Drift Composition and Surficial Geology of the Trutch Map Area (94G), Northeastern British Columbia

Geological Survey of Canada Open File D3815

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Contents

To view glacial limits point data in SurView see "Frequently Asked Questions (how do I pick a point?"

ABSTRACT

This report describes the geochemistry and sedimentological characteristics of glacial deposits collected during mapping the surficial geology of Trutch map sheet (94G), northeastern British Columbia. The work is partially funded by the Geological Survey of Canada's National Geoscience Mapping Program (NATMAP), and is part of a multidisciplinary project including bedrock and subsurface mapping (Lane et al., 1999). The study area straddles the Rocky Mountains, Foothills and Alberta plateau a northwestern extension of the Great Plains, and is currently the focus of intensive hydrocarbon exploration and development. Major gas reservoirs have been found in Triassic strata within and adjacent the eastern Foothills and active exploration is targeting Devonian strata in the western Foothills.

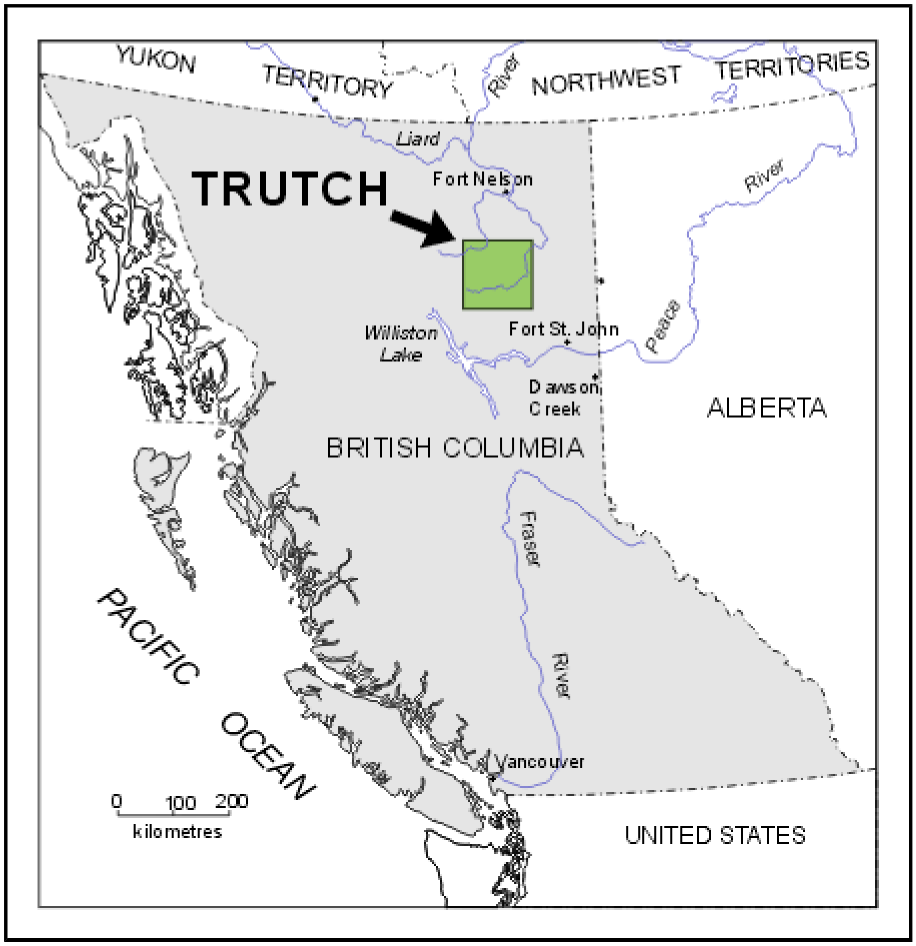
The surficial materials sampling program was designed to characterize the regional till cover and to identify possible anomalies related to mineralization and glacial transport of heavy mineral indicators. This report compliments a 1: 250 000 scale map of the surficial geology of Trutch (Bednarski 2000). An overview of the Quaternary history of the area is given by Bednarski (1999). The mapping procedure consisted of airphoto interpretation of surficial materials followed by ground verification using helicopter, truck and foot traverses during the summers of 1998, 1999 and 2000. One hundred and sixty-five bulk samples of surficial materials were analyzed for grain size, carbon content and a suite of elements. The surficial materials were extracted from shallow pits, natural exposures and road cuts, providing an average density of one sample per 80 km^2. Element concentrations were measured by INAA (Instrumental Neutron Activation Analysis) in the silt and clay fractions. Anomalies were identified and statistically derived contour maps describe the spatial distribution of elements in the surficial materials. Cluster analysis was used to identify tills of montane versus continental provenance. The heavy minerals were counted in 48 samples. All results are presented as interactive Surview maps (Grant, 1999) and html documents on this CD-ROM.

INTRODUCTION

This report describes some of the results of the **Central Foreland NATMAP Project** , a multidisciplinary study of surficial, bedrock and subsurface mapping, covering parts of northeastern British Columbia and the southern Territories (Lane et al., 1999). Specifically, this report deals with the

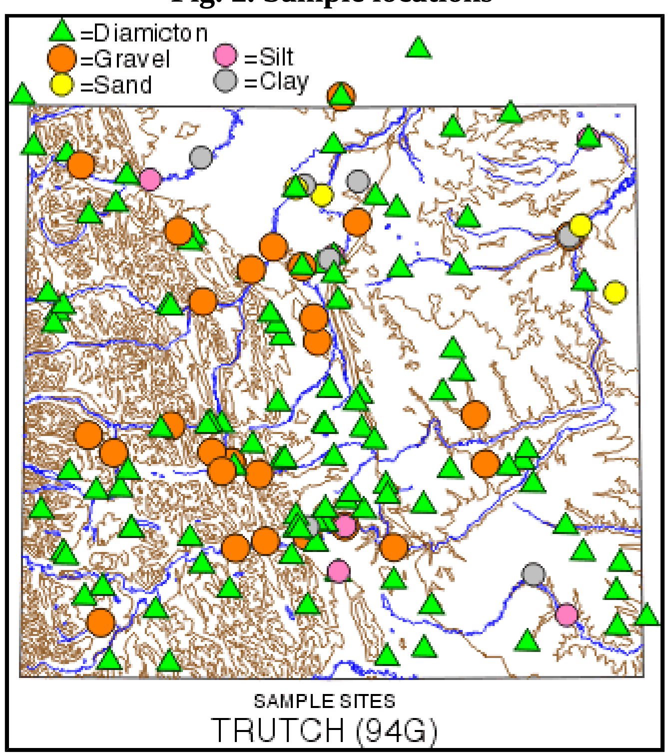
Fig. 1. Location of Trutch (94G)

geochemistry and sedimentological characteristics of glacial deposits found in the Trutch (94G) map area, northeastern British Columbia (Fig. 1). The study area straddles the Rocky Mountains, foothills and great plains, and is currently the focus of intensive hydrocarbon exploration and development. Partial funding for this project was provided by the Geological Survey of Canada's National Geoscience Mapping Program (NATMAP).



The mapping procedure consisted of interpretation of aerial photographs and ground verification by helicopter, truck and foot traverses undertaken during the 1998, 1999 and 2000 field seasons. Till and other surficial materials were extracted from shallow pits, natural exposures and road cuts providing an average density of one sample per 80 km² (Fig. 2). This report compliments a 1: 250 000 scale map of the surficial geology of Trutch (Bednarski, 2000). An overview of the Quaternary history of the area given by Bednarski (1999).

Fig. 2. Sample locations



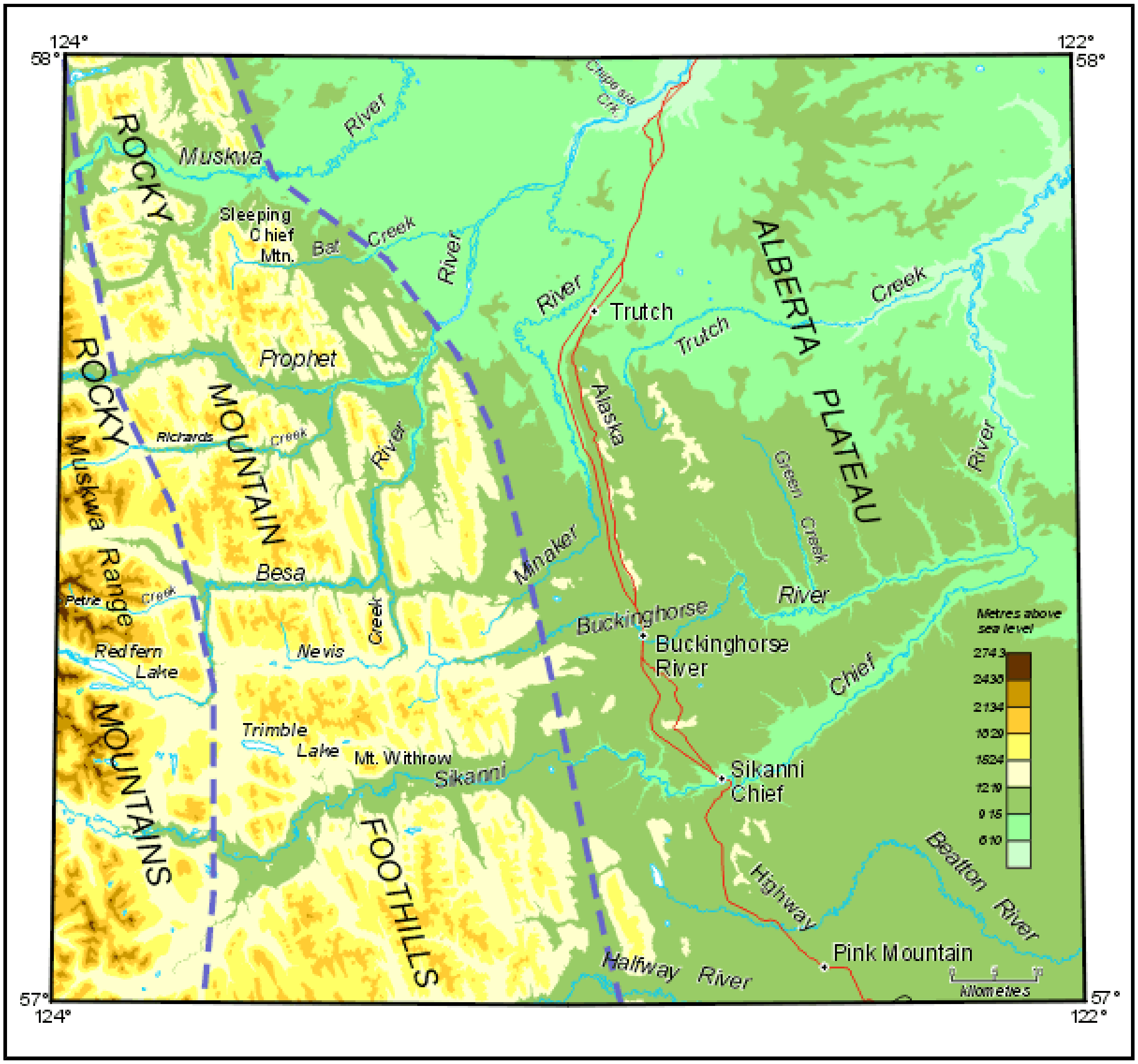
The surficial materials sampling program was designed to characterize the regional till cover and to identify possible anomalies related to mineralization and glacial transport of heavy mineral indicators. The working hypothesis developed during the course of mapping was that surficial deposits derived from three glacial sources influenced the study area. The mountainous region in the west was dominated by Cordilleran and local alpine ice, whereas the east was dominated by continental Laurentide ice. A zone along the mountain front was complicated by the interaction of mountain and continental ice.

Surficial materials, comprising 165 bulk samples of till, glaciofluvial gravel, and lacustrine fines (Fig. 2) were analyzed for grain size, carbon content and a suite of elements. The concentrations of 34 elements were measured by INAA (Instrumental Neutron Activation Analysis) in the combined silt and clay fractions (<0.063 mm). Attempts are made to identify anomalous concentrations and statistically derived contour maps describe the spatial distribution of elements in the surficial materials. Cluster analysis was used in an attempt to group the glacial deposits. Heavy minerals were counted for 45 samples and compared to the drift geochemistry.

PHYSIOGRAPHIC SETTING AND GENERAL GEOLOGY

The study area includes the Rocky Mountains, Rocky Mountain Foothills and Interior Plains physiographic provinces (Fig. 3). The Muskwa Range, trending along the western edge of the map area, approaches 2800 m in elevation. This contrasts with the dissected rolling plains of the Alberta Plateau, part of the interior plains comprising the eastern half of the map sheet, averaging less than 900 m asl. The eastern edge of the Muskwa Range defines the easternmost fault where Paleozoic rocks, as old as the Cambrian, are thrust over folded Triassic units comprising the Rocky Mountain Foothills (Holland 1964). Bedrock exposures vary from Ordovician and Devonian carbonates in the Rocky Mountains, to Devonian and Cretaceous clastic and carbonate successions in the Foothills. The Alberta Plateau is underlain by thick sequences of sandstone and shale of Cretaceous age that are flat lying or dip gently eastward, except for a folded belt immediately east of the foothills.

Fig. 3. Physiography and place names

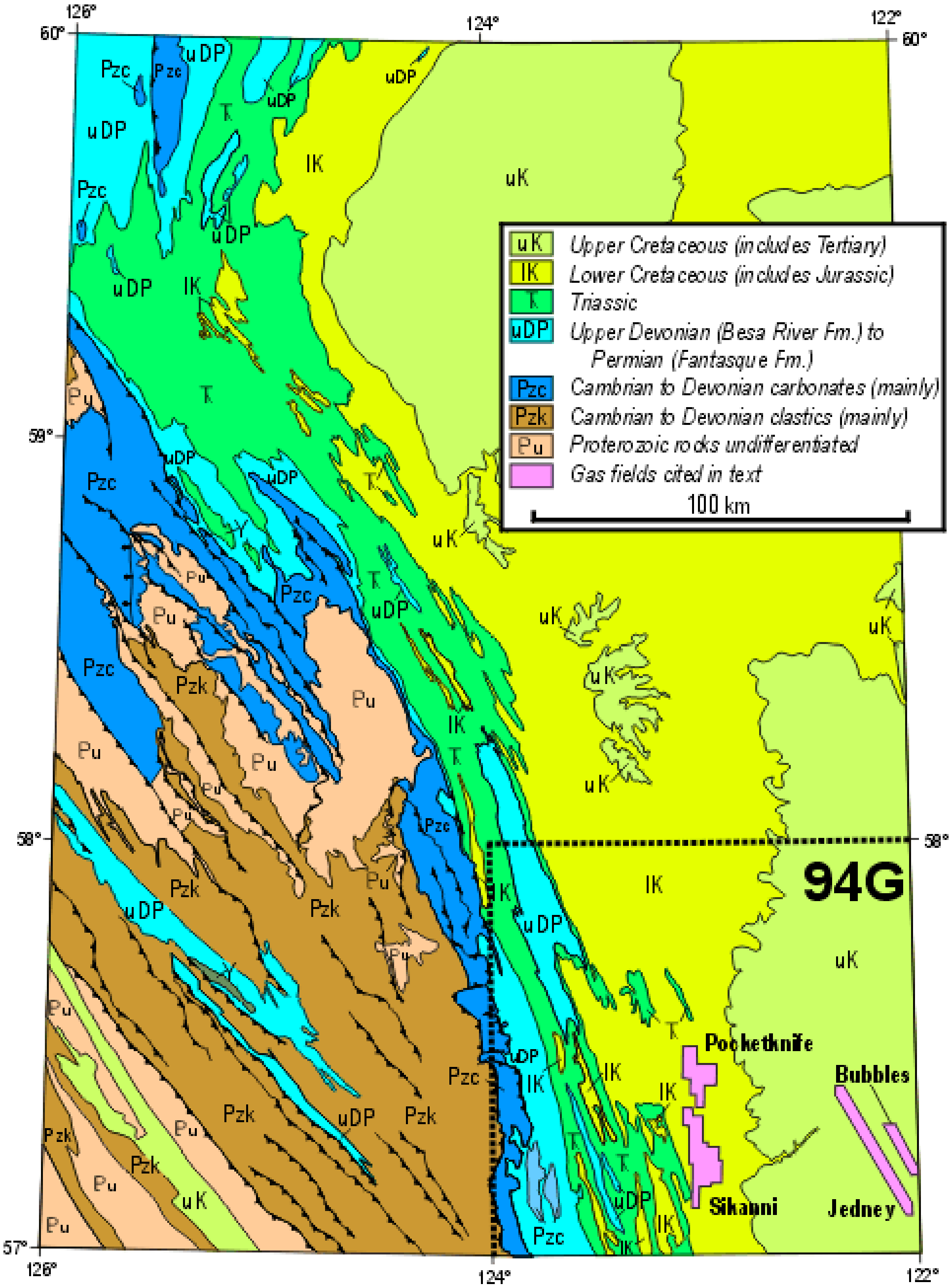


Thirty-six mineral occurrences are listed in the Trutch map area the Geological Survey Branch, Energy and Minerals Division of British Columbia MINFILE database. An abridged version of this database can be viewed with Surview on this CD. Note that a number of these showings are found in drill core, deep below the surface, and have no bearing on the surficial materials. Most of the mineral occurrences in the map area are found in the west associated with the underlying carbonates. These rocks were deposited along the continental shelf of ancestral North America as platformal reefs and turbidites. The Robb Lake Mississippi Valley-type Pb-Zn deposit is located within Paleozoic rocks immediately adjacent the southwest corner of the map area (Nelson et al., 1999a & b, Paradis et al., 1999). Within the map area, lead-zinc deposits are hosted within the Middle Devonian Dunedin Formation, Middle to Lower Devonian Stone Formation, and the Silurian Nonda Formation. Mississippi Valley-type lead-zinc deposits are found around the Redfern Lake area and lead-zinc-copper deposits are found in the Richards Creek area. Significant amounts of germanium within brick-red sphalerite are also found north of Richards Creek. The Besa River Formation, a Devonian to Carboniferous transgressive shale, hosts massive barite deposits near Petrie Creek. Other mineral occurrences include phosphate-bearing strata in Mesozoic to Paleozoic rocks underlying the Rocky Mountain Foothills and native sulphur and coal within Cretaceous sediments underlying Alberta Plateau.

Major gas reservoirs have been found in the eastern Foothills in Triassic strata and in Carboniferous Debolt Formation (e.g. Bubbles and Jedney fields, and Sikanni and Pocketknife fields, respectively, Fig. 4). Active exploration is targeting Devonian strata in the western Foothills.

Longitudinal fold and fault controlled valleys trending northwest characterize the mountains and foothills. The transition from foothills to the plains is abrupt although elements of the northwest trending structural trend are still evident in the western plains. Generally, the mountainous western part has been extensively modified by alpine glaciers and the intensity of glacial erosion decreases eastward across the foothills. The highest peaks in the southwest currently harbor small glaciers in north-facing cirques. Large east-trending valleys crosscut the longitudinal valleys through the foothills every 15 to 25 kilometres where major rivers such as the Muskwa, Prophet, Sikanni Chief, and Halfway flow eastward onto the Alberta Plateau from headwaters in the Rocky Mountains. It is evident that the rivers and creeks have experienced several phases of stream piracy because many of the upper tributaries change direction several times, as they exploit the crosscutting pattern of the valley systems.

Fig. 4. Regional bedrock geology of Northeastern British Columbia (after Lane et al. 1999).



Both the eastern foothills and Alberta Plateau bear remnants of several eastward-dipping erosional surfaces. The oldest surface may be Miocene in age (Williams 1944), however, there has been only one reported occurrence of preglacial gravel, located north of the Sikanni Chief River near the Alaska highway (Denny 1952). These deposits could not be confirmed in this study, but an isolated diamicton underlying Laurentide till near the Sikanni Chief River may be preglacial in age (see below). Oxidized basal gravels of unknown age are exposed along incised rivers on the the Alberta Plateau (see below). Larger deposits of preglacial gravels lie southeast of Trutch in the Charlie Lake area (Mathews 1978). On the plains, the drainage swings to the northeast, into the Liard River system, part of the Mackenzie River drainage basin. The topography is characterized by low plateaus and cuestas dissected by the major rivers (Fig. 3). Resistant sandstone units of the upper Cretaceous Dunvegan Formation form prominent cliffs, whereas, most low areas and major valley bottoms are underlain by recessive shales of the Fort St. John Group. In the extreme northeast part of map area, erosion by the Muskwa, Prophet and Sikanni Chief rivers formed the Fort Nelson Lowland, very flat, poorly-drained muskeg terrain that is less than 600 metres above sea level.

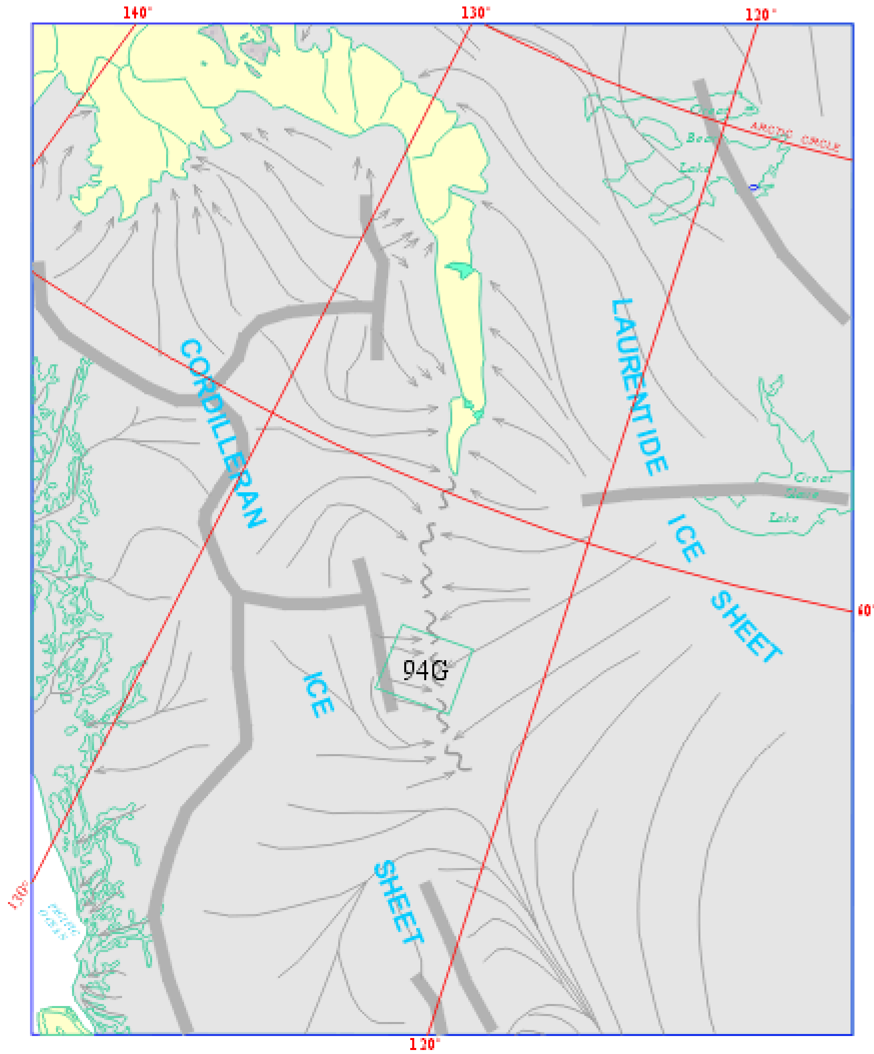
SURFICIAL GEOLOGY AND GLACIAL HISTORY

The major surficial deposits in the Trutch map area are closely related to the history of past glaciations. Three styles of glaciation affected northeastern British Columbia. First, the plains and parts of the foothills were glaciated by the continental Laurentide Ice Sheet, which originated east of Hudson Bay and deposited crystalline erratics from the Canadian Shield. Some of these erratics originate from the Great Bear Batholith, which crops out at least 600 km to the northeast (Hoffman and McGlynn 1977). Secondly, local glaciation occurred when coalescent montane ice, originating from numerous cirques and ice fields in the Rocky Mountains and foothills, flowed down trunk valleys, reaching the mountain front. The third style of glaciation was by Cordilleran ice, which originated in the interior of British Columbia west of the Rocky Mountain Trench and flowed eastward across the topographic trend of the mountains onto the plains (Mathews 1978, 1980). Each of the glacial systems had distinctive source areas that can be identified by ice flow patterns and diagnostic erratics (Figs. 5, 6; also see the Surview surficial geology map on this CD-ROM). Nevertheless, there has been some disagreement about the spatial and temporal interaction of these three glacial systems (cf. Bobrowsky and Rutter 1992).

Fig. 5. The last glacial maximum in northwestern Canada. Major flow lines are indicated by the arrows. The thick lines show probable ice divides. (after Dyke and Prest, 1987)

The Alberta Plateau is covered by various thicknesses of till containing shield erratics deposited by the Laurentide Ice Sheet during the last glaciation. Most of the Plateau is sparsely covered by till, although Hage (1944), reported glacial drift tens of metres thick along the Prophet River. More commonly, Dunvegan Formation sandstone outcrops on the Plateau uplands, but thicker till is found in lowlands and to the west near the mountain front. Hage (1944) described glacial drift up to 222 metres thick from well data near Fort Nelson town site. The predominant flow direction by the Laurentide Ice Sheet over the Alberta Plateau is shown by southwest oriented flutings on the east side of the map area.

The Laurentide Ice Sheet did not leave moraines marking its advance or retreat to the mountain front, however, meltwater drainage was blocked to the northeast by the ice sheet and many channels and spillways were cut. Consequently, extensive glaciolacustrine sediments were deposited throughout the lowlands and valleys. Today, many valleys have very flat bottoms filled with glaciolacustrine sediments. Near the Alaska Highway, the

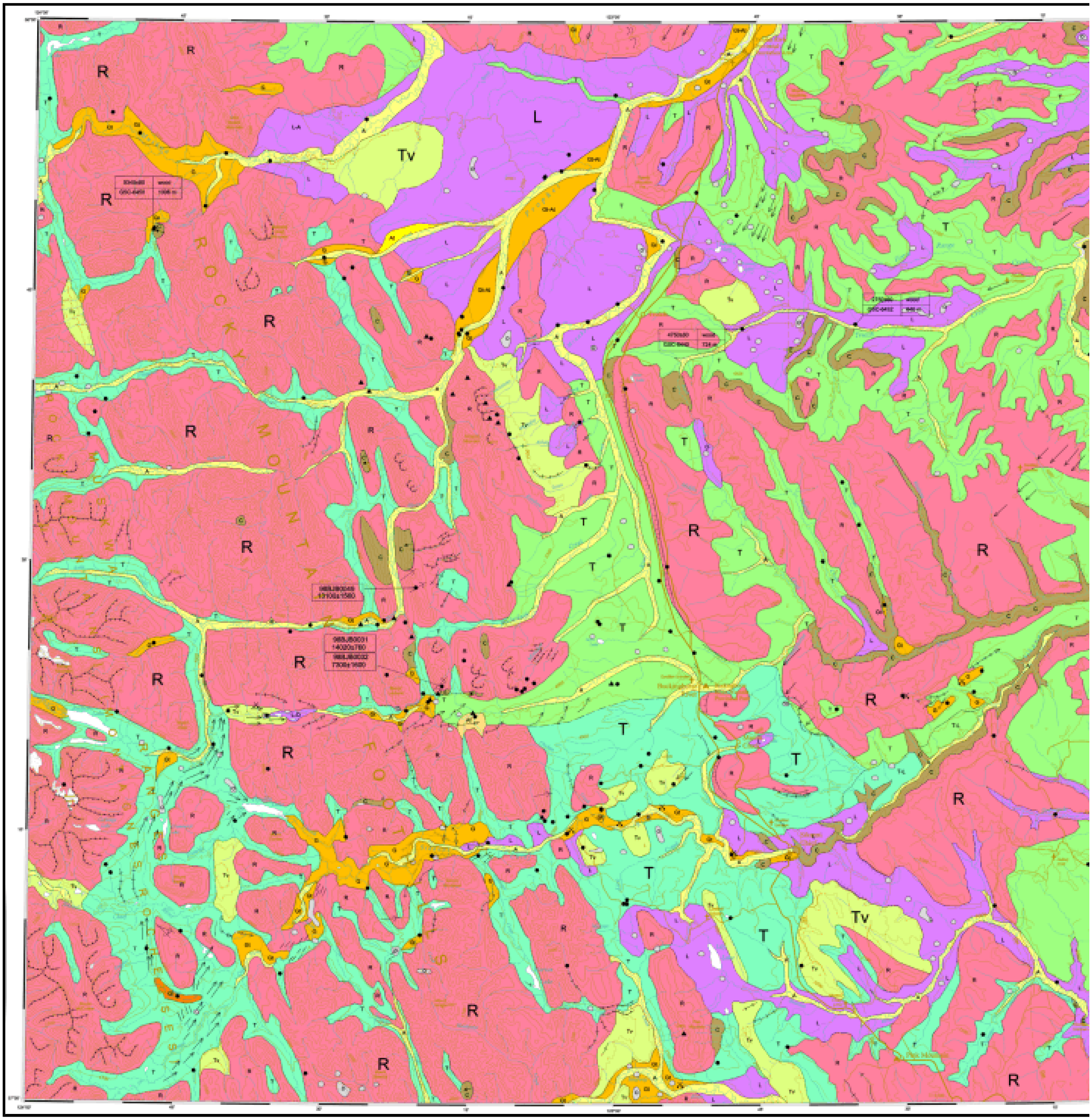


Sikanni Chief River is deeply incised, and exposes up to 15 metres of bedded clay overlain by gravels. Similar thicknesses of glaciolacustrine deposits were reported along the Beatton, Halfway, Minaker and Prophet River valleys (Hage 1944; Denny 1952). Varved silts were found near the surface along the mountain front in the Muskwa River drainage. Hage (1944) described at least 100 varves in the Beatton River valley. Denny (1952) reported varves along the Alaska Highway near the Sikanni Chief and Prophet rivers.

Large areas of glaciolacustrine sediment form the uppermost surficial unit and probably date from recession of the Laurentide Ice Sheet. Nevertheless, the stratigraphic relationship of some glaciolacustrine exposures outside the mountain front may be more complicated. Hage (1944) noted that lake deposits exposed along the Halfway and Minaker rivers, and for 160 kilometres south of Fort Nelson in the Prophet River valley, all rest on montane till. This was not confirmed by this study, however, the same stratigraphic relationship was found within several valleys in the foothills. Sections along upper Sikanni Chief River typically show this sequence (Figs.3, 8). Outside the mountain front, glaciolacustrine deposits are usually found overlying continental till. When the Laurentide Ice Sheet retreated from the foothills, the highland between the Buckinghorse and Sikanni Chief rivers became a drainage divide separating meltwaters draining northward to the Liard River system (Lemmen et al. 1994), from meltwaters draining southward to glacial Lake Peace (Mathews, 1980).

The extent of the Laurentide Ice Sheet during the last glaciation can be inferred from the westernmost extent of surface till containing abundant shield erratics. The ice sheet reached the mountain front and was thick enough to overtop some of the mountains, as indicated by shield erratics deposited up to 1588 m asl. The westernmost extent of the Laurentide Ice Sheet was probably inhibited by the presence of the Cordilleran Ice Sheet. East of the mountain front, the relative abundance of shield erratics varies along the Alaska Highway. Pink granite and gneiss pebbles and boulders are abundant in till north of the Buckinghorse River, but are uncommon from Pink Mountain to Sikanni Chief. This boundary at the Buckinghorse River coincides with the westernmost extension of Laurentide till into the mountain front (Fig. 6).

Fig. 6. Surficial geology of Trutch map area. Lacustrine deposits (L) in purple, Laurentide till T, and (
till T in the west (also see the Legend)) Facsimile of 1: 250 000 scale Trutch surficial geology map (G
Survey of Canada Open File 3885)).

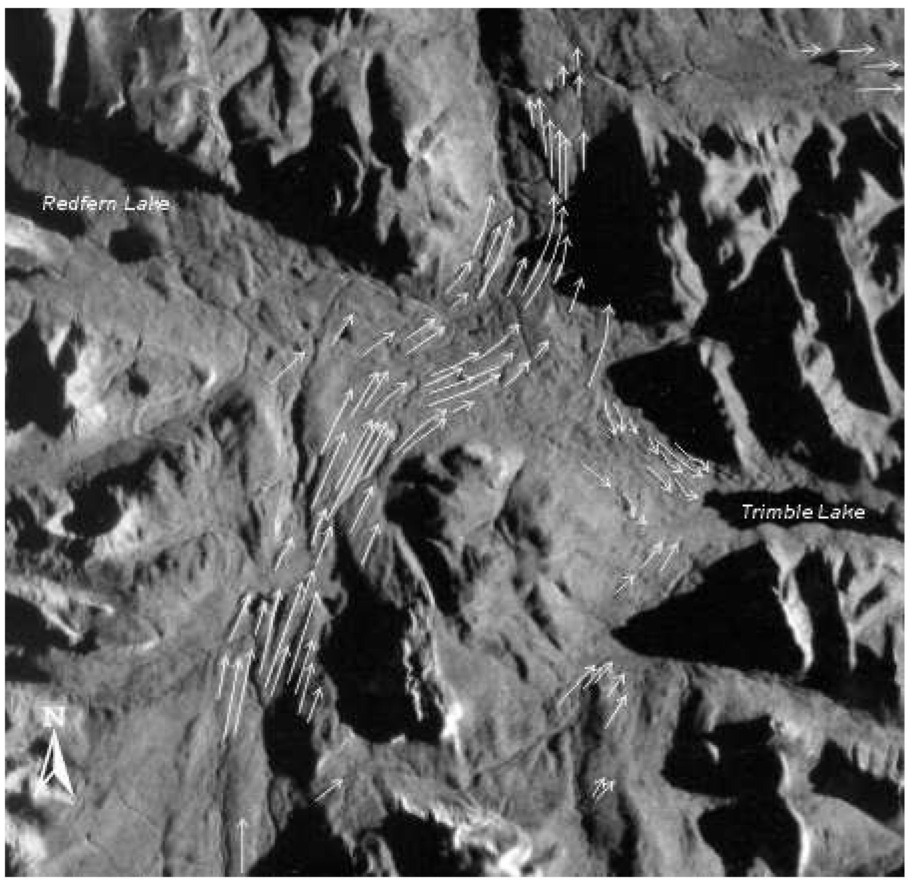


This study mapped the western limit of till containing abundant shield erratics along the upper Buckinghorse River where Laurentide ice apparently pushed into the mountain front (Figs. 3, 6). On the north side of the valley mouth, the uppermost level of granite and gneiss-rich till lies at 1380 m asl. Sandy till and outwash containing granite pebbles crops out about 5 kilometres upvalley on the valley bottom at 1234 m asl. For about 12 kilometres upvalley, shield erratics are abundant on the surface up to an elevation of 1360 m, but granite till is absent. In these cases, the shield erratics may have been ice-rafted up the valleys. Erratics were also redeposited by stream transport. For example, the upper Buckinghorse River has been pirated by Nevis Creek, which transported shield erratics northward to Besa River, albeit to lower elevations.

The relative decrease in shield erratics south of Buckinghorse River, led Mathews (1980) to suggest that there may have been a late readvance of the Cordilleran ice onto the plains, effectively diluting the pre-existing Laurentide till with Cordilleran till. According to Mathews (1980), the Buckinghorse River also coincides with the southern end of local Rocky Mountain glaciation. Mathews' zone of local glaciation extends northward for 245 kilometres to the Liard River (Fig.1). Till within this zone is composed of only local rocks, with no diagnostic Cordilleran erratics. Nevertheless, this study shows that Cordilleran ice covered this area during the last glaciation. North of the upper Buckinghorse River, striations measured along mountain crests, up to 1860 metres above sea level, suggest that Cordilleran ice inundated the foothills in the Trutch map sheet area. Moreover, the measured east-northeastward flow runs across the major topographic trend, implying that a significant thickness of ice flowed across the ranges, unimpeded by topography. Striated bedrock with the same flow direction also occurs at lower elevations within the zone of Laurentide erratics in the upper Buckinghorse River valley. If the upper and lower striations are of the same age, this implies that the Laurentide erratics were deposited after the Cordilleran advance. Samples of the upper striated bedrock were analyzed for cosmogenic ^{36}Cl exposure dating (Philips 1999). The results suggest that Cordilleran ice retreated from the mountain summits as late as 14 020±760 to 13 100±1560 calendar years ago.

Glacial features mapped in western Trutch map sheet show that glaciation of the mountains progressed with initial growth of local alpine glaciers which were later overtopped by the Cordilleran Ice Sheet flowing from the west as glaciation progressed (cf. Clague 1989). During the onset of glaciation, there was undoubtedly growth of local cirque glaciers, which eventually fed valley systems. At later stages, however, this system was overwhelmed by expanding Cordilleran ice from the west and the combined ice mass was thick enough to flow across the foothills unimpeded by topography. Thus, high-level striae on the summits of foothills were made during the last glacial maximum by Cordilleran ice, although the tills at lower elevations are predominantly of local origin. Moreover, diagnostic erratics of Cordilleran till may not have been preserved everywhere. These are predominantly friable pebbles of slate and schist, derived from Hadrynian exposures along the Rocky Mountain Trench (Mathews 1980), and they may have been extensively comminuted during glacial transport.

Fig. 7. Glacial flutings in the Besa River valley show a northward flow of mountain ice. This flow postdates the eastward flow of thick Cordilleran ice that overtopped the mountains. As the mountain ice thinned further, secondary eastward flutings formed near Trimble Lake (Airborne radar image).



Deglaciation likely occurred in a similar fashion, which implies that the late glacial presence of local ice does not preclude a previous ice cover by the Cordilleran Ice Sheet during the last glaciation. During deglaciation, as the Cordilleran ice thinned, the underlying topography exerted greater control on glacial flow. This is evidenced by drumlin and fluting fields within Rocky Mountain valleys (Fig. 7). In some areas, drumlin and fluting fields crosscut one another, suggesting large shifts in flow directions as the ice thinned. Eventually, the diminished Cordilleran ice would acquire the character of alpine glaciation as a system of cirque-fed valley glaciers. At this stage, western till, originating from the Rocky Mountain Trench and beyond, was no longer transported to the map area. In the final stages of deglaciation, the valleys became ice-free and only cirque glaciers remained. During the Holocene most of the cirque glaciers have completely ablated.

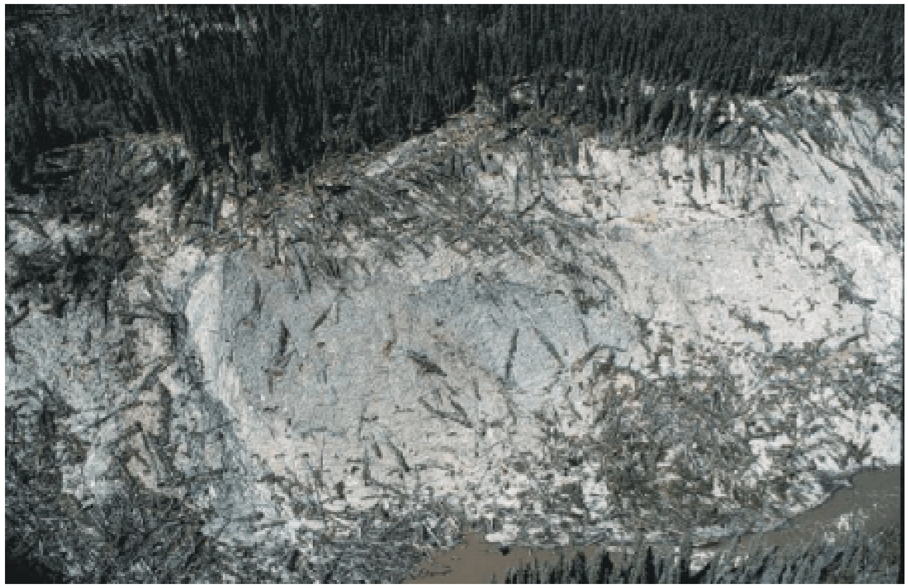
Most of the stratigraphic sections within mountain valleys relate to the advance and retreat of montane ice. In general, these involve thick sequences of outwash, ice-contact stratified drift, till and glaciolacustrine sediments. For example, thick sections along the upper Sikanni Chief River show a lower dark, indurated gravel, overlain by a dark silty diamicton, in turn, overlain by a bedded diamicton (Fig. 8). The whole sequence is capped by laminated silt. It is apparent that the upper Sikanni Chief River valley was dammed to the east after mountain ice retreated from the area. Several sections within crosscutting valleys are topped by glaciolacustrine silt, suggesting that Laurentide ice was blocking drainage at or near the mountain front at this time. As noted above, shield erratics overlying Cordilleran striations suggest that the Cordilleran ice advanced prior to the Laurentide ice reaching the mountain front. Nevertheless, stratigraphic sections showing both Laurentide and mountain glaciations, as reported by Hage (1944), could not be found.

Fig. 8. Stratigraphic section along the upper Sikanni Chief River. Dark shale (R) is overlain by a thick complex of glacial till (T) and ice-contact stratified drift (G). The complex is overlain by glaciolacustrine silt (L) forming the topmost unit. Mountain ice advanced from the foreground to the horizon, downvalley (Note person standing for scale).

Thick sections of glaciofluvial outwash of mountain origin lie at the mouths of major rivers at the mountain front. These sediments are usually overlain by glaciolacustrine deposits forming the uppermost unit. In places within the valleys dissecting the Alberta Plateau, stratigraphic sections of Quaternary sediments tend to be poor because of excessive slumping. Much of this area is underlain by thick units of recessive shale and the banks of most rivers are covered by colluvium. This is particularly true of the deeply incised Buckinghorse and Sikanni Chief rivers, where whole forests are slumping into the river (Fig. 9).

Mass wasting

Fig. 9. Photograph of a large slump along a cutbank of the lower Sikanni Chief River, were it is deeply incised into the Alberta Plateau. The valley bottom is underlain by recessive shale that readily destabilizes the overlying sandstone.



The Trutch area is underlain by thick sequences of interbedded sandstone and shale that are prone to failure. Various types of mass movements are common reflected by distinct landforms. These features range in size, rapidity of movement, and age. Both active and relic landforms are common; suggesting that activity has been relatively steady throughout postglacial time. Rapid, catastrophic failures such as mudflows and debris flows are usually restricted in size, occurring on mountain slopes. A very large landslide/earthflow along Besa River represents the other end of the spectrum. This feature, of approximately seven square kilometres, probably has been mobile for decades. Large slabs of forested bedrock are sliding over a slowly deforming substrate.

Large catastrophic failures have also occurred in the area. For example, a particularly large landslide occurred in a tributary valley to the Halfway River (Fig. 10). When visited in the summer of 1998, the freshness of the feature suggested that the landslide occurred sometime in the spring of that year, however, there are unconfirmed reports from local residents that the failure occurred in 1994. The side of the valley failed along a steep slope (25°) and sent debris, including huge sandstone blocks for distances up to 1.25 kilometres, filling the valley bottom. The landslide covers an area of 0.4 km^2 and currently dams a small lake upvalley. Should this lake drain catastrophically, its small size would probably not pose a risk, but landslide events like these obviously pose a significant hazard and their occurrence unpredictable. Aerial photographs taken in 1958 and 1985 do not show any signs of the impending event. An objective of this project is to try to evaluate areas of potential landslide hazards. Large areas of landslides are mapped as colluvium on the 1: 250 000 scale surficial geology map.

Fig. 10. A catastrophic landslide extending about 1.5 km into a tributary valley to the Halfway River. The photograph is looking to the southeast.

SAMPLE COLLECTION

Till and other surficial materials were collected during foot, truck and helicopter traverses. One hundred and sixty-five samples were collected, giving an average sampling density of one per 80 km², but most samples were collected along valleys because of extensive bedrock outcrops on the uplands (Fig. 2). The primary sampling medium was glacial till (diamicton) but a few sorted deposits of glacial outwash and glaciolacustrine sediments were also collected to characterize the surficial cover. Some of the till-like diamictons sampled may be redeposited glacial sediments (colluvium). Special consideration must be made when assessing these sediments for drift prospecting because their dispersal paths are distinctly different from till. The genesis of each sample was interpreted in the field and the interpretation is included with the data listing (Appendix 1).

Samples weighing ~2 kg were recovered by pick from below any pedogenic or oxidized horizons usually from a depth of 50 cm. The samples were stored in plastic freezer bags and shipped in metal pails. In Calgary, wet samples were air-dried prior to shipment for analysis. The location of each sample site was fixed on 1:60 000 aerial photographs or by averaged GPS readings. Sample locations are given in Latitude/Longitude and UTM (NAD83) coordinates (Appendix 1).

ANALYTICAL PROCEDURES

GSC - Terrain Sciences Division Sedimentology Laboratory, Ottawa measured the sediment size, carbon and carbonate analyses. Grain size was measured by sieving and sedimentation into: < 2 mm, sand (2 mm to 63 µm), and silt-plus-clay (< 63 µm) fractions. The silt / clay boundary was placed at 2 µm. Silt and clay fractions were determined by laser particle size analyzer (PSA, Galia Instrument) to obtain percentage volume. The sieved and PSA results are combined and calculated for percentage weight. Calcite, dolomite and total carbonate content were analyzed by Chittick and carbon content by the Leco method (Appendix 1). Carbonate values derived by the Leco method are commonly about 4% higher than those obtained by the Chittick apparatus (Dredge, 2000).

Table 1. Detection limits for INAA analysis.

The geochemistry of sediment samples was determined with INAA (Instrumental Neutron Activation Analysis), by Intertek Testing Service, Val-d'Or Quebec, for 34 trace elements (Table 1). The silt-plus-clay fraction, was used in each analysis (Appendix 2). The analytical precision of the INAA was assessed using laboratory duplicates. For the most part the results are consistent but occasional discrepancies arise when dealing with trace amounts. The accuracy of the technique was determined by submitting a standard reference till with each batch to be analyzed. In this case a GSC 'in house' till standard (TCA8010) was submitted. The mean, standard deviation and range of the reference till measured by Intertek Testing Services during 1999 and early 2000, is shown in Table 2.

The 63 µm to 250 µm size fraction of 45 sediment samples were separated for ferromagnetic and heavy minerals (heavy liquid separation, 3.3 g cm^{-3}) by the Terrain Sciences sedimentology lab (Appendix 3). Consorminex Inc., Gatineau, Quebec, analyzed the heavy mineral fraction of the 45 samples which were mounted in epoxy on 1 x 3 inch glass slides by the staff of the sedimentology lab. A Zeiss, Stemi SR, stereoscopic microscope with polar and Nicol, in conjunction with a petrographic microscope, were used to count the heavy minerals. The ribbon method was used to count 300 grains. A computer program was used to enter the data by keyboard in the same manner as a Swift blood cell counter. A preliminary scan of all the slides was done before the classification for counting was prepared. The data is presented in (Appendix 4, Paré 2000).

Element		Limit
Au	Gold	1 ppb
Ir	Iridium	50 ppb
Ag	Silver	2 ppm
Zn	Zinc	100 ppm
Mo	Molybdenum	1 ppm
Ni	Nickel	10 ppm
Co	Cobalt	5 ppm
Cd	Cadmium	5 ppm
As	Arsenic	0.5 ppm
Sb	Antimony	0.1 ppm
Fe	Iron	0.2 %
Se	Selenium	5 ppm
Ba	Barium	50 ppm
Cr	Chrome	20 ppm
Sn	Tin	100 ppm
Te	Tellurium	10 ppm
W	Tungsten	1 ppm
Cs	Cesium	0.5 ppm
La	Lanthanum	2 ppm
Ce	Cerium	5 ppm
Sm	Samarium	0.1 ppm
Eu	Europium	1 ppm
Tb	Terbium	0.5 ppm
Yb	Ytterbium	2 ppm
Lu	Lutetium	0.2 ppm
Sc	Scandium	0.2 ppm
	Hafnium	1 ppm
	Tantalum	0.5 ppm
	Thorium	0.2 ppm
	Uranium	0.2 ppm
	Sodium	0.02 %
	Bromine	0.5 ppm
	Rubidium	5 ppm
	Zirconium	200 ppm
	grams	0.01 g

Table 2. Measurement results of reference till (TCA8010).

	Au	Ir	Ag	Zn	Mo	Ni	Co	Cd	As	Sb	Fe	Se	Ba	Cr	Sn	Te	W
	ppb	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm
Mean	161.0	<50	<2	<100	0.2	22.9	10.5	<5	6.9	2.8	2.5	<5	618.0	61.7	<100	<10	0.4
Std.Dev.	20.8	0.0	0.0	0.0	0.4	7.2	1.6	0.0	1.1	0.3	0.3	0.0	74.1	10.4	0.0	0.0	0.8
Min	140.0	<50	<2	<100	<1	12.0	9.0	<5	5.7	2.5	2.1	<5	550.0	49.0	<100	<10	0.0
Max	200.0	<50	<2	<100	1.0	32.0	13.0	<5	9.1	3.3	3.1	<5	770.0	77.0	<100	<10	2.0

	Cs	La	Ce	Sm	Eu	Tb	Yb	Lu	Sc	Hf	Ta	Th	U	Na	Br	Rb	Zr
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
Mean	1.1	27.8	57.8	4.6	1.4	0.5	0.7	0.3	11.1	7.9	0.5	5.7	1.2	2.4	2.6	60.0	252.0
Std.Dev.	0.2	2.7	7.9	0.3	1.0	0.3	1.2	0.2	1.5	0.9	0.3	0.5	0.2	0.2	0.3	6.8	147.0
Min	0.7	24.0	41.0	4.1	<1	<0.5	<2	<0.2	9.0	6.0	<0.5	5.1	0.9	2.1	2.2	51.0	<200
Max	1.5	32.0	67.0	5.1	3.0	0.9	3.0	0.5	13.0	9.0	0.7	6.4	1.6	2.7	3.0	75.0	430.0

DATA HANDLING

Descriptive statistics

Descriptive statistics for each element measured by INAA, the results are tabled in Appendix 5. Values below detection levels were assigned zero values in order to facilitate computation. The background levels of various elements in the surficial materials must be established so that threshold values between background and possible anomalies can be identified. The problem is that a single value usually cannot represent the elemental composition of an entire area. Govett (1983) argued that the geometric mean (antilog of the arithmetic mean of the $\log_{10}$ of the values) provides a useful indicator of background values for geochemical data. Because the geometric mean can not be calculated for data sets that contain zeros, an arbitrary small value of 0.001 replaced zero for these calculations.

Populations of elemental concentrations are usually positively skewed giving lognormal distributions typical in spatial surveys (Appendix 5; Appendix 6; Levinson, 1974; Govett, 1983). The frequency histogram of molybdenum is a typical positively skewed distribution common for many elements (Fig. 11). In order to highlight anomalous values, log-transformations were not done on these distributions because this would have the effect of minimizing the importance of high values. In contrast, sodium appears to be normally distributed (Fig. 12). Normal distributions are symmetrical with skewness near zero and a kurtosis (peakiness) near three. Other histograms are multimodal suggesting a mix of more than one population (Sinclair, 1976). This may be expected because of the region was affected by ice transport from two different directions. Cluster analysis utilizing all elements was used to determine if geochemistry of the drift could identify two or more distinctly different populations. The results are discussed below.

Fig. 11. Histogram of molybdenum concentrations (n=165).

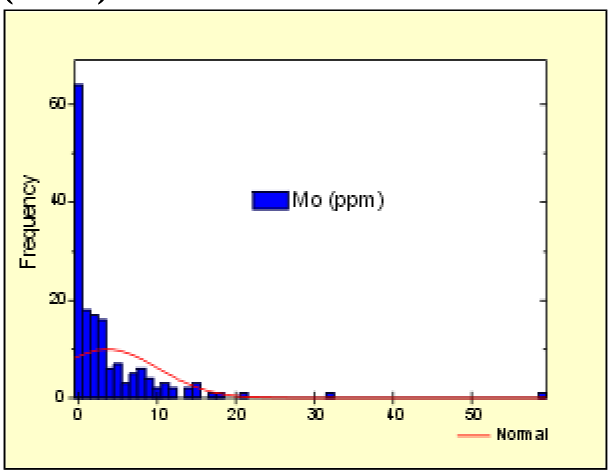
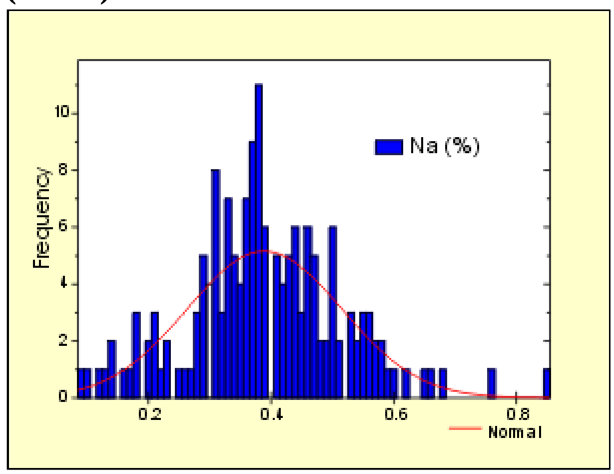


Fig. 12. Histogram of sodium concentrations (n=165).



Anomalies

Although most element values measured in this study fall within ranges typical for soils (Levinson, 1980; Gough et. al, 1988) some values were measured that were much higher than the overall population. Anomalies were identified as outliers which lie so far from the mean that they may not be representative of the normal background fluctuation of the element. Table 3 lists all cases of suspected anomalous values based on the distance from the mean. The distance from the mean is defined by multiples (n) of s (the standard deviation). For a given (n), the probability of such an occurrence increases with sample size. Table 3 lists the cases where multiples of the standard deviations are greater than 4, which means all cases where the probability of finding at least one value at this distance from the mean in a normally distributed sample is < 0.05 (95th percentile). The average abundance and range of values in soils and surficial materials reported elsewhere by Gough et al. (1988) and Levinson (1974) is also provided in Table 3 for comparison.

A limitation of grouping all the sediment types together in this analysis is that the background elemental concentrations may be different for each sediment type. Table 4 presents the results of two separate analyses for gravels (n=28) and for tills (diamictons, n=117). The anomalies are sufficiently high that the same samples emerge as anomalous in the categorized data as for the combined data. This further confirms that the Surview plots, using all the sediment types combined, effectively displays the concentration patterns. Nevertheless, some elements are no longer significant anomalies when the sediment types were separated. However, other elements became significant when the separate analysis was done (see below).

Table 3. Anomalous elemental concentrations found in the glacial drift compared to values for surficial materials reported by Gough et al. (1988) and Levinson (1974).

Sample	Material	Element	Value	ns	p	Soil mean	Soil range	Alaska Surficial Materials
99BJB0081	diamicton	Ni (ppm)	150	3.99975	0.00521	30	5-500	<3-320
		Cd (ppm)	9	4.27917	0.00154	1	—	—
		Fe (%)	14	6.37515	1.51E-08	—	—	0.55-10%
		Cr (ppm)	360	6.31608	2.21E-08	50	5-5000	5-390
		Sm(ppm)	13.4	4.291	0.00146	—	—	—
		Eu (ppm)	6	4.07605	0.00377	—	—	—
		Tb (ppm)	3.4	5.97836	1.86E-07	—	—	—
		U (ppm)	18	7.71464	1.01E-12	1	—	<0.22-45
		Br (ppm)	11	5.16734	1.96E-05	—	—	—
99BJB0077	diamicton	Mo (ppm)	60	8.34565	0	2	1-5	<2-15
		Cd (ppm)	9	4.27917	0.00154	1	—	—
		Sb (ppm)	9	6.28508	2.70E-08	5	—	—
		Se (ppm)	6	4.47176	6.40E-04	0.2	—	—
98BJB0001	diamicton	Sm(ppm)	14.8	5.0326	3.99E-05	—	—	—
		Tb (ppm)	2.3	3.45481	0.04442	—	—	—
98BJB0010	diamicton	Cd (ppm)	13	6.2544	3.29E-08	1	—	—
		U (ppm)	11	3.67766	0.01923	1	—	<0.22-45
98BJB0037	diamicton	Au (ppb)	21	3.78274	0.01271	1	—	—
		Ba (ppm)	4600	5.45181	4.11E-06	500	100-3000	39-3100
99BJB0044	gravel	Au (ppb)	46	8.84415	0	1	—	—
		Ag (ppm)	3	3.9485	0.00646	0.1	—	—
99BJB0052	diamicton	Mo (ppm)	33	4.29906	0.00141	2	1-5	<2-15
		Sb (ppm)	6	3.69097	0.01826	5	—	—
99BJB0053	gravel	As (ppm)	38	4.19424	0.00225	5	1-50	—

Table 4. Anomalou concentrations of el calculated for glaci gravels and diamict separately.

GRAVELS n=28

Sample	Element	Va
99BJB0053	Fe (%)	
	Ba (ppm)	3(
99BJB0044	Au (ppb)	
	Ag (ppm)	
99BJB0023	Ag (ppm)	
98BJB0046	Br (ppm)	
98BJB0020	Co (ppm)	
99BJB0001	Hf (ppm)	
99BJB0063	Na (%)	0

DIAMICTONS n=117

Sample	Element	Va
99BJB0081	Ni (ppm)	
	Co (ppm)	
	Cd (ppm)	
	Fe (%)	
	Cr (ppm)	
	Sm (ppm)	1
	U (ppm)	
	Br (ppm)	
99BJB0077	Mo (ppm)	
	Cd (ppm)	
	Sb (ppm)	
	Se (ppm)	
98BJB0010	Zn (ppm)	

		Fe (%)	14	6.37515	1.51E-08	—	—	0.55-10%
99BJS0001	diamicton	Hf (ppm)	29	4.9278	6.86E-05	—	—	—
		Zr (ppm)	1200	4.34637	0.00114	300	—	—
99BJS0004	diamicton	As (ppm)	36	3.87031	0.00892	5	1-50	—
		Se (ppm)	6	4.47176	6.40E-04	0.2	—	—
99BJS0013	diamicton	Cd (ppm)	18	8.72343	0	1	—	—
		U (ppm)	11	3.67766	0.01923	1	—	<0.22-45
99BJB0010	silt	Ag (ppm)	3	3.9485	0.00646	0.1	—	—
99BJB0012	diamicton	Ag (ppm)	3	3.9485	0.00646	0.1	—	—
99BJB0023	gravel	Ag (ppm)	4	5.34703	7.38E-06	0.1	—	—
99BJB0028	diamicton	Ag (ppm)	3	3.9485	0.00646	0.1	—	—
99BJB0042	diamicton	Ag (ppm)	3	3.9485	0.00646	0.1	—	—
99BJB0054	diamicton	Ag (ppm)	4	5.34703	7.38E-06	0.1	—	—
99BJB0014	diamicton	Se (ppm)	8	6.01885	1.45E-07	0.2	—	—
99BJB0101	diamicton	Se (ppm)	11	8.33949	0	0.2	—	—
99BJS0014	diamicton	Se (ppm)	5	3.69821	0.01775	0.2	—	—
98BJB0046	gravel	Br (ppm)	14	6.87712	5.04E-10	—	—	—
99BJS0005	diamicton	Br (ppm)	10	4.59741	3.53E-04	—	—	—
98BJB0039	diamicton	Ba (ppm)	3600	3.89223	0.00816	500	100-3000	39-3100
99BJS0012	sand	Ba (ppm)	3700	4.04819	0.00424	500	100-3000	39-3100
99BJB0032	diamicton	As (ppm)	46	5.48997	3.32E-06	5	1-50	<10-750
98BJB0020	gravel	Co (ppm)	98	9.34639	0	10	1-40	<2-55
99BJB0001	gravel	Hf (ppm)	24	3.76757	0.0135	—	—	—
98BJB0045	diamicton	Na (%)	0.85	3.67895	0.01913	—	—	<0.07-3.6%

	Cd (ppm)	
	U (ppm)	
99BJS0004	As (ppm)	
	Se (ppm)	
	Br (ppm)	
98BJB0037	Au (ppb)	
	Ba (ppm)	4
99BJS0001	Hf (ppm)	
	Zr (ppm)	1
99BJB0052	Mo (ppm)	
	Sb (ppm)	
99BJS0013	Cd (ppm)	
	U (ppm)	
99BJB0012	Ag (ppm)	
99BJB0028	Ag (ppm)	
99BJB0042	Ag (ppm)	
99BJB0054	Ag (ppm)	
99BJB0014	Se (ppm)	
99BJB0101	Se (ppm)	
99BJB0032	As (ppm)	
99BJB0043	Au (ppb)	
99BJS0005	Br (ppm)	
98BJB0045	Na (%)	0
98BJB0001	Sm (ppm)	1

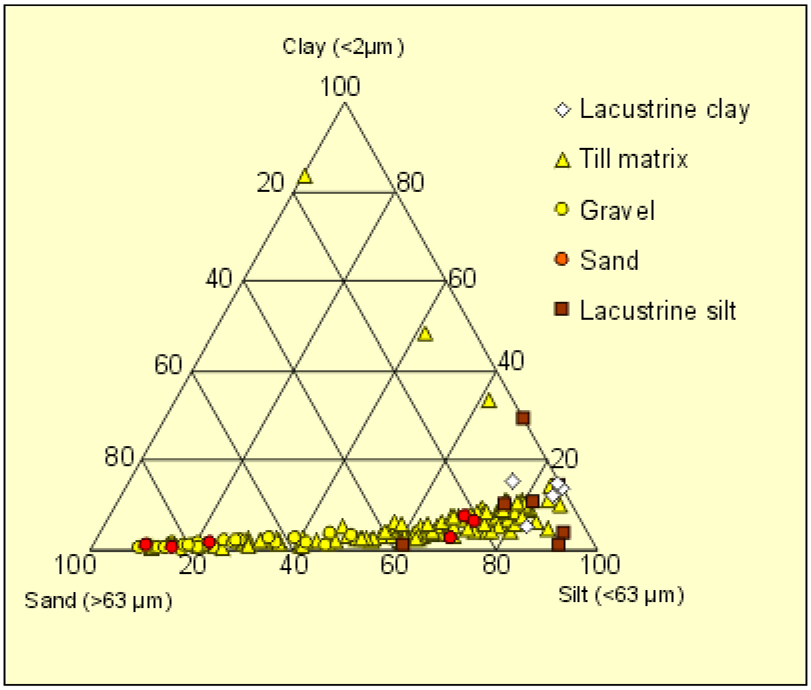
Contour maps

Depiction of the elemental values on maps shows any systematic spatial concentrations of high values that would not be evident in the frequency distributions. Contour maps describing the spatial pattern of elements are shown in the Surview generated maps. The maps were produced by semivariance analysis of each data set, followed by kriging interpolation of gridded values. Moreover, in areas where geochemical signals are weak, the relative values of elements may be important as the absolute content of the element. This may show up as anomalous patterns within background levels.

RESULTS

Grain size

Fig. 13. Sand, silt clay ratios for the 165 samples of glacial drift from the Trutch map area.



Sand, silt and clay ratios for all the samples are presented in Fig. 13 and Appendix 1. The sand-silt-clay fractions of lacustrine fines, glaciofluvial gravels, and tills range from sandy to very silty, with less than 10% clay, despite their varied genesis. The ternary plot shows that most of the surficial materials have very low clay contents, except for three till samples. Thick shale units found throughout the area likely contributed to the high clay contents in these samples. Nevertheless, low overall clay contents in the tills seems unusual. Although this may be due to the nature of the source bedrock or unconsolidated material, large numbers of till samples usually show more scatter on such a the plot. This suggests that some of the samples may not have been completely disaggregated prior to grain size analysis. Pebble contents (> 2 mm) in the tills were as high as 79% by weight and boulders up to 1 m in diameter are common in the tills and glaciofluvial gravels. Most of the till is composed of local bedrock with varying amounts of far-travelled lithologies. Generally, tills from the northeast half of the map area contain many rocks from the Canadian Shield. Local lithologies dominate the composition of mountain tills covering the southeast half of the map area.

Carbon analysis

Fig. 14 shows contoured results of percentage total carbon determined by Leco (see also Surview plots and Appendix 1). Carbonate results were similar with both Leco and Chittick analyses, giving similar general patterns for percent total carbon, inorganic carbon, and carbonate. Since the Rocky Mountains and foothills are predominantly underlain by carbonate strata, higher values are usually found over the mountains and foothills but they also extend eastward along the Prophet and Sikanni Chief rivers, which also seems to coincide with an increase in calcite/dolomite ratios (Fig. 15). These patterns may reflect glaciofluvial transport of carbonate-rich material from the mountain front prior to glaciation; alternatively, this may be a characteristic of dilution in Laurentide till. As noted above, the amount of Canadian Shield material in till, east of the mountain front, increases greatly north of the Buckinghorse River (Figs. 3, 6).

Fig. 14. Contour map of percent of total carbon content measured by LECO.

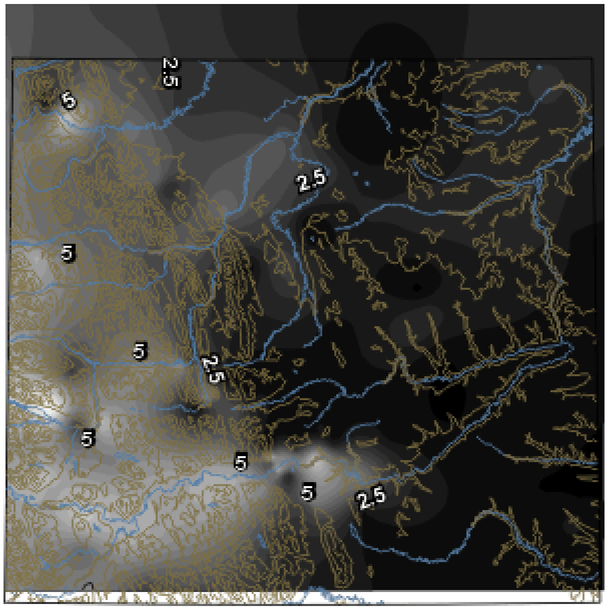
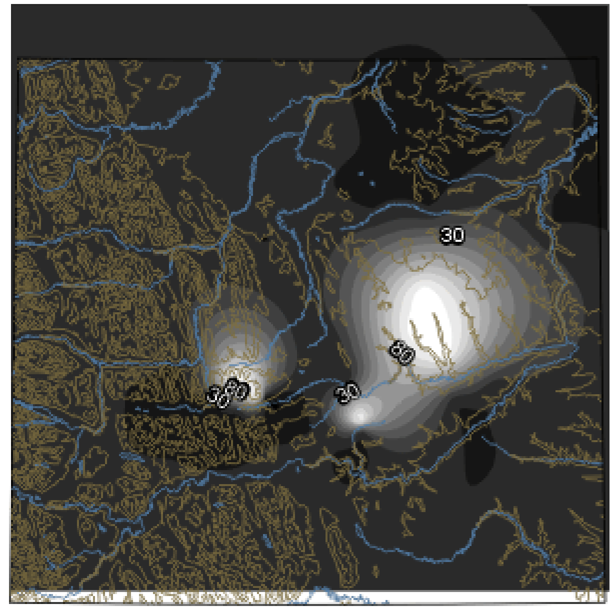


Fig. 15. Contour map of calcite/dolomite ratios.



Contour maps and geochemical anomalies

The spatial variability of element concentrations over the study area shows up as undulating surfaces on the contour maps (see Surview plots). Generally, the contoured surface is more rugged over the mountains because greater differences in elemental concentrations occur over shorter distances than on the Alberta Plateau in the east. Anomalously high values over both the plains and mountains form peaks well above the background undulations.

The anomalous values listed in Table 3 correspond well to the pattern of bulls eyes on the contour maps and provide an independent assessment of the contouring procedure. Some individual samples stand out as having anomalously high values for several elements. For example, sample 99BJB0081 had values significantly above background in nine elements (Table 3). When grouped with diamictons only, the sample was still anomalous in eight elements (Table 4). This sample is unusual because it was taken from an oxidized diamicton of unknown origin exposed in along a road cut north of the Sikanni Chief River. The level of oxidation is much greater than any glacial sediment in the area and the sample probably predates the last glaciation because it is overlain unconformably by about a meter of till. Although the concentrations reported here are anomalous, the absolute values of the elements fall within the range of and mean values reported in soils and surficial deposits elsewhere (Table 3; Levinson, 1980; Gough et al., 1988).

A boulder gravel at the base of a section near the confluence of Trutch Creek and Sikanni Chief River (99BJB0044; Fig. 3) had the highest **gold** and one of the highest **silver** concentrations found in the study (46 ppb and 3 ppm, respectively). This sandstone and quartzite gravel was strongly indurated with an imbrication showing ESE paleocurrent. In contrast to the modern stream bed, no shield rocks where present in this gravel unit, which suggests that they may also be preglacial in age. In general, 56 out of 165 samples had gold concentrations above the detection level (>2 ppb) with a mean value of 2.3 ppb, which is slightly elevated compared to typical values in soils (Levinson, 1980).

In places, gravels deposited during and after the last glaciation had anomalous concentrations of elements. A sample of gravel at the top of a section above Green Creek (99BJB0053) had elevated levels of **arsenic** and

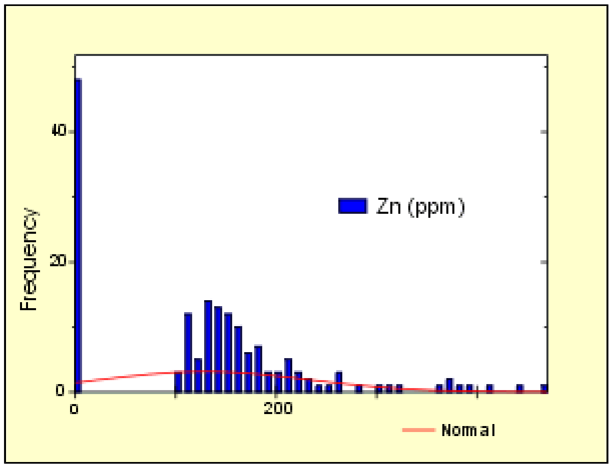
iron. Arsenic is a useful pathfinder for gold, although the values reported here fall within reported range for soils (1-50 ppm, Levinson, 1980). The gravel was cemented and orange stained suggesting enrichment by ground water may have occurred. When the gravels were grouped separately (Table 4), the arsenic level was no longer anomalous but the **barium** concentration became anomalous.

A coarse gravel unit above upper Chipesia Creek, just off northern edge of map area (Fig. 3; 99BJB0023) has anomalous **silver** levels. The gravels are 3 m thick, and overlie interbeds of silt and ripple laminated sand, which are about 5 m thick. These gravels are underlain by a 1 m thick diamicton, lying over bedrock at the base to the section. All these units contain granite clasts.

Other anomalous values in gravels include: i) anomalous **bromine** (98BJB0046) in glaciofluvial outwash forming a large terrace along the north side of Muskwa River, ii) a **cobalt** anomaly of 98 ppm (98BJB0020), which is above the normal range for soils, in thick channel-fill gravels along Petrie Creek, and iii) anomalous **hafnium** from outwash gravel in a kame terrace above Nevis Creek (99BJB0001; Fig. 3; Table 3).

Several diamicton samples, mostly till, also had element concentrations well above background (Table 3). A sample from 15 m thick upper till along the south side of the Besa River (99BJB0077) provided anomalous values in four elements, **molybdenum, cadmium, antimony and selenium**. A diamicton, possibly slumped till from a hillslope north of Mount Withrow (99BJB0052, Fig. 3), also had anomalous **molybdenum** and **antimony** concentrations. In general, these elements have the highest values along the foothills (see Surview plots). In contrast, the rare earth elements **samarium** and **terbium**, which are anomalous in a Laurentide till north of the map area (98BJB0001) and the gravel sample noted above (99BJB0081), have highest values outside of the mountain front. This may be due to the abundance of intrusive lithologies in the Laurentide till.

Fig. 16. Histogram of zinc concentrations (n=165).



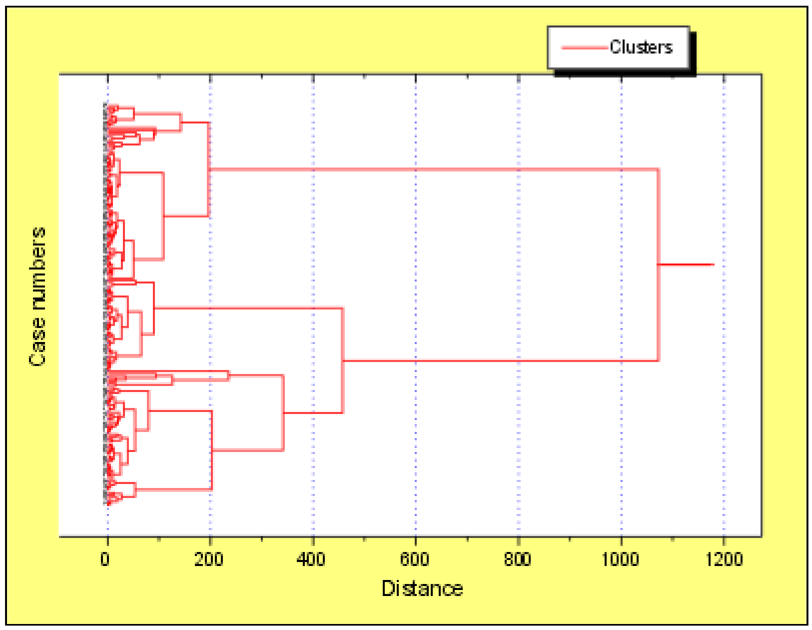
Till sample 99BJB0077 also has a high **zinc** value of 410 ppm (the average and range reported in soils is 50 ppm and 10-300 respectively, Levinson 1980), but not anomalous according to the criteria noted above. In the study area, zinc values are normally distributed with only a slight positive skewness with a clustering around 400 ppm (Fig. 16). Cordilleran till samples 98BJB0010 and 98BJB0037 have high zinc values as well as other anomalies. Sample 98BJB0037, silty till from the core of a drumlin near Trimble Lake, has anomalous **gold** and **barium** concentrations. Sample 98BJB0010, from a very thick till deposit on a mountain slope, has anomalies in **cadmium** and **uranium**. Cadmium has very similar geochemistry to zinc (Levinson 1980). Overall, cadmium was the third most common anomalous element and was only found in association with other anomalies confined to the foothills (4 occurrences, Table 3). Sample 99BJS0013, an upper till marking a readvance of mountain ice at the mountain front near the Prophet River, also has an anomalous uranium concentration and the highest cadmium level recorded by this study (18 ppm).

Some tills found at the contact between Laurentide and Cordilleran ice had anomalous values. Sample 99BJS0001 was high **hafnium** and **zirconium**. Both elements occur together in nature (Boyle 1974). Till sample 99BJS0004 was anomalous in **arsenic** and **selenium** levels. Anomalous selenium concentrations were also found in Laurentide till near the mountain exit of the Prophet River (samples 99BJS0014 and 99BJB0014; see Surview plots). The largest Se anomaly recorded in the study area comes from a massive landslide deposit west of Sleeping Chief Mountain (99BJB0101). Anomalous **arsenic** levels were also found in Cordilleran till above upper Bat Creek (Fig. 3; see Surview plots).

Several samples had anomalous concentrations of only a single element. The most common anomalous element in was **silver** (Table 3), with most of the anomalies in till in the northeastern quadrant of the map area, outside of the mountains (see Surview plots). Samples of lacustrine silt and outwash gravel also had significant silver anomalies (99BJB0010 and 99BJB0023, respectively). **Selenium,** the second most common anomaly, was found in five till samples, although it was the only anomaly in three of those samples. **Bromine** was the sole anomaly in two out of three anomalous samples. In general, bromine anomalies are concentrated in the upper Muskwa River and the Sikanni Chief River near the mountain front. Of the three samples with **arsenic** anomalies, there was only one sample with arsenic as the sole anomaly (99BJB0032). Likewise, **barium** was the sole anomaly in two samples. An isolated barium anomaly comes from one of three distinct till units exposed in a drumlin situated southwest of Trimble Lake (98BJB0032; Fig. 3). A sample from one of the other till units at this site (98BJB0037) was anomalous in barium and gold. Barium was also anomalous in sand at the mouth of the Prophet River (99BJS0012). **Hafnium** was the only anomaly in a sample of gravel (99BJB0001). Finally, gravel sample 98BJB0020 was the only sample anomalous in **cobalt**.

Cluster analysis

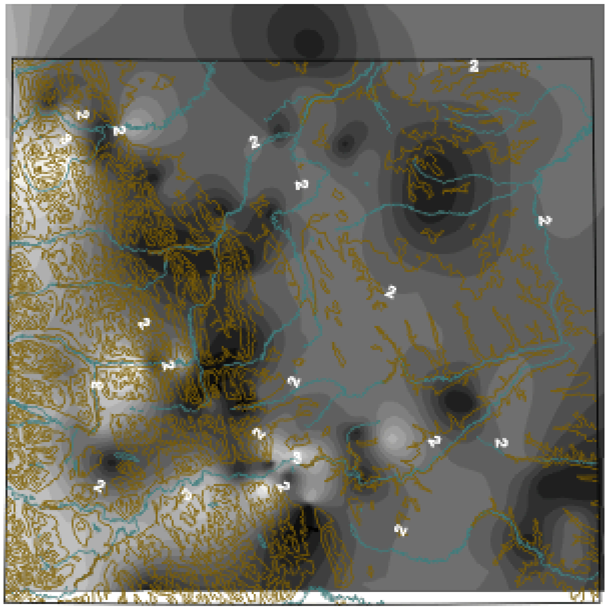
Fig. 17. Dendogram of geochemical data clustered using Ward's method including all samples.

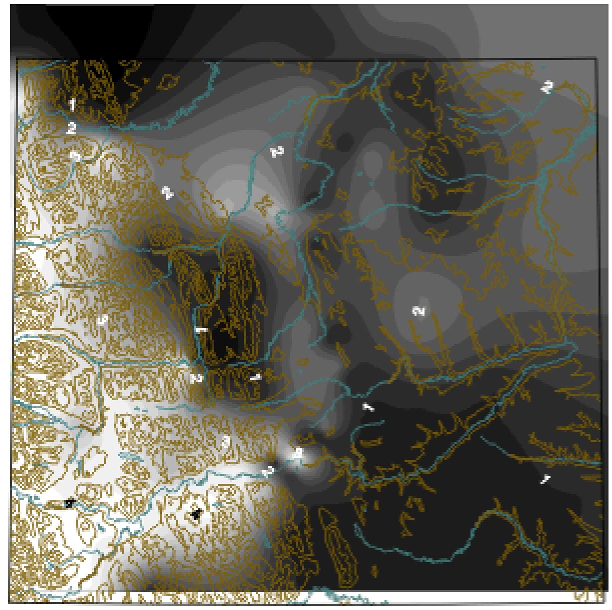


A hypothesis of this study was that the Trutch map area is covered by at least two distinct tills: one from mountain glaciers including the Cordilleran Ice Sheet, and the other deposited by the continental Laurentide Ice Sheet. Cluster analysis was used to determine if the overall geochemistry of glacial drift shows such a pattern by incorporating all the measured elements as variables simultaneously. This procedure attempts to separate observations into more or less homogeneous groups, which are then connected hierarchically with each other until only two clusters remain (Davis 1986). Ward's method linkage (incremental sums of squares) was used to agglomerate the samples. In the first attempt the entire sample set was used irrespective of the type of surficial material. Fig. 17 shows the resulting dendogram. Using a cluster separation of four, a shaded contour map of the results shows a distinct difference between the drift cover in the mountains and foothills versus the drift over the Alberta Plateau (Fig. 18). In particular, there is a large eastward inflection of mountain drift along the Sikanni Chief River valley. This may be related to redeposition of tills by glacial meltwaters flowing from the mountain front. To clarify this, the cluster analysis was repeated using only diamicton (till) samples (Fig. 19, Appendix 7). This resulted in a greater distinction between tills in the mountains versus tills on Alberta Plateau, but plumes of mountain affinities extending eastward outside the mountains are still evident along some of the river valleys. This suggests that mountain provenance till was deposited by glaciers flowing eastward, beyond the mountain front, at some time in the past.

Fig. 18. Contoured clusters including all the samples with all INAA geochemistry as variables. Agglomeration was to four groups using Ward's method.

Fig. 19. Contoured clusters including only diamicton (till) samples with all INAA geochemistry as variables. Agglomeration was to four groups using Ward's method.





Heavy mineral analysis

As noted above, 45 bulk samples yielded 0.028–1.26 % heavy minerals by weight and only three samples had any measurable magnetics (Appendix 3). Consorminex Inc. analyzed the heavy mineral grains and the results are presented in Appendix 4 and a report by Paré 2000. No kimberlite indicator minerals were found. Plots of the relative percent of various heavy mineral grains (see Surview maps) show distinct differences within the drift samples. In some cases the differences seem to relate to montane versus continental tills, however, with only four samples of continental till, a statistical comparison was not made. The results of cluster analysis are show in Fig. 20 and 21 (Appendix 8). Note that, despite the limited data set, the overall pattern of drift is similar to cluster analysis of the geochemical data shown above.

Fig. 20. Dendogram of heavy mineral grain data clustered using Ward's method.

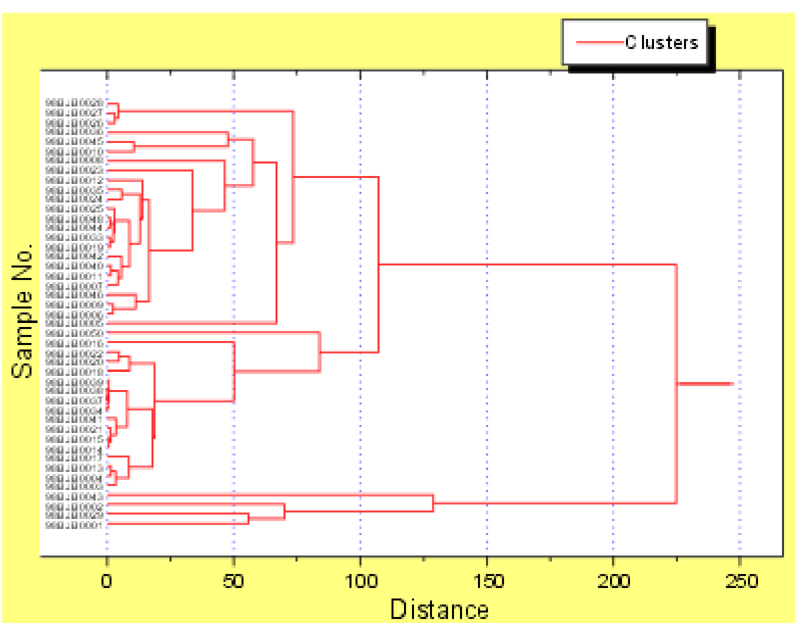
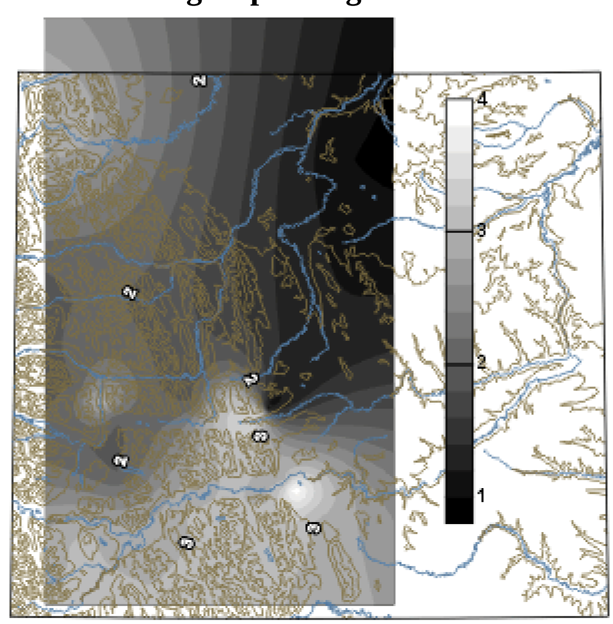


Fig. 21. Contoured clusters of percentage heavy mineral grains (n=45). Agglomeration was to four groups using Ward's method.



SUMMARY OF RESULTS

The Surview maps effectively depict the spatial variations in drift geochemistry, heavy minerals and carbon content. The background trends in elemental concentrations fluctuate around median values but the overall variability is greater in the mountains and foothills. The broad-scale patterns of many elements reflect the underlying bedrock with a strong influence from glacial transport. This is especially true outside the mountains where rock debris from the Canadian Shield was transported by the Laurentide Ice Sheet. The drift samples can be separated by cluster analysis into at least two groups with distinctive affinities, mountain and continental.

Background levels of geochemistry can be estimated from the summary statistics (Appendix 5). The mode or median of a geochemical distribution is often used as a measure of background value (Levinson, 1974) but if trends or multiple populations exist in the data set this may not be a valid procedure. Nonetheless, several samples in this study were found to have element concentrations well above the normal background levels, although most fall within the range of values reported in other areas (Table 3). To determine the significance of these requires more detailed sampling. For example, there may be trends imparted by the underlying bedrock or dilution effects by geomorphic processes that should first be subtracted from the data set.

Carbon analysis of the drift samples shows regional variability related to the physiography and presumed glacial history, like the drift geochemistry. Of particular interest is the distinct pattern of high calcite/dolomite rations between the Sikanni and Buckinghorse rivers (Fig. 15). The significance of this pattern is not known, but it should be noted that the absolute values producing the ratios are quite small.

In conclusion, this study shows distinct differences in drift composition and several anomalous samples. The significance of the anomalies as mineral indicators requires more detailed study, especially with the high variability expressed in mountainous areas. To utilize surficial materials their erosional and depositional history must be known. For glacial drift this means an understanding of glacial processes and Quaternary history. Eastern parts of the Trutch map area were covered by the Laurentide Ice Sheet, which not only transported abundant material from the Precambrian shield, but affected the regional drainage as it approached and later receded from the mountain front. Similarly, in the west, the Cordilleran Ice Sheet was able to transport material, from the Rocky Mountain Trench, to beyond the foothills onto the the Alberta plateau. During the retreat phase of both ice sheets extensive meltwater reworking of sediment took place which would diffuse the geochemical patterns.

REFERENCES

Bednarski, J.M. 1999: Preliminary Report On Mapping Surficial Geology Of Trutch (94G), Northeastern British Columbia. Current Research 1999A, Geological Survey of Canada. p. 35-43.

Bednarski, J.M. 2000: Surficial geology Trutch, British Columbia. Geological Survey of Canada Open File 3885, Map, scale 1: 250 000.

Bobrowsky P.T. and Rutter N.W. 1992: The Quaternary geologic history of the Canadian Rocky Mountains. Géographie physique et Quaternaire, v. 46, p. 5-50.

Bostock, H.S. 1970: Physiographic regions of Canada. Geological Survey of Canada, Map 1254A, scale 1:5 000 000.

Boyle, R.W. 1974: Elemental associations in mineral deposits and indicator elements of interest in geochemical prospecting. Geological Survey of Canada, Paper 74-45, 40 p.

Burwash, R.A., and Culbert, R.R. 1976: Multivariate geochemical and mineral patterns in the Precambrian basement of Western Canada. Canadian Journal of Earth Sciences, v.13, p.1-18.

Clague, J.J. 1989: Cordilleran Ice Sheet. *in* Chapter 1 of Quaternary Geology of Canada and Greenland, R.J. Fulton (ed.); Geological Survey of Canada, Geology of Canada, no.1.

Davis, J.C. 1986: Statistics and data analysis in geology. John Wiley and Sons, New York, 646 p.

Denny C.S. 1952: Late Quaternary geology and frost phenomena along Alaska highway, northern British Columbia and southeastern Yukon. Geological Society of America Bulletin, v. 63, p. 883-922.

Dredge, L.A. 2000: Carbonate dispersal trains, secondary till plumes, and ice streams in the west Foxe Sector, Laurentide Ice Sheet. Boreas, v. 29, p. 144-156.

Gough L.P., Severson R.C., and Shacklette H.T. 1988: Element concentrations in soils and other surficial materials in Alaska. U.S. Geological Survey Professional Paper 1458. 53p.

Govett G.J.S. 1988: Rock geochemistry in mineral exploration. *in* Volume 3, Handbook of exploration geochemistry. G.J.S. Govette (ed.) Elsevier, New York. 461 p.

Grant, John A. 1999: SurView - an enhanced viewer (for Microsoft Windows), for digital geological and geophysical data sets distributed by the Geological Survey of Canada. *in* Yukon digital geology, S.P. Gordey and A.J. Makepeace (comp.); Geological Survey of Canada Open File D3826 and Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1999-1(D) (extensively upgraded from original version released as Geological Survey of Canada Open File 2661 (1992)).

Hage, C.O. 1944: Geology adjacent to the Alaska highway between Fort St. John and Fort Nelson, British Columbia. Geological Survey of Canada Paper 44-30, 22 p.

Holland, S.S. 1964: Landforms of British Columbia: a physiographic outline. British Columbia. Dept. of Mines and Petroleum Resources, Bulletin no. 48, 138 p.

Hoffmand P.F. and McGlynn J.C. 1977: Great Bear Batholith: a volcano-plutonic depression. *in* Volcanic Regimes in Canada. W.R.A Baragar, L.C. Coleman and J.M. Hall (editors). The Geological Association of Canada Special Paper Number 16, p. 169-192.

Lane L. S., Cecile, M. P., Currie L.D., and Stockmal G.S. 1999: Summary of 1998 fieldwork in Trutch and Toad River map areas, Central Forelands NATMAP Project, northeastern British Columbia. *in* Current Research 1999-E, Geological Survey of Canada, p.1-8.

Lemmen, D.S., Duk-Rodkin, A., and Bednarski, J.M. 1994: Late glacial drainage systems along the northwestern margin of the Laurentide ice sheet. Quaternary Science Reviews, v. 13, p. 805-828.

Levinson, A.A. 1974: An Introduction to Exploration Geochemistry. Applied Publishing Ltd., Wilmette, Illinois. 612 p.

Levinson, A.A. 1980: An Introduction to Exploration Geochemistry. The 1980 Supplement; Applied Publishing Ltd., Wilmette, Illinois.

Mathews, W.H. 1978: Quaternary stratigraphy and geomorphology of Charlie Lake (94A) map area, British

Columbia. Geological Survey of Canada Paper 76-20, 25 p.

Mathews, W.H. 1980: Retreat of the last ice sheets in northeastern British Columbia and adjacent Alberta; Geological Survey of Canada Bulletin 331, 22 p.

Nelson J.L., Gabites, J.E., and Paradis, S. 1999a: New galena Lead isotopic data from carbonate rocks in northeastern B.C. – Implications for regional MVT fluid migration. *in* Geological Fieldwork 1998; British Columbia Ministry of Energy and Mines, Paper 1999-1, p. 81-87.

Nelson J.L., Paradis, S., and Zantvoort, W. 1999b: Robb Lake carbonate-hosted lead-zinc deposit, northeastern British Columbia. *in* Geological Fieldwork 1998; British Columbia Ministry of Energy and Mines, Paper 1999-1, p. 81-87.

Paradis, S., Nelson, J.L., and Zantvoort, W. 1999: A new look at the Robb Lake carbonate-hosted lead-zinc deposit, northeastern British Columbia. *in* Current Research 1999-A,, Geological Survey of Canada, p. 61-70.

Paré D. 2000: Heavy Mineral Analysis of 45 Tills, Northeastern British Columbia, Report presented to Jan Bednarski, Geological Survey of Canada. Consorminex Inc.

Phillips F.M. 1999: Cosmogenic ^{36}Cl Ages of Glacial Samples from Northeastern British Columbia, Report of Results, prepared for Dr. Jan Bednarski, Geological Survey of Canada, October 1999. Department of Earth and Environmental Science, New Mexico Tech.

Sinclair A.J. 1976: Applications of Probability Graphs in Mineral Exploration; The Association of Exploration Geochemists, Special Volume No. 4, 95 p.

Williams, M.Y. 1944: Geological reconnaissance along the Alaska Highway from Fort Nelson, B.C. to Watson Lake , Yukon; Geological Survey of Canada Paper 44-28, 33 p.

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