeting the specifications; and standard scientific terminology. The work of the technical teams will be defined specifically enough that the tasks can be accomplished within one year. This requirement is meant to allow the membership of technical teams to vary from year to year as needed by the teams and by the organizations that employ the team members. Technical team members are specialists in scientific or technological disciplines, and usually the work of the team falls within the member's professional responsibilities.