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See table of contents

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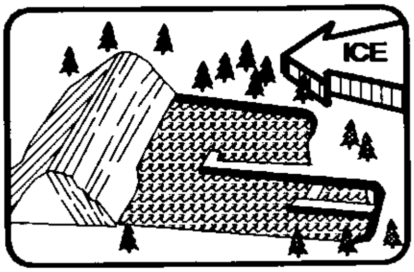

Metallic Mineral Exploration on the Interior Platform: Quaternary Contribution

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Introduction

Knowledge of the Quaternary geology and history of a particular target area can help maximize the return from mineral exploration on the Interior Platform. The purpose of this paper is to provide brief background information for an individual or company considering starting mineral exploration in this region, and to provide direction to additional sources of information. This is an overview rather than a comprehensive document dealing with all aspects of the Quaternary geology. Outlined herein are sources of pre-existing data; geologic setting, Quaternary deposits; and suggested approaches to different types of exploration situations/targets. The assumption is that the reader has some experience with drift prospecting in Canada and is familiar with the variety of glaciogenic deposits of importance to mineral exploration in glaciated terrain.

The boundaries of the Interior Platform are essentially those of the Interior Plains: the Canadian Shield to the east and northeast, the Cordillera to the west, and the Arctic Platform (Arctic Lowlands) to the north (Bostock, 1970a, b). This paper focusses on that portion of the Interior Plains lying between the border with the United States and the 60th parallel. Most of the region is a flat to gently, rolling plain traversed by broad shallow depressions and narrow incised valleys, and punctuated by scattered groups of low hills or uplands. The Quaternary deposits mantling the Interior Platform differ in a number of respects from those present on the Canadian Shield. The former are generally much thicker; overlie poorly consolidated bedrock composed of mainly sandstone, mudstone and shale; and form some types of terrain rare or absent on the Shield.

Data Types and Sources

Pre-existing. There are a number of data types and data sources available to the mineral explorationist. Data types include air photographs, maps, and borehole lithologs and geophysical logs. Types of data are generally consistent within all three provinces but the exact sources of data will vary between provinces and occasionally with time as responsibility for certain data files is transferred from one government department to another.

Air Photographs. These are very useful in identifying terrain types, particularly in the treeless portions of the Interior Plains. Conventional black and white panchromatic air photographs together with other types of remote sensing data are available from outlets in each province and from Ottawa for photography flown by the Federal Government (Department of Energy, Mines and Resources). The entire Interior Plains have been photographed and the scales are commonly between 1:20,000 and 1:80,000, although other scales are available for some areas. Information on the sources of these photos can be obtained from the provincial agencies responsible for air photographs and the Surveys, Mapping and Remote Sensing Sector, Department of Energy, Mines and Resources, Ottawa. A number of private companies can also both fly and interpret air photos and other remote sensing data.

Maps. In addition to topographic maps, three types of maps are of importance to mineral exploration in glaciated terrain: surficial geology, bedrock topography and drift thickness maps. The coverage by each of these map types is incomplete for the Interior Plains, however, and the map scale can vary from region to region. Surficial geology maps have been published at scales varying from 1:1,000,000 to 1:25,000, but most of the large scale maps cover only a small portion of the Plains. Reconnaissance scale (1:250,000) surficial geology maps are available for all of Manitoba and most of Saskatchewan, but only the southern two-thirds and northeastern portion of Alberta. Coverage of bedrock topography and drift thickness maps is less complete.

Subsurface. Through a combination of petroleum and water well exploration, there have been many hundreds of thousands of test holes drilled on the Interior Platform. All of the petroleum test holes and some of those drilled for ground water and coal are logged geophysically. These logs may include natural gamma, focussed electric, caliper, density (gamma-gamma), sonic (interval transit time), neutron, dipmeter (3 pad microresistivity), and strength index (synthetic log from sonic and density data). Geophysical logs are the main tool used in correlating bedrock units. Both the lithologs and geophysical logs from many of these test holes are available through provincial agencies and private industry.

Sources. There are a number of sources for each particular type of data. The following are four key ones to allow the explorationist to begin gathering data for a particular target area.

1. Alberta Research Council,
   Terrain Sciences Department and
   Alberta Geological Survey Department
   Box 8330, Station F
   Edmonton, Alberta T6H 5X2.
2. Geological Survey of Canada
   Geophysical Surveys
   Hazards and Terrain Sciences Branch
   601 Booth Street
   Ottawa, Ontario K1A 0E8.
3. Manitoba Energy and Mines
   Geological Services
   535 – 330 Graham Avenue
   Winnipeg, Manitoba R3C 4E3.
4. Saskatchewan Research Council
   Sedimentary Resources Program
   15 Innovation Blvd.
   Saskatoon, Saskatchewan S7N 2X8.

New Data. There are a variety of data types and acquisition methods commonly used on the Interior Platform. These include air photo interpretation, surface geophysics, drilling and downhole geophysics. Air photo interpretation is the least expensive method of obtaining information on the surficial geology, and is particularly effective within the treeless portions of the Platform. Surface geophysics, including both seismic and electrical methods, has been found effective for both deep petroleum exploration and shallow (0-70 m) plains coal exploration (Green *et al.*, 1988). Traditionally, subsurface data is collected from the bedrock by a combination of rotary drilling and rotary coring with all of the holes being logged geophysically. Data on the Quaternary sediments is usually collected by either dry auger drilling or rotary drilling, and, at some sites, rotary coring. At some sites, hollow stem augers have been used to allow collection of oriented A-casing samples (Fenton *et al.*, 1987). The rotary holes are logged geophysically.

Geological Setting and Quaternary History

Bedrock Geology. The Interior Plains are underlain by nearly flatlying sedimentary rocks which consist largely of a narrow belt of Paleozoic carbonates which subcrop along the edge of the Shield, poorly consolidated sandstones of late Cretaceous and Early Tertiary age subcropping along its western margin, and Cretaceous shales in the central area (Green, 1972; Whitaker and Pearson, 1972; Manitoba Mineral Resources Division, 1979).

Pre-glacial Setting. By late Tertiary time, a system of generally eastward-flowing streams had been established. Pre-glacial topography consisted of northeast-trending valleys separated by broad uplands. Tertiary sediment deposited by these streams consist predominantly of quartz sand and gravels dominated by pebbles of resistant quartzite, argillite, and chert derived from the Cordillera or reworked from older Tertiary and Cretaceous deposits. The Interior Platform is essentially covered by Quaternary-aged sediment that in most places masks, or nearly masks, the pre-glacial topography.

Quaternary History. Quaternary history of the Canadian prairies was reviewed by Fenton (1984). Prior to glaciation, the prairies consisted of broad, northeast-trending valleys separated by low uplands. During each ice advance this drainage was dammed by the upslope advancing Laurentide glacier, such that lakes developed in the valleys and depressions, and drainage was diverted to the south. Material from the Precambrian Shield and adjacent fringe of Paleozoic carbonates was transported southward and westward, sometimes as far as southwestern Alberta. During the ice front retreat, ice marginal lakes developed as the ice front retreated downslope. Steep-walled valleys were cut where meltwater flowed from one lake basin to the next, where flow was channelled southward along the ice margin, and where drainage was re-established in drift-filled segments of pre-glacial valleys. The drainage during non-glacial time roughly followed pre-glacial valleys, but in places was diverted from one valley system to another through trenches cut by meltwater. In many places, meltwater streams flowed on a thick fill of drift left behind by the retreating ice. Stream deposits laid down during non-glacial periods consisted, in part, of sands and gravels containing resistant pebbles similar to those deposited during pre-glacial times, but also included important and distinctive admixtures of material from the Shield and the Paleozoic carbonates. Repeated glacial and non-glacial intervals produced a complex of valley fills of different ages. Major Holocene rivers have cut new valleys in this complex of Quaternary sediments.

Four major glacial advances, with the ice flowing at least as far as southwestern Saskatchewan, have been recorded over the last 2 million years. The record is incomplete, however, with large intervals of time for which there is currently no identifiable sedimentary record. The Late Wisconsinan advance terminated just east of the Rocky Mountains and extended into Montana and North Dakota.

Explorationists should remember that although the ice advanced generally westward and southwestward across the plains, during each glaciation, the direction and source of the flow varied through time. Also, the waning phase of the glaciation, the retreat, is characterized by the development of a number of comparatively small lobes that responded to local flow direction. Retreat was generally a cycle of stagnation of a broad band of ice along the lobe margin, followed by a minor re-advance that overrides some of the stagnant ice (*e.g.*, Dyke and Prest, 1987b; Fenton *et al.*, 1983; Prest, 1969).

Additional information can be found in Christiansen (1979), Clayton and Moran (1982), Dyke and Prest (1987a), Klassen and Vreeken (1987), Prest (1984), Rutter (1984), Shetsen (1980), Stalker (1976, 1977), Teller and Fenton (1980) and Teller and Clayton (1983).

Quaternary Deposits

Drift Thickness. The thickness of Quaternary sediment is highly variable throughout the Interior Platform. Thickness of glacial and non-glacial sediment can vary from essentially zero to at least 300 m, with the thinnest cover on the broad interfluve areas and the thickest sediment lying within the pre-glacial channels or in the areas of intensive glacial tectonism. The glacial diamicton (till) can also be expected to be thicker in areas of stagnant ice deposits, and in areas of ice marginal stillstands.

Sediment Types. Quaternary sediment covering the Interior Platform is of glacial, fluvial, lacustrine, eolian and organic origin. The major proportion of this sediment is diamicton deposited either directly or indirectly by glaciers. One of the most noticeable properties of this sediment is the presence of Precambrian Shield and Paleozoic clasts glacially transported from the east. This is likely to be the unit of most concern to the explorationist implementing a drift prospecting program. The diamicton can be subdivided into a number of units or facies which can be recognized by their properties (*e.g.*, Proudfoot, 1985). A description or discussion of glacial facies is beyond the scope of this paper.

Stratigraphy. Fenton (1984) reviewed the extensive evidence for at least four major glaciations that advanced across the Interior Plains. Deposition during these advances, the minor re-advances during glacial retreat, and the lacustrine and fluvial processes active during both the glacial and non-glacial events have resulted, in many areas, in a complex stratigraphy composed of both glacial diamicton and non-glacial stratified sediment. The till units can be identified and traced or correlated over extensive areas, both on the surface and in the subsurface, on the basis of properties such as texture, mineralogy and geophysical log signature (*e.g.*, Andriashek and Fenton, *in prep.*; Christiansen, 1968a, b; Klassen, 1979; Shetsen, 1984). These properties also can provide data necessary for an understanding of the source and transport direction of the glacier that deposited the units. Within a particular exploration area, the Quaternary stratigraphy may be simple or complex, or vary areally from a layer of till or gravel less than a metre thick overlying bedrock highs, to a sequence of interbedded tills and lacustrine and/or fluvial sediment within pre-glacial channels.

Terrain Types. The Interior Plains are composed of a variety of terrain types of which about 70% are of glacial origin and 20% of lacustrine origin. The glacial terrain can be divided into a number of terrain types including some that are poorly developed in other glaciated portions of North America. All of these types can be recognized on air photographs; some easily, others with less certainty. Each type is characterized by certain sediment types. A simple subdivision of glacial terrains to be expected on the Interior Platform is shown in Table 1. Other examples are Prest (1970) and Clayton *et al.* (1980a, b). Although a discussion of terrain types is beyond the scope of this paper, some comments on deformation terrain are appropriate. Being absent from the Shield, this terrain type is most likely new to an explorationist moving operations onto the Interior Platform. More importantly, the sediment forming this unit is always highly variable and failure to recognize it could have serious ramifications for drift prospecting and associated stratigraphic studies.

Deformation terrain, or glaciotectonic terrain, consists of masses of pre-existing sediment, bedrock and/or drift, that have been transported more or less intact by glaciers (Figure 1). Also included, where present, are the associated depressions up-glacier of the thrust features. Glaciotectonic features are widespread having been recognized in Alberta, Saskatchewan, Manitoba, North Dakota, Minnesota, and South Dakota (Andriashek and Fenton, *in prep.*; Bluemle and Clayton, 1984; Byers, 1960; Christiansen and Whitaker, 1976; Fenton, 1987 a,b; Fenton *et al.*, 1986; Hopkins, 1923; Kupsch, 1962; Moran, 1971; Moran *et al.*, 1980; Slater, 1926, 1927). Morphologically, the terrain can consist of a single hill or ridge situated down-glacier of a source depression or a series of smaller hills, called rubble terrain, extending down-glacier from a broad source depression. Large-scale folding or faulting may be present. The sediment is always crushed and the original stratigraphy disrupted. Syngenetic till or diamicton may be included,

Table 1 Examples of major glacial terrain types

Major Terrain Type	Sediment Type
Streamlined terrain	Basal till and/or pre-existing sediment
Hummocky stagnant ice terrain	Superglacial minor basal sediment
Deformation terrain	Sub-glacial drift and bedrock
Palimpsest terrain	Basal-superglacial sediment
Low relief terrain	Variety basal-superglacial sediment

particularly in the rubble terrain. Overall the thrusting increases markedly the lithologic variability of the sediment.

This terrain can be recognized using air photographs, where the morphologic expression has not been removed or buried by subsequent glacial action; surface geophysical and downhole geophysical techniques; and drilling (Fenton *et al.*, 1986; Sartorelli *et al.*, 1986; Green *et al.*, 1986).

Post-Glacial Effects. Major post-glacial effects likely to be of concern to the mineral explorationist centre around the erosion and redeposition of Quaternary sediment. In hummocky moraine areas, for example, there has often been transport of the finer fraction of the till into the low areas, resulting in a concentration of coarse sediment near the tops of the hills. Within the grasslands forming the southern and central portions of the Plains, the pedoclimatic conditions have been and still are very different from those within the Boreal forest of the Shield. This could have a significant effect on the mobility and deposition of metallic elements within and below the soil profile. Accordingly, geochemical sampling procedures designed for use on the Shield may not be directly transferable to grassland areas of the Interior Platform.

Drift Prospecting: Status

A search of geological data bases, such as GeoRef and GeoDial, together with the author's own experience, and consultation with colleagues at the Saskatchewan Research Council, Manitoba Mines Branch and Geological Survey of Canada, reveals an almost total lack of publications dealing with drift prospecting on the Interior Plains. The comprehensive review and summary papers by Coker and DiLabio *(in prep.)* and DiLabio *(in press)* provide information on the areas of the adjacent Shield, but do not record any publications on the Plains. One paper by Nielsen *(in prep.)* focusses on the Manitoba Lowlands and is the only paper the author was able to locate.

This lack of information is both important and encouraging to the explorationist because it clearly demonstrates the untried potential of the Interior Platform for mineral exploration and development.

Exploration Strategy: Some Comments

The following are some comments intended to help mineral explorationists implement plans for drift prospecting programs on the Interior Platform.

As noted above, there is great variety within the Quaternary sediments mantling the Platform, and thus a single exploration strategy is not likely to be applicable throughout this area. An understanding of both the Quaternary stratigraphy and the glacial terrain types present in a prospective area is needed to obtain the maximum return from exploration budgets.

Two basic exploration strategies are suggested — one for areas where the Quaternary sediment is thin, and the other for areas of thick sediment.

Thin Drift. Likely only one till sheet will be present. Topography will reflect that of the underlying bedrock. The glacial sediment exposed on the surface usually will reflect the underlying bedrock up-glacier from the sample sites. Air photos should allow the identification of the glaciogenic units most suitable for sampling according to normal drift prospecting procedures. Deformation terrain is generally, although not always, detectable on air photos by its morphologic signature.

Thick Drift. These include areas such as those overlying buried channels. Here the stratigraphy is more complex, and acquisition of exploration data will be more expensive. Surface till will reflect more distant source areas, as it is insulated from the bedrock by the thick sequence of sediment. Air photo interpretation will not yield as much glaciogenetic information directly applicable to exploration. The technique can, however, identify areas of major glaciotectonism.

Glaciotectonic terrain may provide data on the local subsurface stratigraphy. The thrust masses will include sediment from the underlying strata and, if the thrust is deep enough, samples of the bedrock. The depression up-glacier from a thrust mass may serve as a window into the underlying stratigraphy. It will often have thinner drift cover than the surrounding terrain and in some places the bedrock itself may be exposed.

If a prospective target area overlies a preglacial channel, the lowest sediments will likely be pre-glacial fluvial deposits reflecting a Cordilleran and Plains bedrock source upstream, that is, generally a source westward of the drill site. If an interglacial channel is intersected, the fluvial sediments likely will reflect their Mesozoic, Paleozoic and Precambrian bedrock source. In either situation, the lithology and texture of the lowest till will tend to reflect the composition of the underlying channel sediments. Also, the character of the till can change from one channel system to a second, reflecting the different sediment composition in that channel.

Drilling, downhole logging, and surface geophysics are the main techniques applicable to thick drift areas. Drilling likely will be the only means of sampling the lowest diamicton and the underlying bedrock.

Conclusions

The Interior Platform has been covered by a number of glacial advances which resulted in the deposition of a variety of materials including till. These till layers have been correlated over many thousands of square kilometres in some regions. Accordingly, a proper evaluation of any proposed mineral exploration target area must include knowledge of the surficial geology, drift thickness and the bedrock topography and geology. Knowledge of the types and origin of glaciogenic units is essential to developing a surface sampling program. Recognition of deformation terrain is important, as sediment composition will be highly variable and likely will contrast the glacial sediment of the surrounding terrain.

Target areas of thin drift are generally characterized by till that reflects the composition of the bedrock up-glacier from the sample site. Thick drift areas will require deeper sampling. In these areas, the lower till may best reflect the composition of the bedrock and the channel sediments over which the glacier passed.

The lack of published data on drift prospecting clearly demonstrates the untried potential of the Interior Platform. Knowledge of Quaternary geology and history is essential to help maximize the return from mineral exploration and development in this region.

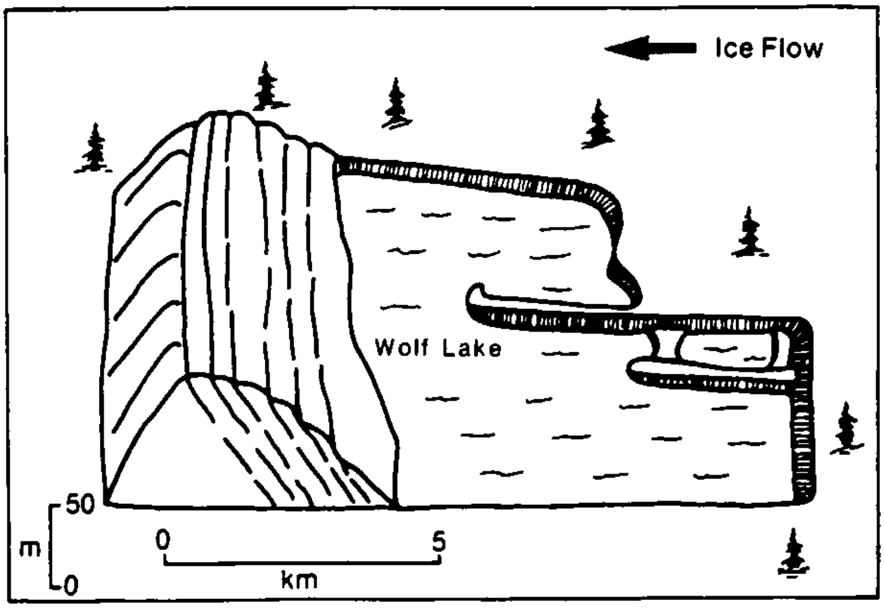

Figure 1 *Sketch of the Wolf Lake thrust (Tp. 66, Rg. 6W4); Sand River map sheet, east-central Alberta.*

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