Mapping and Resource Evaluation of the Tertiary and Preglacial Sand and Gravel Formations of Alberta

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Preface

This study is sponsored by the Canada-Alberta Partnership Agreement on Mineral Development (MDA) and the Alberta Geological Survey (AGS). The AGS provided 77% of the funding and the MDA provided 23%. Total manpower for the entire study was 3.2 professional man-years, 2.0 technical man-years, and 1.0 man-years of student assistance spread over a period of four years.

Preliminary information was released at the end of each of the first three years of study. The preliminary reports and maps are superseded by this report. Use of, or reference to, any data from this study, conclusions made, or interpretations presented should be from this report and not the preliminary releases.

Acknowledgements

We want to acknowledge the operators of many large and small gravel pits for permission to access their deposits and for their information, support, and suggestions.

We acknowledge Bill Spearn of Alberta Transportation and Utilities and Dmitry Alman formerly of that department for their excellent petrographic analyses; John Pawlowicz and Mark Fenton of AGS for their assistance in supplying bedrock topography data and their co-operation in sample analyses; Rick Richardson of AGS for his support and efforts in obtaining this project and negotiating its renewal; Reg Olson of APEX Geoscience Ltd. for his technical direction in designing the sampling program and critically reviewing parts of the manuscript; Mike Dufresne of APEX Geoscience Ltd. for his assistance with indicator mineral interpretation; and Robin Wyllie of APEX Geoscience Ltd. for critically reviewing parts of the manuscript.

These AGS staff worked on the project in the following ways: Doug Boisvert (fieldwork, heavy mineral concentration), Dianne Goulet (laboratory analyses), Tim Berezniuk (heavy mineral concentration, Scanning Electron Microscopy), and Roy Eccles (computing). We also had able help during the summers from students: Rob Brown (fieldwork, computer programming) and Oliver Irlam (fieldwork, laboratory analyses). Special thanks are due to the diligent efforts of contractor Shauna Miller. Shauna built our database and developed the GIS component of the study.

Executive Summary

A study of the preglacial sand and gravel deposits of Alberta started in 1992 with the support of the Canada-Alberta Partnership Agreement on Mineral Development and the Alberta Geological Survey. Preglacial sands and gravels are not just interesting geological features, they are valuable economic resources. Each year about $50 million worth of sand and gravel is mined from the preglacial deposits for use as mineral aggregate and almost $1 million worth of gold is recovered as a by-product of that mining. Supplies of gravel for use as mineral aggregate are dwindling. This study identifies over 200 deposits and records them on a single map and in a data base. The preglacial sources of aggregate are superior aggregate material. The study defines criteria for establishing the identity of sand and gravel deposits as preglacial and proposes a model to explain their formation. This model can be used to explore for more preglacial aggregate deposits, to identify deposits with the greatest gold concentrations, or to trace diamond indicator minerals (found in certain preglacial deposits) back to possible diamondiferous sources.

Sand and gravel deposits which rest directly on bedrock, contain no pebbles, cobbles, or boulders of Precambrian Shield origin, and predate Laurentide or Cordilleran glaciation are preglacial deposits. Preglacial deposits generally are coarse grained, average over 70% gravel, exhibit cross bedding with a southwest to northeast streamflow direction, exhibit a decrease in maximum clast size toward the east, and are often covered by till.

The source of the gravel in the preglacial deposits is primarily rock formations in the mountains. Pebbles were collected from ten preglacial deposits that range from the U.S. border to north of Peace River. The lithologies of the pebbles, cobbles, and boulders in these samples are described in detail. Comparison of the lithologies from the deposits studied resulted in the identification of seven distinct regions or groups. These groups reflect the source formations in the mountains and help define the extent of the river basins which existed on the Plains in preglacial time.

There appears to be at least four distinct levels, or ages, of deposits within the groups. These levels were created by erosion of the Plains surface over a period of about 50 million years and the preglacial deposits are remnants marking stages in the process.

Mountain building ceased during the Early Tertiary. The Mountains, at their highest and most massive, eroded and boulders and blocks of rock

swept out onto the Plains in the preglacial rivers. The hardest and toughest rocks survived as pebbles and cobbles and in some places were deposited in thick beds. The first level (Unit 4) marks the level of the earliest rivers or braidplains. Deposits preserved from this time (Eocene to Miocene) cover the highest hills on the Plains: the Cypress Hills, the Swan Hills, and Obed Mountain. The sands and gravels reveal the direction of flow in these ancient rivers through the orientation of the clasts and the shape of the beds. The rivers swept laterally and gradually eroded the Plains and lowered the base level. In some places the thick gravel beds protected the underlying, generally softer, bedrock from erosion and these armoured areas gradually rose relative to the surrounding land as it eroded away.

Continental uplift increased the elevation of the Plains during this period as the rivers continued to erode through underlying bedrock, ultimately as much as a kilometre in some places. The second major level (Unit 3) is characterized by hills or ridges capped by heavy gravel and includes the Hand Hills (Pliocene age), the Wintering Hills, Whitecourt Tower, Pelican Mountain, and Halverson Ridge. Again the gravel armour protected the former river beds and left them as positive features.

Unit 2 marks the third erosion surface at about present Plains level, and is represented by deposits at Grimshaw, Entwistle, Cluny, and Fort Macleod. The fourth, and lowest, level (Unit 1) is incised into the Plains and includes deposits at Simonette, Watino, Villeneuve, and Kipp. These deposits are dated as Late Wisonsinan and contain faunal remains such as mammoth teeth and tusks, which attest to a cold climate and the approaching Laurentide glacier.

The preglacial deposits formed in fluvial systems capable of carrying large clasts and destroying weak material. Cobbles and large pebbles are common in all Groups so that coarse crushed stone can be manufactured and the hard, resistant rocks result in aggregate which is often above average in quality. Gold, present in the Mountains, also was carried onto the Plains and deposited as fine placer gold. Placer gold concentrations as high as 0.17 g/m^3 exist with the best grades occurring in the Peace River region (Group 6) and the Edmonton region (Group 3/4). These values represent a viable by-product of large volume mineral aggregate operations such as at Villeneuve. Diamond indicator minerals also are found in deposits near Edmonton and in the Peace River region (diamond inclusion field, chrome diopside and chromite, and G10 garnet). Several scenarios of kimberlite emplacement and erosion in a Plains setting are described in the report to aid in diamond exploration.

Background

Tertiary sand and gravel deposits and Pleistocene deposits that predate Laurentide glaciation (hereafter collectively called preglacial deposits) are geologically interesting and economically valuable. Deposits of this type in Alberta yield high quality mineral aggregate worth about $50 million annually, and placer gold valued at almost $1 million annually. Increased exploitation of preglacial deposits for mineral aggregate and placer gold is expected. Preglacial sand and gravel deposits provide a geological record of events on the Alberta Plains from about 50 million years ago until about 25 000 years ago, a period poorly described and explained. Preglacial deposits contain indicator minerals which may prove useful in locating the source of diatremes and diamonds.

This study of the preglacial sand and gravel deposits was supported by the MDA and AGS. The objectives of the project are to:

- establish criteria for the identification of sand and gravel deposits of preglacial age in Alberta
- delineate all probable preglacial sand and gravel deposits in Alberta in a database and on a map
- collect field data on mineral aggregate, placer gold, and diamond indicator minerals from a select set of preglacial sand and gravel deposits
- establish a stratigraphy and develop a model for the deposition of preglacial sand and gravel

Many preglacial sand and gravel deposits have been identified and described in Alberta (Figure 1). The sedimentologic, stratigraphic, and paleontologic characteristics of preglacial deposits are:

- deposits are composed of bedded sands, interbedded sands and

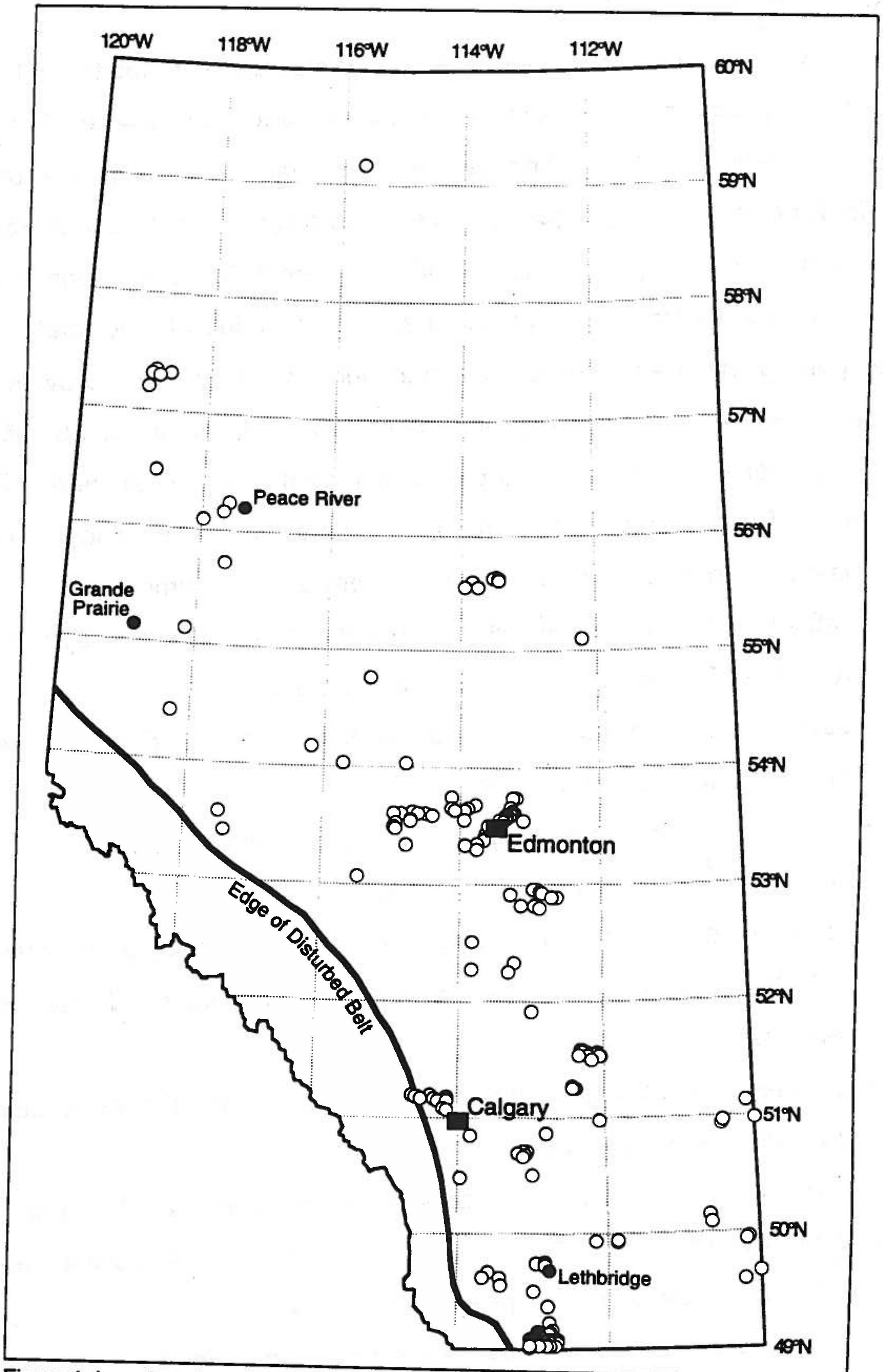

Figure 1. Location of preglacial deposits.

gravels, or massive gravels

- cross-bedding and pebble imbrication is common
- gravels do not contain granitic or gneissic clasts from the Precambrian Shield of northeastern Alberta, although the overlying tills or Recent gravels commonly contain these clasts
- gravels are composed of rock types, especially quartzites, presumed to be of Rocky Mountain origin
- deposits rest unconformably on bedrock. There is never any intervening till
- deposits commonly are covered by till, glaciolacustrine or glaciofluvial materials or Recent gravels
- oldest deposits may contain horse, rhinoceros and other semi-arid plains mammal remains, and younger deposits may contain mammoth, bear, bison, and musk ox remains that indicate cold climate

Using these criteria, a total of 203 deposits and 170 sites of probable preglacial origin (Figure 2, Appendix A) are identified, primarily from Alberta Research Council (ARC; former home of AGS) maps and reports (Figure 3), plus 15 journal articles and two theses. Mineral aggregate data also are generated from ARC publications plus two theses and four other reports/journal articles. A new AGS digital database is used to plot the deposits (Figures 2 and 3). Placer gold data are recovered from one ARC report and two theses. The only published information for indicator minerals in preglacial sand and gravel in Alberta is from a report by Dufresne et al (1996) which uses data supplied from this study. References are cited in the text of the report, in Appendix A, and in the References section. This study reviews the fundamental geological criteria used to identify preglacial sand and gravel deposits and revises them. The ability to distinguish these deposits is crucial for the proper interpretation of sample results in mineral aggregate, gold, or diamond exploration.

Probable preglacial sand and gravel deposits are described in over three dozen separate publications, usually along with deposits of other origins, and it was necessary to bring together the deposit locations and descriptions into a single database. Published data were assembled and the areas of probable preglacial sand and gravel deposits were digitized using ARC/INFO geographic information system software mounted on a Compaq 386 computer. Each deposit was assigned an unique number. A limited amount of data about each deposit (if available) was recorded and linked to the polygon data in ARC/INFO. The digital data were transferred to a VAX system and a Calcomp 1044 plotter was used to prepare working maps that outline the deposits.

The preliminary maps were used to select deposits of presumed preglacial origin, from all parts of Alberta, for field examination (Appendix B). Data were collected in order to define preglacial deposits sedimentologically and for use in correlating deposits (for example current direction measurements, grain size, and pebble lithology). Data also were collected to help define the mineral aggregate and placer gold resource potential of the preglacial deposits and their heavy mineral characteristics for use in diamond exploration.

Data collected for mineral aggregate purposes include determination of the Petrographic Number for the gravels and the collection of relatively large samples (about 600 kg) for grain size analysis.

Gold is present in several types of gravel deposits in Alberta. The

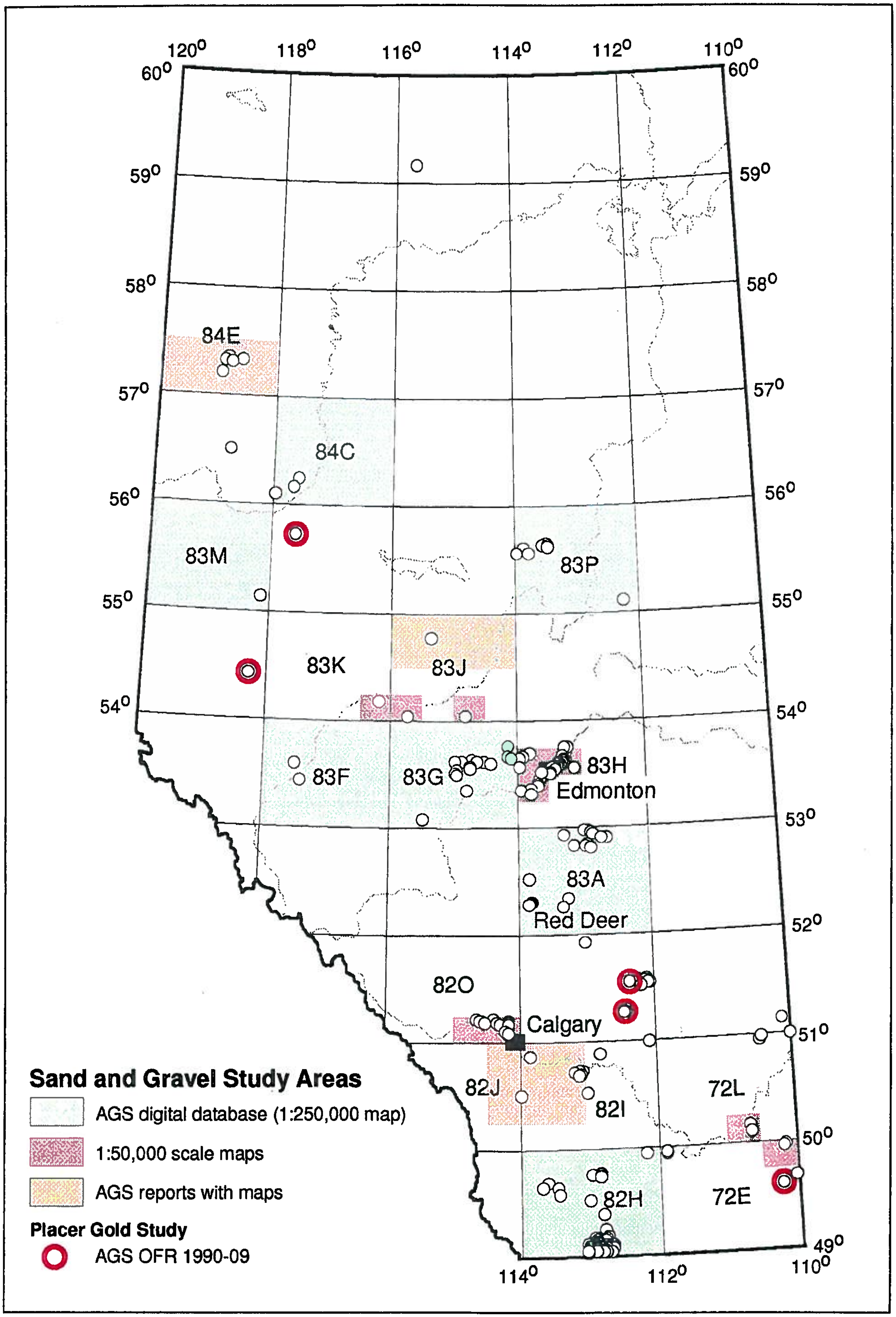

Figure 3. Sources of preglacial sand and gravel deposit locations.

identification of gold specifically in the preglacial deposits is used to delineate regions in which there is potential for by-product gold recovery. A known weight and volume of sample was collected and tested for free gold so that placer gold values could be reported as recoverable grade per weight or volume.

The search for diamonds in Alberta is just beginning. A major technique used in diamond exploration is to identify diamond indicator minerals and then trace these minerals back to their rock source, which may contain diamonds. Preglacial sand and gravel is an excellent medium for indicator mineral sampling. Potential indicator minerals were separated from sand matrix samples and sent for Scanning Electron Microscopy or Electron Microprobe analysis.

Similar data from different deposits are compared and Alberta is divided into seven regions or Groups based on the lithology of the gravels (Figure 4). The deposits within a Group are divided into a four fold stratigraphy. Following section refer to these Groups and present data to substantiate them.

Grain size analyses were performed at the AGS lab. Petrographic Number analyses were performed by Alberta Transportation and Utilities (AT&U) at their Materials Testing Lab. Concentration of heavy minerals were made at AGS, Saskatchewan Research Council (SRC) and at Loring Laboratories Ltd. Diamond indicator minerals were picked at Loring Laboratories Ltd. and SRC, and were analysed on the SEM at AGS and on the Electron Microprobe at the universities of Calgary and Alberta. Gold assays and gold amalgamations were performed at Loring Laboratories Ltd. Thin sections were prepared at AGS and Vancouver Petrographics Ltd., and petrographic interpretations were made by Vancouver Petrographics Ltd.

of Langley, B.C. and Cosmic Ventures of Edmonton.

Sedimentology

Grain size analysis

Sampling procedure and introduction

Samples of known volume were collected by sampling from measured trenches cut into the faces of natural or pit exposures (Plate 1a, Table 1). Trenches measuring about 1 m high, 1/3 m wide, and 1/4 m deep (0.0833 m^3) were dug in 16 deposits (Table 2). Smaller volumetric samples, ranging in size from 0.0052 m^3 to 0.0625 m^3, were recovered from an additional four deposits (Table 2). In total, 54 sand and gravel samples representing 20 deposits were collected from measured trenches. All material excavated during volumetric sampling were returned to the laboratory for grain size analysis (Appendix C). In general, the trenches represent the major beds exposed at the site and are a reasonable approximation of the grain size of sections exposed in the deposit (Plate 1b and c).

Figure 5 shows the grain size distributions for all volumetrically collected sand and gravel samples. Total sample weight is 8950 kg. This sample set includes multiple samples from single deposits and samples from deposits with widely divergent locations and ages. This collection of data (Figure 5) shows the bi-modal nature (gravel and medium sand) of preglacial deposits.

In general, preglacial deposits can be described as clean, coarse gravel deposits (Plate 1a to d). The average sample (Figure 5) contains some cobbles (7% >3"), about 44% coarse pebbles (3/4" to 3"), a medium sand matrix (14% between #120 and #40 mesh), and 1% fines.

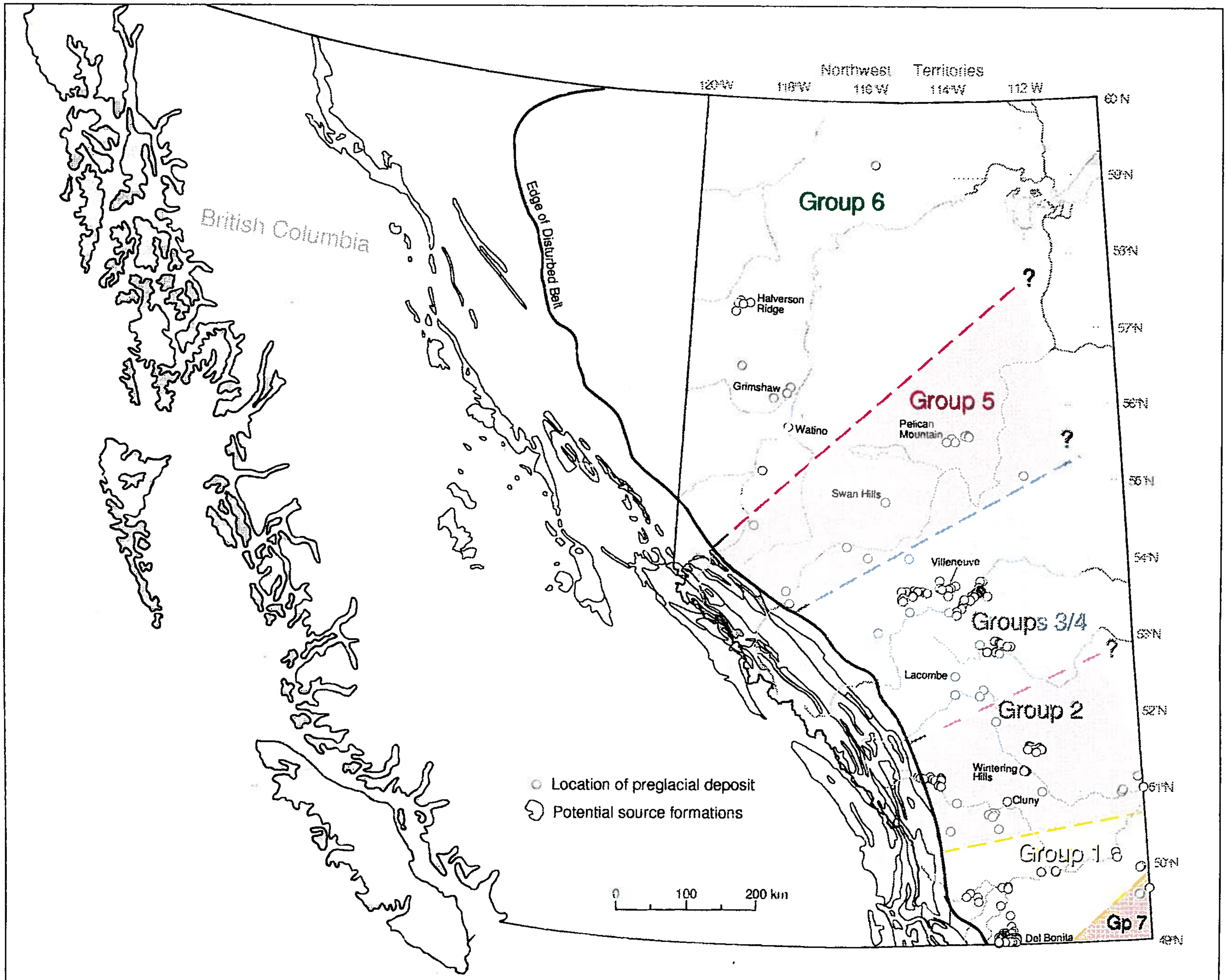

Figure 4. Preglacial deposit groups.

Table 1. Deposits sampled and investigated, types of samples collected, and stratigraphic observations.

Deposit Name	Deposit Number	Type and Number of Samples				
		Trench	Screened	Crushed	Till	Bedrock
Arrowwood	5855	1		1	1	o
Cluny	3913	3		1	o	
Cypress Hills	4213		3	1	absent	o
Del Bonita(east)	5570	3		1	1	
Del Bonita(west)	5566	1			o	
Entwistle	6424		1	2	1	
Grimshaw	6692	3	1	2	o	1
Halverson Ridge	6815	3		1	1	
Hand Hills (west)	3958	3			o	o
Hand Hills Lake	3964	3			1	
Heatherdown	6402			2	o	
Lacombe	6106	3	1	2	o	
Magnolia	6422		1		o	
Magrath	5669	1	1		1	
Nanton	5812	1		1	1	
Obed Mountain	3915		1	1	1	o
Calgary	6050	3		1	1	
Pelican Mountain	6824	3			1	
Simonette	4028	1				o
Smoky Tower	3914		3			
Swan Hills	3973	1	1		1	1
Villeneuve	3975		1	2	o	o
Watino	4212	3				o
Wetaskiwin	6119	1			o	
Whitecourt Tower	6573		3		o	o
Wintering Hills	6811	3		1	1	1
Total Samples	26 deposits	40	17	19	12	2

Trench samples are pit run samples of a known volume. Screened samples were reduced by field screening through a half inch screen. Crushed samples are from stockpiles of crushed gravel (6 mm to 25 mm) or have been crushed in the lab to this size. Till samples were taken directly above the sand and gravel beds. Bedrock samples were taken from bedrock exposed immediately below the sand and gravel beds. Sites where till and/or bedrock were observed, but not sampled, are denoted by the symbol 'o'.

Table 2. Weights, volumes, and percentages of sand and gravel for preglacial samples.

Deposit Number	Deposit Name	Sample Number	Volume (m^3)	Total Weight (kg)	Gravel %	Sand %
6815	Halverson Ridge	1	.0825	199.98	64	36
		2	.0825	195.72	58	42
		3	.0825	190.16	52	48
6692	Grimshaw	1	.0825	187.61	66	34
		2	.0825	193.07	70	30
		3	.0825	196.12	64	36
6692	Grimshaw (Fairview)	A(lower)	.0052	14.08	80	20
		A(coarse)	.0052	19.20	76	24
		E	.0052	23.37	73	27
4028	Simonette	1	.0052	20.68	83	17
		2	.0052	21.75	77	23
		3	.0052	19.65	69	31
		4	.0052	22.65	78	22
		5	.0052	20.70	75	25
		6-12	.0481	140.73	75	25
4212	Watino	1	.0825	240.89	73	27
		2	.0825	238.39	81	19
		3	.0825	233.50	66	34
3973	Swan Hills	1	.0825	243.32	79	21
6824	Pelican Mountain	1	.0825	201.25	84	16
		2	.0825	175.58	59	41
		3	.0825	185.40	19	81
6424	Entwistle (south)	A	.0625	210.90	80	20
6424	Entwistle (west)	A	.0432	145.90	76	24
		B	.0262	88.80	40	60
6422	Magnolia	A	.0625	169.40	78	22
6119	Wetaskiwin	1	.0825	203.36	60	40
		A	.0403	131.30	74	26
6106	Lacombe	1	.0825	212.49	80	20
		2	.0825	213.25	81	19
		3	.0825	194.14	76	24
		A	.0625	165.20	85	15
3958	Hand Hills (west)	1	.0825	207.65	78	22
		3	.0495	135.88	73	27
6811	Wintering Hills	1	.0825	277.59	81	19
		2	.0825	259.81	77	23
		3	.0825	265.57	79	21
		A	.0625	196.04	79	21
		B	.0403	123.70	79	21

Table 2 (continued). Weights, volumes, and percentages of sand and gravel of preglacial samples.

Deposit Number	Deposit Name	Sample Number	Volume (m^3)	Total Weight (kg)	Gravel %	Sand %
3964	Hand Hills Lake	1	.0825	191.63	76	24
		2	.0825	196.98	79	21
		3	.0825	246.50	74	26
5855	Arrowwood	1	.0825	269.93	76	24
6050	Calgary	1	.0825	276.68	82	18
		2	.0825	239.87	65	35
		3	.0825	270.42	78	22
3913	Cluny	1	.0825	244.49	82	18
		2	.0825	274.10	74	26
		3	.0825	267.14	73	27
5812	Nanton	1	.0825	264.15	77	23
5566	Del Bonita (west)	1	.0825	263.09	70	30
5570	Del Bonita (east)	1	.0825	201.59	68	32
		2	.0825	220.81	71	39
		3	.0825	211.99	74	26
5669	Magrath	1	.0125	38.84	70	30

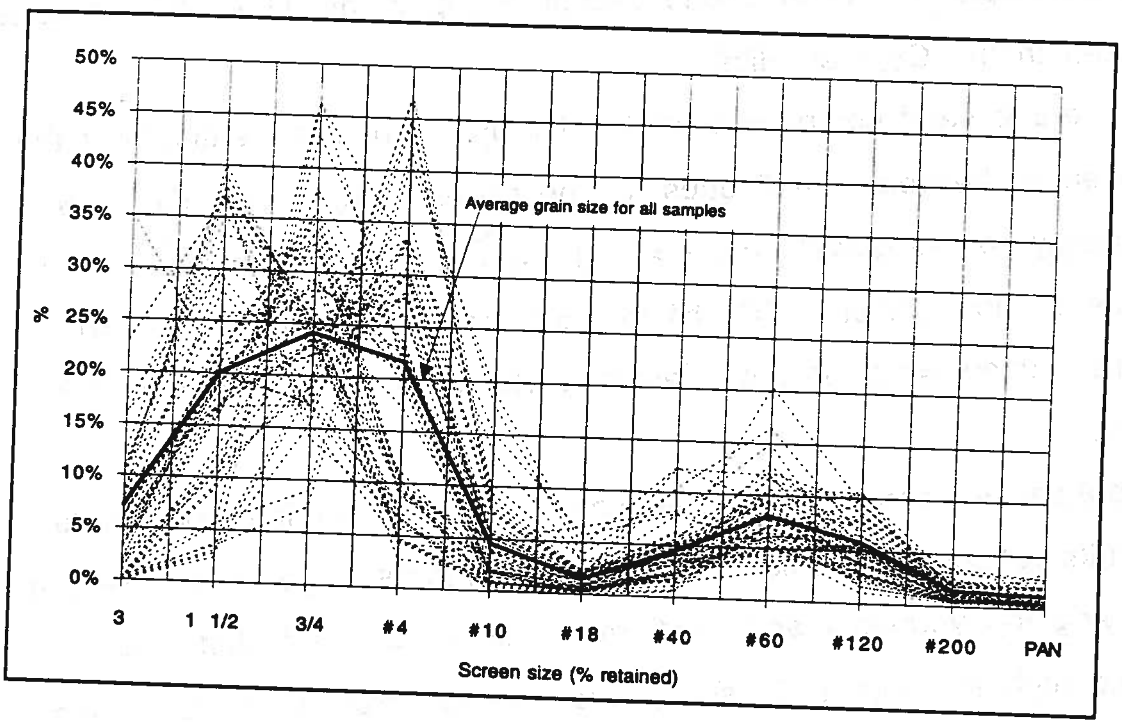

Figure 5. Grain size distribution curves for all volumetric samples.

Seventeen sand and gravel samples were collected from 11 deposits primarily for indicator mineral analyses (Table 1). These samples were scalped in the field with a 0.5" screen to remove gravel. The ≥0.5" fraction was weighed in the field and discarded. The ≤0.5" fraction was returned to the laboratory for grain size and indicator mineral analyses. These samples were not gathered volumetrically but provide useful grain size information. Sample results and locations for deposits 3914, 4213, and 6573 are listed in Appendix C and Table 2 respectively.

Comparison of grain size data by region (Group) and age (Unit)

The preglacial deposits are categorized in this report into six Groups based on their regional distribution and pebble lithology, which probably reflects the source areas for the gravel component and the fluvial basins in which the deposits formed. Figure 6a shows an average of all volumetric samples for each Group except Group 7 (no volumetric samples were taken in the Cypress Hills).

The average sand component for the Groups is nearly identical but there are differences between the Groups for the gravel component. Group 5 is predominantly coarse gravel (>50% >1.5"); Groups 1, 2 and 6 are predominantly fine gravel (~50% #4 to 1.5"); and Group 3/4 has broad gravel distribution which includes equal parts coarse and fine gravel but ~15% >3".

The preglacial deposits are categorized in this report into four Units. These Units reflect the erosional history and probable age of the deposits, Unit 1 being the youngest and stratigraphically lowest and Unit 4 the oldest and highest. Figure 6b shows the average grain size distribution for each unit.

There is less obvious difference in the grain size of the Units than in

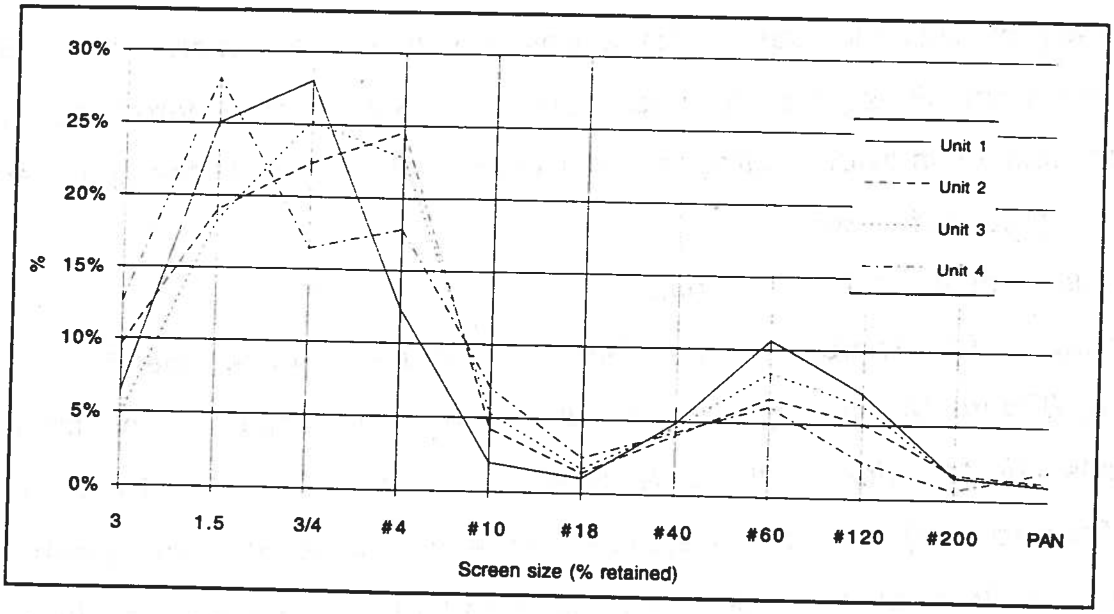

Figure 6a Average grain size distribution curves for preglacial Units.

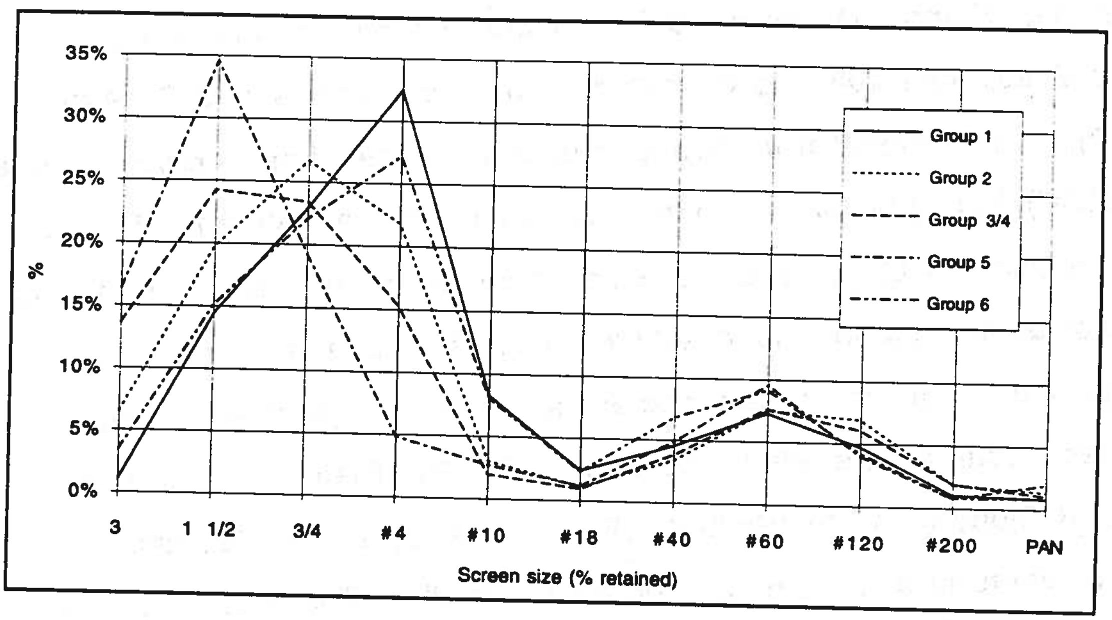

Figure 6b Average grain size distribution curves for preglacial Groups.

the Groups. This lack of distinction between units is reasonable. A summary by Unit includes deposits from the length of Alberta and includes samples from all regional Groups. Unit data will be considered later in the context of individual Groups. A closer examination of the grain size for the groups follows.

Grain size description for Groups

Group 1 data represent three deposits and five samples weighing 936 kg (Figure 7). The grain size curves are very similar for the three deposits and the three Units represented. The average grain size for Group 1 is finer (gravel) than the preglacial average (Figure 5). The similarity is due in part to a similar distance of transport of the clasts (described in detail later). The pebble lithology described at Del Bonita (5566-1) is sandstone, quartzite and argillite (Plate 2e). These rock types include flat argillite (Plate 4, Del Bonita 1) and bedded sandstone pebbles (Plate 4, Del Bonita 7 and 11) which would produce the smaller gravel sizes.

Group 2 supplied 4080 kg of material from 16 samples and 6 deposits (Figure 8). The material from Group 2 is coarser than from Group 1 (more gravel >3/4") but very similar to the overall preglacial average (Figure 5). Deposits within the Group show a wide variation in grain size. In addition to the typical sandstone and quartzite rock, significant amounts of carbonate and conglomerate are present and local sandstones. Local sandstones occur at the Wintering Hills (6811-2) (Plate 4, Wintering Hills 1) and Cluny (3913-1) (Plate 4, Cluny 1 and 6) as pebbles and are seen as boulders in a number of deposits (Plate 3b). The broad range in gravel sizes in the grain size distribution for Group 2 appears to reflect the wide variety of rock types and source formations. A greater

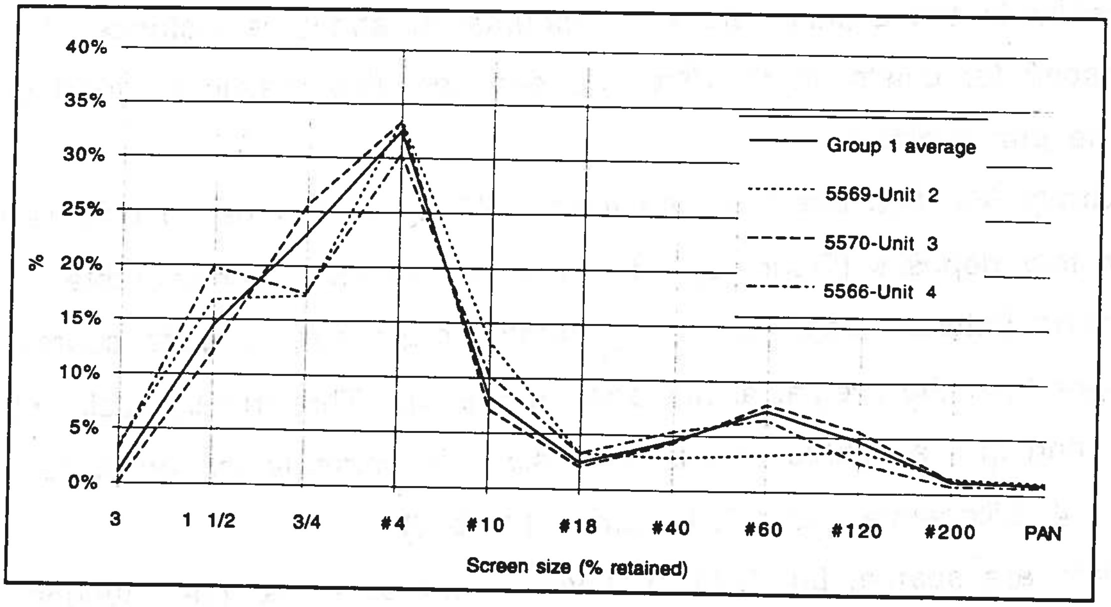

Figure 7. Average grain size distribution curves for samples from three deposits in Group 1 and an average curve for all samples in Group 1.

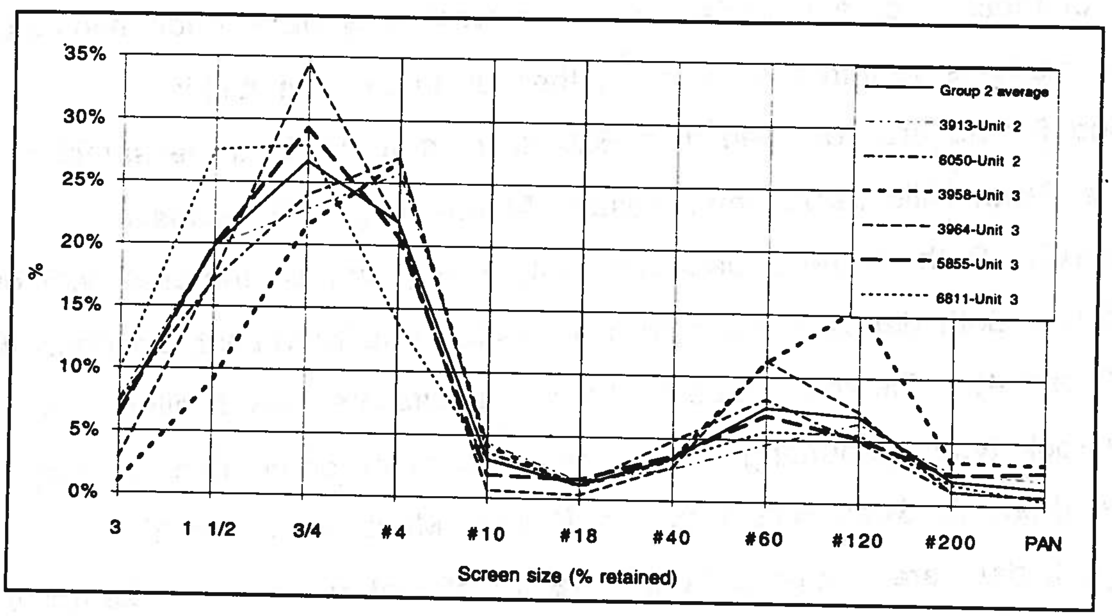

Figure 8. Average grain size distribution curves for samples from six deposits in Group 2 and an average curve for all samples in Group 2.

variation in the distance from the mountains, and thus distance of transport for clasts, in the Group 2 samples also results in great variation in the gravel sizes.

Group 3/4 data are compiled from 1646 kg of material in nine samples from four deposits (Figure 9). The gravel data show considerable variation between deposits but, generally, grain size is quite coarse, coarser than the preglacial average (Figure 5). The primary rock unit occurring in the cobble and boulder sizes is primarily tan quartzite (Plate 4, Villeneuve 1 and 5, Lacombe 1 and 2).

Data are sparse, but field observation indicates that the younger, lower deposits (Unit 1) contain finer gravel (Plate 3d) than the higher deposits (Unit 2) (Figure 9, Plate 2b). The fluvial systems depositing the Unit 1 material may have been less competent to carry the larger rocks or the supply of these coarse materials from the west may have been eliminated. Further study is required to verify either of these possibilities.

Group 5 data are compiled from 620 kg of material in three samples from the Swan Hills (3973) and Pelican Mountain (6824) deposits (Figure 10). Both of these deposits contain very coarse material with over 50% >1.5". Both deposits are high in elevation and represent old deposits (Units 3 and 4). The rock types at these deposits are very similar. The primary rock type accounting for the cobble-boulder component is gray quartzite (Plate 5, Swan Hills 1 and 2, Pelican Mountain 1 and 2).

Group 6 data are compiled from 2178 kg of material from 17 samples and four deposits (Figure 11). The grain size data appear to be composed of two distinct sets of gravel data. The more northerly Unit 2 (Grimshaw 6692) and Unit 3 (Halverson Ridge 6815) samples are finer than the

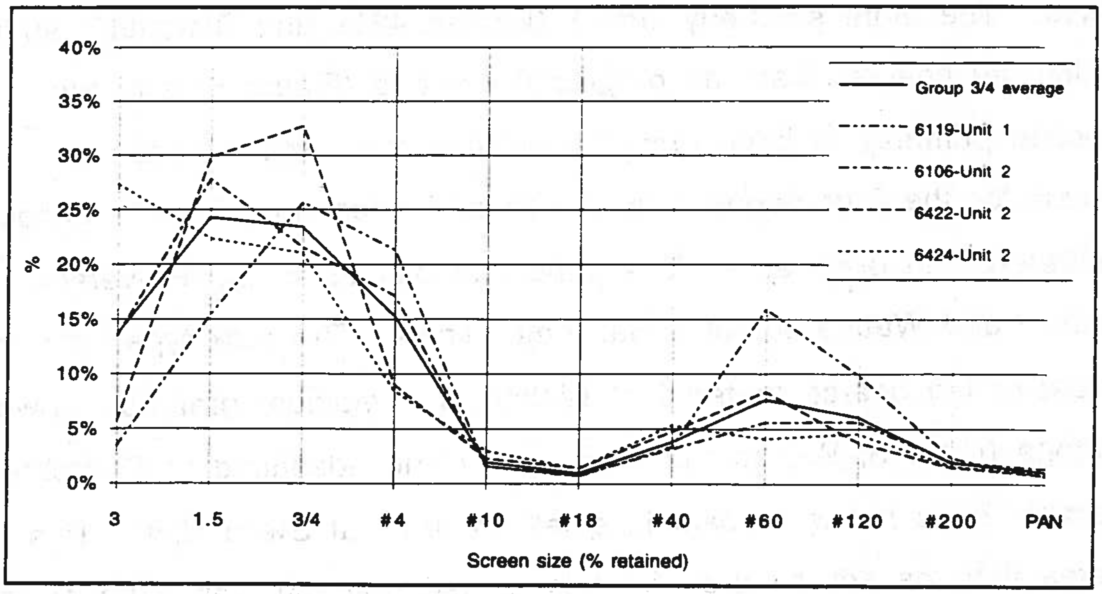

Figure 9. Average grain size distribution curves for samples from four deposits in Group 3/4 and an average curve for all samples in Group 3/4.

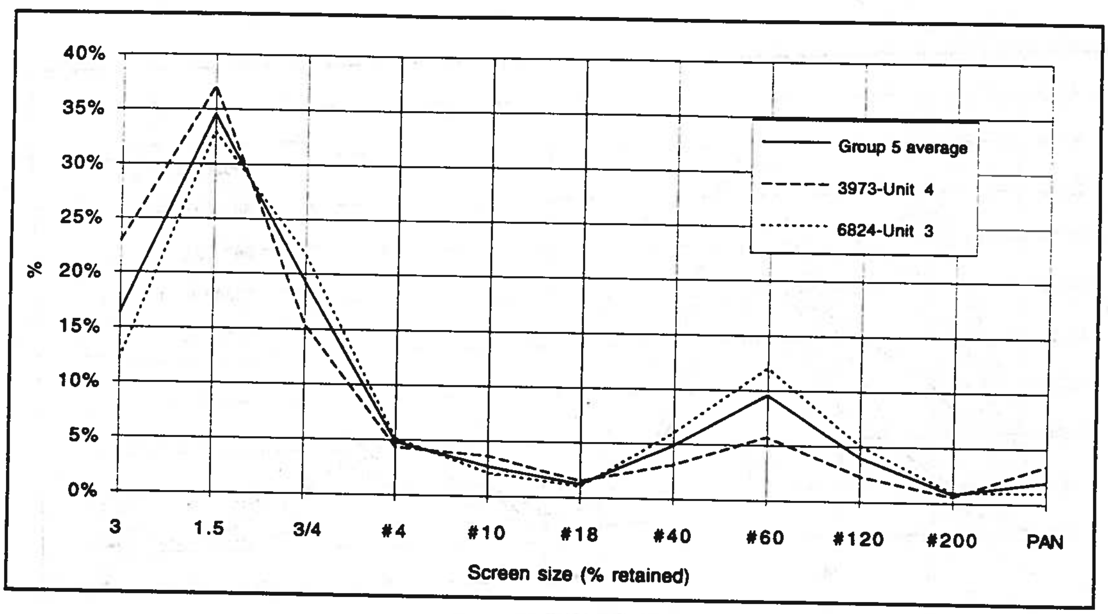

Figure 10. Average grain size distribution curves for samples from two deposits in Group 5 and an average curve for all samples in Group 5.

preglacial average (Figure 5) and are comprised primarily of small pebbles. The more southerly Unit 1 (Watino 4212 and Simonette 4028) samples are coarser than the preglacial average (Figure 5) and are composed primarily of large pebbles and cobbles. The distance of transport for the four deposits is similar and does not seem to account for the difference in grain size. The pebble lithologies in the Halverson Ridge, Grimshaw and Watino samples was determined. The rock type accounting for most of the coarse material at Watino is a medium grained, brown sandstone (Plate 5, Watino 8). This rock is not identified at Grimshaw or Halverson Ridge but is present in small amounts at Swan Hills. This indicates that the source area for this coarse material was exposed in the southern portion of the Group 6 source zone. The bi-modal nature of the gravel makes the average grain size curve for Group 6 a poor representation.

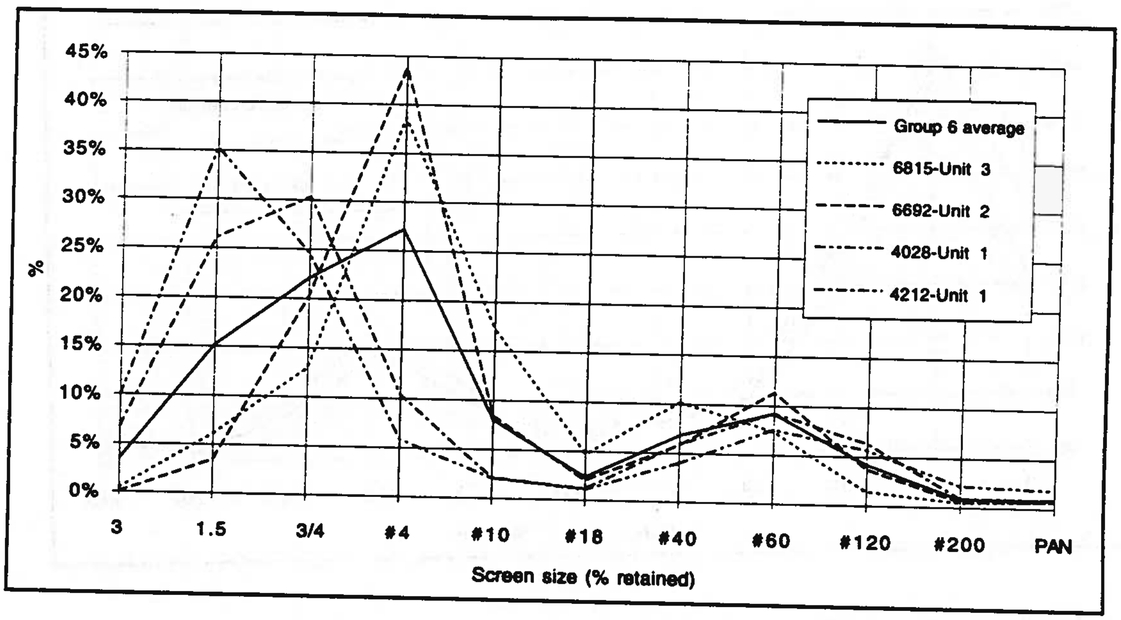

Figure 11. Average grain size distribution curves for samples from four deposits in Group 6 and an average curve for all samples in Group 6.

Maximum clast size data

The greatest variety in gravel sizes is for Groups with the greatest range in distances from deposits to the disturbed belt. This distance is a measure of the distance which clasts from the mountains travelled (distance of transport). At several sites the size of the largest clast (length of longest axis) visible in the deposit is recorded. This measure is highly dependent on the amount and type of exposure but is an easy source of data to acquire and demonstrates the effect of distance of transport on clast size. Figure 12 shows the maximum clast size plotted against distance from the disturbed belt for all deposits where measurements were made.

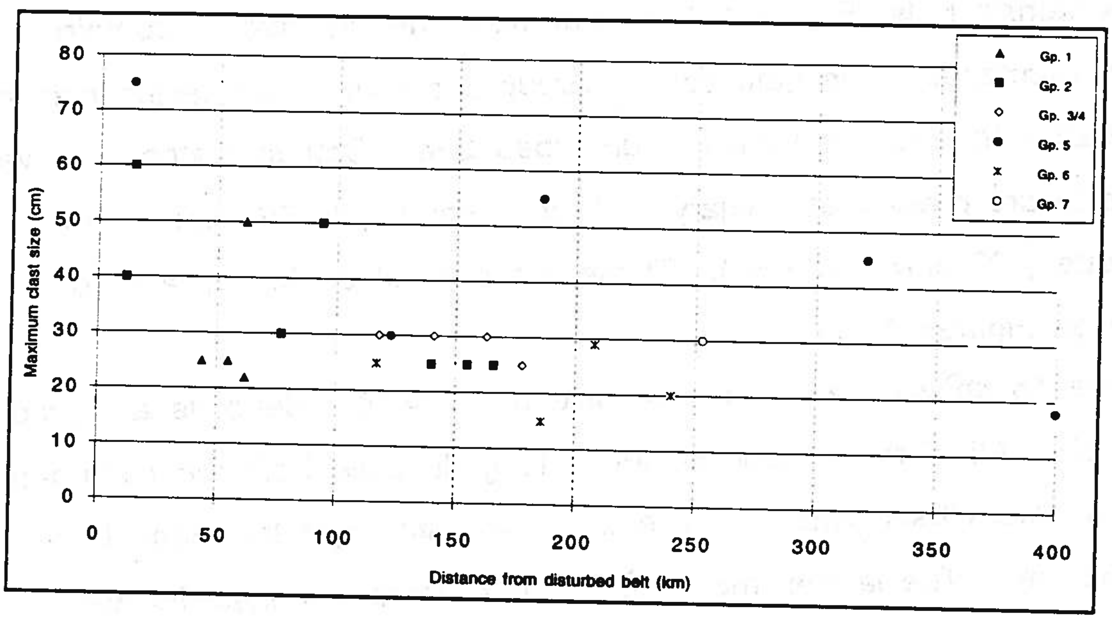

Figure 12. Maximum clast size plotted against distance from the disturbed belt for all deposits where measurements were made. The symbols identify the Group.

Figure 12 shows that there is a decrease in maximum clast size away from the disturbed belt. It also appears to indicate a difference between the Groups.

Figure 13 shows the distribution of maximum clast size versus distance from the disturbed belt for four deposits assigned to Group 1. The coarsest deposit (Magrath 5669) contained a quartzite clast 50 cm long. The other deposits in Group 1 have argillites as their largest clasts (Plate 2e).

The data for Magrath appear to fit well with the data for Group 2 (Figure 14) because the largest clasts in Group 2 (30 to 60 cm) are quartzites or hard sandstones. The largest clasts occur in the deposits in the southern part of Group 2 (Calgary 6050, Nanton 5812, Cluny 3913, Arrowwood 5855) and in deposits closer to the mountains. The Hand Hills and Wintering Hills (Figure 14), further from the mountains, contain smaller quartzites. The data set for Group 2 shows a decreasing maximum clast size with distance from the disturbed belt. Soft sandstones of very large size are present at Calgary (150 cm), Hand Hills (70 cm), and Simonette (100 cm) (Plate 3b). These are of local origin and are not plotted on Figures 12 to 18.

Figure 15 shows maximum clast size data for four deposits assigned to Group 3/4. All of these deposits are a long distance from the disturbed belt and have clasts similar in size to those present at the Hand Hills sites (30 cm). The largest rock types in the Group 3/4 deposits are quartzites and hard sandstones.

Figure 16 shows the largest clast sizes for five deposits in Group 5. The quartzites at Obed Mountain (3915), Swan Hills (3973), and Pelican Mountain (6824) are extraordinarily large. They show a decrease in size away from the disturbed belt but are twice as large at distances over 150 km as material from any other deposit in other Groups. All of these

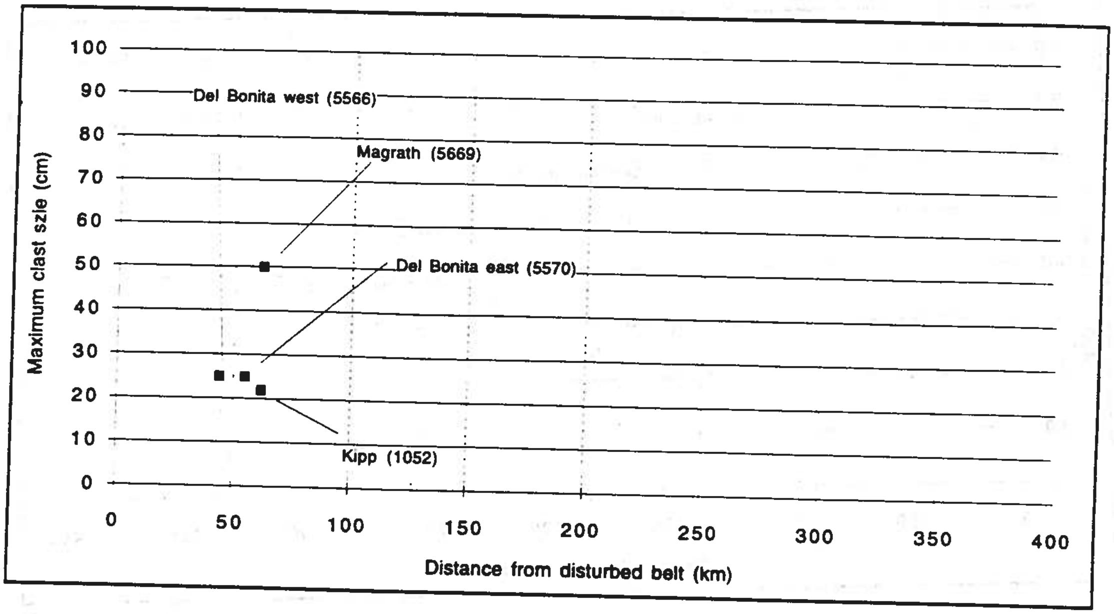

Figure 13. Maximum clast size for four deposits assigned to Group 1.

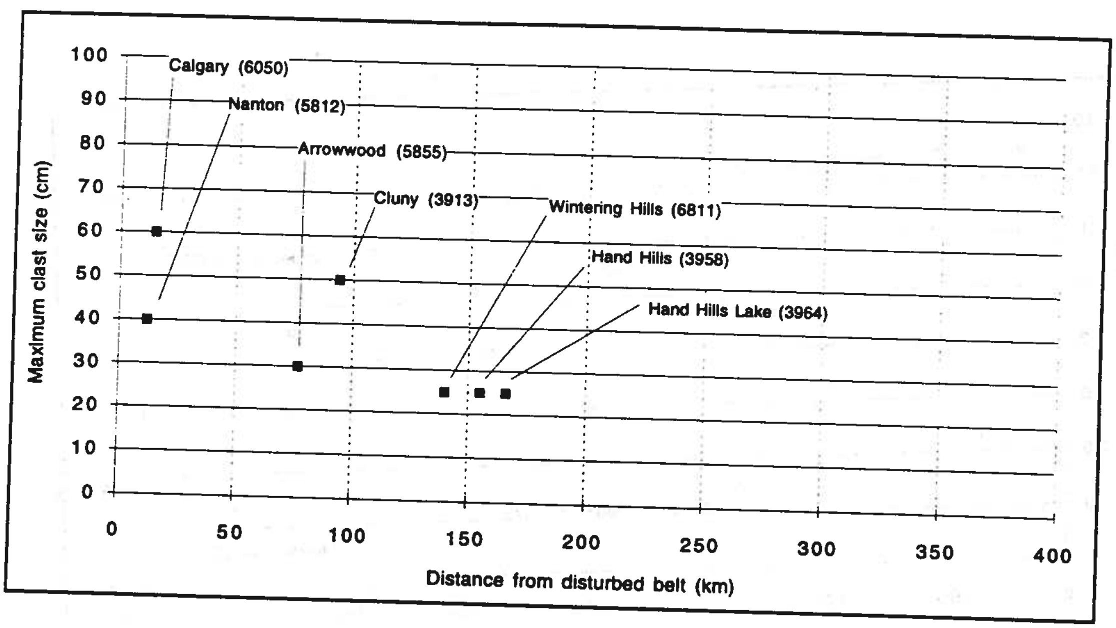

Figure 14 Maximum clast size for seven deposits assigned to Group 2.

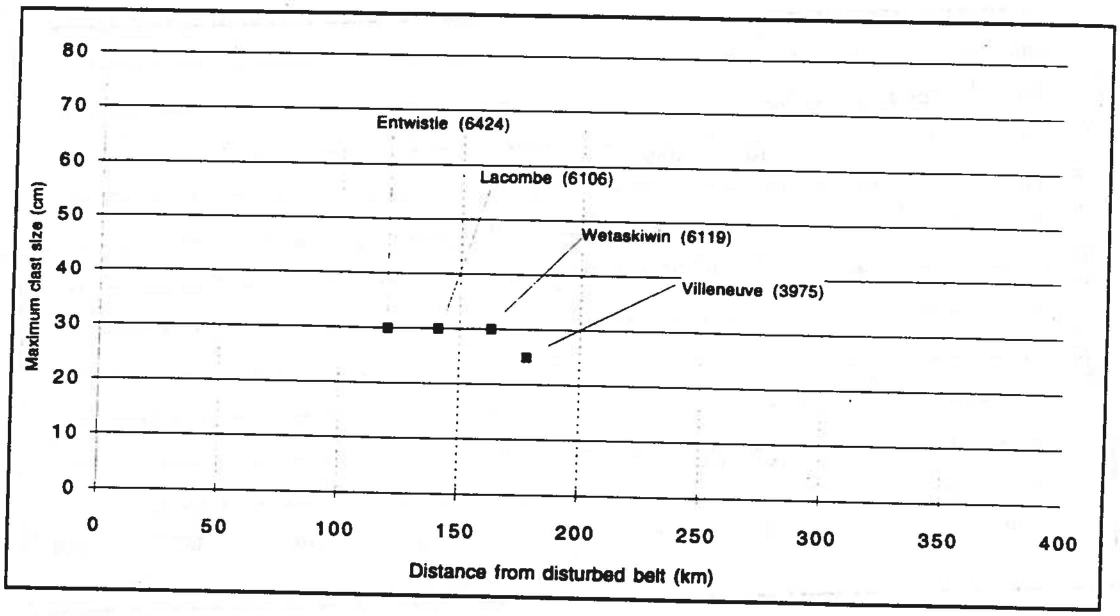

Figure 15 Maximum clast size for four deposits assigned to Group 3/4.

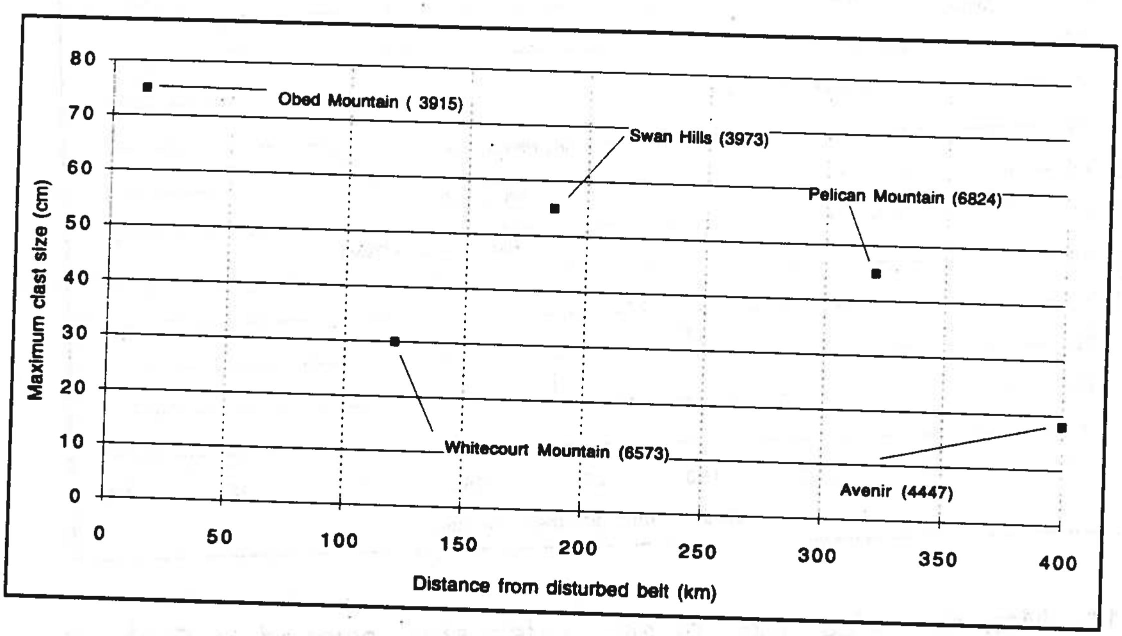

Figure 16. Maximum clast size for three deposits assigned to Group 5.

deposits in this data set are very high in elevation and are presumed to be quite old (Units 3 and 4). The Whitecourt Tower (6573) and Avenir (4447) deposits are south of the older deposits and more closely resemble Group 3/4 values.

Figure 17 shows the largest clast sizes for four deposits in Group 6. Quartzites form the largest clasts in these deposits although some large pieces of massive quartz are present in the Grimshaw (6692) deposit. The maximum clast sizes in Group 6 are similar to Groups 2 and 3/4 for deposits >100 km from the disturbed belt (Figure 12).

Figure 18 shows the largest clast size (quartzite) for the Cypress Hills (Group 7) (Plate 3c). Quartzites in the Cypress Hills are rumoured to be exceptionally large. However, they are less exceptional than the Swan Hills (3973) and Pelican Mountain (6824) quartzites (Figure 18).

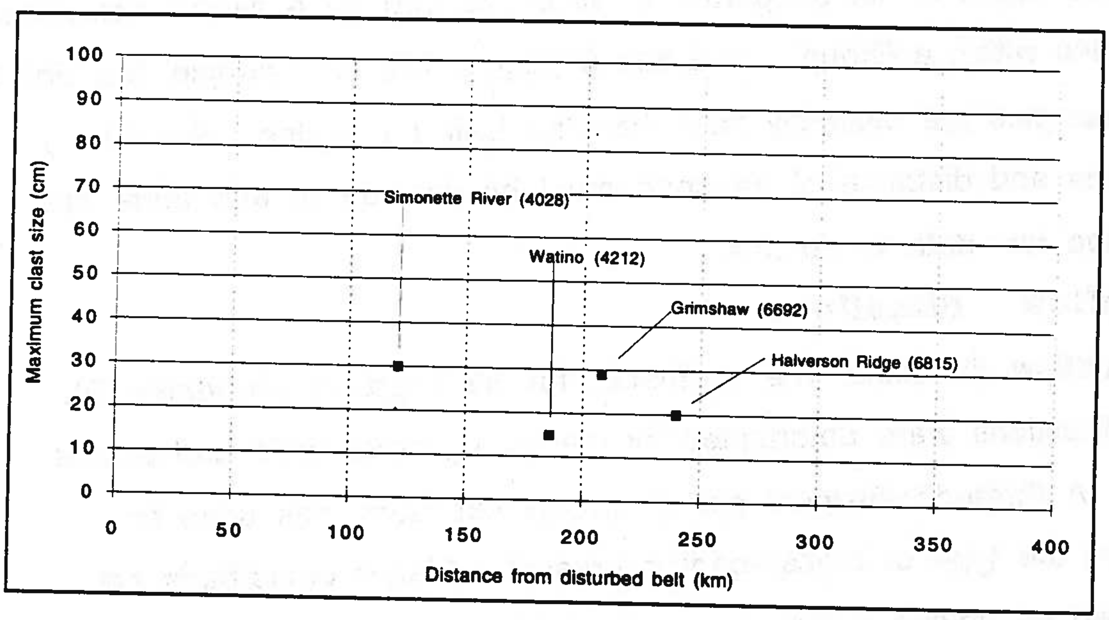

Figure 17 Maximum clast size for four deposits assigned to Group 6.

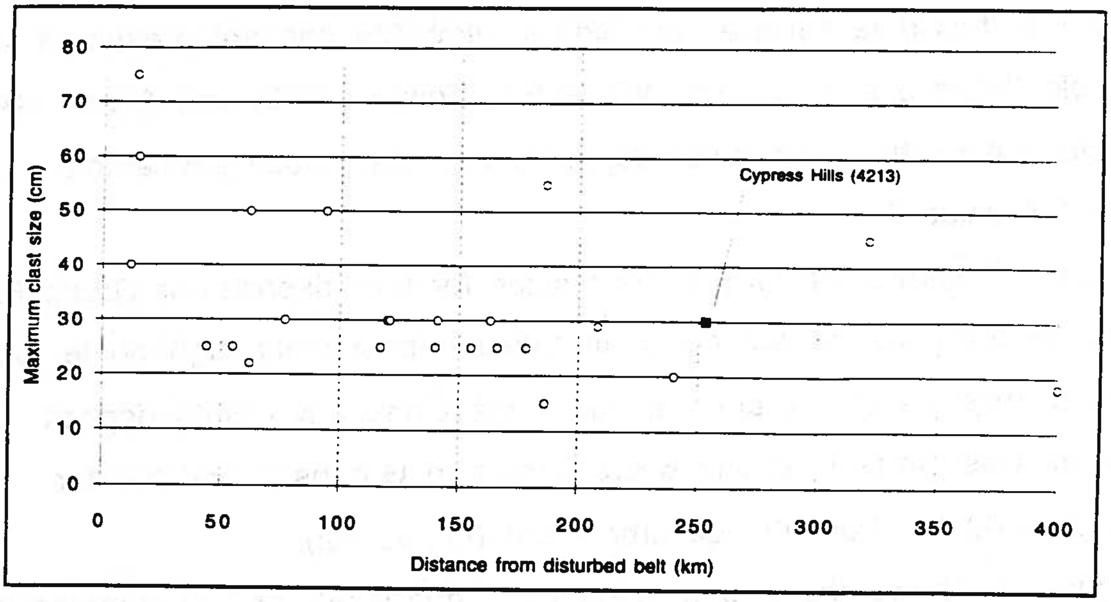

Figure 18. Maximum clast size for quartzites at Cypress Hills (Group 7).

Field observations lead the authors to believe that maximum clast size and gravel grain size decreases with age, that is from Unit 4 to Unit 1. This observation is not supported in all cases through a simple comparison of samples within a Group. In Group 6 (Figure 11), for example, the Unit 2 and 3 samples are distinctly finer than the Unit 1 samples. Source formations and distance of transport must be considered and there are simply too few data to do this.

Streamflow directions

Streamflow directions are estimated for 39 deposits (Appendix D). These directions were determined by measuring cross-beds and pebble fabrics. A three-dimensional cut or natural exposure was used to determine the type of cross-bedding present. Planar cross-beds are recognized as having a planar, erosional lower surface. Flow directions from planar cross-beds are taken to be the direction of maximum dip of the foreset beds (Plate 1d). Trough cross-beds are recognized as having a curved surface of erosion for the lower surface (Plate 1a). Flow directions from trough cross-beds are along the axis of the trough. In many deposits, flat pebbles assume a shingled or imbricate fabric (Plate 1e). The direction of flow is measured from these pebbles as the direction opposite the maximum dip of the AB plane where A is the long axis and B is the intermediate axis. The manner of determining streamflow directions is similar to that employed by Vonhof (1969) and Leckie and Cheel (1989) and results appear to be compatible.

Vonhof (1969) concludes that the averaging of cross-bed and pebble fabric measurements for preglacial deposits provides a generalized picture of the streamflow. There is no way of ensuring that beds in different outcrops are time correlative. Liverman et al (1989) recovered and dated wood from different levels of the Watino section (Figure 19). The age from the lowest bed varies by almost 10 000 years from the age of the highest bed sampled. There also may be considerable variation within a single outcrop as a result of changing local conditions which affect the current flow direction. Leckie and Cheel (1989) record a variation of almost 90° in vector directions of pebble imbrication from eight beds over a 17 m vertical interval at one outcrop in the Cypress Hills (Figure 20). Several measurements from a single bed vary even more widely.

Vonhof (1969) notes, and the authors concur, that the visual estimation of the overall orientation of pebbles in the outcrop closely agrees with the actual measured directions of 50 pebbles. This quick method is considered to be a useful and a much quicker method of estimating flow direction at many outcrops. The authors made this visual estimate first and then confirmed it using a small number of measurements on pebbles in

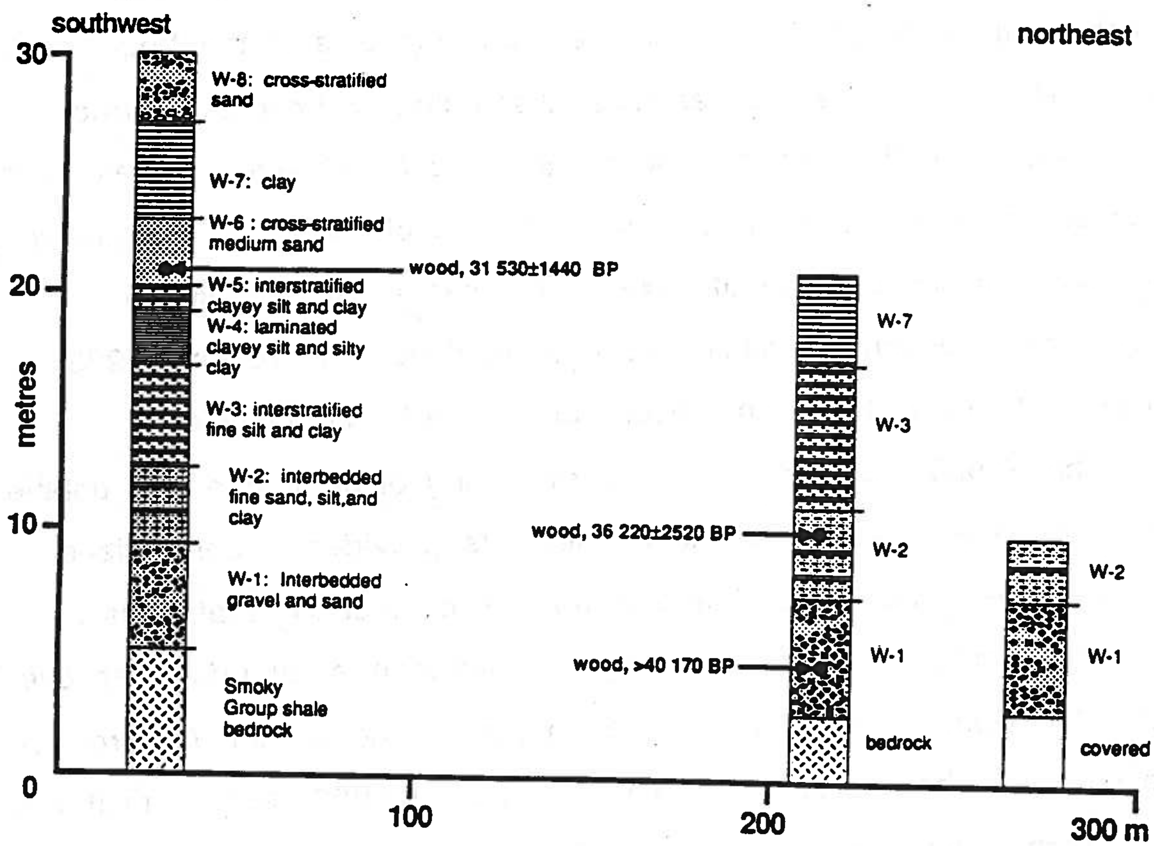

Figure 19. The stratigraphy of the Watino (4212) section along the west bank of the Smoky River (Liverman et al, 1989).

the outcrop. Individual measurements are recorded in Appendix D. Figure 21 shows the average streamflow directions for deposits or groups of deposits. Vectors for the Swan Hills, Villeneuve, Hand Hills, Wintering Hills, Hand Hills Lake, Del Bonita (high gravels and low gravels), and Cypress Hills areas are averages of all measurements for deposits in the area.

The vectors in Figure 21 indicate an easterly streamflow. The only exceptions are measurements from Grimshaw, the Wintering Hills, and the Cypress Hills where streamflow measurements are from redeposited beds

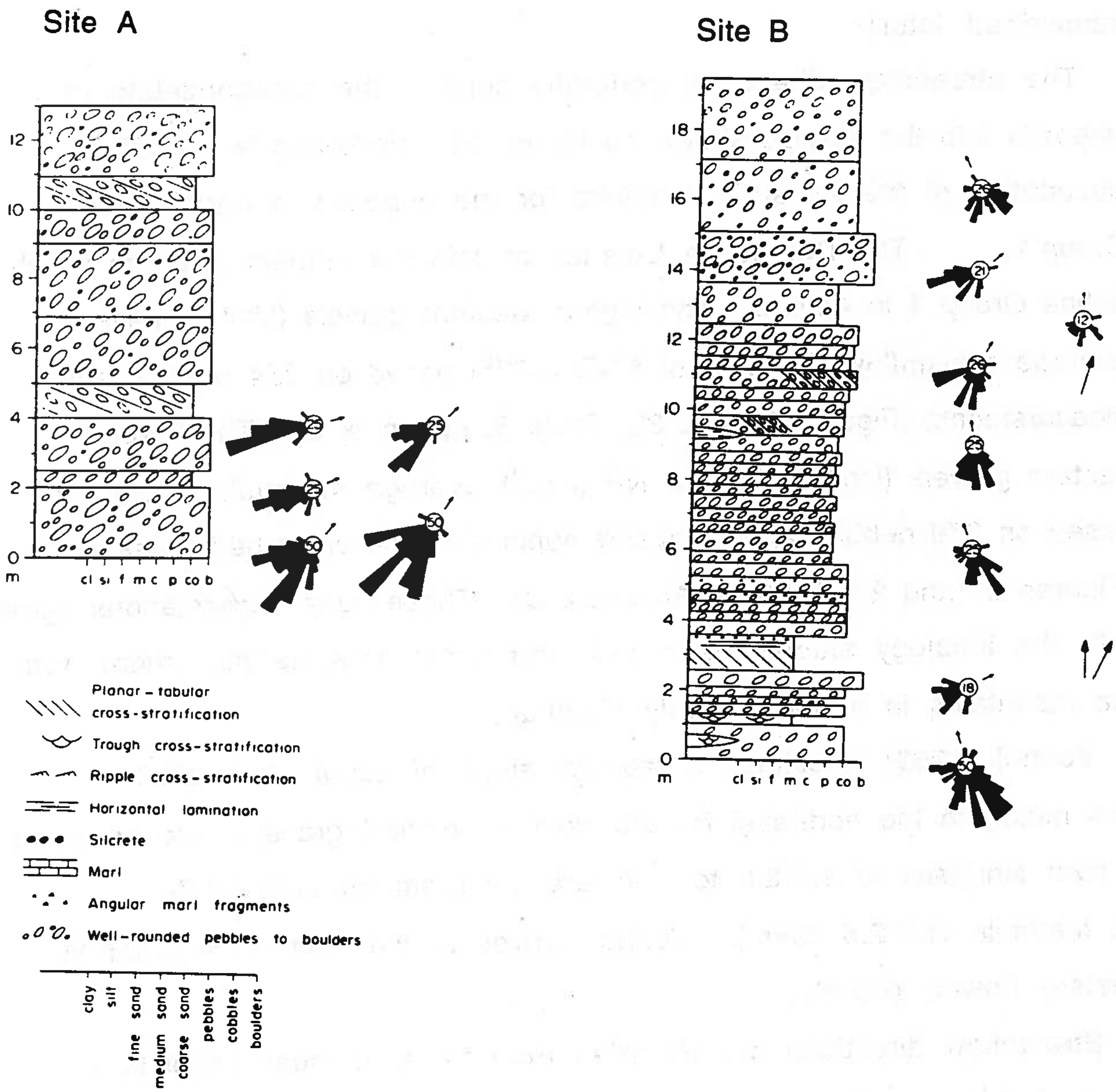

Figure 20. Sections from the Cypress Hills Formation. The section at site A (Figure 29) is a composite section from a 2 km long outcrop. The section at site B (Figure 29) is a measured section. Rose diagrams are based on pebble imbrication, numbers in the circles represent the number of measurements and the small arrow is the resultant vector direction. The single arrows are cross-bed dip directions (Leckie and Cheel, 1989).

(described later).

The streamflow directions generally support the categorization of deposits into the Groups shown on Figure 21. Following is a brief description of the streamflow results for the deposits in each group.

Group 1. The Del Bonita Uplands contain the primary deposits which define Group 1 in Alberta. The higher, western gravels (Unit 4) have an average streamflow direction of NNE (039^0) based on 254 pebble fabric measurements (Figures 21 and 22, Table 3, Appendix D). The lower, eastern gravels (Unit 3) have a NE (056^0) average streamflow direction based on 370 pebble fabric measurements and one cross-bed measurement (Figures 21 and 22, Table 3, Appendix D). These current orientations agree with the lithology studies described later which indicate movement from the mountains in a northeasterly direction.

Vonhof (1969) calculates a regional slope of about 18 feet/mile (3.4 m/km) to the northeast for the western (higher) gravels. He assumes a river sinuosity of 1.5-2.6 to calculate a stream gradient of 7-13 feet/mile (1.3-2.5 m/km). Vonhof arrives at the same values for the eastern (lower) gravels.

Streamflow directions are recorded from three younger deposits in Group 1: Magrath (5669) and Fort Macleod (5720) in Unit 2, and Kipp (1052) in Unit 1 (Figure 21). Magrath (067^0) and Fort Macleod (010^0) (Table 3) exhibit current directions generally away from the mountain front. The southeasterly streamflow recorded at the Kipp site (140^0) (Table 3) appears to reflect the more meandering nature of the channels in the youngest deposits.

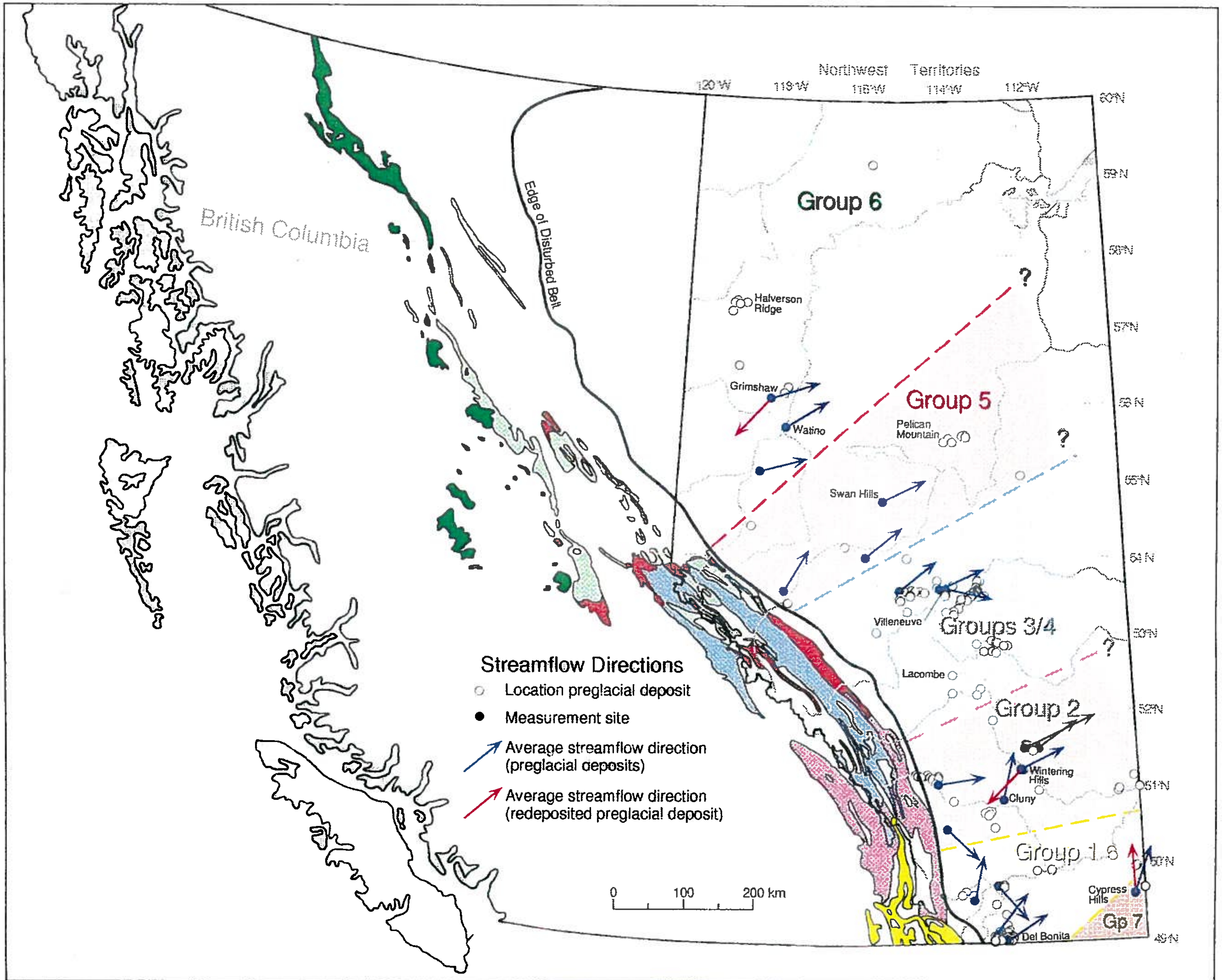

Figure 21. Average streamflow direction for preglacial deposits and redeposited preglacial deposits.

Table 3. Streamflow directions.

Deposit/area	Unit	Average Direction	Numbers of measurements Gravel Fabric	Cross-beds	Source
Group 1					
Del Bonita	4	039	250		Vonhof, 1969
			4		this study
Del Bonita	3	056	350	1	Vonhof, 1969
			20		this study
Ft. Macleod	2	067	15		this study
Magrath	2	010	6	1	this study
Kipp	1	140	10	1	this study
Group 2					
Hand Hills	3	066	200	5	Vonhof, 1969
			15	2	this study
Hand Hills Lake	3	056	150	2	Vonhof, 1969
			10	-	this study
Wintering Hills	3	063	100	1	Vonhof, 1969
			11	1	this study
Wintering Hills (reworked)		226	-	1	Vonhof, 1969
			5	-	this study
Calgary	2	079	6	3	this study
Cluny	2	012	5	1	this study
Nanton	2	133	4	1	this study
Group 3/4					
Villeneuve	1	104	100	17	this study
Entwistle	2	050	10	2	this study
Heatherdown	2	063	12	2	this study
Wabamun	2	045	-	1	this study
Group 5					
Whitecourt Tower	3	030	5	-	this study
Obed Mountain	4	048	3	1	this study
Swan Hills	4	065	200	2	Vonhof, 1969
			5	1	this study
Group 6					
Grimshaw	2	098	25	14	this study
Simonette	1	073	1	2	Liverman et al, 1989
Watino	1	057	25	3	this study
			-	5	Liverman et al, 1989
Group 7					
Cypress Hills	4	021	481	3	Leckie and Cheel, 1989
			10	-	this study
Cypress Hills (redeposited)		355	600	2	Vonhof, 1969
			100	-	Vonhof, 1969

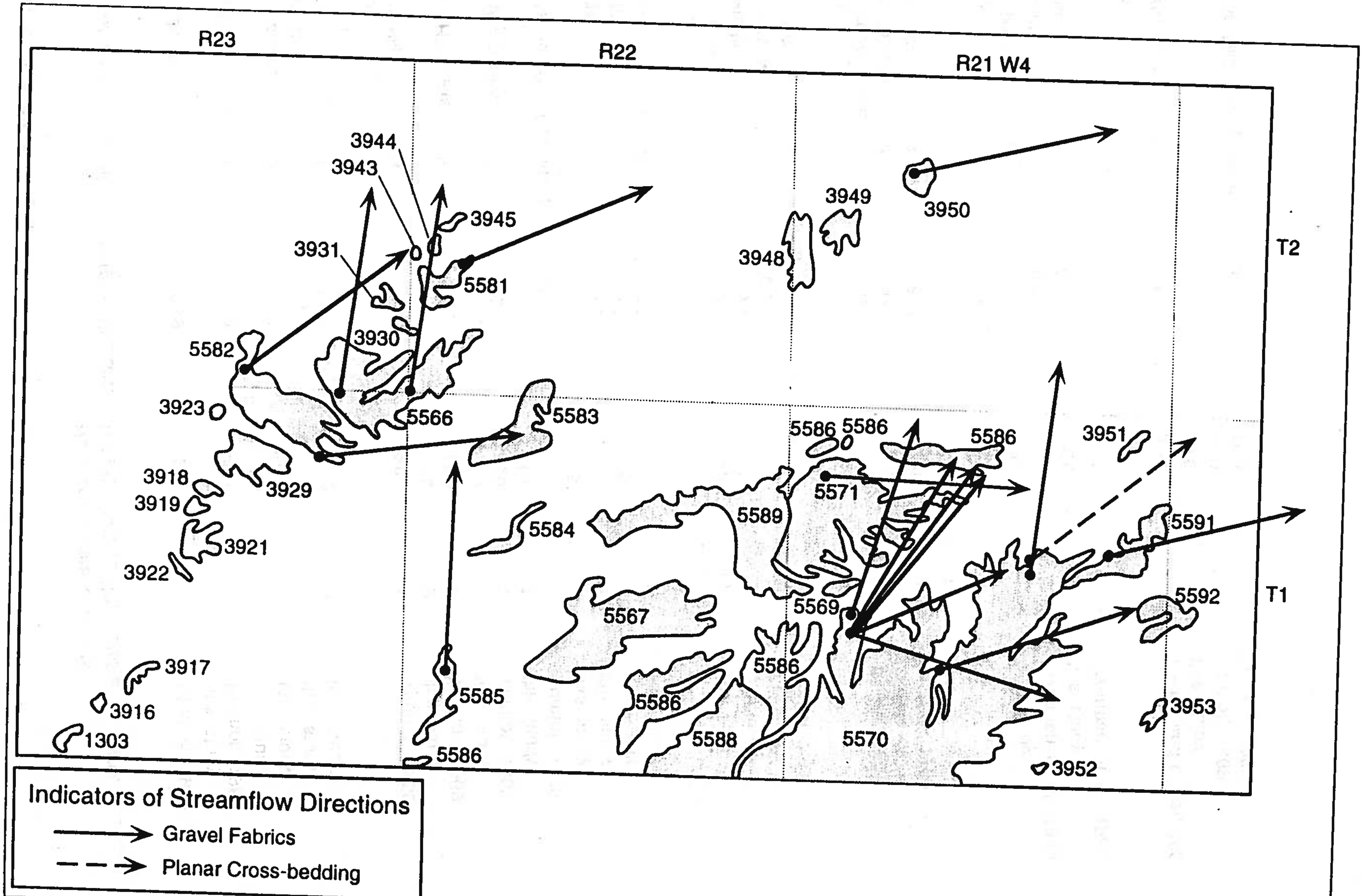

Figure 22. Location and vectors of streamflow indicators measured in the Del Bonita area. Some results from Vonhof (1969).

Group 2. The Hand Hills Formation (Hand Hills, Wintering Hills, and Hand Hills Lake areas) contain the primary deposits which define Group 2 in Alberta. Deposits in these three areas are all in Unit 3. Streamflow indicators were measured by Vonhof (1969) and the authors in all three areas. The Hand Hills have an average streamflow direction of ENE (066^0) based on 215 pebble fabric measurements and seven cross-bed measurements (Figures 21 and 23, Table 3, Appendix D). The Wintering Hills have an average streamflow direction of ENE (063^0) based on 111 pebble fabric measurements and two cross-bed measurements (Figures 21 and 24, Table 3, Appendix D). The Hand Hills Lake deposits have an average streamflow direction of ENE (056^0) based on 160 pebble fabric measurements and two cross-bed measurements (Figures 21 and 25, Table 3, Appendix D). These current orientations agree with the lithology studies (described later) which indicate clasts moved from the mountains in an easterly direction.

A southwest streamflow direction is recorded in the Wintering Hills by both Vonhof (1969) and the authors (Figure 21). The authors note that the pebbles which provide this measurement occur in the upper part of the outcrop, 3 m above a boulder bed. The upper beds at Wintering Hills are interpreted as having a different age and origin than the underlying gravel. The streamflow direction to the southwest is not believed to represent the original stream direction.

Vonhof (1969) compares the elevations of the lower contacts of the gravels at Wintering Hills and Hand Hills Lake and calculates a regional slope of 3.5 feet/mile (0.66 m/km). Vonhof assumes a river sinuosity of 1.5-2.6 and calculates a stream gradient of 1.4-2.3 feet/mile (0.3-0.4 m/km). This is comparable to present day streams about 150 miles

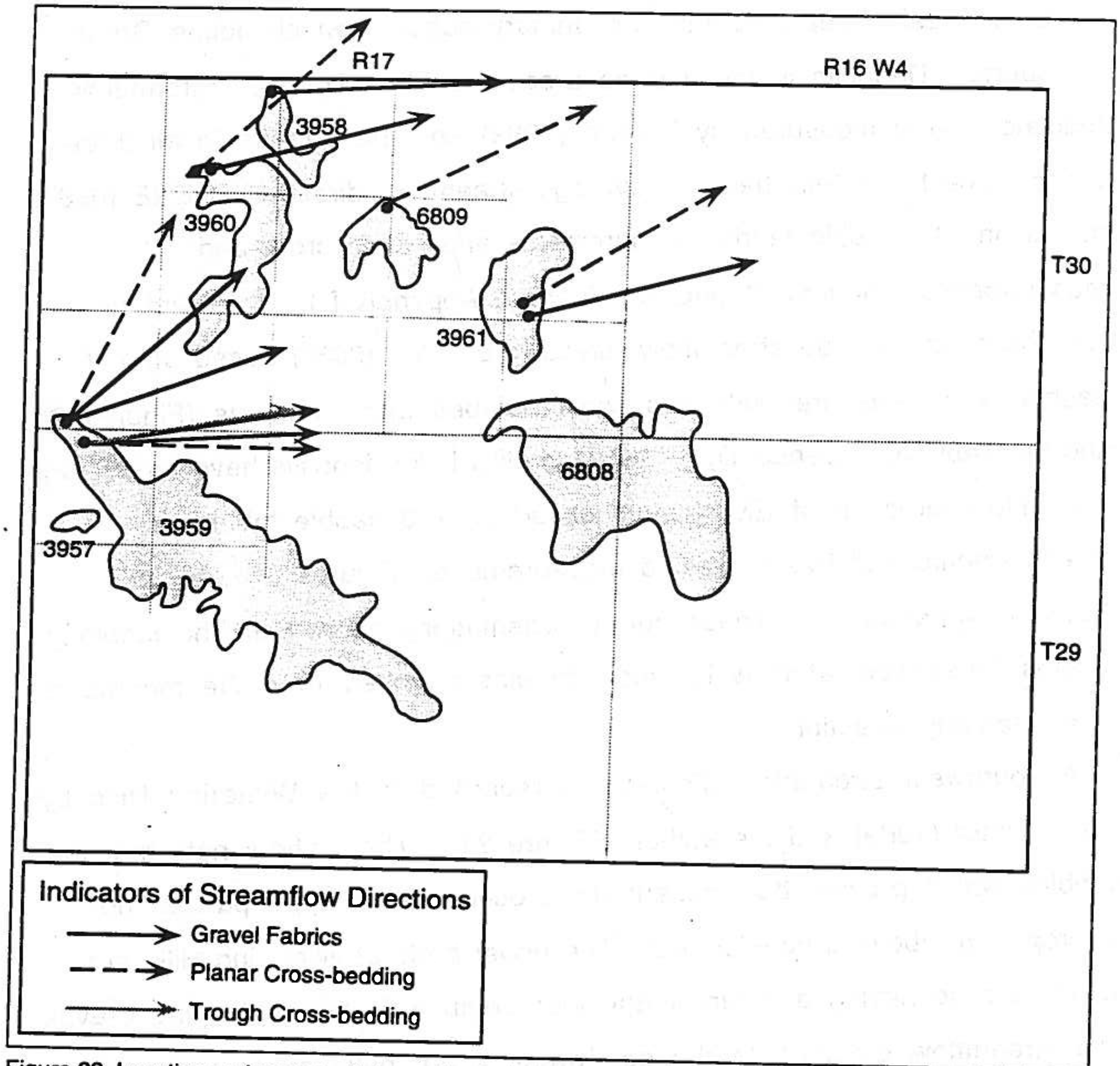

Figure 23. Location and vectors of streamflow indicators measured in the Hand Hills area. Some results from Vonhof (1969).

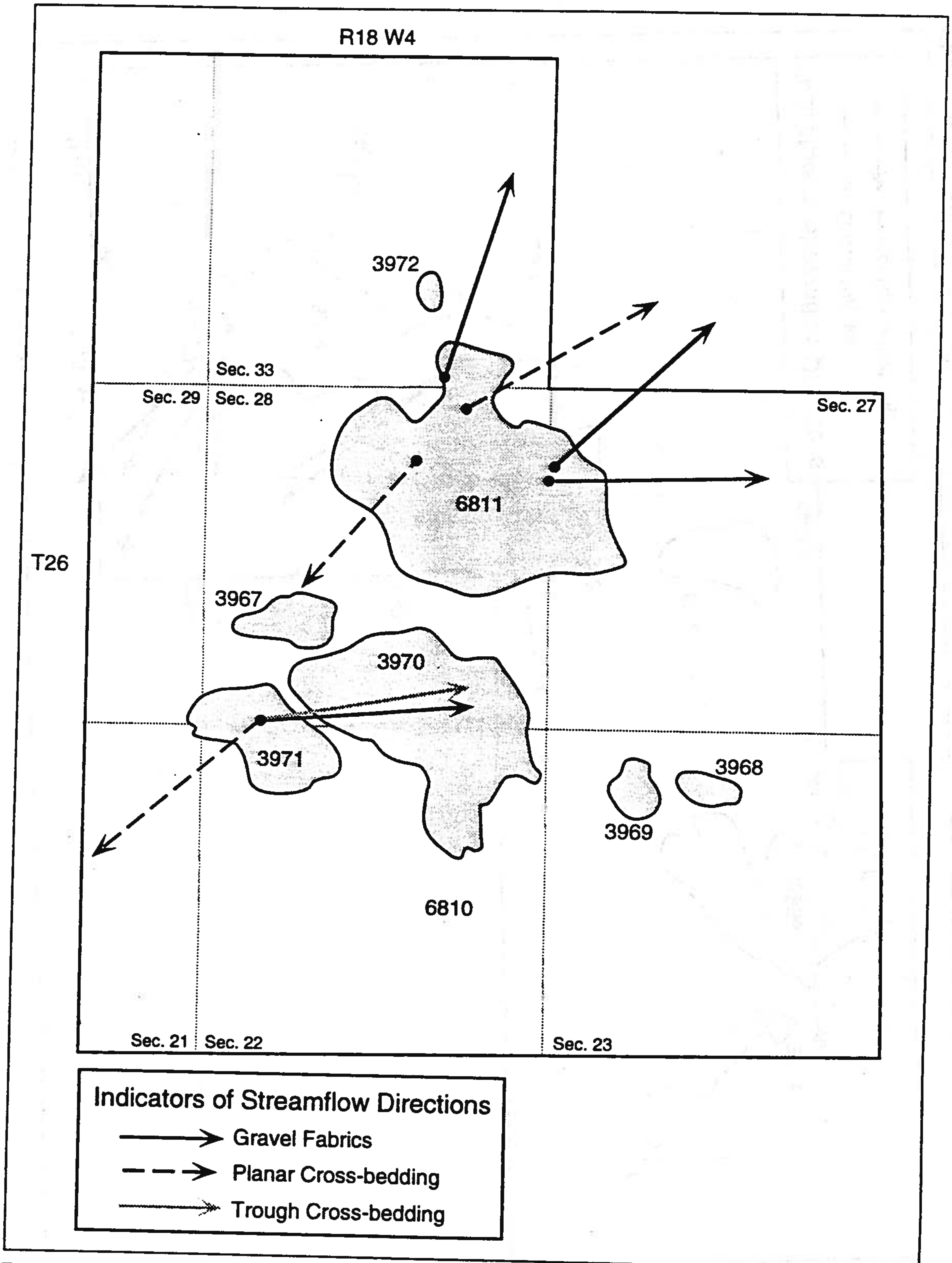

Figure 24. Location and vectors of streamflow indicators measured in the Wintering HIlls area. Some results from Vonhof (1969).

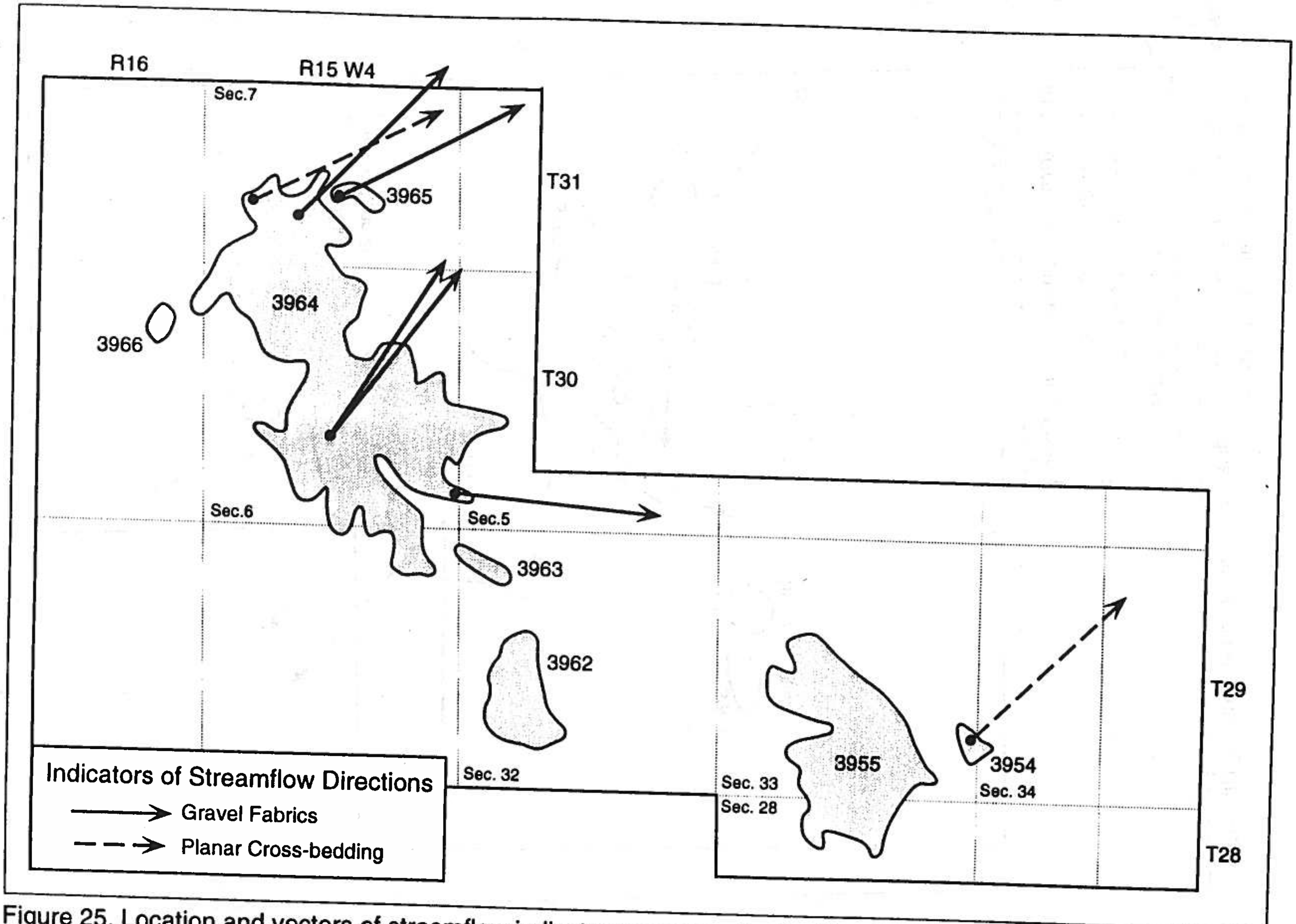

Figure 25. Location and vectors of streamflow indicators measured in the Hand Hills Lake area. Some results from Vonhof (1969).

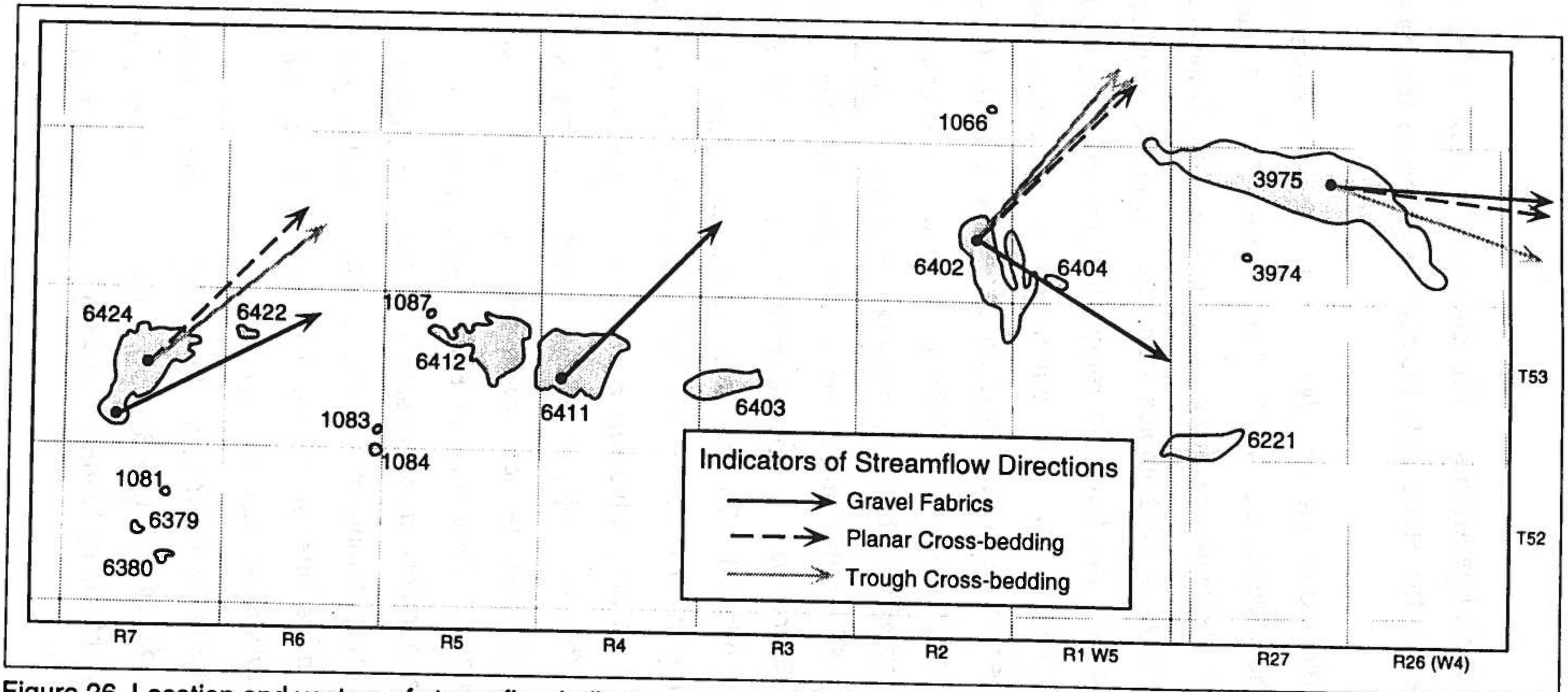

Figure 26. Location and vectors of streamflow indicators measured in the Entwistle-Villeneuve (Edmonton) Area.

(240 km) from their headwaters. The elevation change of the lower contact of gravel in the Hand Hills indicates a slope to the east (Vonhof, 1969).

Streamflow directions are recorded from three other areas in Group 2: Cluny (012^0), the Calgary area (079^0), and Nanton (133^0) (Figure 21, Table 3). These deposits are assigned to Unit 2. Streamflow directions at Calgary fit with flow at right angles from the mountain front and at Cluny with flow around or away from the regional highlands near Arrowwood and the Buffalo Hill (Figure 21). The southeasterly streamflow direction at Nanton may reflect a local flow direction or it may cast doubt as to the preglacial origin of this deposit. Although mapped by Shetsen (1980) as preglacial, the deposit could be of mountain outwash origin.

Group 3/4. All of the streamflow information for Group 3/4 was gathered in Unit 3 and Unit 4 deposits west of Edmonton (Figures 21 and 26, Table 3, Appendix D). The average streamflow measured at Entwistle (6424) and Heatherdown (6402) is NE (050^0 and 063^0, respectively). This direction is based on 22 pebble fabric and four cross-bed measurements. At Villeneuve (3975), the major aggregate supplier for Edmonton, 17 cross-beds and 100 gravel fabrics were measured. The average streamflow direction at Villeneuve is ESE (104^0) (Table 3).

The lack of streamflow data outside the Entwistle-Villeneuve area is one reason why the grouping of the deposits in central Alberta (Group 3/4) is uncertain. As more streamflow and lithologic data become available a more definitive correlation may be possible.

Group 5. Streamflow information for Group 5 was gathered from three of the older deposits (Units 3 or 4). The average streamflow direction measured at Obed Mountain (3915), Whitecourt Tower (6573), and Swan Hills (3973) is NE (048^0, 030^0, and 065^0 respectively). These directions are based on 213 pebble fabric and four cross-bed measurements, with most of the data coming from the Swan Hills (Figure 27, Table 3, Appendix D). Vonhof (1969) maps a large number of isolated patches of gravel in the Swan Hills area and notes that there are no continuous deposits as at the Cypress Hills. The AGS has chosen to outline a single deposit but cautions the reader that any given site within the area of deposit 3973 may not be gravel covered.

Vonhof (1969) estimates the regional slope of the Swan Hills gravels to be about 15 feet/mile (2.9 m/km) to the east. Assuming a river sinuosity of 1.5-2.6 Vonhof calculates a stream gradient of 5.8-10 feet/mile (1.1-1.9 m/km).

Vectors for Groups 5 and 7 record the direction for two of the earliest fluvial channel or braidplain systems in the predominantly erosional history of Alberta during the Tertiary (Figure 21).

Group 6. Streamflow information for Group 6 is gathered from Unit 1 deposits at Simonette (4028) (Plate 2a) and Watino (4212) and from the Unit 2 Grimshaw (6692) gravels (Figure 21). The Watino streamflow directions are based on 25 pebble fabric and eight cross-bed measurements (Table 3). Data for the Simonette deposit includes a general estimate of flow direction from gravel fabrics (Plate 1e) and two cross-bed measurements (Table 3). The extensive Grimshaw deposit was investigated at several sites. Measurements are recorded for the area east of Cardinal Lake (the Grimshaw end of the deposit) and the area west of Cardinal Lake (the Fairview end of the deposit) (Figure 28). Streamflow directions for the Grimshaw area are based on five pebble fabric and 10 cross-bed measurements (Plate 1a). Streamflow directions for the

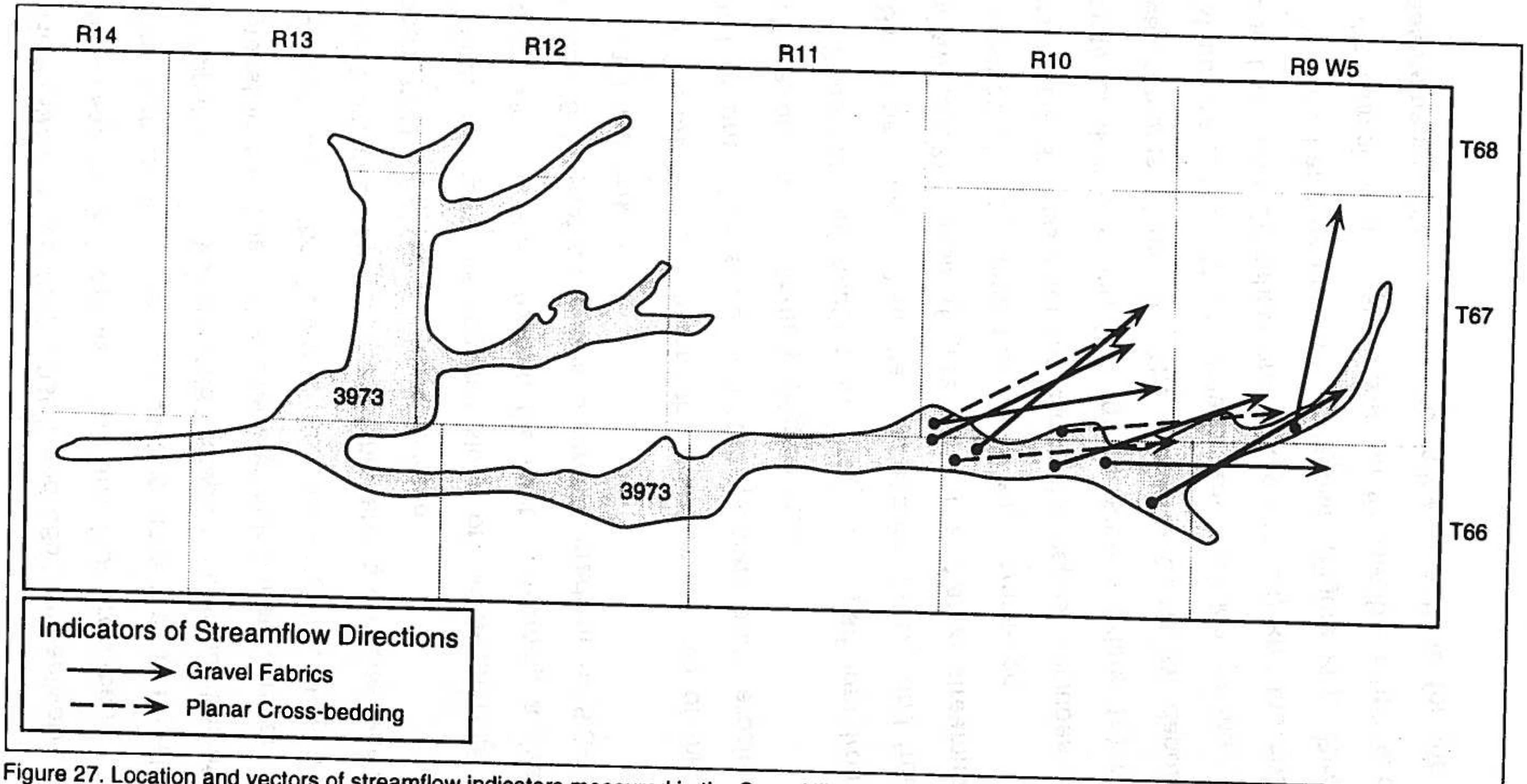

Figure 27. Location and vectors of streamflow indicators measured in the Swan Hills Formation. Some results from Vonhof (1969).

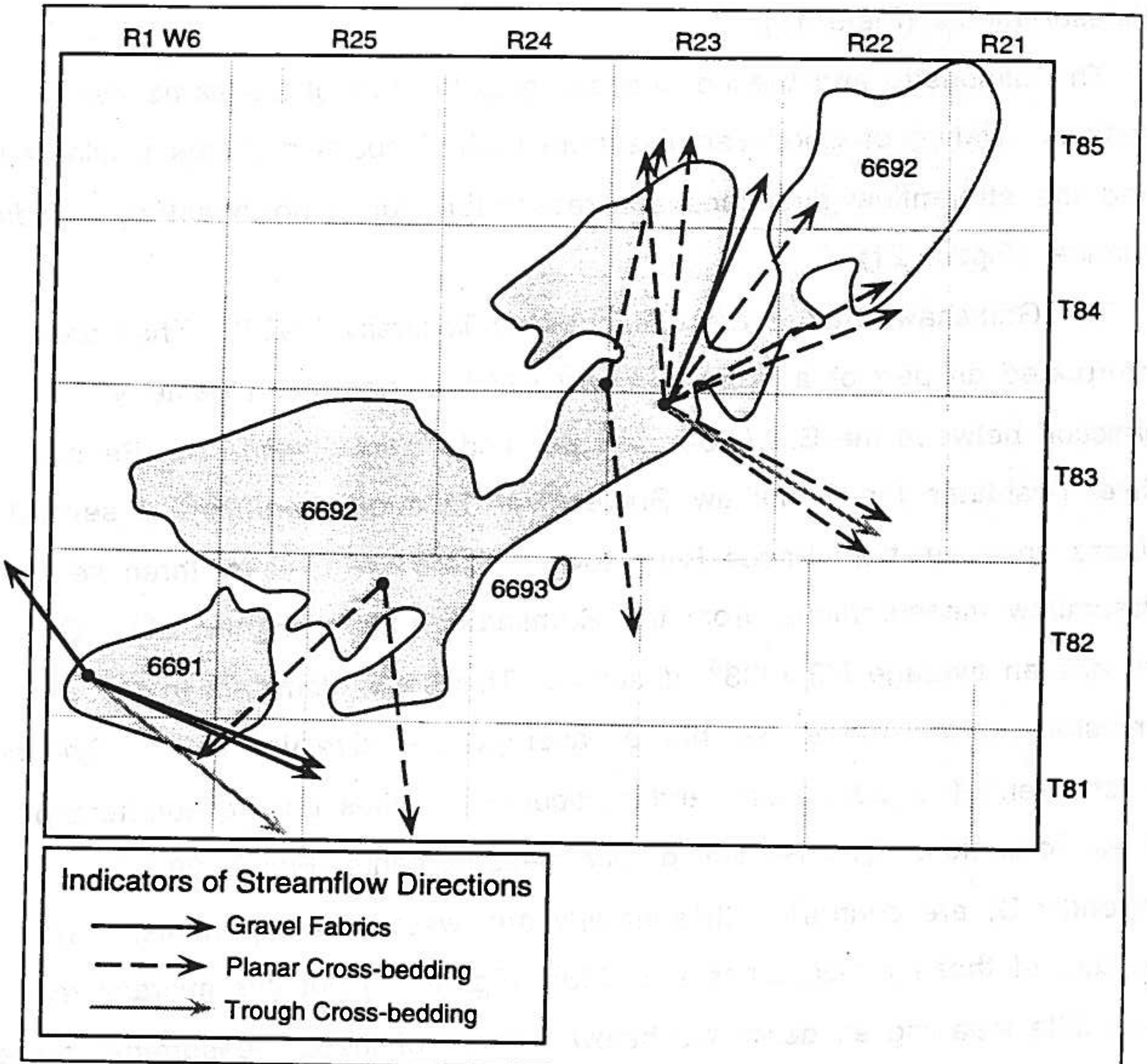

Figure 28. Location and vectors of streamflow indicators measured in the Grimshaw Gravels. Some results from Tokarsky (1967).

Fairview area are based on 20 pebble fabric and four cross-bed measurements (Plate 1d).

The Simonette and Watino deposits may be part of the same river system. Dating of wood samples from both deposits provides similar ages and the streamflow directions are reasonable for a northeasterly trending channel (Figure 21).

The Grimshaw Gravels are described by Tokarsky (1967). They are interpreted as part of a broad channel which trends in an easterly direction between the B.C./Alberta border and Peace River. The Peace River postdates the Grimshaw Gravels and cuts the formation at several places upstream from Peace River town. There are at least three sets of streamflow measurements from the Grimshaw Gravels (Figure 28). One set has an average NE (033^0) direction. This set is dominant in the Grimshaw area. Another set has an average ESE direction (117^0). This set is represented in both areas and particularly in sites on the southern part of the formation. The remaining four measurements (Figure 28, Appendix D) are contrary with southerly and westerly components. The average of these measurements is 223^0 (Figure 21) but this average may have little meaning as described below. Three of these measurements are recorded by Tokarsky (1967) and the other by the authors. This latter measurement is from a lag gravel bed (Plate 1d) in the middle to upper part of the deposit. It is probable that these measurements are recorded from redeposited gravels which mark a change in flow pattern from the original deposition. The phenomenon of reworking or redeposition is identified by contrary streamflow measurements at both the Wintering Hills and Cypress Hills areas. Lithologies of upper beds should be checked if streamflow directions appear odd. In the Edmonton area (deposit 6200),

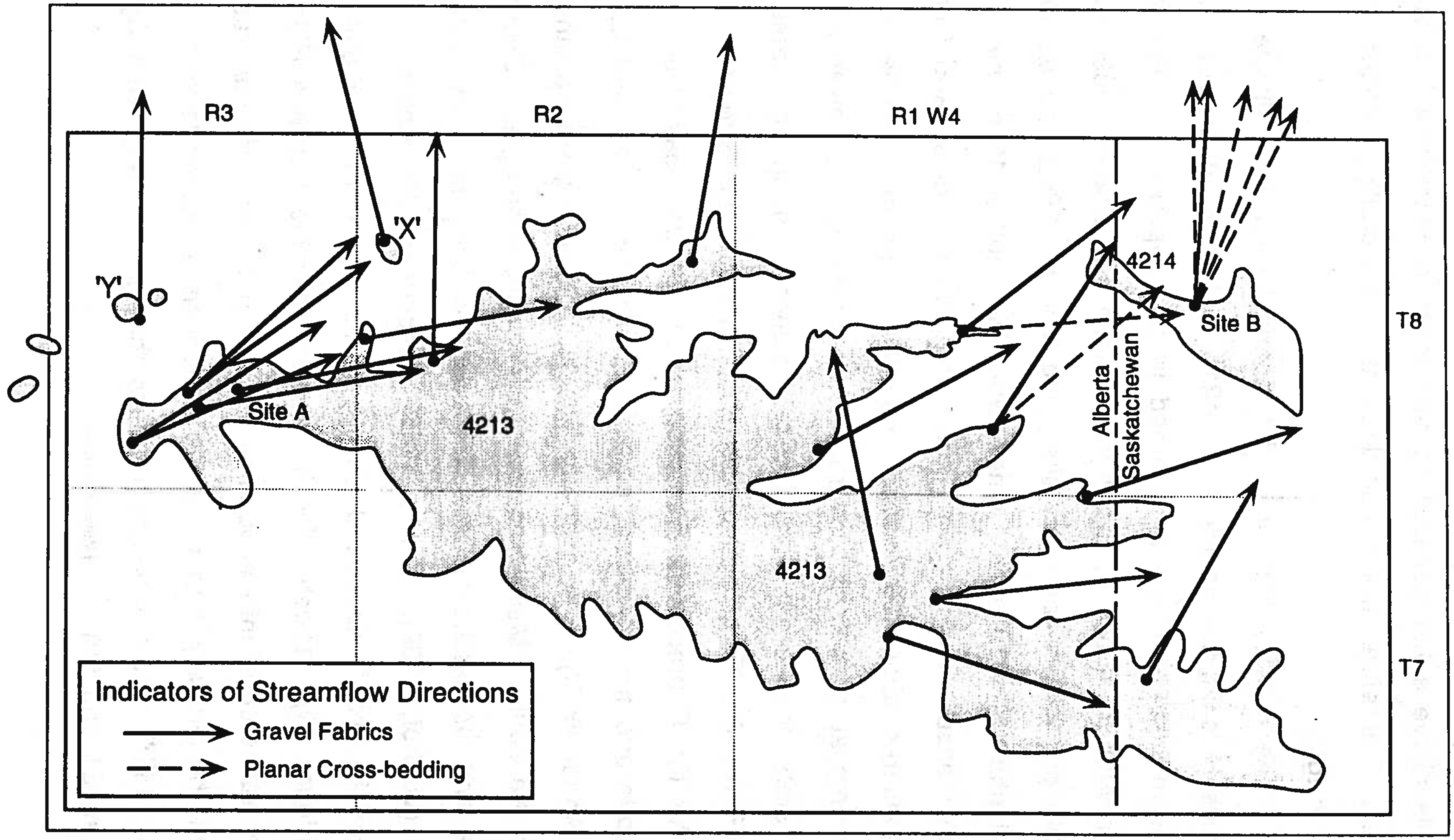

Figure 29. Location and vectors of streamflow indicators measured in the Cypress Hills Formation (4213 and 4214) and redeposited Cypress Hills Formation ('X' and 'Y'). Most results from Vonhof (1969) and Leckie and Cheel (1989).

the gravels above a boulder bed contain rocks of glaciofluvial or Recent river origin. Therefore, the upper beds are significantly younger and of different origin.

Group 7. The primary deposits which define Group 7 in Alberta are in the Cypress Hills Formation (deposits 4213 and 4214, Plate 3c). Streamflow measurements are recorded in the Cypress Hills Formation (Unit 1) in Alberta in two publications. Leckie and Cheel (1989) measured 273 pebble orientations at three sites and Vonhof (1969) measured 450 pebble orientations at 10 sites. The AGS adds another 10 pebble orientation measurements at two sites. In addition, Leckie and Cheel (1989) measured about 208 pebble orientations and made three cross-bed measurements at an outcrop several km east into Saskatchewan and Vonhof (1969) measured a cross-bed orientation at about the same location (Figure 29, Table 3, Appendix D). The average streamflow direction for the Cypress Hills Formation is NNE (021^{0}) based on 1091 pebble fabric and five cross-bed measurements (Figures 21 and 29, Table 3, Appendix D). The northerly flow is in keeping with a lithologic source to the south. Measurements from gravels fringing the Cypress Hills in Alberta and Saskatchewan give directions which radiate away from the highlands (Vonhof, 1969). Vonhof (1969) measured 100 pebble orientations in two "redeposited Cypress Hills Formation" deposits in Alberta (Figure 29). These deposits formed after the Cypress Hills Formation was eroded into a positive feature and when gravels washed down from the primary formation into redeposited accumulations. Current directions (355^{o}) record the movement of this gravel away from Cypress Hills (Figure 21 and 29).

Lithology of pebbles, cobbles, and boulders

Pebble lithology data and the deposit locations provide the primary evidence for dividing the preglacial deposits into 6 Groups. These Groups or suites of deposits are considered to have similar origins for the gravel component. Detailed pebble lithology descriptions (Appendix H) together with a literature review of Mountain and Plains formations (Appendix E) were used to identify potential source formations for the pebbles. A series of figures shows the distribution of the potential source formations and the extent of the associated preglacial deposit groupings. The lithologic data are described in detail in the following section. These data are supplemented by streamflow data, elevation, maximum clast size, and mineralogical data such as indicator minerals and placer gold to define the Groups.

A lithologic identification was made of the pebble, cobble, and boulder size clasts from samples taken from 10 preglacial deposits (Table 4, Figure 30). The samples, which weighed several hundred kilograms (Appendix C), were returned to the laboratory and scalped at the 0.75" size. Material <0.75" was used in grain size, placer gold, and indicator mineral analyses. The >0.75" fraction was screened into three sizes (0.75-1.5", 1.5-3.0", and +3.0") and weighed. A suite of one hundred 0.75-1.5" size pebbles was randomly selected and a detailed examination was made of each pebble. Specimens were identified and grouped into rock types and examples retained as a standard collection. After this detailed examination the remaining pebbles in the 0.75-1.5" size category were examined. Any pebbles not of a type already noted were described and added to the collection. The number of pebbles in each rock type were counted and a percentage frequency calculated. Clasts in the 1.5-3.0"

Table 4. The number of clasts examined from each deposit for each fraction and the weight of that fraction as a proportion of the entire sample.

Sample Number	Site Name	0.75-1.5" Clasts	%	1.5-3.0" Clasts	%	+3.0" Clasts	%	Total Clasts	%
6815-2	Halverson Ridge	625	9	58	6	1	1	684	16
6692-2	Grimshaw	1426	19	43	4	0	0	1469	23
4212-1	Watino	2165	35	362	22	9	6	2536	63
6824-3	Pelican Mountain	1533	3	363	7	32	5	1928	15
3973	Swan Hills	1041	15	376	37	40	23	1457	75
3975	Villeneuve	544		not analysed		not analysed		544	
6106-2	Lacombe	498	14	365	37	26	23	889	74
6811-2	Wintering Hills	1677	29	277	20	10	6	1964	55
3913-1	Cluny	1861	25	255	23	18	11	2134	59
5566-1	Del Bonita	1224	17	251	20	9	3	1484	40

(large pebble) and >3.0" (cobble, boulder) categories then were categorized according to the rock types noted in the pebble analysis or added to the list as a new rock type. The number of clasts examined in each clast fraction are listed in the Table 4.

The detailed examination included breaking each pebble to expose the interior and photographing representative examples of each rock type (Plate 4 and 5). A description was made of the fresh and weathered colour, grain size or internal texture, clast roundness, shape and surface texture, and other obvious characteristics (Appendix H).

Following is a general discussion of the rock types identified at each site and the possible correlation of these rock types with adjacent deposits. Table 5 is a summary of the pebble lithology data for all deposits. A more detailed lithologic description is provided in Appendix H.

The deposit correlation and comparison is subjective and results are given in qualitative terms. Pebbles that appear to be lithologically identical and probably have the same source formation are described as identical. Pebbles that appear very similar and could come from the same

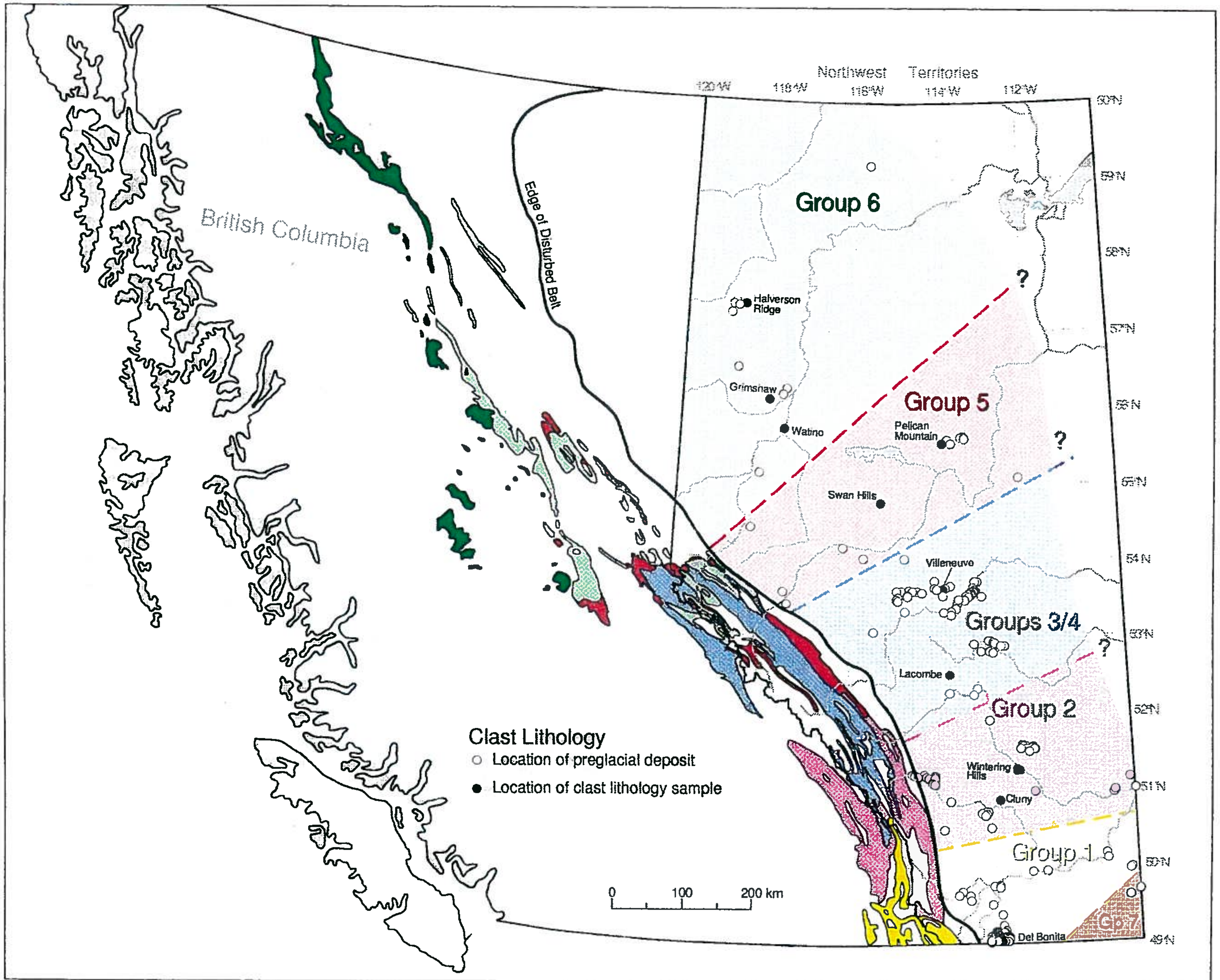

Figure 30. Preglacial deposits and source formations.

Table 5. Summary of pebble lithology data for the 10 deposits sampled.

	Halverson Ridge 6815	Grimshaw 6692	Watino 4212	Swan Hills 3973	Pelican Mtn 6824	Villeneuve 3975	Lacombe 6106	Wintering Hills 6811	Cluny 3913	Del Bonita west 5566
	%	%	%	%	%	%	%	%	%	%
Quartzite	26	16	24	53	28	10	35	26	57	29
Sandstone	38	28	68	35	70	67	49	42	4	32
Shale/Siltstone			P	P	1	3		2	P	1
Ironstone			P			P	3			
Conglomerate		6	4	11	P	6	1	P	6	14
Carbonate							8	29	25	
Chert	4	5	2	P	1	12	4	1	6	P
Chalcedony	7	7	P					P		
Argillite	1	1					P			23
Quartz	25	14	2			2		P	2	
Granite		6								
Diorite										1
Basalt		5								P
Schist		2								
Metasediment		10				P				
Metavolcanic			P							
Total	101	100	100	99	100	100	100	100	100	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

source are described as similar. Rocks which appear lithologically dissimilar and which probably had different sources are described as dissimilar.

Halverson Ridge (6815) The pebble component (0.75-1.5") at Halverson Ridge is composed primarily of quartzite (7 varieties, 26%), sandstone (5 varieties, 38%), and white quartz (25%) (Plate 5, Halverson Ridge). Chalcedony and two varieties of chert add another 11% (Table 5).

The larger pebble size (1.5-3.0") is dominated by quartz (33%) and quartzite (5 varieties, 52%). Sandstone decreases in variety (1 type) and amount (2%) and chalcedony increases in relative significance (14%). The cobble and boulder size is represented by one clast of quartzite.

Appendix E lists the potential source formations of the pebbles at

Halverson Ridge and Figure 31 shows the distribution of these formations.

A Petrographic Number (PN) description (Appendix F) of a crushed sample from the site is very similar to the lithologic description above. The crushed sample is dominated by quartzite and sandstone. Only minor amounts of chert are evident as these are present in the small pebble size and break down into finer particles during the crushing process. The chalcedony is included with the quartzite. Quartz content is high (10%). Halverson Ridge gravel produces an above average aggregate (see Mineral Aggregate).

Following is a comparison of the rock types in the Halverson Ridge sample with a sample from Grimshaw (6692) (Table 6).

Seventy per cent of the pebbles in the Halverson Ridge sample are lithologically identical or similar to the pebbles identified at Grimshaw. This is a very strong correlation for pebble lithology comparison. The correlation indicates that the source formations for material found at Halverson Ridge are similar to those for the Grimshaw gravels. Deposits on Halverson Ridge are believed to be older than the Grimshaw gravels. It is possible that deposits left by the fluvial system which deposited the Halverson Ridge deposits may have been eroded and supplied material to the younger Grimshaw deposits.

Grimshaw (6692) The pebble component (0.75-1.5") at Grimshaw is composed primarily of quartzite (5 varieties, 16%), sandstone (4 varieties, 28%), quartz (14%), and a metasediment (10%) (Plate 5, Grimshaw, Appendix H, Table 5). There also are significant amounts of chert pebble conglomerate (6%), chert (5%), chalcedony (7%), white granite (6%), and volcanics (4 varieties, 5%) (Table 5).

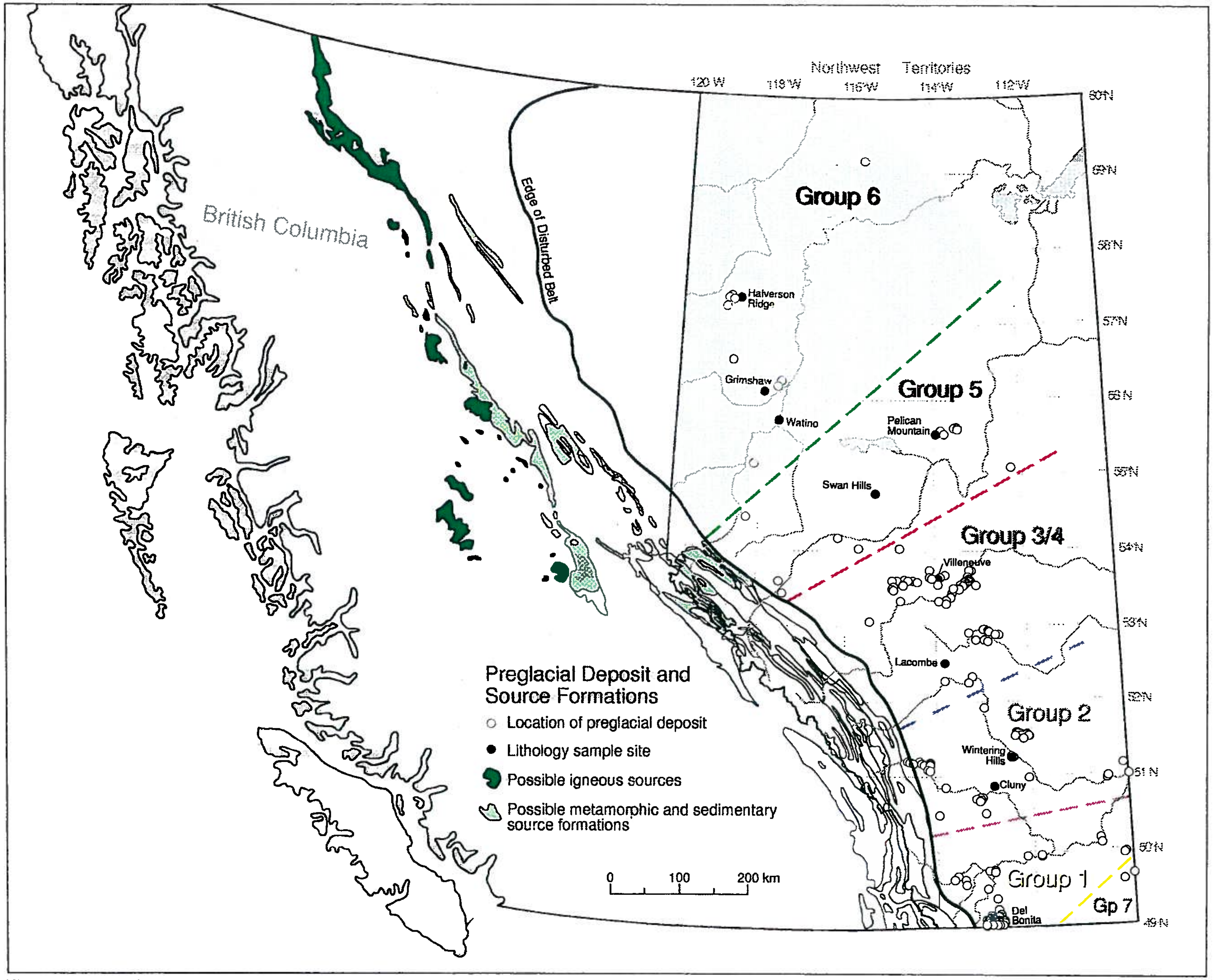

Figure 31. Location of clast lithology sample sites and possible source formations for the clasts.

Table 6. Comparison of Grimshaw lithologic data with Halverson Ridge clasts (0.75-1.5" size).

Halverson Ridge 6815	Grimshaw 6692			
	Identical %	Similar %	Dissimilar %	Total %
Quartzite	11	15	1	26
Sandstone	33		4	37
Shale/Siltstone				
Ironstone				
Conglomerate				
Carbonate				
Chert	4			4
Chalcedony	7			7
Argillite			1	1
Quartz			25	25
Granite				
Diorite				
Basalt				
Schist				
Metasediment				
Metavolcanic				
Total	55	15	31	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

The larger pebble size (1.5-3.0") is dominated by quartzite (3 varieties, 53%) and sandstone (3 varieties, 33%). Clasts of quartz, chert, chalcedony, and conglomerate still are found in this size. No cobble or boulder size is represented in the sample.

Appendix E lists the potential source formations of the pebbles at Grimshaw and Figure 31 shows the distribution of these formations.

Crushed gravel was sampled from the same gravel formation but in a pit about 25 km west of the sample site for the lithologic sample. A PN analysis (Appendix F) on the crushed sample is very similar to the petrographic description above. The crushed sample is dominated by quartzite and sandstone (89% combined). Chert occurs in higher amount than at Halverson Ridge, probably because it is present in larger sizes at Grimshaw and survives the crushing process. The quartz, volcanics, and granites are described in the PN analysis. Grimshaw gravel makes an above average aggregate (see Mineral Aggregate).

A comparison of the rock types in the Grimshaw sample was made with samples to the north (Halverson Ridge, 6815) and south (Watino, 4212). These comparisons are shown in (Table 7).

Fifty per cent of the pebbles present in the Grimshaw sample have pebbles of identical lithology present in samples from both Halverson Ridge and Watino. The granite and volcanic suite (11%) at Grimshaw is not duplicated at Halverson Ridge or Watino. The granite pebbles are well rounded and are primarily in the smaller sizes. They may represent a restricted mountain source which supplied pebbles subsequent to Halverson Ridge gravel deposition. Some of the volcanic rocks are very soft. They would comminute rapidly and their occurrence at Grimshaw may indicate a (currently unidentified) local origin on the Plains. As they occur in only the smaller sizes, their source still would be some distance up-stream. Quartz is a very durable rock type and will withstand long distances of transport so encountering quartz pebbles is not extraordinary. At Grimshaw some quartz is present in larger sizes. This indicates that there may have been a proximal source. Metasediment is present at Grimshaw and Watino but not at Halverson Ridge. The source for the metasediment may be from formations exposed later than those during deposition at Halverson Ridge or from formations exposed south of those supplying material to Halverson Ridge. The opposite explanation (early and northerly exposure) could explain the occurrence of equivalent

Table 7. Comparison of Halverson Ridge and Watino petrographic data with Grimshaw clasts (0.75-1.5" size).

Grimshaw 6692	Halverson Ridge 6815				Watino 4212			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite	6	1	9	16	8	6	2	16
Sandstone	26		2	28	26		2	28
Shale/Siltstone								
Ironstone								
Conglomerate	6			6	6			6
Carbonate								
Chert	5			5		5		5
Chalcedony	7			7			7	7
Argillite			1	1			1	1
Quartz			14	14			14	14
Granite			6	6			6	6
Diorite								
Basalt			5	5			5	5
Schist			2	2			2	2
Metasediment			10	10	10			10
Metavolcanic								
Total	50	1	49	100	50	11	39	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

chalcedonic pebbles at Halverson Ridge and Grimshaw but not Watino. Watino may represent a subsidiary channel that did not derive gravels directly from the older Grimshaw deposit.

Watino (4212) The pebble component (0.75-1.5") at Watino is composed primarily of sandstone (4 varieties, 68%) and quartzite (5 varieties, 24%). There are also significant amounts of quartz pebble conglomerate (4%), chert (2%), and white and smoky quartz (1% each) (Table 5, Appendix H, Plate 5, Watino).

The larger pebble (1.5-3.0") and the cobble/boulder (+3.0") sizes are dominated by a medium grained, brown sandstone (68% and 78%

respectively). A light gray, glassy quartzite occurs in 19% abundance in the large pebble size and 22% in the cobble/boulder size (Appendix H).

Appendix E lists the potential source formations of the pebbles at Watino and Figure 31 shows the distribution of these formations.

A comparison of the rock types in the Watino sample with pebbles from the Grimshaw (6692) and Swan Hills (3973) samples is shown in (Table 8).

Seventy per cent of the pebbles present in the Watino sample appear to be identical lithologically with pebbles present at Grimshaw. No pebbles at Swan Hills appear to have identical lithologies with pebbles from the Watino sample. Seventy-four per cent of Swan Hills clasts are similar in lithology to pebbles present at Watino but almost all of this similarity (66%) is in the form of a single, common rock type (brown sandstone). The pebble lithology sample data at Watino are interpreted as describing a genetic relationship between the material at Watino and Grimshaw but not with Swan Hills.

Watino and Swan Hills have a vast difference in age so different source formations could have been exposed to erosion at the different times. Watino and Swan Hills also may represent different fluvial drainage systems. Halverson Ridge, Grimshaw, and Watino are grouped together (Group 6) based on the lithologic similarity of pebble constituents and are considered to represent a single, maturing, fluvial system.

A comparison between the lithologies of pebbles at Watino and the Swan Hills shows less similarity and supports the hypothesis that the two deposits were formed in different fluvial systems.

Swan Hills (3973) The pebble component (0.75-1.5") at Swan Hills is composed primarily of quartzite (5 varieties, 53%) and sandstone (8 varieties, 35%). Quartz pebble conglomerate (11%) also is present

Table 8. Comparison of Grimshaw and Swan Hills lithologic data with Watino pebbles (0.75-1.5" size).

Watino 4212	Grimshaw 6692				Swan Hills 3973			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite	3	21		24		8	16	24
Sandstone	67		1	68		66	2	68
Shale/Siltstone			P	P			P	P
Ironstone	P			P			P	P
Conglomerate			4	64			4	4
Carbonate								
Chert		P	2	2			2	2
Chalcedony	P		P	P			P	P
Argillite								
Quartz			2	2			2	2
Granite								
Diorite								
Basalt								
Schist								
Metasediment								
Metavolcanic			P	P			P	P
Total	70	21	9	100	0	74	26	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

(Table 5, Plate 5 Swan Hills, Appendix H).

The larger pebble size (1.5-3.0") is dominated by quartzite and sandstone. Eighty per cent of the pebbles are quartzite (4 varieties present) and 20% is sandstone (4 varieties). The cobble/boulder (+3.0") size is 95% gray quartzite.

Appendix E lists the potential source formations of the pebbles at Swan Hills and Figure 32 shows the distribution of these formations.

A comparison of the pebble lithologies represented at Swan Hills is made with pebbles at Watino (4212) and Pelican Mountain (6824). These comparisons are shown in (Table 9). None of the pebbles at Swan Hills

Table 9. Comparison of Watino and Pelican Mountain lithologic data with Swan Hills pebbles (0.75-1.5" size).

Swan Hills 3973	Watino 4212				Pelican Mountain 6824			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite		44	9	53	46	7	1	53
Sandstone		5	30	35	25		10	35
Shale/Siltstone			P	P			P	P
Ironstone								
Conglomerate			11	11	9		2	11
Carbonate								
Chert			P	P	P			P
Chalcedony								
Argillite								
Quartz								
Granite								
Diorite								
Basalt								
Schist								
Metasediment								
Metavolcanic								
Total	0	49	50	99	80	7	13	99

Totals ≠100% are due to rounding or rock types present <1%

P = amount <1%

appear to be identical lithologically with pebbles present in the Watino sample and 50% are dissimilar. Eighty per cent of the pebbles at Swan Hills appear to be identical to pebbles present in the Pelican Mountain sample and only 13% appear to be lithologically dissimilar.

The sample data from Swan Hills and Watino show that the two deposits carry different rock suites. They are interpreted to represent different fluvial drainage systems. The pebble lithologies at Swan Hills and Pelican Mountain are very similar. These deposits probably represent a genetically similar fluvial system.

Pelican Mountain (6824) The pebble component (0.75-1.5") at Pelican

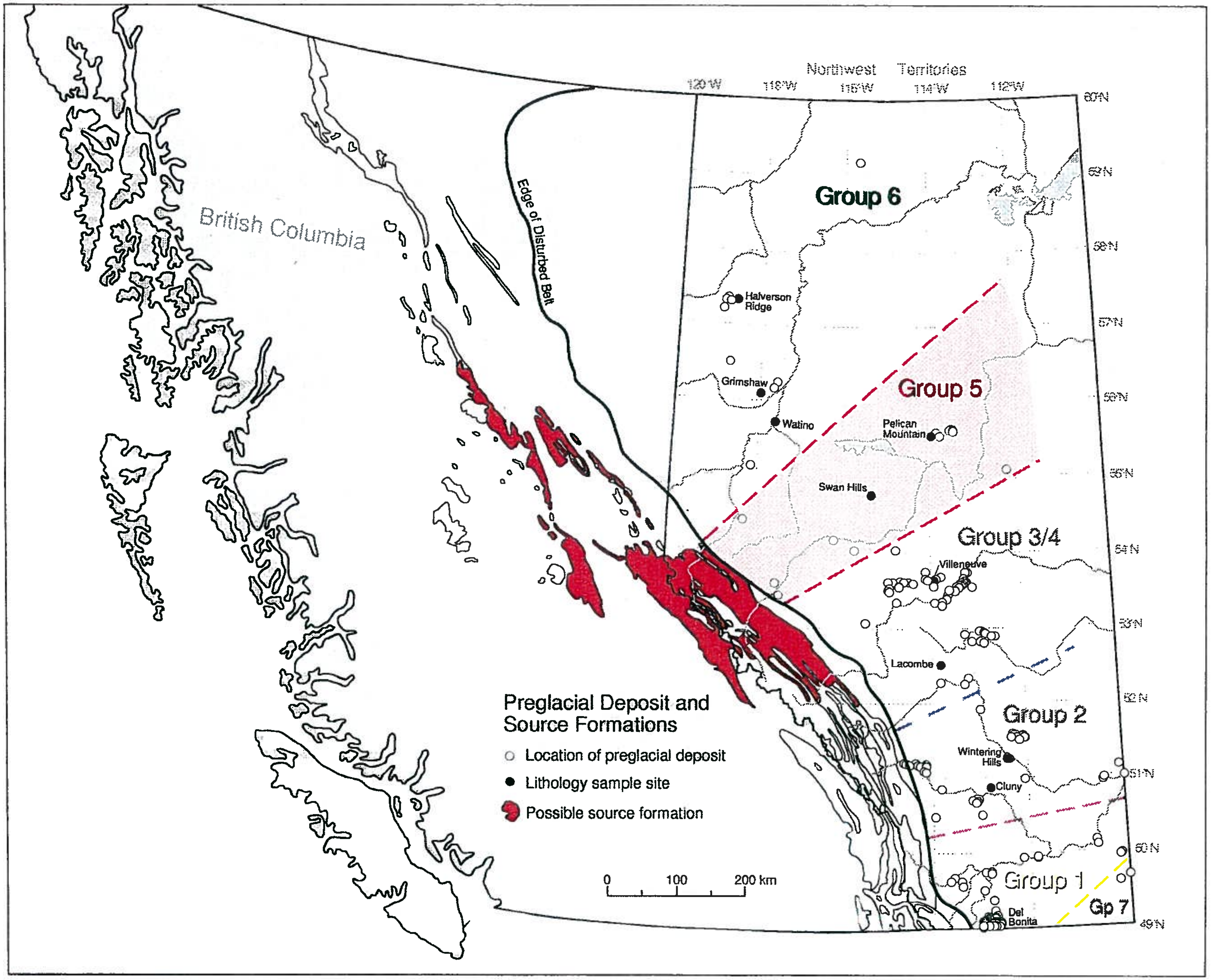

Figure 32. Location of clast lithology sample sites and possible source formations for the clasts.

Mountain is composed almost exclusively of sandstone (10 varieties, 70%) and quartzite (6 varieties, 28%) (Table 5, Plate 5, Pelican Mountain, Appendix H). The larger pebble (1.5-3.0") and cobble/boulder (+3.0") sizes carry 5 varieties of quartzite (55% and 44% respectively) and 7 varieties of sandstone (43% and 53% respectively). As at Swan Hills single clasts of chert occur in both the larger pebble and cobble/boulder sizes.

Appendix E lists the potential source formations of the pebbles at Pelican Mountain and Figure 32 shows the distribution of these formations.

A comparison of the pebble lithologies in the Pelican Mountain sample was made with pebbles from the Swan Hills (3973) and Villeneuve (3975). These comparisons are shown in (Table 10). Ninety per cent of the pebbles in the Pelican Mountain sample appear to be lithologically identical to pebbles present in the Swan Hills sample. Only 2% of the pebbles in the Pelican Mountain sample appear identical lithologically to pebbles from the Villeneuve sample and 96% are dissimilar. The Pelican Mountain and Swan Hills deposits probably formed in related fluvial systems. The Pelican Mountain and the Villeneuve deposits probably formed in fluvial systems of different age and distribution.

Samples were collected from two beds separated by ~7 m at the Pelican Mountain site. These samples were analyzed and the results are shown in Table 11. Ninety-four per cent of the pebbles from the upper sample (6824-1) have identical lithology to pebbles from the lower sample (6824-3) and 91% of the pebbles from the lower sample are identical lithologically to pebbles in the upper sample. The major difference is a locally derived claystone present in the pebble size in the lower but not the upper sample. An outcrop of this formation probably

Table 10. Comparison of Swan Hills and Villeneuve lithologic data with Pelican Mountain pebbles (0.75-1.5" size).

Pelican Mountain 6824	Swan Hills 3973				Villeneuve 3975			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite	25		3	28		2	26	28
Sandstone	65		5	70	2		68	70
Shale/Siltstone			1	1			1	1
Ironstone								
Conglomerate	P			P			P	P
Carbonate								
Chert	P		1	1			1	1
Chalcedony								
Argillite								
Quartz								
Granite								
Diorite								
Basalt								
Schist								
Metasediment								
Metavolcanic								
Total	90	0	10	100	2	2	96	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

was exposed to erosion during deposition of the lower gravels but not exposed during deposition of the upper gravels.

Villeneuve (3975) The pebble component (0.75-1.5") at Villeneuve is composed primarily of sandstone (8 varieties, 67%) with lesser amounts of quartzite (5 varieties, 10%), chert (4 varieties, 12%), and conglomerate (2 varieties, 6%) (Table 5, Plate 4, Villeneuve, Appendix H). A comparison of the Villeneuve sample with a sample from Pelican Mountain (Table 12) shows that 76% of the rock types are dissimilar. A similar comparison with a sample from Lacombe identified 77% of the rock types as identical.

Appendix E lists the potential source formations of the pebbles at

Table 11. Comparison of lithologic data for two samples at the Pelican Mountain site (0.75-1.5" size).

Pelican Mountain 6824	Pelican Mountain 6824-1				Pelican Mountain 6824-3			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite	28		P	28	31			31
Sandstone	66		6	71	58		2	60
Shale/Siltstone	P		P	P			7	7
Ironstone								
Conglomerate	P			P	1			1
Carbonate								
Chert	P		P	1	2			2
Chalcedony								
Argillite								
Quartz								
Granite								
Diorite								
Basalt								
Schist								
Metasediment								
Metavolcanic								
Total	94	0	6	100	91	0	9	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

Villeneuve and Figure 33 shows the distribution of these formations.

This comparison indicates that pebbles in the Pelican Mountain deposit were deposited in a fluvial system with a different origin from the fluvial system which deposited pebbles in the Villeneuve sample. The Villeneuve and Lacombe samples appear to have common or similar source formations.

Crushed gravel from a sand and gravel operation in the Villeneuve deposit was sampled. A PN analysis (Appendix F) on the crushed sample produces very similar results to the petrographic analysis description above. The crushed sample is dominated by sandstone and has significant

Table 12. Comparison of Pelican Mountain and Lacombe lithologic data with Villeneuve pebbles (0.75-1.5" size).

Villeneuve 3975	Pelican Mountain 6824				Lacombe 6106			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite	P		10	10	7	1	2	10
Sandstone		23	44	67	58		9	67
Shale/Siltstone			3	3			3	3
Ironstone			P	P			P	P
Conglomerate			6	6	4		2	6
Carbonate								
Chert	1		11	12	8		4	12
Chalcedony								
Argillite								
Quartz			2	2			2	2
Granite								
Diorite								
Basalt								
Schist								
Metasediment								
Metavolcanic								
Total	1	23	76	100	77	1	22	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

amounts of quartzite and chert. A small amount of carbonate and volcanic rock are noted in the crushed sample but not in the petrographic sample. Two other sites in the region in deposits generally correlative with the Villeneuve deposit (Heatherdown 6402, Entwistle 6424) have PN analyses and the results are comparable. However, Entwistle also contains a rock described as carbonate and Heatherdown has a minor amount of rock described as volcanic and granitic. The carbonate rock probably is from a mountain source and occurs in the region in minor amounts. In the pebble lithology sample analyzed in this study one piece of chert has some carbonate in the specimen. The granitic rock in the PN sample may have

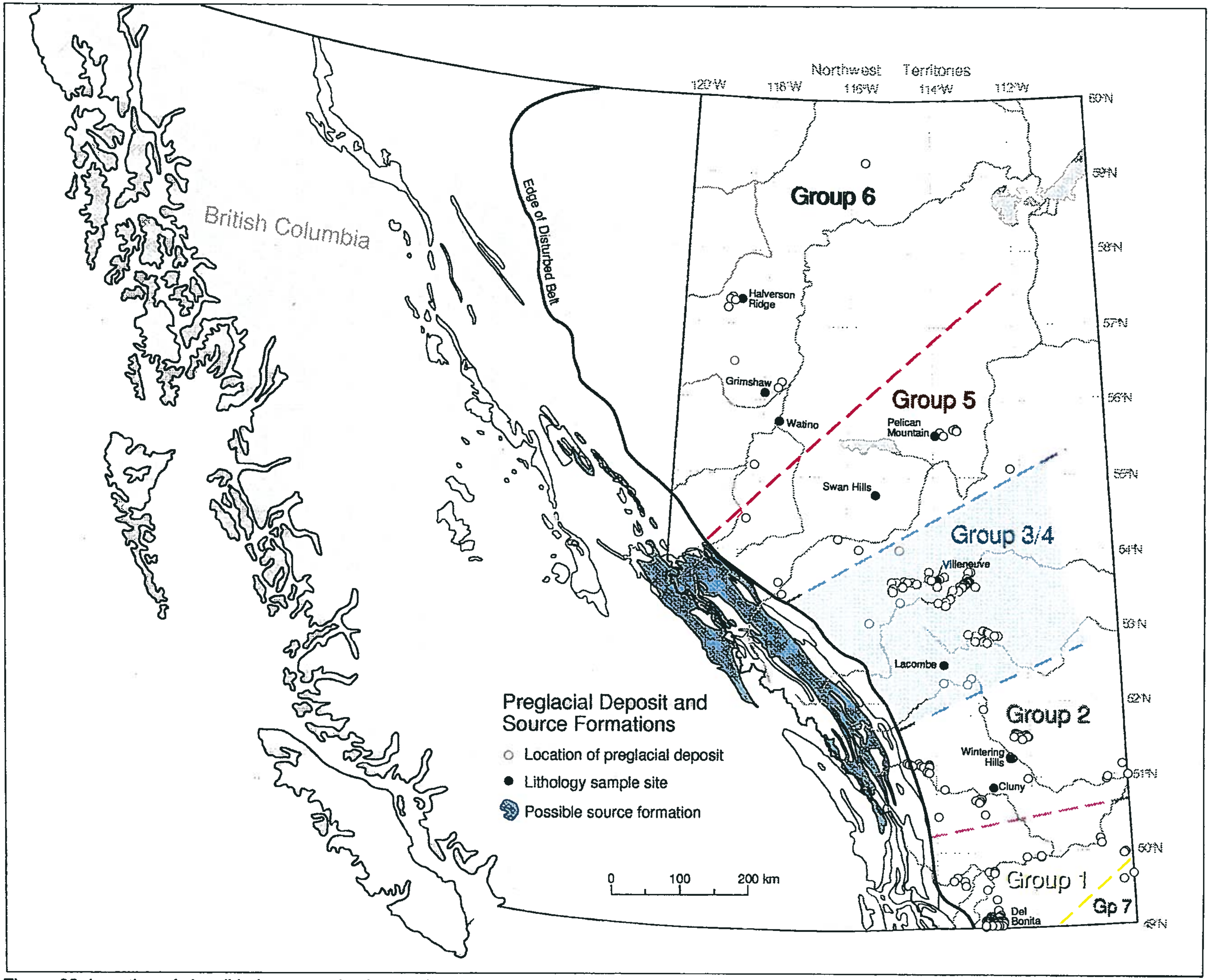

Figure 33. Location of clast lithology sample sites and possible source formations for the clasts.

been included in the crushed sample from overlying outwash (Laurentide glacial origin) which has been described at the Heatherdown and Villeneuve sites. No origin for the volcanic rock is known. The Villeneuve gravel makes an above average aggregate (see Mineral Aggregate).

Lacombe (6106) The pebble component (0.75-1.5") at Lacombe is composed primarily of sandstone (4 varieties, 49%) and quartzite (7 varieties, 35%) (Table 5, Plate 4, Lacombe, Appendix H). A significant amount of carbonate is present in the Lacombe sample (4 varieties, 8%). Seventy-six per cent of the quartzite and sandstone component at Lacombe appears identical to pebbles in the Villeneuve sample but only 23% appears identical with the sample from the Wintering Hills (Table 13). All of the carbonate pebbles at Lacombe appear identical to rocks in the sample from the Wintering Hills but only one quarter are the same as examples in the Villeneuve sample. Lacombe is in a transitional position between the quartzite-sandstone dominated deposits to the north to the carbonate-rich deposits to the south.

The larger pebble (1.5-3.0") size is dominated by quartzite (5 varieties, 19%) and sandstone (3 varieties, 78%), particularly a coarse, tan sandstone which accounts for 75% of the sandstone. One carbonate clast was present in the larger pebble size. The cobble/boulder (+3.0") size is all sandstone and quartzite with the tan sandstone accounting for 77%.

Appendix E lists the potential source formations of the pebbles at Lacombe and Figure 33 shows the distribution of these formations.

The Lacombe site originally was assigned to a separate group (Group 3) based on its geographic location. The lithologic comparison indicates an affinity with the Villeneuve sample. Groups 3 and 4 now are interpreted as having a similar origin and these groups are combined into Group 3/4.

Table 13. Comparison of Villeneuve and Wintering Hills lithologic data with Lacombe pebbles (0.75-1.5" size).

Lacombe 6106	Villeneuve 3975				Wintering Hills 6811			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite	33		2	35	2	4	29	35
Sandstone	43	4	2	49	21	8	20	49
Shale/Siltstone								
Ironstone			3	3		3		3
Conglomerate	1			1	1			1
Carbonate	2		6	8	8			8
Chert	1		3	4		3	1	4
Chalcedony								
Argillite				P	P		P	P
Quartz								
Granite								
Diorite								
Basalt								
Schist								
Metasediment								
Metavolcanic								
Total	80	4	16	100	32	18	50	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

Petrographic Number analysis (Appendix F) completed on the crushed sample from the Lacombe deposit is similar to the lithologic PN analysis. The crushed sample is dominated by sandstone. Two per cent carbonate is present in the crushed sample. This low percentage probably is because the carbonate occurs as smaller clasts which are comminuted during the crushing process. As at Villeneuve (3975) and Heatherdown (6402), a minor amount of rock described as volcanic is noted. No origin for the volcanic rock is known. Based on the PN analysis the Lacombe gravel is classified as an average Alberta aggregate (see Mineral Aggregate).

Wintering Hills (6811) The pebble component (0.75-1.5") at

Wintering Hills is composed of sandstone (3 varieties, 42%), carbonate (6 varieties, 29%), and quartzite (5 varieties, 26%) (Table 5, Plate 4, Wintering Hills, Appendix H). Eighty per cent of the rock types in the Wintering Hills sample appear identical to pebbles present in the Lacombe sample (Table 14). Forty-six per cent of the rock types at Wintering Hills are identical or similar to those described in the sample taken at the Cluny site. The primary difference in the rock descriptions between Wintering Hills and Cluny is a deeply weathered, friable, tan sandstone which accounts for 30% of the sample at Wintering Hills but is not present at Cluny. This rock probably is derived locally from the Paskapoo Formation which underlies the preglacial deposit. If this local rock is excluded, 66% of the rock types at Wintering Hills are identical or similar to those described at the Cluny site. Most of the similarity between Wintering Hills and Lacombe is due to a wide variety, but low percentage, of carbonate at Lacombe and a similarity in locally derived components. Together, this accounts for 55% of the identical lithologies. The Wintering Hills site is assigned to Group 2 because of its affinity with deposits to the south in Mountain source formations.

At Wintering Hills the carbonate clasts are present in the larger sizes. Twenty-seven percent of the larger pebble (1.5-3.0") size and 20% of the cobble/boulder (+3.0") size is carbonate. Some of this carbonate may be from the Paskapoo Formation. Sandstone accounts for 39% of the large pebbles and 50% of the cobbles/boulders. All of the sandstone cobbles/boulders and >90% of the large sandstone pebbles probably are from the Paskapoo Formation. Quartzite accounts for 24% of the large pebbles and 30% of the cobbles/boulders.

Table 14. Comparison of Lacombe and Cluny lithologic data with Wintering Hills pebbles (0.75-1.5" size).

Wintering Hills 6811	Lacombe 6106				Cluny 3913			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite	25		1	26	1	24	1	26
Sandstone	29	10	3	42		10	32	42
Shale/Siltstone		1	1	2		P	2	2
Ironstone								
Conglomerate	P			P			P	P
Carbonate	26		3	29	11		18	29
Chert			1	1	P		1	1
Chalcedony								
Argillite				P	P		P	P
Quartz								
Granite								
Diorite								
Basalt								
Schist								
Metasediment								
Metavolcanic								
Total	80	11	9	100	12	34	54	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

Appendix E lists the potential source formations of the pebbles at Wintering Hills and Figure 34 shows the distribution of these formations.

Petrographic Number analysis (Appendix F) was completed on a crushed sample from a pit in a deposit (3971) adjacent to the Wintering Hills pebble lithology site (6811). The results from the lithologic study and PN analysis are almost identical. Based on the PN analysis, the Wintering Hills gravel is classified as an above average Alberta aggregate (see Mineral Aggregate). This is evidence that the hard components of the Paskapoo Formation can provide a source for above average aggregate.

Cluny (3913) The pebble component (0.75-1.5") at Cluny is composed primarily of quartzite (5 varieties, 57%) and carbonate (6 varieties, 25%). Modest amounts of conglomerate (6%), chert (6%), sandstone (4%), and quartz (2%) are present in the sample (Table 5, Plate 4, Cluny, Appendix H). A similar, wide variety of rock types occur in the large pebble size. Conglomerates account for 27% of the large pebbles and 11% of the cobbles/boulders.

The Cluny sample is very different from the Del Bonita sample with 99% of the pebble lithologies at Cluny described as dissimilar to the Del Bonita suite (Table 15). Cluny appears to be different from the Wintering Hills sample as well (69% dissimilar). However, fine to medium grained, yellowish brown to orange sandstone to quartzite accounts for 46% of rock identified as dissimilar (pebble types 1, 6, and 14 in Plate 4 Appendix H). Similar rock (Paskapoo Formation) is present in outcrop about 30 km southwest of the site so the authors speculate that this rock type represents a locally derived material. Excluding this locally derived material from the correlation, 63% of the pebble lithologies at Cluny are identical or similar to rock types identified at Wintering Hills.

Appendix E lists the potential source formations of the pebbles at Cluny and Figure 34 shows the distribution of these formations.

Petrographic Number analysis (Appendix F) was completed on a crushed sample from the Cluny deposit. The major disparity between the results from the lithologic study and the PN analysis is the amount of sandstone and quartzite. The PN analysis identifies large amounts of sandstone and minor amounts of quartzite and the lithologic study is the reverse. The reason is due to two rock types accounting for 45% which, depending on the specimen, have characteristics of either a quartzite or sandstone. These rock types are listed as part of the quartzite suite in the lithologic

Table 15. Comparison of Wintering Hills and Del Bonita west lithologic data with Cluny pebbles (0.75-1.5" size).

Cluny 3913	Wintering Hills 6811				Del Bonita west 5566			
	Identical %	Similar %	Dissimilar %	Total %	Identical %	Similar %	Dissimilar %	Total %
Quartzite	1	7	49	57	1		56	57
Sandstone		1	3	4			4	4
Shale/Siltstone		P		P			P	P
Ironstone								
Conglomerate	P		6	6			6	6
Carbonate	20		5	25			25	25
Chert	P		6	6			6	6
Chalcedony								
Argillite								
Quartz	2			2			2	2
Granite								
Diorite								
Basalt								
Schist								
Metasediment								
Metavolcanic								
Total	23	8	69	100	1	0	99	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

description. The conglomerate described in the lithologic study probably breaks down during crushing into clasts which are identified as sandstones. Based on the PN analysis the Cluny gravel is classified as an above average Alberta aggregate (see Mineral Aggregate).

Del Bonita (5566) The pebble component (0.75-1.5") at Del Bonita is composed of nearly equal amounts of sandstone (32%), quartzite (29%), and argillite (23%) (Table 5, Plate 4, Del Bonita, Appendix H, Plate 2e). A significant amount of conglomerate (14%) also occurs in the sample. The Del Bonita sample is very different from the Cluny sample, with 95% of the rock types in the pebble fraction described as dissimilar (Table 16).

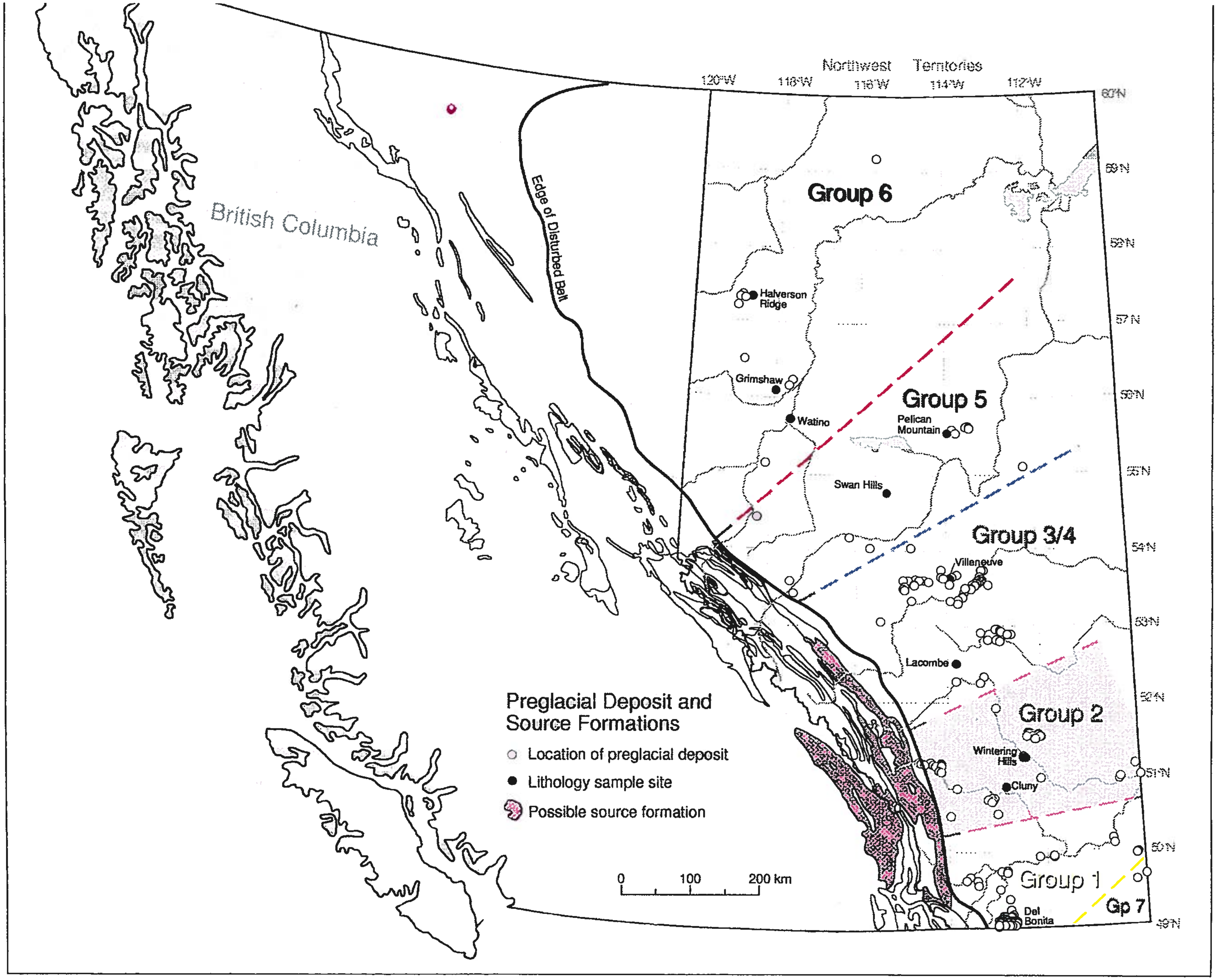

Figure 34. Location of clast lithology sample sites and possible source formations for the clasts.

Table 16. Comparison of Cluny lithologic data with Del Bonita west pebbles (0.75-1.5" size).

Del Bonita west 5566	Cluny 3913			
	Identical %	Similar %	Dissimilar %	Total %
Quartzite	5		24	29
Sandstone			32	32
Shale/Siltstone			1	1
Ironstone				
Conglomerate			14	14
Carbonate				
Chert			P	P
Chalcedony				
Argillite			23	23
Quartz				
Granite				
Diorite			1	1
Basalt			P	P
Schist				
Metasediment				
Metavolcanic				
Total	5	0	95	100

Totals ≠100% are due to rounding or rock types present <1%
P = amount <1%

Carbonates are absent from the Del Bonita sample. The southerly location and distinctive lithology is the basis for classifying Del Bonita as a separate group.

Appendix E lists the potential source formations of the pebbles at Del Bonita and Figure 35 shows the distribution of these formations.

Petrographic Number analysis (Appendix F) was completed on a crushed sample from a pit in a deposit (5570) some distance from the Del Bonita pebble lithology site (5566). The results from the lithologic study and PN analysis are almost identical. Based on the PN analysis the Del Bonita gravel is classified as an average Alberta aggregate (see Mineral

Table 17. Lithologic data for the Cypress Hills (after Vonhof, 1969 and Leckie and Cheel, 1989).

Cypress Hills 4213	64 mm	32-64 mm	16-32 mm
	%	%	%
Quartzite	96.85	92.59	82.5
Sandstone	0.7	1.47	1.47
Conglomerate			P
Chert breccia		0.16	0.16
Arkose			P
Carbonate	0.1	0.03	0.09
Chert	0.95	2.28	11.16
Agate		0.09	0.09
Petrified wood			P
Argillite	0.4	1.85	2.47
Quartz	0.95	1.47	2.03
Qtz-feld. porphyry	0.05		0.03
Trachyte		0.06	
Granite			P
Basalt			P
Andesite			P
Obsidian			P
Volcanic breccia			P
Phonolite			P
Rhyolite and tuff			P
Granite gneiss			P
Total %	100	100	100
Total number clasts	2000	3195	3200

Totals (%) and Totals (number clasts) from Vonhof (1969)
P = rock type present (Leckie and Cheel, 1989) but in unknown amount

Aggregate).

Cypress Hills (4213) The gravel lithology at Cypress Hills was investigated by Vonhof (1969) and Leckie and Cheel (1989). Vonhof identifies rock types and lists the frequency of occurrence in 3 size fractions (Table 17). A comparison with Del Bonita is not possible as specimens from Cypress Hills or detailed descriptions of the rocks are not available. In general, quartzite, sandstone, argillite, conglomerate,

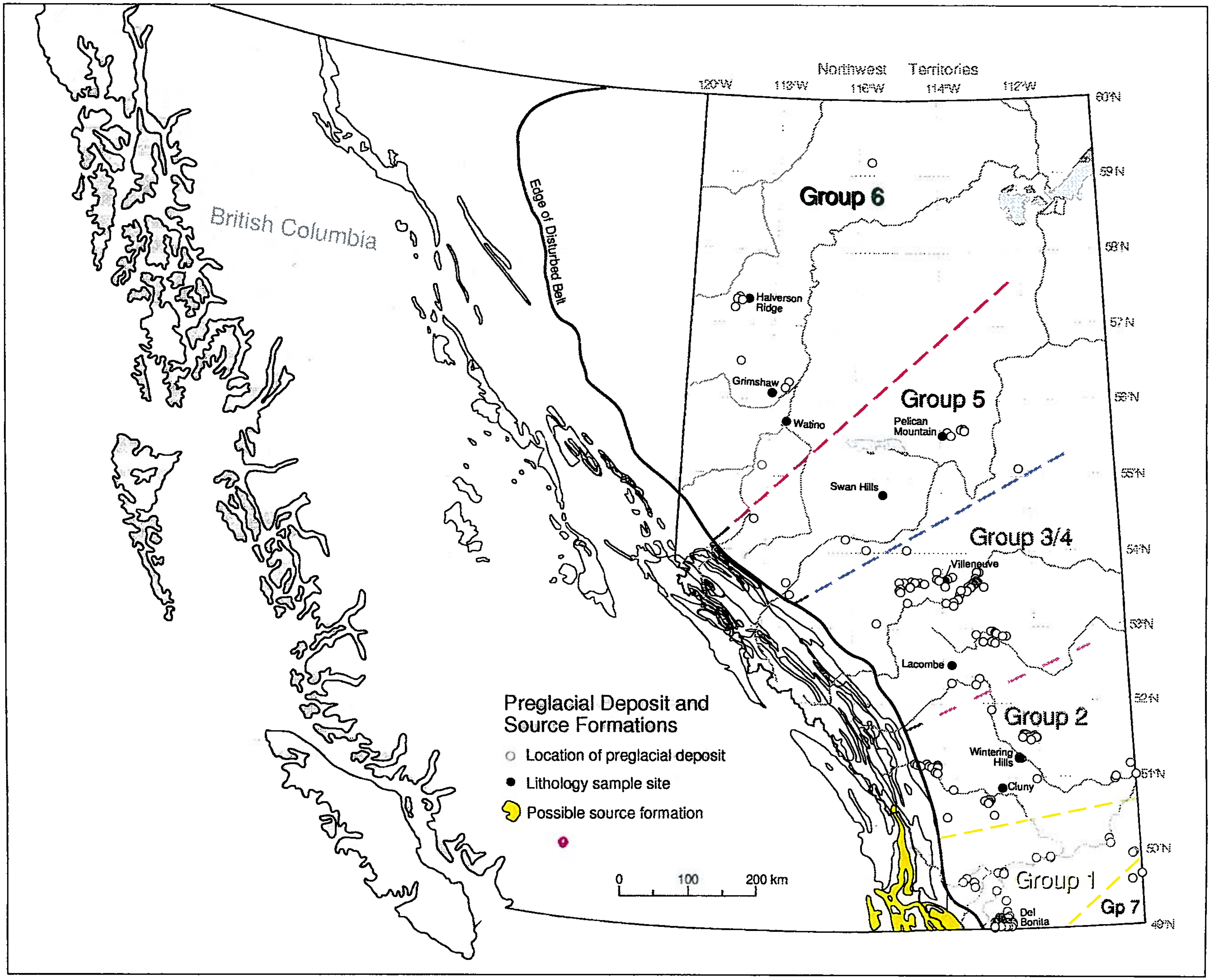

Figure 35. Location of clast lithology sample sites and possible source formations for the clasts.

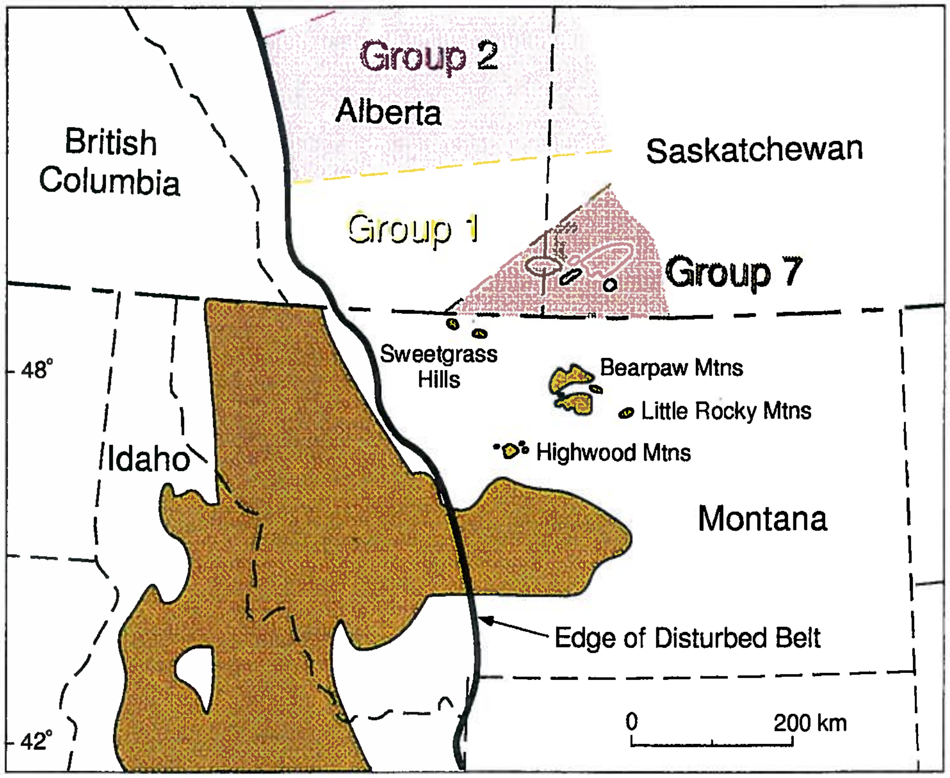

Figure 36. Location of Group 7 deposits and possible source formations (after Leckie and Cheel, 1989)

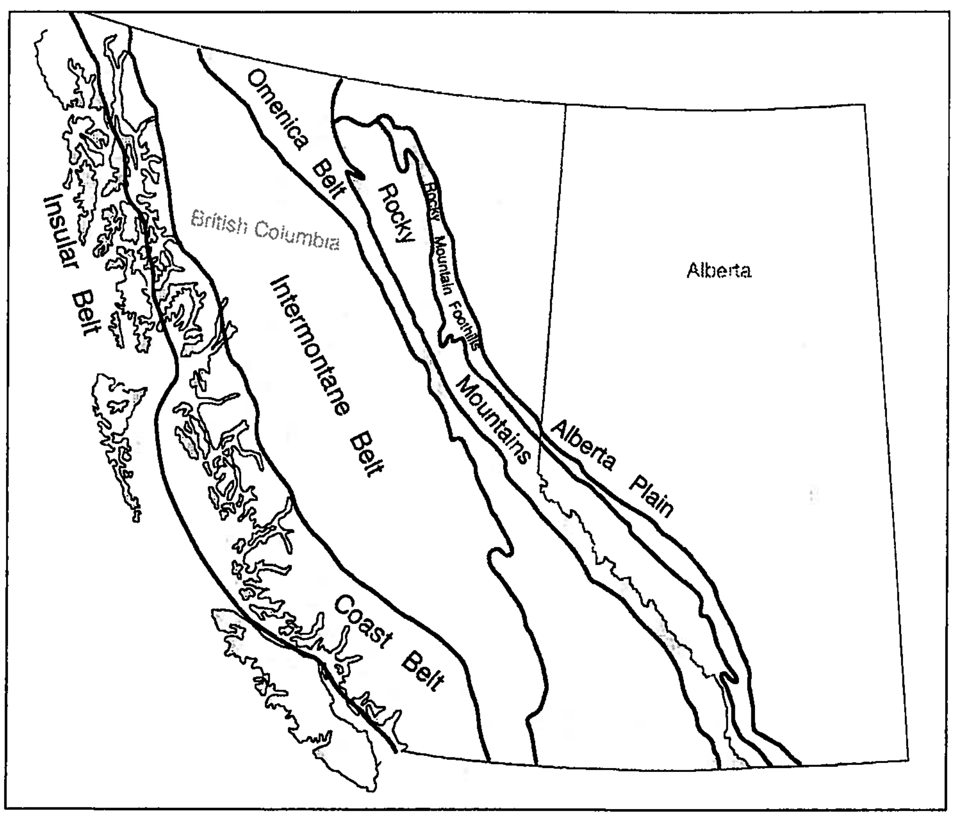

Figure 37. Major physiographic and geologic divisions in Alberta and British Columbia.

basalt, arkose, and chert are present at both the Cypress Hills and Del Bonita. Rock types which appear at Cypress Hills but not at Del Bonita include chert breccia, carbonate, agate, petrified wood, quartz, quartz-feldspar porphyry, trachyte, granite, andesite, obsidian, volcanic breccia, phonolite, rhyolite, tuff, and granite gneiss. The agate and petrified wood likely are from the local Frenchman Formation. Leckie and Cheel (1989) suggest that the rhyolite and tuff may be derived from the Elkhorn Mountains Volcanics. The trachyte, porphyry, phonolite, and volcanic breccia may be derived from the Highwood Mountains, Little Rocky Mountains, Bearpaw Mountains, or Sweetgrass Hills to the south and southwest (Figure 36). The suite of rock types in the Cypress Hills and streamflow directions are distinctive and the Cypress Hills are assigned to a separate group (Group 7 in Figures 30 and 36).

Potential Source Rocks

The consensus that rocks in the preglacial gravels came from the west (Spence et al, 1964) allows speculation about formations that could supply the materials present. Lithologic analysis (Appendix H) provides a suite of rocks for each Group that can be compared with descriptions of rocks in formations to the west. The Lexicon of Canadian Stratigraphy, Volume 4 (Glass, ed., 1990) and Geology of the Cordilleran Orogen in Canada (Gabrielse and Yorath, eds., 1992) were consulted for description of the composition and geographic extent of formations to the west of the preglacial gravels present in Alberta. Summaries of formation characteristics are shown in Appendix E.

It is assumed that pulses of uplift during the Laramide orogeny, which extended from Jurassic to late Eocene time, were the tectonic events that formed the Rocky Mountains and provided the elevation necessary to erode potential source rocks and to move the resistant, coarse materials in stages to their present geographic location on the Plains. Appendix E lists the formations whose lithology best match that of material described in the gravels (Appendix H). These formations seem to be the most likely suppliers of material for the gravels. Several of the potential formations are of such geographic extent that they could be the source of material for more than one Group. Figures 31 to 36 show the present geographic distribution of these potential formations for source material relative to the Groups. The figures show, that for Group 1 to Group 7, the potential source formations all are west of the eastern edge of the disturbed belt in the Rocky Mountain Foothills, Rocky Mountains and Omenica Belt (Figure 37). This does not imply that local rocks are absent from the preglacial gravels. The rocks east of the edge of the disturbed bed generally are soft, and are destroyed easily by short distances of fluvial transport. However, lithologic analyses (Appendix H) indicate the presence of local rocks (0.1 to 10%) in all deposits (Plate 4 Villeneuve 7, Del Bonita 7, Plate 5 Grimshaw 6, Pelican Mountain 13) and significant amounts of local rocks (>40%) in the Lacombe (6106) (Plate 4, Lacombe 1, 4 and 12), Wintering Hills (6811) (Plate 4, Wintering Hills 1), and Cluny (3913) (Plate 4, Cluny 1 and 6) deposits (Plate 2a, c and 3b).

Sand mineralogy

The mineralogy of the sand portion of the preglacial deposits could be as diagnostic as the gravel fraction. The mineralogy of the heavy fraction of the sand is described by Allong (1967) for the Saskatchewan Sands and Gravels (equivalent to Unit 1) and by Leckie and Cheel (1989) for the Cypress Hills Formation (Unit 4). A summary of the heavy mineral data from Allong (1967), and Leckie and Cheel (1989) is shown in Appendix G.

Gold and diamond indicator minerals from the sand fraction are discussed in the Resource characterization section.

Sedimentological interpretation

The sedimentological aspect to this study includes sampling and grain size measurements, measurement of current indicators, lithologic examination of pebbles/cobbles, and general observations of sections.

The grain-size distribution, planar and trough cross-bedding, clast fabric orientation, and clast rounding indicate the deposits are of fluvial origin and were deposited in drainage systems with a general west-southwest to east-northeast streamflow direction. The coarseness of the sediments and the massive nature of the beds indicates that flow was strong. The lithology of the boulder/cobble/pebble fraction supports the interpretation that most rock components are from the mountains to the west or are locally derived from Plains bedrock.

Stratigraphy

Field observations

Eleven of the 26 preglacial deposits examined rest unconformably on bedrock (Table 1). The bedrock ranges from Paleocene age Ravenscrag Formation below the Cypress Hills deposits and Paskapoo Formation below Hand Hills and Swan Hills deposits to Late Cretaceous age Kaskapau Formation below the Grimshaw Gravels, Dunvegan Formation at the base of the Watino gravels, Wapiti Formation below the Simonette deposit, and Horseshoe Canyon Formation under the Villeneuve deposit. At many deposits the basal contact is not visible.

Till or glaciolacustrine sediment overlies preglacial deposits at 22 of the 26 deposits (Plate 1c and Plate 2b). The overlying material is not visible at three sites and till does not cover the sands and gravels on the

Cypress Hills (Table 1).

Cementation of the sand and gravel occurs at Cypress Hills, Nose Hill (Calgary), Wintering Hills, and Hand Hills. The greatest amount of cementation occurs in the Cypress Hills Formation (Plate 3c) and the western edge of the Hand Hills. It is not known whether the cementation is related to age or if it is related to location (little cementation in northern Alberta).

Paleontology and dating

Fossils and radiometrically datable material are present in six preglacial deposits (Table 18). Faunal remains in the Cypress Hills Formation (Table 18) establish its age as Early Eocene to Miocene (Storer, 1978). Horse bones in the Hand Hills Formation, originally thought to indicate a probable Pliocene age (Russell, 1958), may be Pleistocene (Storer, 1978). Detailed faunal lists are presented in Holman (1969, 1972), Russell (1972), and Skwara (1988). Wood collected at Watino (4212) has radiocarbon dates of 31,530 ± 1400 to >40,170 BP (Liverman et al, 1989). Wood collected from the Simonette (4028) deposit yields radiocarbon dates of 32,120 ± 3,430 to 37,010 ± 2690 BP (Liverman et al, 1989). At Villeneuve (3975) dates on bone vary from 27,730 ± 1060 to >41,190 BP (AGS). Dates on wood at the base of the deposit vary from 35,500 ± 2530 to 42,910 ± 3940 (Young et al, 1994). Preglacial sands and gravels for which age has been determined are shown in Table 19 by Unit and Group.

Vonhof (1969) suggests that the higher, western Del Bonita gravels are late Miocene to early Pliocene in age. This estimate is based on synchronism with the No. 1 Bench of the Flaxville Plain of Montana (Alden, 1932) from which vertebrate faunal remains have been recovered (Collier

Table 18. Paleontologic and radiometric dates from preglacial gravels in Alberta

Location	Material Dated	Age	Reference
Watino (4212)	wood	35,500 +2300/-1800	Westgate et al (1971, 1972)
	wood	35,000 +3300/-2300	Westgate et al (1971, 1972)
	wood	34,900 ±3000	Westgate et al (1971, 1972)
	detritus	27,400 ±850	Reimchen (1968)
	detritus	43,500 ±620	Westgate et al (1971, 1972)
	detritus	>38,000	Westgate et al (1971, 1972)
	wood	>40,170	Liverman et al (1989)
	wood	36,220 ±2520	Liverman et al (1989)
	wood	31,530 ±1400	Liverman et al (1989)
	wood	39,780 ±3680	Alberta Geological Survey
Simonette (4028)	wood	37,010 ±2690	Liverman et al (1989)
	wood	33,940 ±1970	Alberta Geological Survey
	wood	32,120 ±3430	Alberta Geological Survey
Villeneuve (3975)	mammoth	>30,650	Alberta Geological Survey
	bone	>41,190	Alberta Geological Survey
	wood	35,500 ±2530	Young et al (1994)
	wood	35,760 ±2130	Young et al (1994)
	wood	>39,690	Young et al (1994)
	wood	41,110 ±3750	Young et al (1994)
	wood	41,400 ±3990	Young et al (1994)
	wood	42,910 ±3940	Young et al (1994)
	caribou	27,730 ±1060	Young et al (1994)
	cervid	31,520 ±450	Young et al (1994)
	mammoth	39,960 ±3950	Young et al (1994)
Cypress Hills (4213)	bone	Late Eocene-Miocene	Storer (1978)
Medicine Hat (1068)	wood	>36,600	Westgate (1968)
Hand Hills (3958)	horse bones	late Pliocene	Russell (1958)
	same bones	probably Pleistocene	Storer (1978)

and Thom, 1918). This study assumes a slightly older age correlation based on data from deposit elevation versus distance from the disturbed belt but the late Miocene age suggested by Vonhof may be reasonable.

Location and elevation

Criteria such as stratigraphic position relative to bedrock and the pebble lithology define sand and gravel deposits as preglacial. Fossils and

Table 19. Distribution of age determinations in Alberta

	Group 6	Group 5	Group 3/4	Group 2	Group 1	Group 7
Unit 1 Saskatchewan Sands & Gravels	Simonette (4028) Watino (4212)		Villeneuve (3975)		Medicine Hat (1068)	
Unit 2 Upland Gravels						
Unit 3 Hand Hills Fm Equivalents				Hand Hills W. (3958)		
Unit 4 Cypress Hills Fm Equivalent						Cypress Hills (4213)

age dating can fix a time of deposition and would provide an excellent base to develop a time stratigraphy except that deposits are discontinuous, often widely separated, and the discovery of datable material or fossils in preglacial deposits is rare (to date only 6 of the more than 200 deposits and 180 sites in Alberta). If formations were extensive they could be mapped and development of a stratigraphy would be easier. In fact the youngest preglacial deposits in Saskatchewan (Figure 38) are very extensive and mappable. They are buried and traced primarily through the use of water well data. Unit 2, 3, and 4 deposits in Alberta are not laterally continuous. One way of correlating isolated deposits is through a stratigraphy based in part on the elevation of the deposit.

The elevation of the base of each deposit is estimated from topographic maps. These values are listed in Appendix A. The location of each deposit was calculated as the distance at right angles from the edge of the

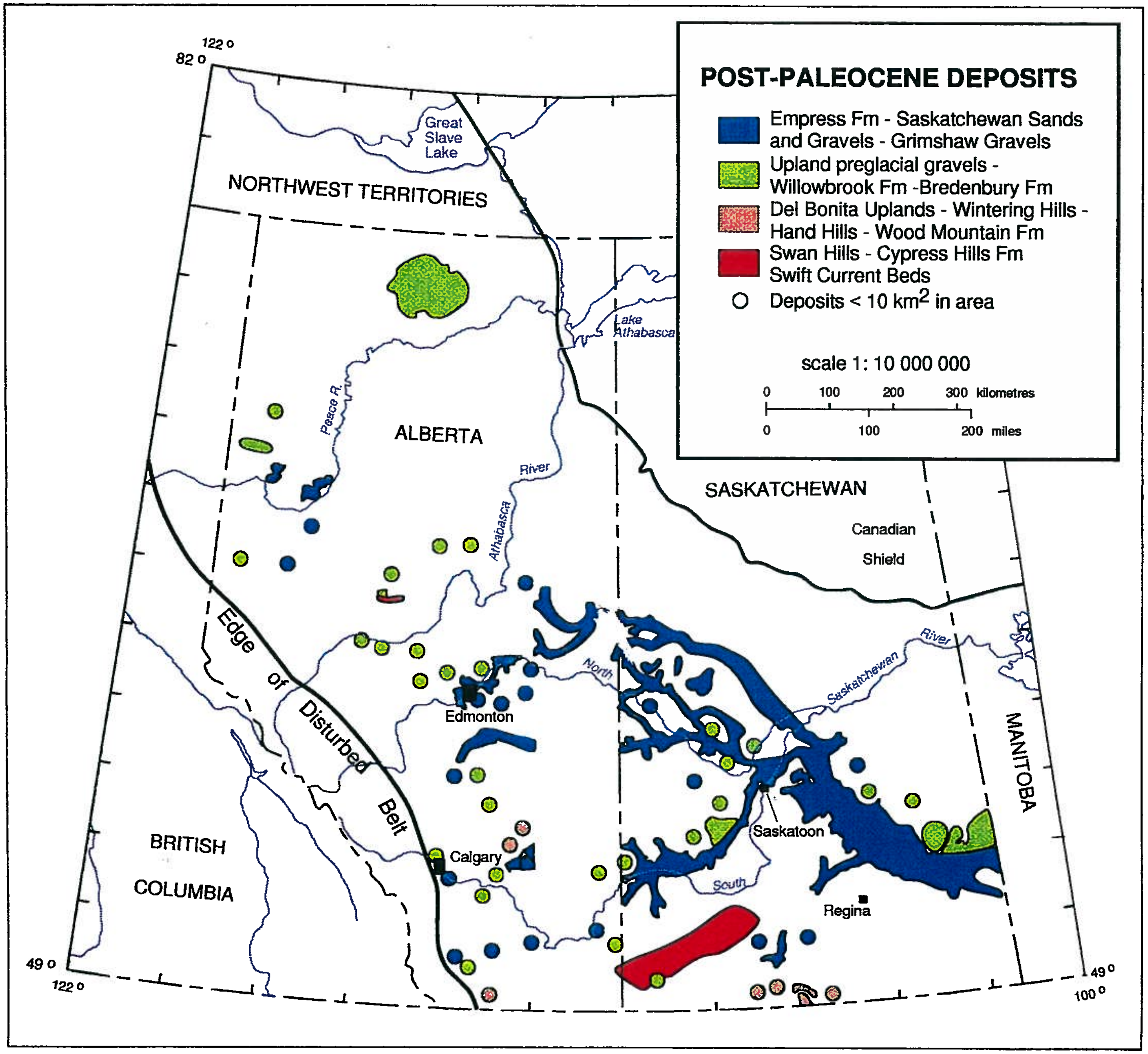

Figure 38. Western Canada distribution of preglacial sediments. (after Edwards in Mossop and Shetson, 1994)

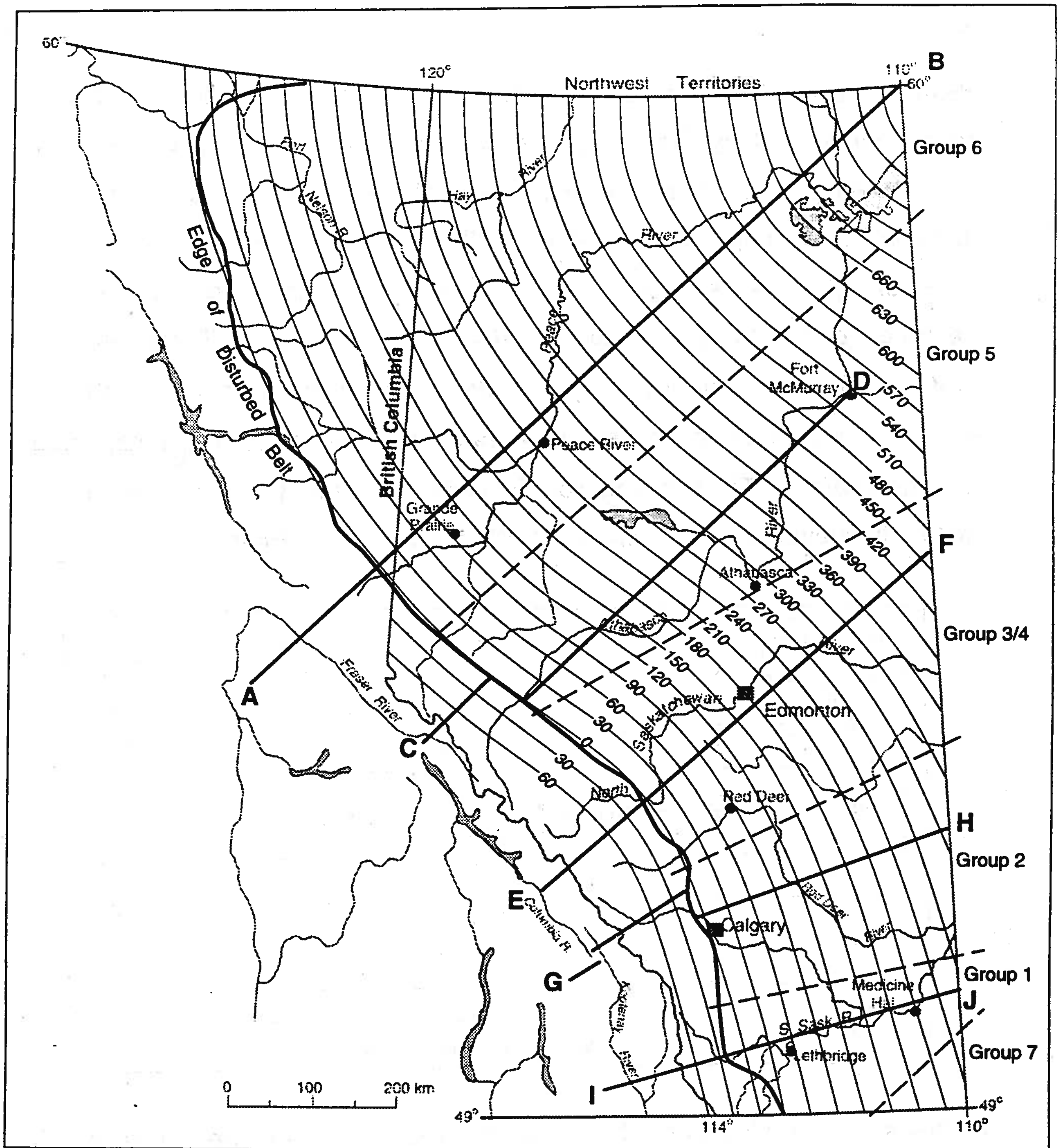

Figure 39. Longitudinal profiles and orthocontours (km from edge of disturbed belt).

disturbed belt. To make this easier and more consistent an orthocontour map, represented by Figure 39, was prepared with the zero contour line established parallel to the general trend of the disturbed belt. The location of the deposits calculated in this way are listed in Appendix A.

Plots of deposit elevation versus distance from the edge of the deformed belt show a west to east decrease in elevation (Figure 40). This profile agrees with a fluvial system flowing from west to east and is similar in shape to the profile of present day rivers flowing away from the mountains. Thus, preglacial deposits near the foothills typically are higher in elevation than deposits further out on the Plains.

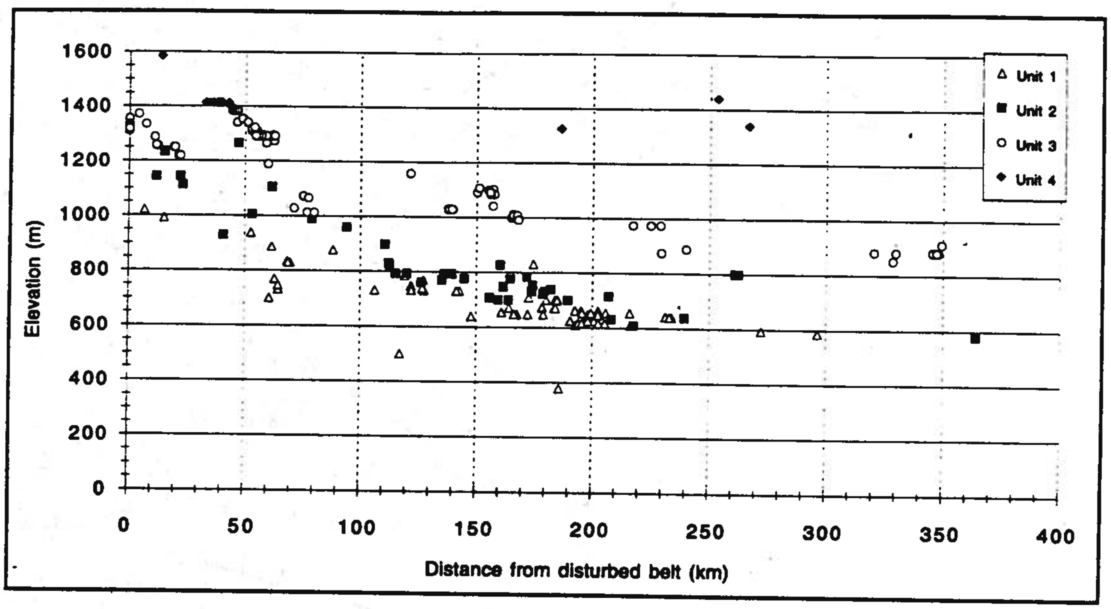

Figure 40. The elevation of preglacial deposits versus their distance east from the edge of the disturbed belt.

The scatter of data in Figure 40 is wide. Sense can be elicited from this plot by considering the elevations and locations of deposits which have been dated. The oldest deposit, Cypress Hills, is very high and also is one of the farthest from the Mountains (Figure 40, Unit 4). The Hand Hills deposits are slightly lower and younger (Figure 40, Unit 3), and the lowest deposits (Villeneuve, Watino, Simonette) are the youngest (Figure 40, Unit 1). Parallel profiles (levels) drawn through the dated points on the

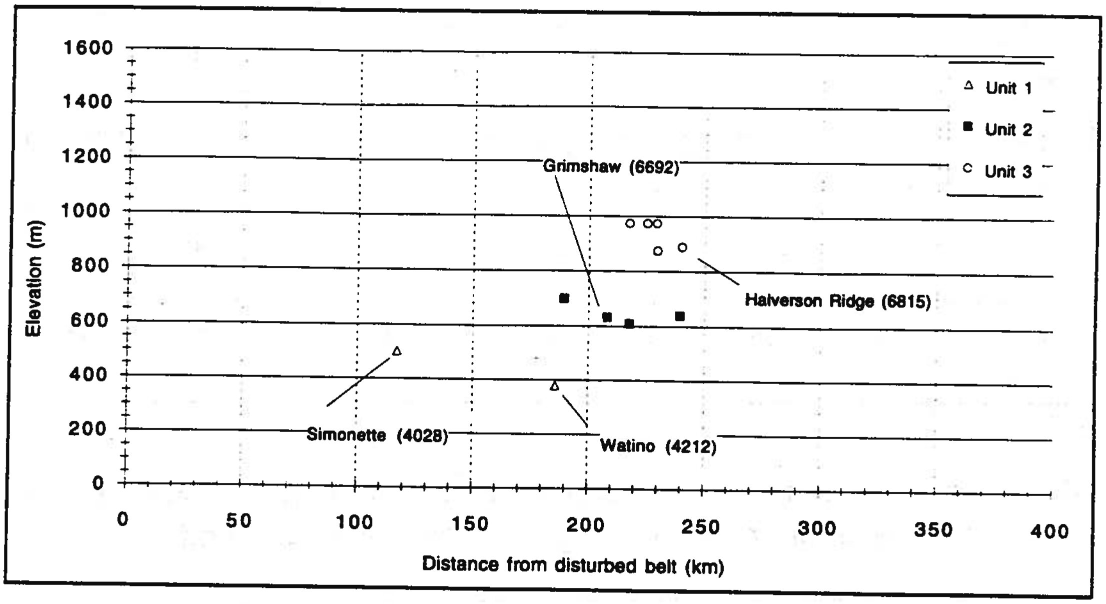

Figure 41. The elevation of preglacial deposits in Group 6 versus their distance east from the edge of the disturbed belt.

plot define three levels and intersect many points (Figure 40, Units 1, 3, and 4). Field observation is used to identify a fourth set of data or level. Preglacial deposits are observed to occur at or slightly above Plains level at Grimshaw, Entwistle, Lacombe, and Cluny. The age of these deposits is unknown, but they are distinctly lower than the deposits which cap hills (Hand Hills equivalents, Unit 3) and higher than the deposits which are buried below Plains level (Villeneuve) or exposed in river valleys (Oldman, North and South Saskatchewan Rivers). A fourth profile drawn through these Plains level deposits intersects another major set of deposits (Figure 40, Unit 2).

Considerable range still exists amongst one set of levels when all

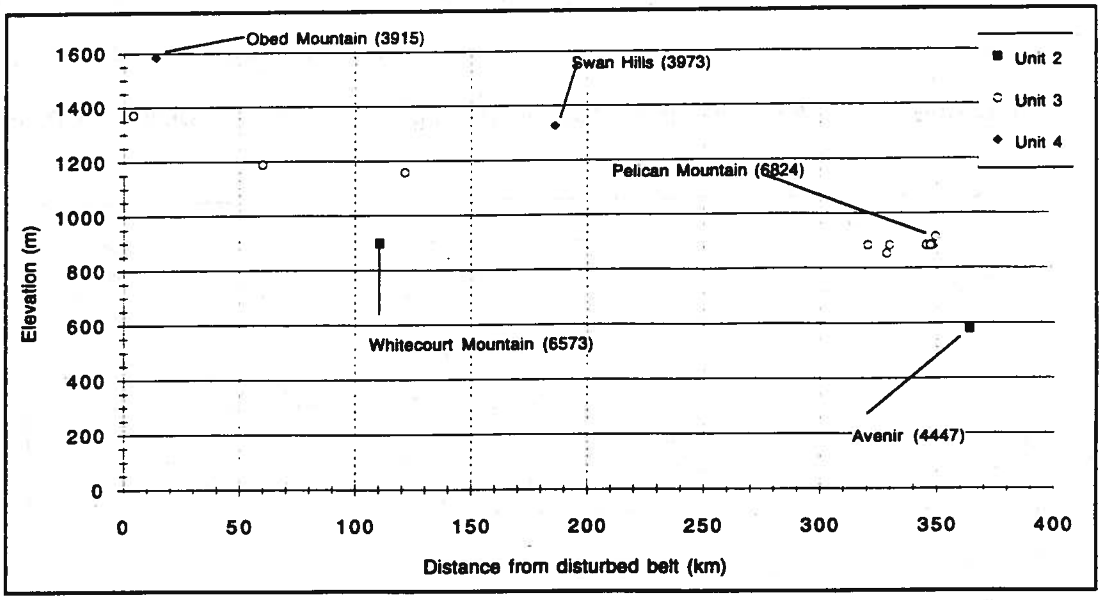

Figure 42. The elevation of preglacial deposits in Group 5 versus their distance east from the edge of the disturbed belt.

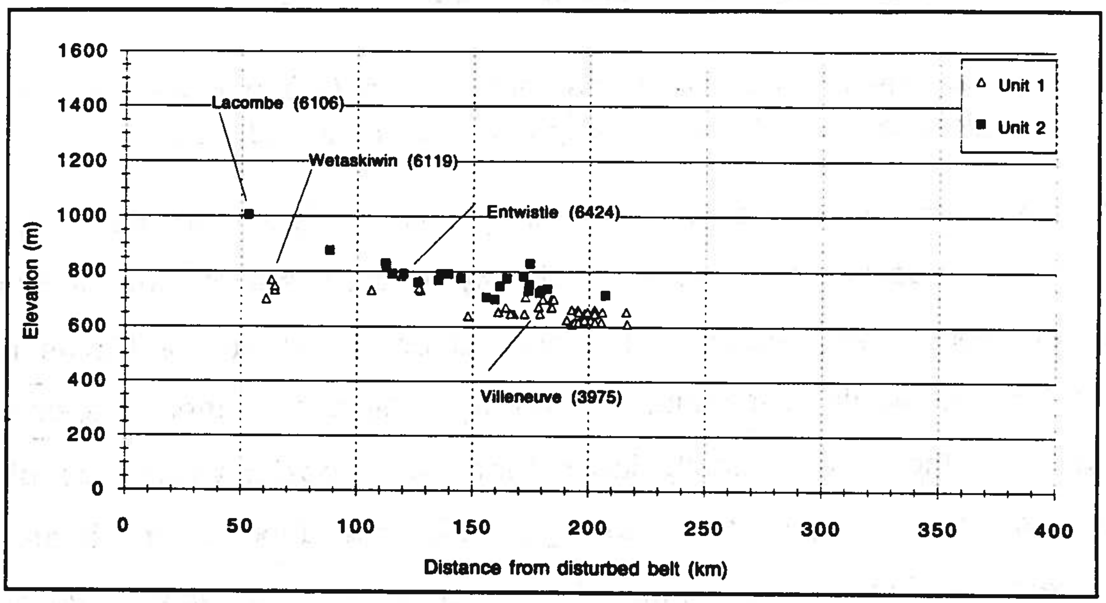

Figure 43. The elevation of preglacial deposits in Group 3/4 versus their distance east from the edge of the disturbed belt.

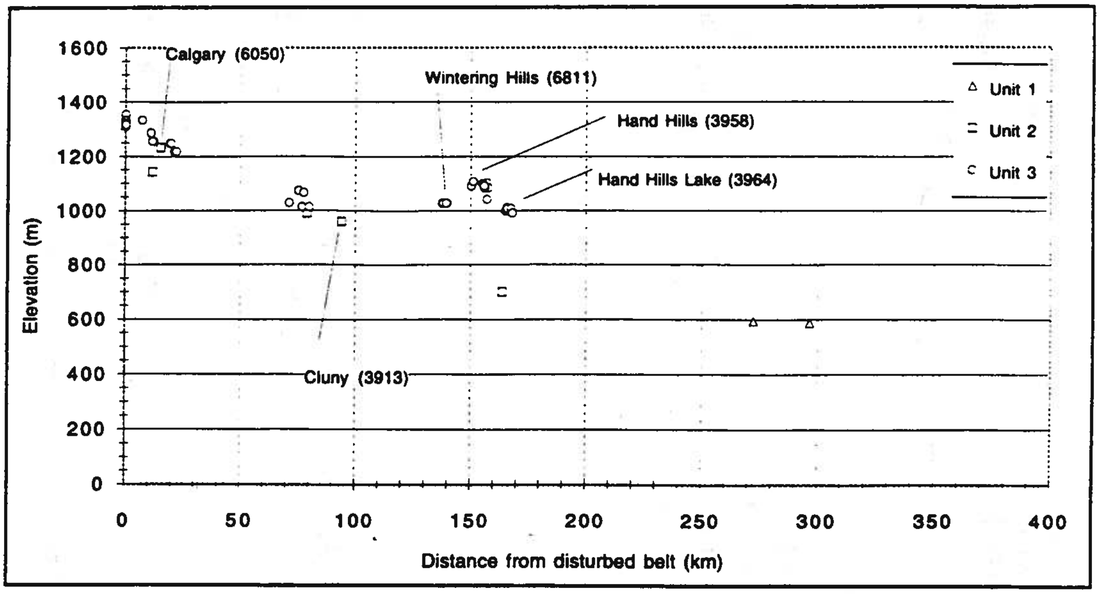

Figure 44. The elevation of preglacial deposits in Group 2 versus their distance east from the edge of the disturbed belt.

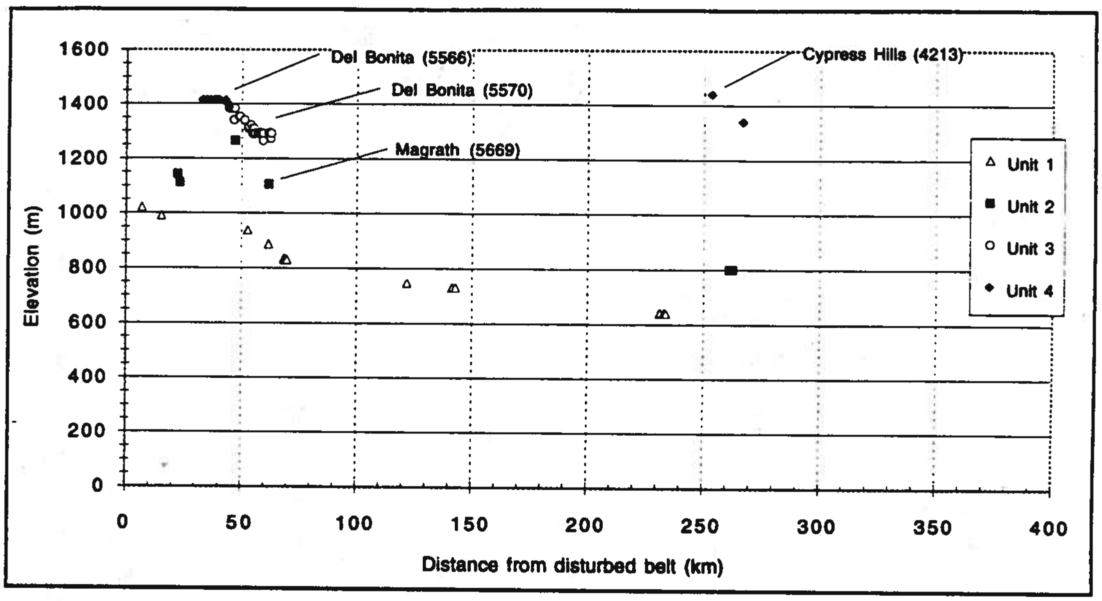

Figure 45. The elevation of preglacial deposits in Group 1 versus their distance east from the edge of the disturbed belt.

Table 20. Preliminary stratigraphic categories of the major preglacial deposits. Groups 3 and 4 now are considered as a single group.

	Group 6	Group 5	Group 3/4	Group 2	Group 1	Group 7
Unit 1 Saskatchewan Sands & Gravels	Simonette 4028 Watino 4212		Villeneuve 3975 Wetaskiwin 6119		Wolf Island 1100	
Unit 2 Upland Gravels	Grimshaw 6692	Smoky Tower 3914	Entwistle 6424 Magnolia 6422 Wabamun 6411 Heatherdown 6402 Lacombe 6106	Olympic Hill 6050 Nanton 5812	Magrath 5669	
Unit 3 Hand Hills Fm. Equivalents	Halverson Ridge 6815	Pelican Mountain 6824 Whitecourt Tower 6573		Hand Hills W. 3958 Wintering Hills 6811 Arrowwood 5855	Del Bonita E. 5570	
Unit 4 Cypress Hills Fm. Equivalents		Swan Hills 3973 Obed Mountain 3915			Del Bonita W. 5566	Cypress Hills 4213

deposits for Alberta are plotted (Figure 40), for example, a deposit in the lowest level at Watino (187 km from the disturbed belt) has an elevation below 400 m whereas deposits, in the same Unit, with equal or greater distance near Edmonton or Lethbridge have elevations in excess of 600 m. There appears to be north-south differences in elevations for deposits of similar age, perhaps due to different base levels. For this reason, plots of elevation versus distance from the disturbed belt are shown for each of the groups (Figures 41 to 45).

A four-fold stratigraphy is proposed, based on this model of decreasing age with decreasing elevation (Table 20). It appears that the highest deposits (Cypress Hills, Swan Hills (Plate 2c)) formed near the beginning of fluvial erosion of the Plains during the Early to Mid Tertiary (Unit 4). Continued fluvial action during the Tertiary eroded deeper into the Plains and deposits that formed in the Late Tertiary now occur on modest hills or ridges (Hand Hills, Pelican Mountain) (Plate 2d) (Unit 3). A set of deposits (Unit 2) occur at what is now Plains level (Grimshaw, Entwistle, Wetaskiwin, Lacombe, Cluny). The most widespread set of deposits (Villeneuve, Simonette, Watino, Kipp) were formed in channels eroded into the Plains surface (Plate 2a) immediately prior to continental glaciation (Late Wisconsinan) (Unit 1). Appendix A lists the stratigraphic unit numbers for all deposits.

There is independent evidence from coal quality studies that erosion of Plains bedrock over about 40 million years exceeded 1000 m in many areas (Nurkowski, 1984). This provides an estimate of the erosional progress by fluvial action (Figure 46) and a cross check with an independent source of data.

Group 6. Group 6 (northwestern Alberta) is interpreted to have three

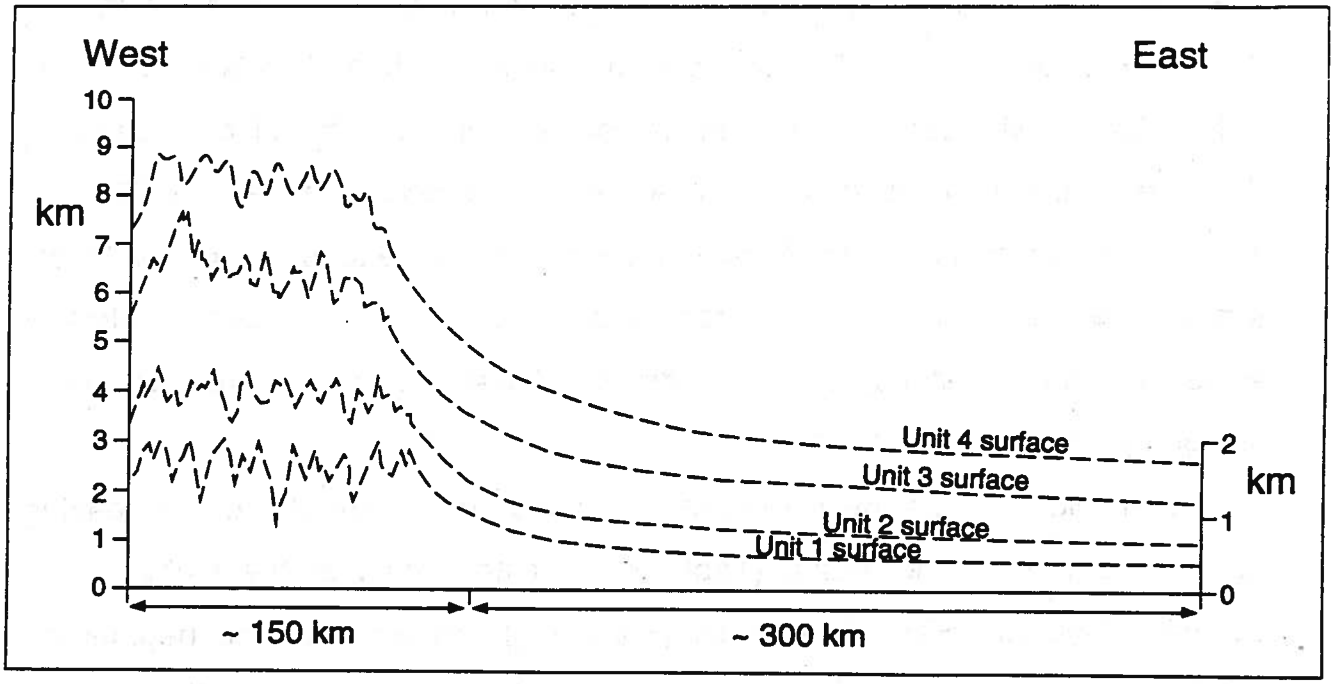

Figure 46. Schematic representation of preglacial erosional surfaces from Early Tertiary (Unit 4) to Late Pleistocene (Unit 1).

stratigraphic units (Appendix A, Figure 41). Figure 47 shows deposits from these units projected onto a profile of the modern Peace River and of the Mountains along line A-B (Figure 39). The Watino (4212) and Simonette (4028) deposits (Plate 2a) belong to the lowest and youngest sub-set (Unit 1). These deposits may be equivalent to the Saskatchewan Sands and Gravels (Stalker, 1968) of southern Alberta or the Empress Formation of central Alberta or Saskatchewan (Andriashek, 1988). The Grimshaw Gravels (6692) (Plate 1a and 1c) are higher and probably older (Unit 2) than Watino and Simonette. The Halverson Ridge deposit (6815) and others cap a prominent highland in the region and represent the oldest deposits in Group 6. Halverson Ridge is placed in Unit 3.

Group 5. Three stratigraphic units are proposed within Group 5 (Appendix A, Figure 42). Figure 48 shows deposits from these units projected onto a profile of the modern Athabasca River and of the Mountains along line C-D (Figure 39). The profile also shows the estimated elevation of the Early Tertiary land surface based on coal quality data (Nurkowski, 1984). This group is dominated by the older deposits. The Swan Hills (3973) (Plate 3a) is the highest and oldest deposit in the region. It is estimated to be Oligocene in age and probably is equivalent to the Cypress Hills (Unit 4). The Obed Mountain (3915) deposit (Plate 1b and 2c), exposed above the Obed Mountain Coal Ltd. mine, also is classified as Unit 4, equivalent to the Cypress Hills. The Pelican Mountain (6824) deposits are placed in Unit 3. Whitecourt Tower (6573) and Smoky Tower (3914) are assigned to Unit 2, equivalent to the Hand Hills. No deposits at the lowest elevations, correlative to the Saskatchewan Sands and Gravels or Empress Formation, have been noted in this region.

Group 3/4. Only the youngest stratigraphic units are represented within Group 3/4 (Appendix A, Figure 43). Figure 49 shows deposits from these units projected onto a profile of the modern North Saskatchewan River and of the Mountains along line E-F (Figure 39). The profile also shows the estimated elevation of the Early Tertiary land surface based on coal quality data (Nurkowski, 1984). The Villeneuve (3975) deposit (Plate 3d) is considered a typical Saskatchewan Sands and Gravels or Empress Formation deposit. The Entwistle (6424), Magnolia (6422), Wabamun (6411), and Heatherdown (6402) deposits are at slightly higher elevations and are classified as Unit 2, equivalent to the Grimshaw Gravels. Deposits in the Wetaskiwin and Lacombe areas originally were assigned to Group 3. Lithologic and gold data are not significantly different so Groups 3 and 4 now are combined into Group 3/4.

Group 2. Group 2 includes the Hand Hills which are interpreted to be of Miocene to Pliocene age based on the fossil assemblage (Appendix A, Figure 44). Figure 50 shows deposits from these units projected onto a profile of the modern Red Deer River and of the Mountains along line G-H (Figure 39). The profile also shows the estimated elevation of the Early Tertiary land surface based on coal quality data (Nurkowski, 1984). The Hand Hills (3958) and Wintering Hills (6811) are assigned to Unit 3. The preglacial deposit that occurs on top of Olympic Hill in Calgary (6050) is topographically higher than the Hand Hills deposits but is further 'upstream' and is classified as Unit 2.

Group 1 and Group 7. All four stratigraphic units are represented in Group 1 (Appendix A, Figure 45). Deposits to the west of the Del Bonita area (ie. 5566) are assigned to Unit 4 (highest and oldest) and deposits further east are assigned to Unit 3. Deposits exposed in the South Saskatchewan and Oldman River valleys (Figure 51) are assigned to Unit 1. Fort Macleod (5721) (Plate 1c) and Magrath (5669) are at or above Plains level and are assigned to Unit 2.

The Cypress Hills Formation (Group 7, Unit 4) also is plotted on Figures 45 and 51. These are the most extensively studied and best understood of the Tertiary deposits. The Cypress Hills Formation, best defined in Alberta by deposit 4213, is estimated to be Eocene-Oligocene in age and probably is the oldest preglacial sand and gravel deposit in Alberta (Plate 3c). The Cypress Hills have an anomalously high elevation for their apparent distance from the Mountains when plotted with Group 1. The river or braidplain creating the deposit flowed from the south and the land slope from this direction was enhanced by plutonic activity in the Montana region (Leckie and Cheel, 1989). Distance to source for some of the

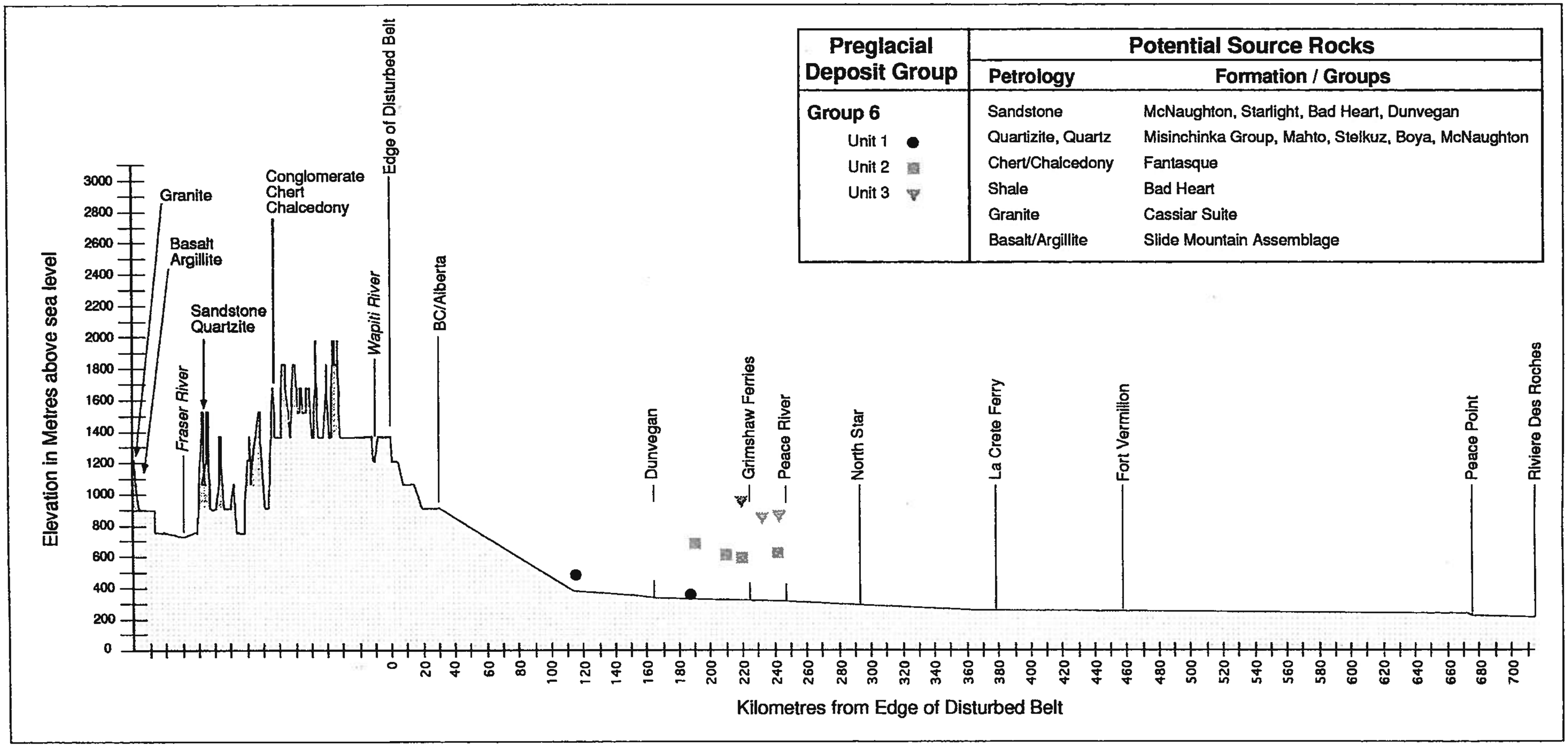

Figure 47. Longitudinal profile A-B (figure 39) for preglacial deposits in Group 6 and the Peace River.

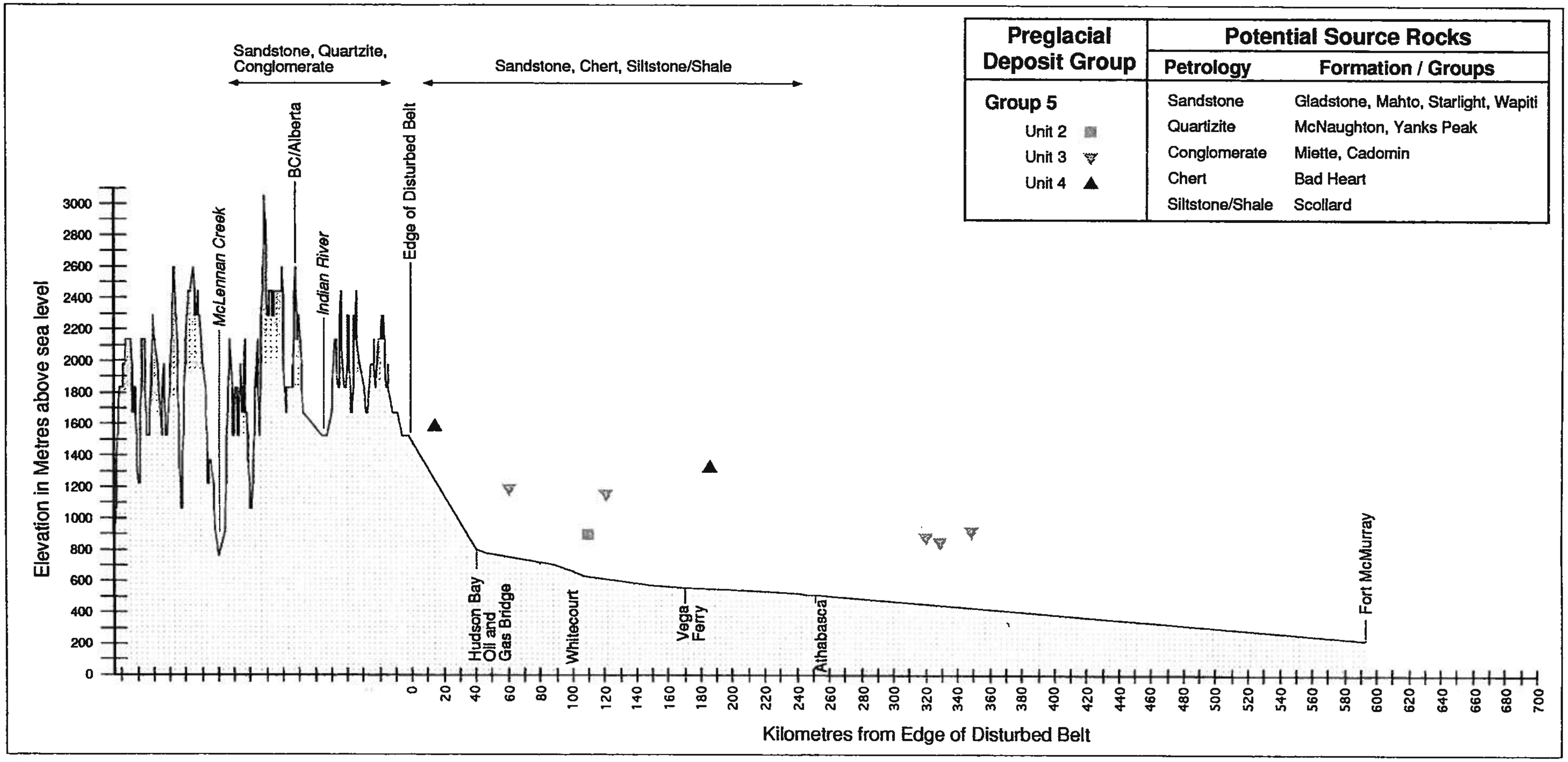

Figure 48. Longitudinal profile C-D (figure 39) for preglacial deposits in Group 5 and the Athabasca River.

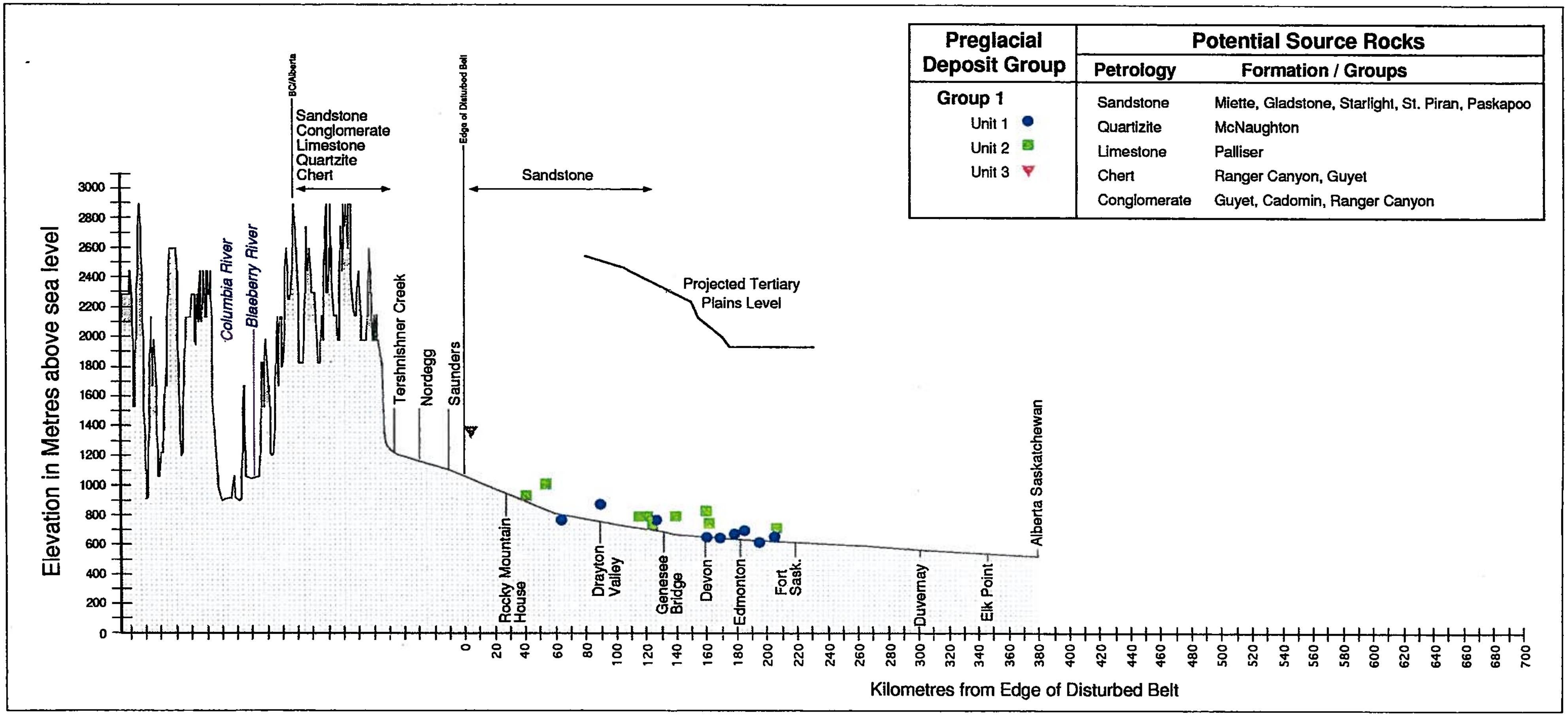

Figure 49. Longitudinal profile E-F (Figure 39) for preglacial deposits in Group 3/4 and the North Saskatchewan River and the projected Tertiary Plains Level (after Nurkowski, 1984).

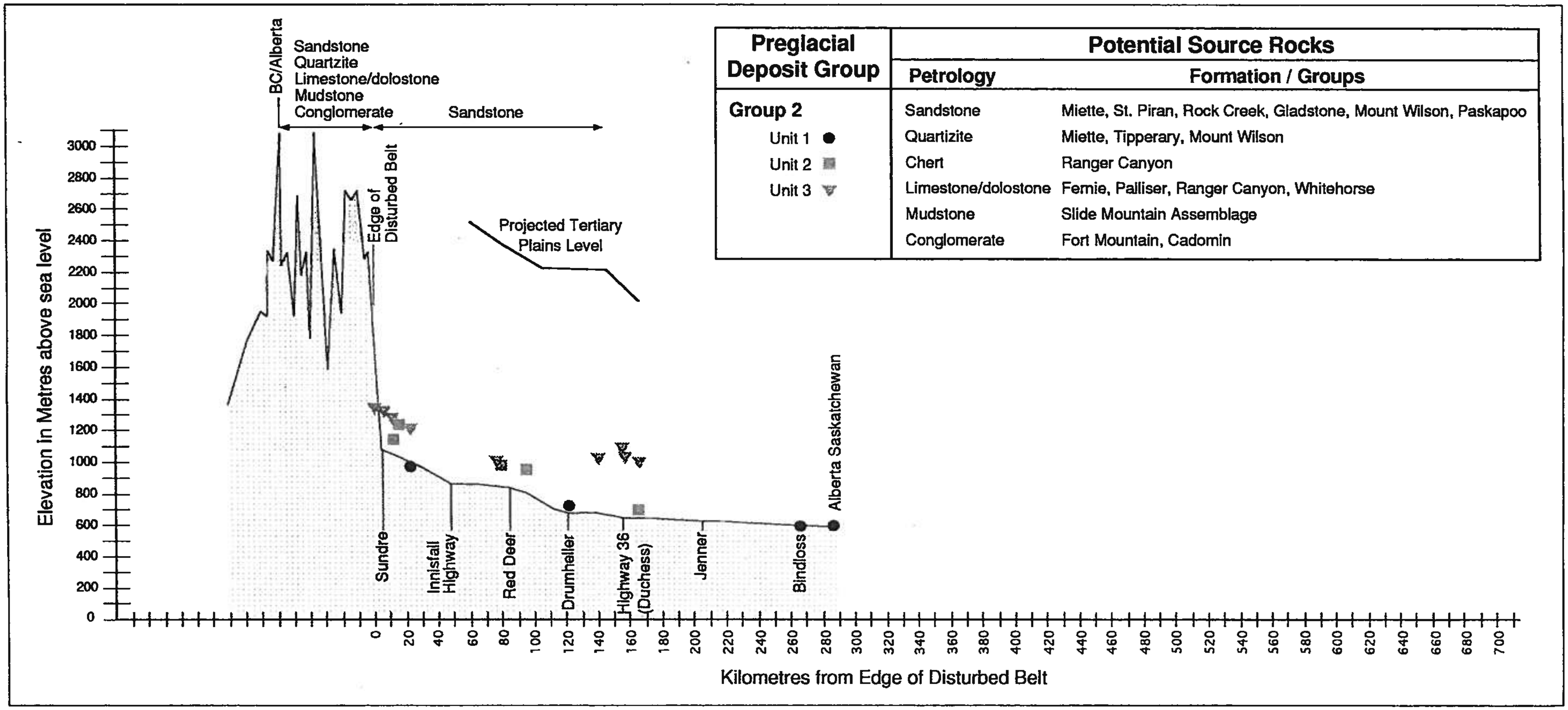

Figure 50. Longitudinal profile G-H (figure 39) for preglacial deposits in Group 2 and the Red Deer River and the projected Tertiary plains level (after Nurkowski, 1984).

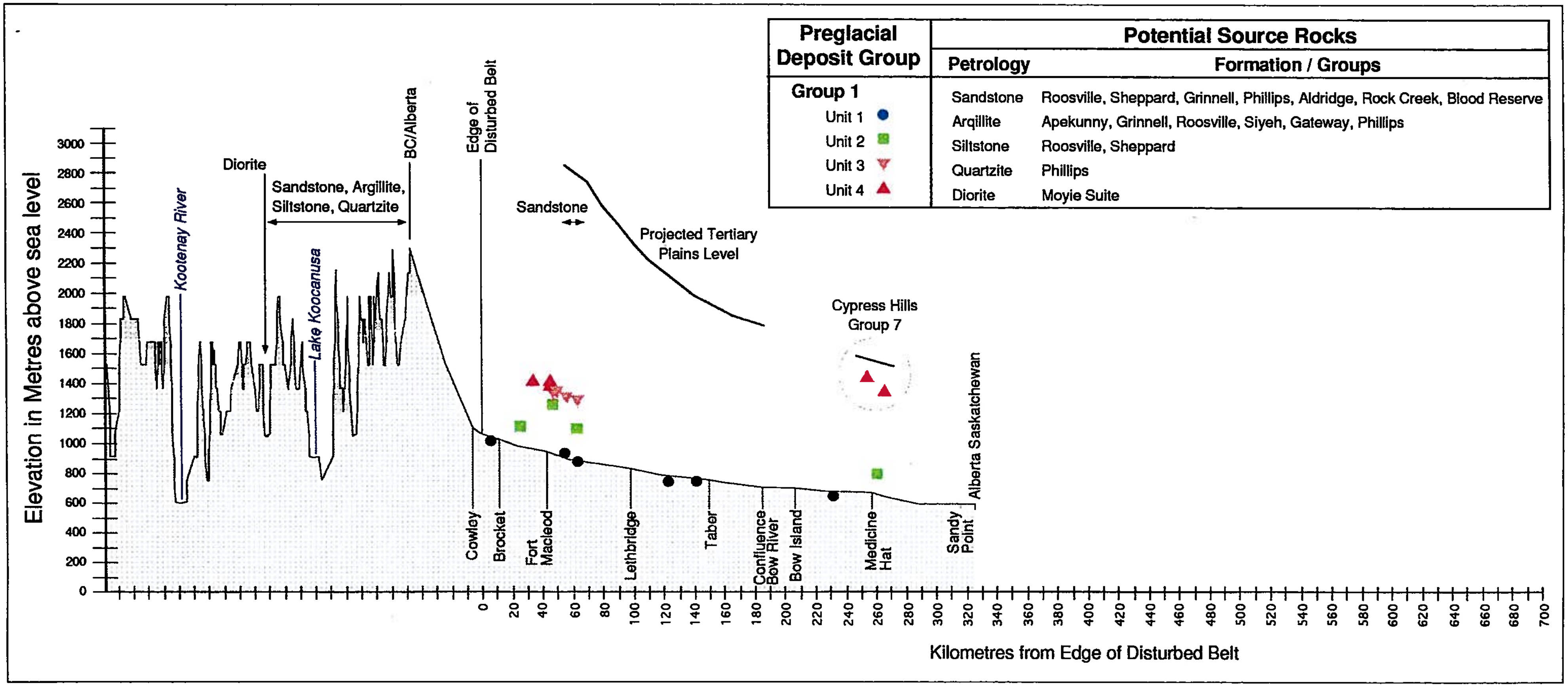

Figure 51. Longitudinal profile I-J (Figure 39) for preglacial deposits in Group 1 and the Oldman and South Saskatchewan Rivers. Also shown are the Cypress Hills deposits (Group 7) and the projected Tertiary plains level (after Nurkowski, 1984).

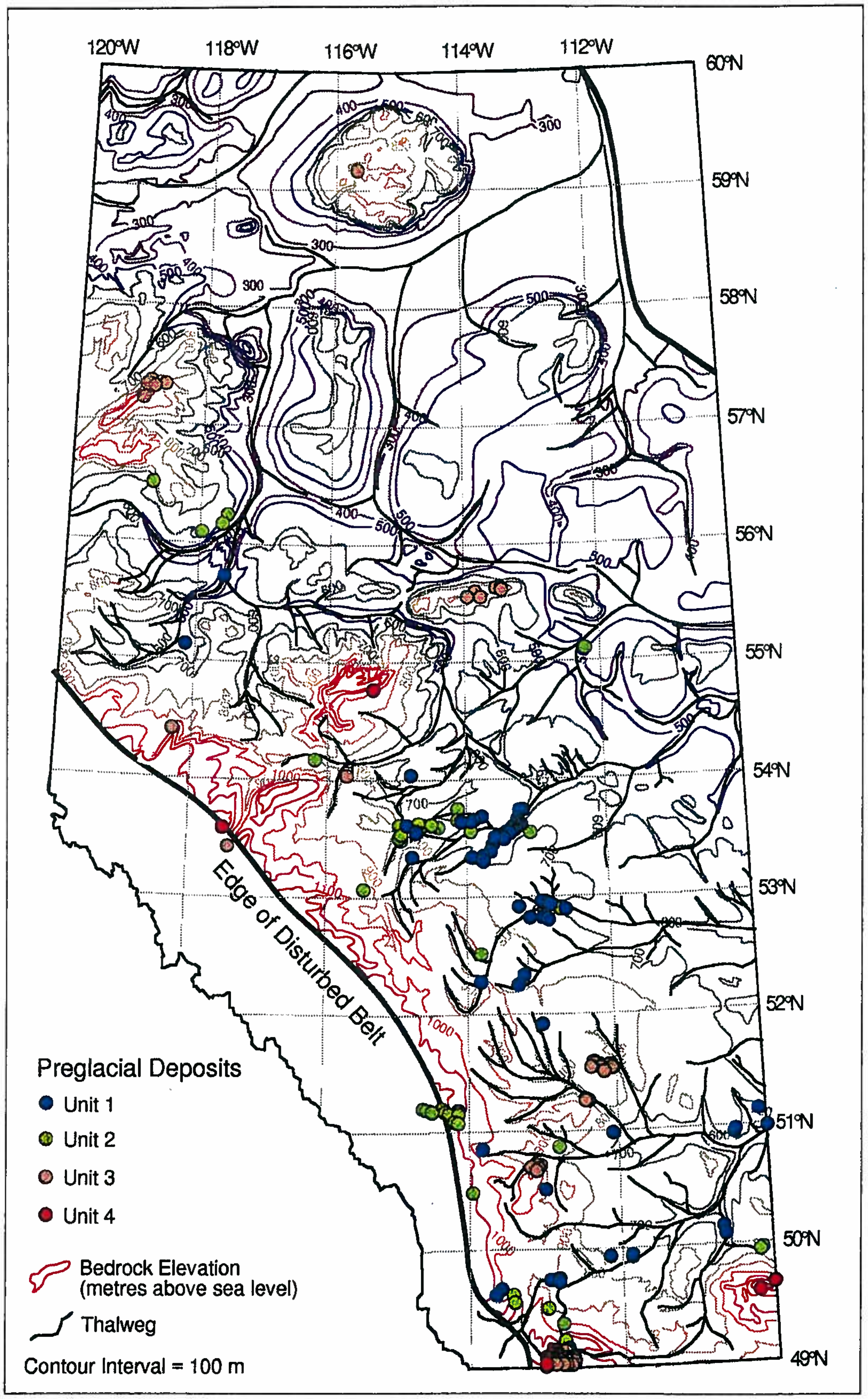

Figure 52. Preglacial channels (thalwegs), bedrock topography (after Pawlowicz and Fenton, 1995), and preglacial deposits.

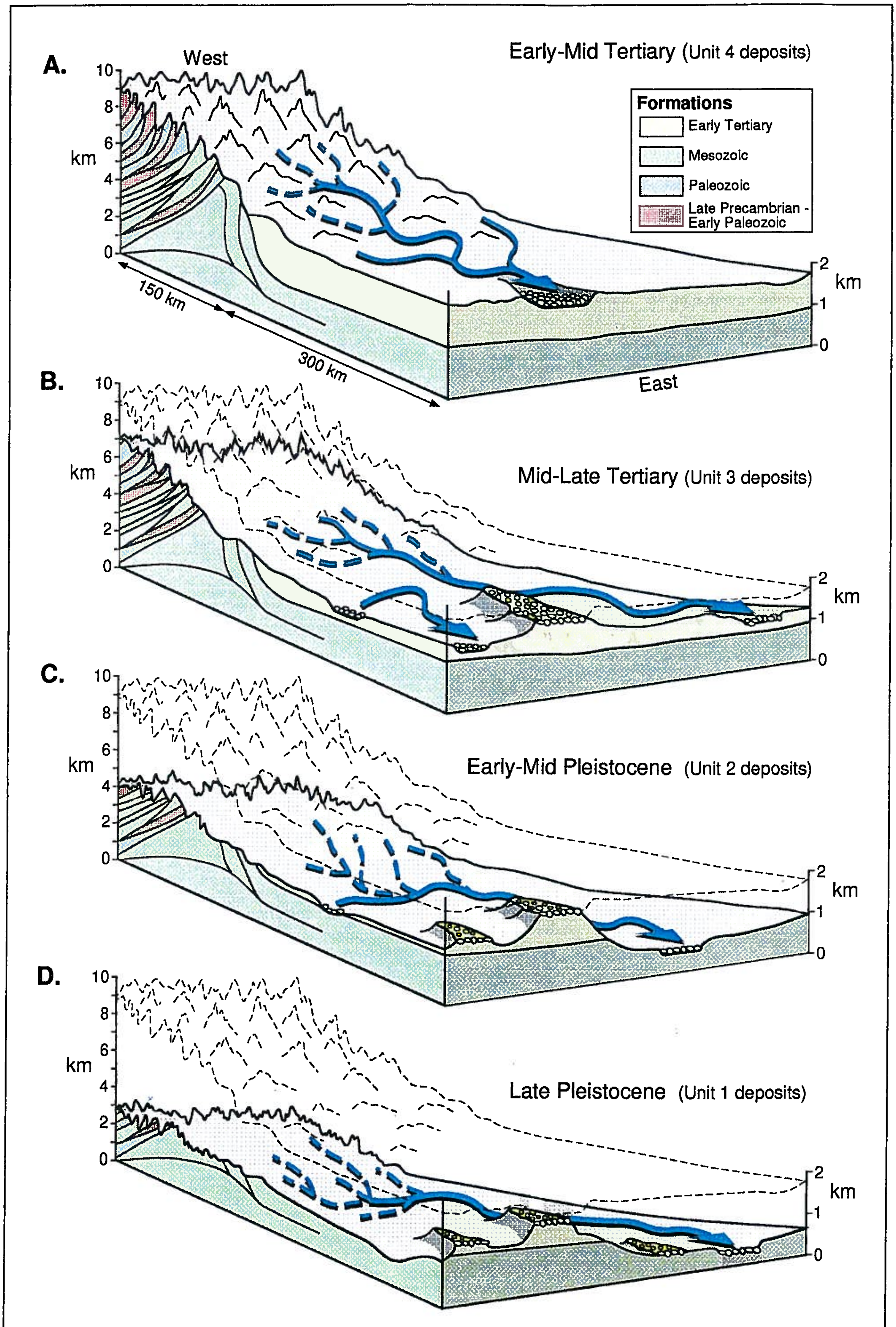

Figure 53. Possible depositional history of preglacial gravels in Alberta.

Cypress Hills gravels was only 50 to 90 km, for other types it was over 250 km.

Unit 1 is the most continuous and traceable of the preglacial data sets as it is the youngest (least length of time for erosion) and least exposed to erosion (situated below Plains level). The lowest areas in the bedrock topography (Figure 52) are believed to have been carved primarily by this youngest preglacial set. These bedrock lows often mark aquifers and have been studied because of their groundwater potential. The occurrence of sand and gravel in these lows has led to their identification as bedrock or 'preglacial' channels, the deepest parts of which are called thalwegs. The other preglacial units also are plotted on Figure 52 and clearly correspond with the topography, as they should, for the deposits rest directly on bedrock and are assigned to units partly on the basis of elevation.

Before and during development of the preglacial drainage on the Plains there was tremendous erosion of the Mountains. Some estimates have been made, through palinspastic reconstruction, of the mass of the material removed and of the missing parts of the section. Figure 53 shows, schematically, the progressive erosion of the Mountains and the Plains from Early Tertiary to Late Pleistocene time using the four levels represented by preglacial sand and gravel deposits.

Resource characterization

Preglacial sand and gravel deposits in Alberta are important sources of mineral aggregate and placer gold. A brief history of these commodities and an analysis of the economic potential of preglacial deposits follows.

In addition to these primary commodities, several other materials in or associated with preglacial deposits have economic potential. Placer platinum is found in preglacial deposits at <5% of the grade of gold.

Platinum is recovered at the same time as gold at several operations in the Villeneuve-Onoway area. Garnet and magnetite are the most abundant heavy minerals in Alberta preglacial gravels (Allong, 1967). Garnet has uses in sandblasting, the manufacture of coated abrasive products and as a filter medium. Magnetite also is used as a filter medium, as a pigment in inks and as a heavy medium in some coal processing operations. The total amount of heavy minerals recovered for preglacial samples is described in the section on placer gold. Although none of the two dozen diamonds recovered to date from drift in Alberta are specifically identified with a preglacial source, it is almost certain that preglacial deposits will contain alluvial diamonds. Minerals associated with diamond sources have been found in preglacial deposits. These indicator minerals are being used to search for a bedrock occurrence for diamonds. This search is described in a following section.

Preglacial deposits commonly are overlain by glaciolacustrine sand, silt, or clay, by till, or by alluvial silt, clay, or loam. This overburden can have economic value. Glaciolacustrine deposits are the source of the silt and clay used in the Edmonton area as a source of material to make synthetic aggregate. In 1983 about 40 000 m^3 of synthetic aggregate was manufactured in the Edmonton region (Edwards et al, 1985). Alluvial sediment often has value as an agricultural soil especially when returned to the original site of excavation during reclamation.

The excavation of the preglacial deposit for mineral aggregate often exposes the underlying bedrock because the best gravel often occurs in the lower part of the deposit. This bedrock can have economic value. Shale for brick or ceramics, coal for thermal power generation, ammolite as a gemstone, and bentonite for drilling fluids are, or have been, produced from open pits in Alberta. These rock types could occur below preglacial sand and gravel deposits. The greatest possibility for economic use of underlying bedrock probably is with shale. Shale with potential as ceramic raw materials is addressed in a following section.

Mineral aggregate

Mineral aggregate is any mass of hard, inert rock or mineral fragments used for the physical properties of good load bearing capacity in a bound or unbound condition, for the free draining nature, as biological or drainage filter media, in metallurgical and chemical applications, in protective uses, or for general fill ('aggregate' includes artificial, reclaimed, or recycled materials as well). In 1991, in Alberta, 45.8 million tonnes of mineral aggregate worth $156.8 million was mined. Primary use was for concrete in construction (~11%), in road construction and maintenance (~69%), or in asphalt (~7%) (Edwards, 1995).

Ninety-nine percent of this mineral aggregate was extracted from sand and gravel deposits (Vagt, 1994). Almost all production was from preglacial fluvial, post glacial fluvial (alluvial), and glaciofluvial deposits (Table 21). Production from preglacial deposits accounts for about $50 million annually.

Table 21. Estimated occurrence and sources of production of sand and gravel in Alberta in 1988 (Edwards, 1991).

Type of deposit	Occurrence %	Production %
Preglacial	20	25
Glaciofluvial	70	30
Alluvial	10	45
Total	45×10^9 tonnes	42×10^6 tonnes

Factors in the viability of a mineral aggregate operation include: the extent and thickness of the deposit, the grain size, rock quality, overburden thickness, the groundwater conditions, the presence of other minerals, the demand for aggregate within the region, and the regulatory, environmental, and community setting.

Extent and thickness   Preglacial deposits can be very extensive (>1000 ha) and can exceed 10 m in thickness. Deposits of this size contain hundreds of millions of cubic metres of sand and gravel. Examples of preglacial deposits with huge granular volumes include Cypress Hills (4213), Del Bonita (multiple deposits), Hand Hills (multiple deposits), Villeneuve (3975) (Plate 3d), Swan Hills (3973) (Plate 3a), and Grimshaw (6692) (Plate 1a and d).

The AGS has a database of sand and gravel deposits for about 30% of Alberta. If preglacial deposits fall within this area (Figure 3) and were mapped and tested by AGS an estimated volume of the deposit is available.

Deposits with large volumes and high quality are essential to satisfy the demands of large markets such as Calgary and Edmonton, the two regions with the greatest population. Permanent processing plants have been established in preglacial deposits in both of these areas. An informal rule of thumb applied to sand and gravel development is that a volume of 100 million tonnes is required to ensure the long term viability of a permanent processing plant. High volume production in the Edmonton region also makes by-product placer gold-platinum production possible.

Preglacial deposits can be huge and provide long term supplies for a very large region. For this reason Crown resource managers will make the preglacial deposits a priority for investigation and evaluation as potential sources of mineral aggregate for the future.

Grain size The total sample weight, total volume, percentage of gravel (>4 mesh), and percentage of sand (<4 mesh, >200 mesh) are listed in Table 2 for each of 40 trench samples taken in preglacial deposits and Appendix C lists the complete grain size analysis and a histogram for each sample. The trench samples represent the major gravel units exposed and used, and are a reasonable approximation of the grain size of the sections exposed in the deposit.

A description of grain size character of each of the preglacial Groups is provided in a previous section. Preglacial deposits typically are coarse gravel: 50% is >3/4" and 25% is >1.5" (Figure 5). The coarse nature of these sediments is the result of their fluvial deposition and results in attractive deposits from the point of view of the production of coarse aggregate. Deposits in Group 1 and Group 6 (Plate 1a and d) contain more fine gravel but are still exploitable for almost all aggregate uses. The most important criteria in the coarseness of the aggregate are the distance from the disturbed belt (Figure 12) and predominant types of source rocks. As distance increases away from the disturbed belt (flow direction) the overall size of the coarse aggregate decreases. Groups with a quartzite-sandstone source (northern part of Group 1, southern part of Group 2, and Group 5) contain very coarse gravel.

There is some difference in the overall grain size character for deposits of different units. Deposits in Units 1 or 2 often have upper sand beds and lower sand and gravel or gravel beds. This stratigraphy is present at Grimshaw (6692), Watino (4212), Simonette (4028), Villeneuve (3975), and Entwistle (6424). Although the lower gravel of Unit 1 deposits (ie. Villeneuve) (Plate 3d) appears to be somewhat finer it is still ideal for the production of many aggregate products including coarse, crushed stone.

Highly distinctive is the very coarse nature of many Unit 4 deposits. In fact, portions of some deposits (ie. Swan Hills, Obed Mountain) (Plate 1b) may present processing difficulties as a result of the overly large clasts.

The identification of a deposit as preglacial provides a good indication that the deposit will contain coarse aggregate. Testing of Unit 1 deposits should be to the base of the deposit to ensure that lower gravel is not missed because it is masked by sand as much as 10 m thick.

Rock quality Petrographic number analyses, performed at Alberta Transportation and Utilities (ATU), of samples from 14 deposits, are listed in Appendix F. Preglacial deposits in Alberta are recognized as providing hard, coarse gravel which is suitable for use as crushed gravel in concrete. This contention is supported by the limited analyses of this study: 8 of the 14 samples analysed are above average in hardness and the other 6 are all average.

Samples from Groups 2, 3/4, 5, and 6 are analysed as above average in hardness. This broad distribution across Groups suggests that the destructive fluvial process is an important factor in eliminating weak rocks. Although other rock types are important for Group identification, for aggregate purposes preglacial coarse gravel is primarily sandstone and quartzite. This makes a hard, tough aggregate. Testing of this quartzitic aggregate for possible alkali reactivity has been underway for some time by Alberta Environment and should be checked by companies considering using preglacial gravels for uses where the deleterious effects of this reaction is critical.

Deleterious and poor components in preglacial deposits come primarily from proximal, Plains bedrock sources such as local sandstone, ironstone, coal, or clay, or from in-situ components such as carbonate cementations. If a large pebble or cobble component is abundant then the amount of this local component (usually smaller) can be eliminated through screening.

Petrographic number (PN) analyses are a quick, preliminary method for assessing the quality of the rock in a deposit. This test was developed and is used frequently and to good effect in Ontario. In Alberta, the test is applied less frequently and some difficulty has been found in standardizing the test. Edwards and Scafe (1992) investigated the application of PN analyses in Alberta and made some recommendations to ATU for its use in Alberta.

Overburden thickness and groundwater conditions Unit 1 and 2 preglacial deposits can have exceedingly thick overburden (Plate 2a and b). In the Edmonton area preglacial sand and gravel formations have overburden as thick as 20 m which effectively prohibits aggregate development. The thick overburden is typically glacial and alluvial. The higher deposits (Units 3 and 4) had thinner ice cover and consequently have little glacial overburden cover. Deposits in southern Alberta (Units 2 to 4) have thinner overburden as the ice cover was less (Plate 1c). The Cypress Hills never were covered by the continental glacier (some windblown silt overburden occurs) and the overburden on the Hand Hills is so thin that it also originally was mapped as unglaciated.

Unit 1 deposits have the lowest elevation of the preglacial deposits and commonly occur below plains level. The water table often is within or above these deposits. Extraction may require dredging or pumping water from the pit, for example at Villeneuve (3975) and Grimshaw (6692), and great care must be taken to ensure that aquifers are not damaged or polluted.

Other minerals Preglacial deposits are exploited almost exclusively for their mineral aggregate value. A number of these deposits have ancillary or by-product possibilities (placer gold, platinum, silica, garnet, magnetite, or diamonds; shale, coal, ammolite, bentonite). In many cases, deposits are not considered for these additional economic opportunities. This represents a lost resource both to the producer and to the province. All deposits producing sand and gravel for mineral aggregate should be evaluated for by-product recovery, and possible exploitation of the underlying bedrock and overburden.

The technology for processing mineral aggregate from sand and gravel is well established. There is, however, a need for research into more effective methods for the recovery of by-product minerals.

Regional aggregate demand Sand and gravel is produced, transported, and used within Alberta in market regions about the size of Counties or Municipal Districts. The larger urban areas (Edmonton, Calgary, Lethbridge, Red Deer) consume supplies from regions constituting a number of surrounding jurisdictions and represent market areas larger than most rural markets. Figure 1 shows the wide distribution of preglacial deposits. This makes them (or will make them) useful in many market regions.

Although the amount of sand and gravel apparently is vast, available reserves are actually much smaller than assumed and are dwindling. It was stated at the 1995 Annual General Meeting of the Alberta Sand and Gravel Association that mineral aggregate resources are being consumed at twice the rate at which they are being discovered. No public mapping has taken place in Alberta for the last five years and existing resources are being removed from access through restrictions near watercourses and by other land use restrictions. Mineral aggregate producers report that most supplies of sand and gravel available to them now will be consumed in the next 30 years (Edwards, 1995).

A recent survey of producers (Edwards, 1995) assembled data on prices and production for all market regions in Alberta. This is the type of information required by the Crown to do long range planning for conservation of aggregate supplies, especially for the large preglacial deposits.

Regulatory, environmental, and community setting The regulations governing the development of a mineral aggregate operation include standard provincial regulations and municipal by-laws specific to that jurisdiction. Environmental conditions include both the regulatory demands for reclamation and restrictions to development imposed as a result of an environmental setting which requires protection from development. The relationship between the developer and the community is becoming an increasingly important aspect in the development of aggregate operations. Highest consumption takes place in the urban areas (ie. Edmonton and Calgary regions). It is in these areas where mineral aggregate producers come into the greatest contact with residents. Conflict can result over differing visions of land use. These areas are also centres which have required aggregate for long periods of time and now may have limited sources of supply without long haul distances. These regions require very intense land use assessments as to the need and value of future mineral aggregate resources.

Regulatory, environmental, and community issues are independent of the age of sand and gravel deposits but can have a serious impact on the development of preglacial deposits. These issues were covered in a report by Edwards (1995) and therefore will not be repeated here. Edwards (1995) describes in detail residential opposition to the development proposals of Burnco Rock Products Ltd. and Consolidated Aggregates of a preglacial deposit in northwest Calgary in 1994 and 1995. Although issues centred around concerns such as truck traffic, noise, and dust, an important factor was the volume of aggregate which could be produced from the deposit and the length of time the deposit would could remain in operation.

Summary The formational models developed and the stratigraphic correlations proposed in this study may assist in the search for new deposits or easier ways to evaluate deposits. The model provides a technique for estimating the elevation and general location for deposits and the identification as preglacial provides an estimate of quality.

Ninety-three deposits have been mapped by AGS and have known or probable potential. These deposits are in the AGS database. Two previously unmapped deposits were investigated as part of this study and are considered to have mineral aggregate potential (3913 and 3915).

Some preglacial deposits are not potential sources of mineral aggregate due to their inappropriate setting (exposed in steep banks along modern rivers valleys) (Plate 2a), thick overburden or inadequate thickness (<1 m). Care should be taken to understand while using Appendix A that all deposits listed are not economic. Sites listed in Appendix A and Figure 2 are identified from the literature and the aggregate potential is unknown.

Clay and shale

With the clay content of most preglacial gravels in Alberta <1% (Appendix C), these deposits are not sources of clay through by-product extraction. However, because many of the preglacial deposits rest on bedrock shale, the potential exists for ceramic use of some of these underlying shales. There are several advantages to extracting bedrock shale from below preglacial gravels. Since shale/clay quarries commonly use the same extraction and transport equipment as gravel quarries (e.g., front-end loaders, trucks) there would be no need to purchase extra equipment. As well, extraction and stockpiling of shale during breaks in gravel extraction would make more efficient use of the equipment. Removing the saleable gravel as overburden to the shale would reduce the extraction cost of the shale. Lastly, deepening of an existing pit, in general, does not disturb additional surface area.

The shales of the Kaskapau Formation, which crop out in a few locations in northwestern Alberta, exhibit high potential for ceramic use (Scafe, 1991). A sample of this formation now has been tested from below preglacial gravels in the Grimshaw area and the results confirm the desirable ceramic qualities that are indicated in outcrop samples.

Sediments of the Paskapoo Formation underlie preglacial gravels in the Arrowwood, Wintering Hills, Lacombe, Entwistle and Obed areas. This formation consists of sandstone and shale. It is not known, at present, how many of the preglacial gravels from the areas mentioned above are underlain by shale, but this could be determined easily by drilling into the floor of preglacial gravel pits. The shales of the Paskapoo Formation may be less desirable than those of the Kaskapau Formation (Scafe, 1991), but they have been used to improve the quality of bricks manufactured in Edmonton.

Shales of the Ravenscrag Formation underlie the gravels of the Cypress Hills Formation. These shales can be used for ceramic purposes

(Scafe, 1991) and current preglacial gravel pits are only a short distance away from other shale pits that do not contain the Ravenscrag Formation, but which do supply other shales for products manufactured in Medicine Hat. The small increase in transportation costs probably could be negated by the likely lower cost of the material from operating aggregate pits.

Preglacial gravels commonly are overlain by glacial till or lacustrine silts and clays. Till, because of its usually stony nature, probably is most useful for reclamation of the gravel pit, but the lacustrine silts and clays could be used as the raw material for brick manufacture as is the case in Edmonton. As mentioned above, it also is possible that a good ceramic body would result from combining silts and clays overlying a preglacial gravel deposit with shales underlying the deposit.

Placer gold

Placer gold has been recovered from the North Saskatchewan River in the Edmonton area since 1859. Peak activity was reached in 1898 when an estimated 300 miners worked a 200 km stretch of river centred on Edmonton and up to 12 dredges were in operation. Between 1895 and 1897 a total of 7500 troy ounces of gold were recovered (Morton and Mussieux, 1993). Placer gold also has been recovered by panning and sluicing from the Peace River, the Athabasca River, and the Red Deer River.

The Edmonton region has experienced another resurgence in gold production in the last 20 years. This increased production is due to higher gold prices and the opportunity to recover gold as a by-product of large volume sand and gravel operations in the Villeneuve (3975) (Plate 3d) and Onoway (6402) areas. These operations prove that the recovery of placer gold, at least as a by-product, is an economic reality in Alberta. Both of these producing deposits are preglacial in age.

Placer gold is difficult to sample and deposit concentrations are difficult to estimate due to the irregular occurrence of gold. In general, the larger the sample size, the more specifically the various lithologic units are sampled, and the better determination made as to 'recoverable' versus 'assayable' gold content, the more accurate is the prediction of economic or potentially economic concentration of gold occurrences in aggregate deposits. For this reason, moderately large samples of known weight, volume, and stratigraphic position, were collected to test for placer gold (Table 1).

Gravel and cobbles were scalped from the samples and the sand portion then was concentrated using a jig, followed by hand panning. The concentrates were sent to Loring Laboratories Ltd. where the gold was extracted by amalgamation with mercury. As well, sand and gravel at many of the sites was panned in the field to get a preliminary indication of the presence of gold (Plate 3a) and to test this procedure as a method of initially evaluating the gold content of aggregate deposits.

Placer gold is recovered as a by-product of sand and gravel operations in Alberta. Thus, economic potential for gold recovery in Alberta's preglacial deposits depends not only on factors which make the gold economically recoverable but also on the viability of the deposit as a mineral aggregate producer. One sand and gravel operation which is successfully recovering by-product gold, has reported as much as 100 oz. of gold per 100 000 tons of sand and gravel. Thus, because a gold grade of about 0.001 ounces of gold per ton (oz. Au/T) of sand and gravel produced (which is equivalent to about 0.0343 grams of gold per metric tonne) is being economically recovered at this one operation, this may provide a 'rough standard' against which the gold concentrations of other potential aggregate deposits can be assessed. That is, if the gold concentration in a prospective aggregate deposit is >0.001 oz. Au/T, then it may mean that gold can be economically recovered, whereas if it is less than this amount it may not be economic to recover the gold during aggregate processing. However, this 'rough standard' is very imprecise because economic viability for gold recovery depends on several factors. These factors include:

- the price of gold
- the size, shape, and amount of gold grains which affect recovery characteristics and hence recovery methodologies
- the distribution of gold in the aggregate deposit (e.g., is it only in the coarse gravel beds, only on gravels immediately overlying bedrock, etc.)
- whether the gold is free gold or tied in or with other minerals
- the viability of the aggregate operation, including aggregate products, prices, and haul distances
- legal access to both the sand and gravel (surface material) and the placer gold (mineral)
- the volume of sand and gravel produced by the aggregate operation and the longevity of the production
- the availability of water for washing or sluicing.

This economic connection between the gold and aggregate can be positive for placer gold exploitation in that extracting a much lower concentration of gold is viable as much of the mining cost is born by the aggregate mining. Stand-alone placer gold operations in the Yukon have a minimum grade cut-off of about 300 ppb (Dufresne, 1987). The gold by-product operation noted above has a tested gold concentration of less than

300 ppb and an apparent recovery in the order of 50 ppb gold.

Samples were collected for gold analysis from deposits in all six preglacial Groups. The results of the analyses of these samples are shown in Table 22 and Appendix I and is discussed by Group. An extrapolated gold occurrence per 100 000 tons is calculated in order to compare with the 'rough standard' described above for an economic operation.

Group 1 (southern Alberta). Volumetric sample results from five samples taken at three sites range from 0.0001 g of gold per m^3 of sand and gravel to 0.0017 g/m^3 (Table 22). The average grade for all sites (0.34 m^3 of sample) is 0.0012 g/m^3 of sand and gravel. Gold grades, by weight for an extrapolated 100 000 tons of sand and gravel, range from 0.84 oz. gold to 1.62 oz. The average gold grade per ton for all samples taken from Group 1 (936 kg) is 1.32 oz. gold per 100 000 tons of sand and gravel. The total amount of heavy minerals ranges from 21 g/t to 54 g/t and averages about 39 g/t. Panning recovers up to 2 gold flakes (colours) per pan. Magnetite dominates the other heavy minerals.

Group 2 (south central Alberta). Volumetric sample results from 17 samples taken at seven sites range from 0.0001 g of gold per m^3 of sand and gravel to 0.0017 g/m^3 (Table 22). The average grade for all sites (1.46 m^3 of sample) is 0.0007 g/m^3 of sand and gravel. Gold grades, by weight for an extrapolated 100 000 tons of sand and gravel, range from 0.04 oz. gold to 2.02 oz. The average gold grade per ton for all samples taken from Group 2 (4025 kg) is 0.73 oz/100 000 tons of sand and gravel. The total amount of heavy minerals ranges from 11 g/t to 102 g/t and averages 37 g/t. Panning recoveries up to 5 gold flakes (colours) per pan, plus other heavy minerals, primarily magnetite.

Group 3/4 (central Alberta). Volumetric sample results from nine samples taken at seven sites range from 0.0013 g of gold per m^3 of sand and gravel to 0.0687 g/m^3. The average grade for all sites (0.38 m^3 of sample) is 0.0166 g/m^3 of sand and gravel. Gold grades, by weight for an

Table 22. Summary of placer gold results by group.

	Volumetric results g gold/m^3	Results by weight oz. gold/100 000 tons	Panning colours/pan
Group 1			
range	0.0001-0.0017	0.84-1.62	<2
average	0.0012	1.32	
Group 2			
range	0.0001-0.0017	0.04-2.02	<5
average	0.0007	0.73	
Group 3/4			
range	0.0013-0.0687	1.02-52.06	<45
average	0.0166	18.04	
Group 5			
range	0.0004-0.0061	0.38-7.98	<25
average	0.0025	3.31	
Group 6			
range	0.0028-0.1723	0.99-57.62	<50
average	0.0102	13.97	
Group 7			
	0.0009	0.52	

extrapolated 100 000 tons of sand and gravel, range from 1.02 oz. gold to 52.06 oz. The average gold grade per ton for all samples taken from Group 3/4 (1012 kg) is 18.04 oz/100 000 tons of sand and gravel. Note that it is from Group 3/4 that a grade of 100 oz gold per 100 000 tons of sand and gravel was realized for one operator. The total amount of heavy minerals ranges from 30 g/t to 622 g/t and averages 79 g/t. Panning recovers up to 45 gold flakes (colours) per pan and consistently averages more than 25 colours. Other heavy minerals include garnet and magnetite.

Group 5 (north central Alberta). Volumetric sample results from six samples taken at four sites range from 0.0004 g of gold per m^3 of sand and gravel to 0.0061 g/m^3 (Table 22). The average grade for all sites (0.41 m^3 of sample) is 0.0025 g/m^3 of sand and gravel. Gold grades, by weight for an extrapolated 100 000 tons of sand and gravel, range from 0.38 oz. gold to 7.98 oz. The average gold grade per ton for all samples taken from Group 5 (914 kg) is 3.31 oz/100 000 tons of sand and gravel. The total amount of heavy minerals ranges from 13 g/t to 484 g/t and averages 225 g/t. Panning recovers up to 25 gold flakes (colours) per pan, plus other heavy minerals that include garnet and magnetite.

Group 6 (northwest Alberta). Volumetric sample results from 21 samples taken at four sites range from 0.0028 g of gold per m^3 of sand and gravel to 0.1723 g/m^3 (Table 22). The average grade for all sites (0.99 m^3 of sample) is 0.0102 g/m^3 of sand and gravel. Gold grades, by weight for an extrapolated 100 000 tons of sand and gravel, range from 0.99 oz. gold to 57.62 oz. The average gold grade per ton for all samples taken from Group 6 (2101 kg) is 13.97 oz gold per 100 000 tons of sand and gravel. The total amount of heavy minerals ranges from 27 g/t to 192 g/t and averages 110 g/t. Panning recovers up to 50 gold flakes (colours) per pan and abundant garnet and magnetite.

Group 7 (southeast Alberta). The Cypress Hills Formation was sampled at only one location. This sample contains the equivalent of 0.0009 g of gold per m^3 of sand and gravel (Table 22). The weight of gold recovered would be equivalent to 0.52 oz. gold per 100 000 tons of sand

and gravel. A significant amount (172 g/t) of heavy minerals were recovered.

The number of colours recovered by panning are similar to the gold results from the volumetric sample analyses (Groups 3/4 and 6, with the highest number of colors per pan, positively correlate with the volumetric gold content). This indicates that panning is a quick, effective indicator of the gold concentration in preglacial sands and gravels.

At three deposits in central Alberta, various types of beds were panned. The massive beds (>1m thick, pebble to cobble size gravel, cross bedded) yield three to five times more gold than thinner beds of sand or pea gravel. This is significant because the coarser, more massive beds also provide the best source of mineral aggregate.

The stratigraphy developed in this report may aid in the location of deposits stratigraphically equivalent to deposits with known grades of gold. The correlation of deposits by group may identify regions containing deposits with known grades of gold and can provide a focus for exploration. The theory of formation of preglacial deposits presented can provide clues to the source of minerals and the time at which they were added to the system. This may be of use in locating local sources of gold (based on time of exposure of the source) or identifying placers with the highest gold grade.

Diamonds (Indicator mineral tracing for diamonds)

It is probable that diamonds occur in preglacial sands and gravels in Alberta and certain that diamond indicator minerals are present. These indicators, which are useful in the search for alluvial or bedrock diamonds, are described in this section. Diamonds have become increasingly important in Canada as the first mines in the Northwest

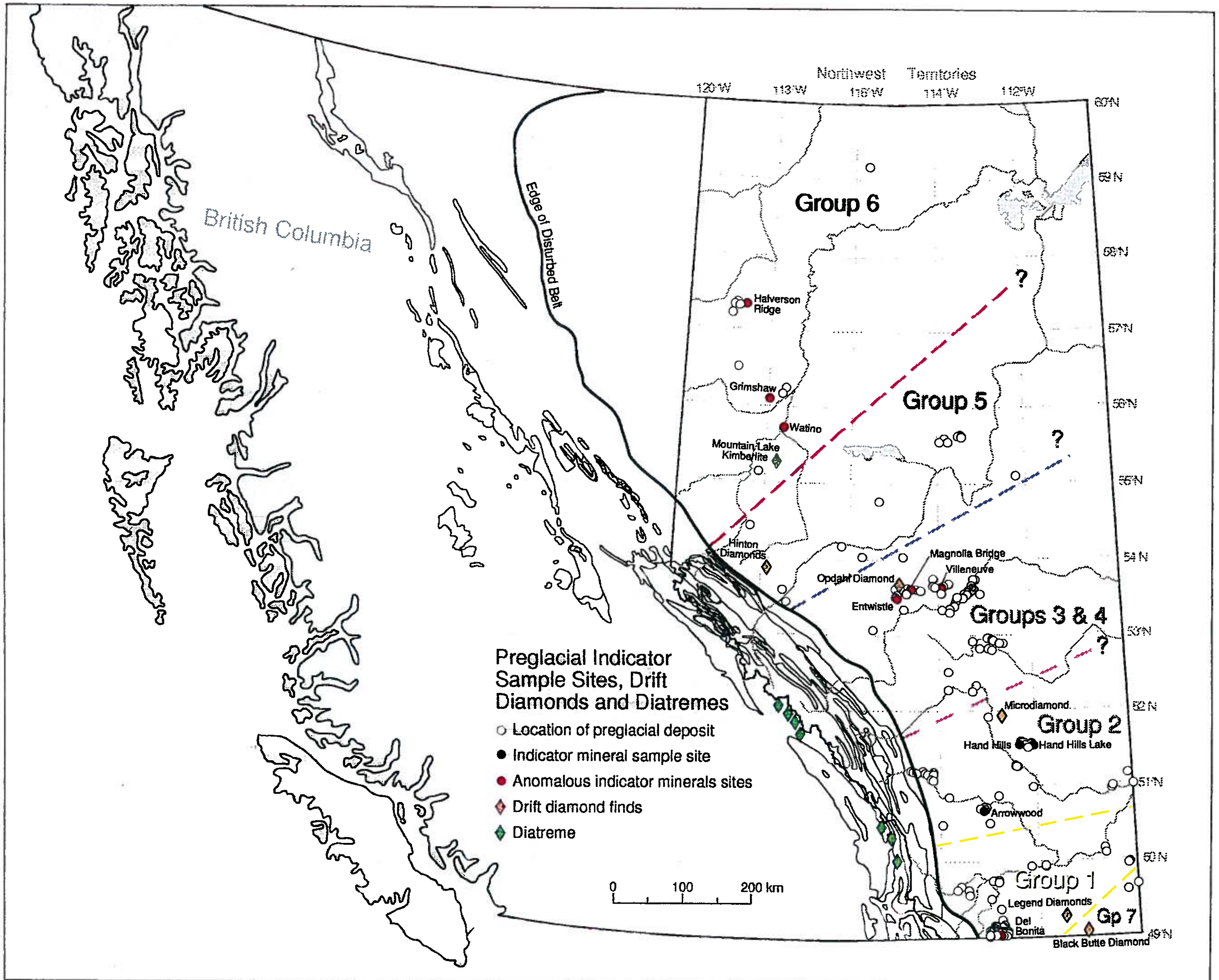

Figure 54. Location of diamond indicator sample sites, drift diamond finds, and diatremes in and adjacent to Alberta (after Dufresne et al, 1996).

Territories near production and more kimberlites are found throughout the country. During 1988 a diamond-bearing kimberlite pipe was discovered near Prince Albert, Saskatchewan. In 1991 Dia Met Minerals Ltd. announced the discovery of diamond-bearing kimberlite near Lac de Gras in the Northwest Territories.

Alberta has a forty year history with diamonds. In 1958 a diamond of about 1 carat ('Opdahl diamond' in Figure 54) was discovered in the Entwistle area (Edmonton Journal, 1992a). The first documented diamond discovery was of two alluvial microdiamonds ('Legend diamonds' in Figure 54) in 1988 by prospector Tom Bryant near Legend in southern Alberta (Edmonton Journal, 1992b). Extremely small microdiamonds ('Microdiamond' in Figure 54) were reported in 1992 in sedimentary bedrock at the Cretaceous-Tertiary boundary near Red Deer (Science City News, 1992). These may be of extraterrestrial origin, however, and not from a diatreme. A kimberlite was confirmed in 1995 by Monopros Ltd. in the vicinity of Mountain Lake, about 75 km northeast of Grande Prairie (Wood and Williams, 1994, 'Mountain Lake Kimberlite' in Figure 54). Recovery of indicator minerals and 23 diamonds ('Hinton Diamonds' in Figure 54) was reported in 1995 from a small stream in the Hinton area (New Claymore Resources 1995). A microdiamond is reported to have been recovered from one of the Sweetgrass Intrusives near the Alberta-Montana border ('Black Butte Diamond' in Figure 54).

Alberta seems to be surrounded by provinces and states in which kimberlites or lamproites have been found. The Jack diatreme (lamproite?), north of Golden, British Columbia (Pell, 1987) and the Cross kimberlite, northwest of Elkford, British Columbia (Hall et al, 1989) are near the Alberta border ('Diatreme' in Figure 54). At Fort à la Corne,

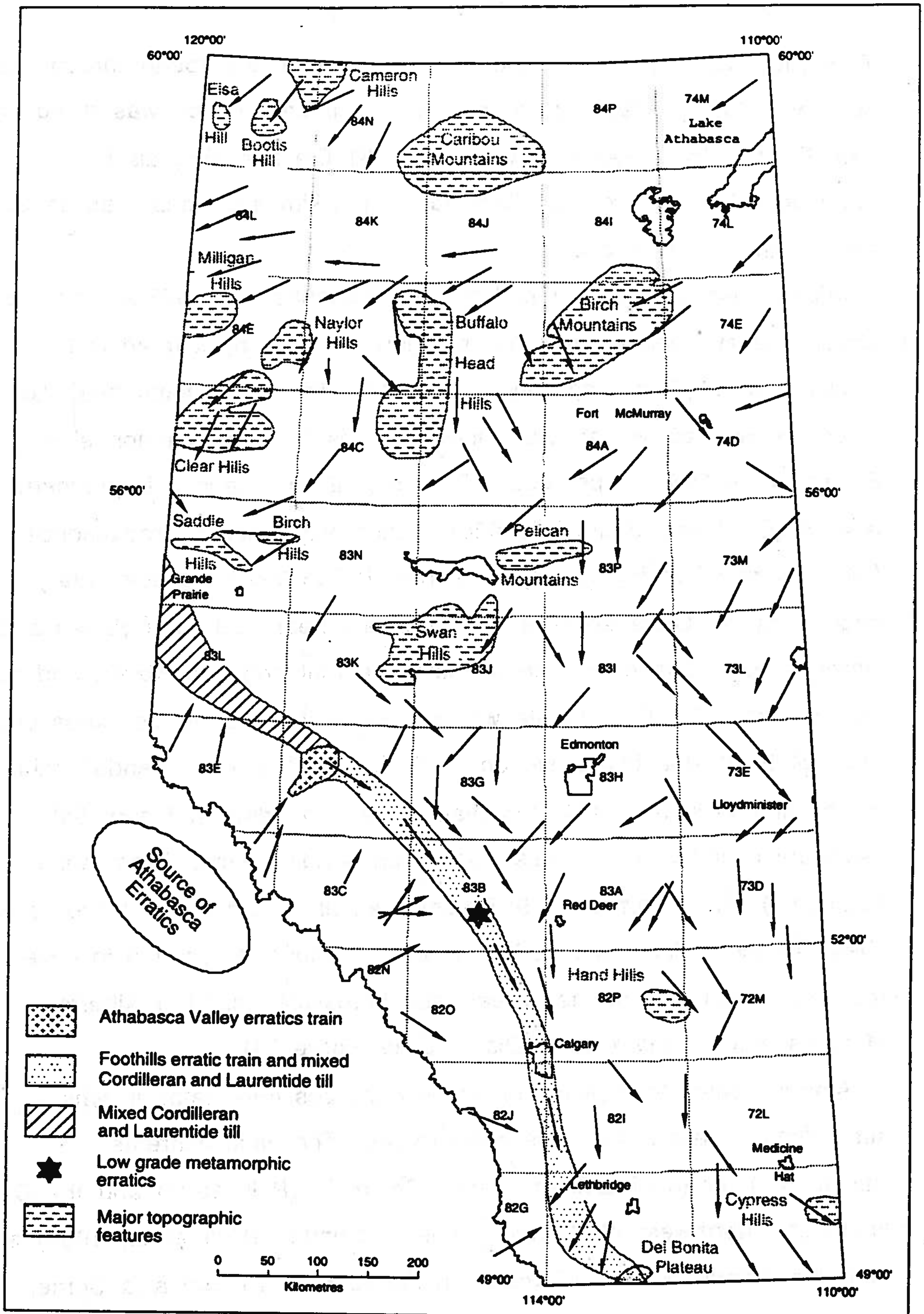

Figure 55. Glacial flow directions and location of major topographic features in Alberta. (after Dufresne et al, 1996)

Saskatchewan up to 70 kimberlitic bodies have been identified by geophysics and 41 have been confirmed by drilling (Lehnert-Thiel et al, 1992). Kimberlites in the Fort à la Corne area are believed to range in age from 94 to 101 million years before present. Exploration in the Lac de Gras area of the Northwest Territories has identified more than 120 pipes in the region. Several of the diamondiferous BHP-Dia Met pipes in the Lac de Gras area are Tertiary in age (Dufresne et al, 1996). Early to Middle Tertiary kimberlites and lamproites have been discovered in New Mexico, Utah, and Montana.

One way of narrowing the search for diamondiferous diatremes is to sample preglacial sand and gravel deposits for indicator minerals. Preglacial sand and gravel deposits are an excellent medium from which to take diamond indicator mineral samples. The fluvial process eliminates much of the silt and clay and concentrates heavy minerals including indicator minerals. Preglacial deposits are particularly useful in that they have a simpler transport history than glacially transported sediments (Figure 55) or Recent alluvial sand and gravel deposits.

Samples were collected from the sites shown in Figure 54 and submitted to Loring Laboratories Ltd. and the Saskatchewan Research Council for concentration, indicator mineral picking, and electron microprobe analysis (Appendix J). Sites from which anomalous minerals were collected are shown in red in Figure 54). These minerals are identified as anomalous based on their chemistry compared to the chemistry of diamond inclusion minerals and minerals collected from diatremes. Following are descriptions of the anomalous grains.

One garnet picked from a sample taken in the Villeneuve deposit (3975) plots as a G10 on a CaO vs Cr_2O_3 graph (Figure 56, Appendix J). This grain

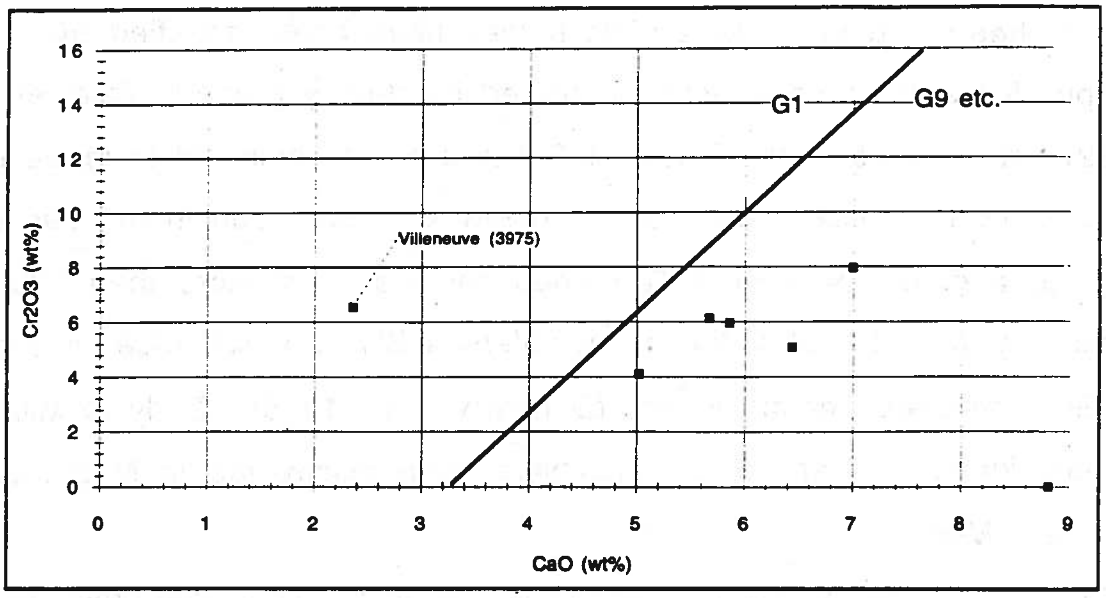

Figure 56. CaO vs Cr_2O_3 for peridiotitic garnets from preglacial sand and gravel deposits (after Dufresne et al, 1996).

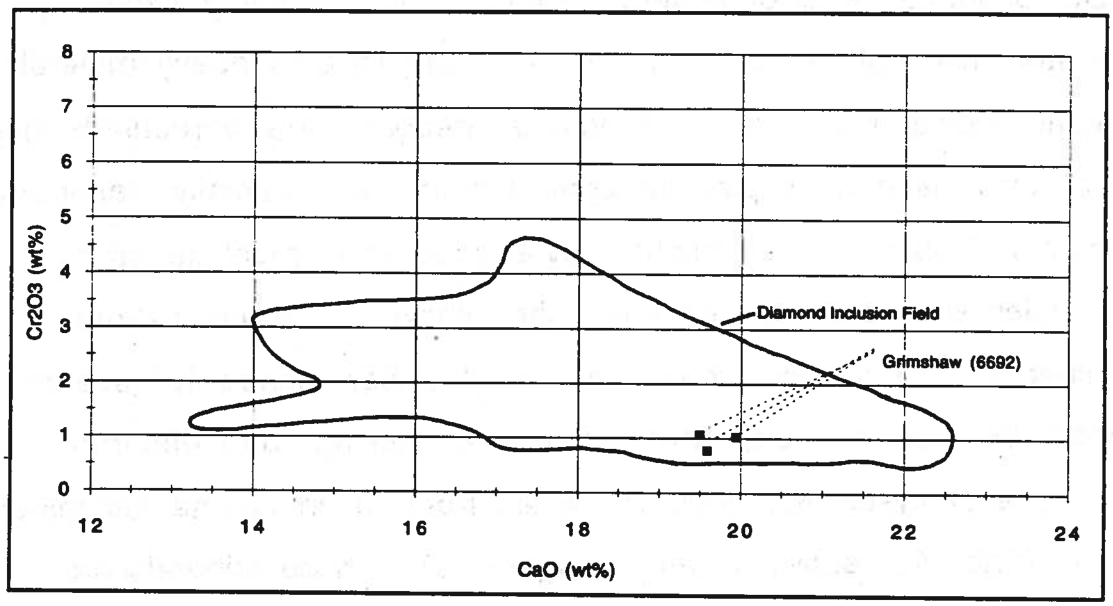

Figure 57. CaO vs Cr_2O_3 for peridiotitic clinopyroxenes from preglacial sand and gravel deposits (after Dufresne et al, 1996).

falls well within the diamond inclusion field for peridotitic garnets and is an excellent indicator of a potential diamond-bearing source (Dufresne et al, 1996).

Thirty-seven bright green diopside grains were picked from a Grimshaw deposit (6692) sample. Three of these grains were analysed by electron microprobe and the CaO vs Cr_2O_3 results plotted (Figure 57). The chemistry of these grains places them within the diamond inclusion field for peridotitic Cr-diopsides.

Chromite grains, picked from a number of deposits, were sent for microprobe analysis (Appendix J) and the results plotted (Figure 58). Two anomalous areas stand out. The first area includes Halverson Ridge (6815), Grimshaw (6692), and Watino (4212) in Group 6, (Figure 54) and the second area is Entwistle (6424), and Magnolia (6422) in Group 3/4 (Figure 54). The only grain to plot in an anomalous field that does not come from these two groups is a chromite grain from Arrowwood (5855) with a single pair of results (Cr_2O_3 versus MgO, in the Argyle field of chromites).

Analytical results from chromite grains from Group 3/4 plot in the diamond inclusion field for Cr_2O_3 versus Al_2O_3, TiO_2, and Ni; for TiO_2 versus Al_2O_3 and Ni; and for Zn versus Ni (within analytical error box) (Figure 58a, c, d, e, f, and h). Grains from Group 3/4 plot in the Argyle field of chromites for Cr_2O_3 versus Al_2O_3, MgO, TiO_2, and Ni; for TiO_2 versus Al_2O_3 and Ni; and for MgO versus Ni (Figure 58a, b, c, d, e, f, and g). As mentioned above a superior garnet also comes from this area.

Analytical results from chromite grains from Group 6 plot in the diamond inclusion field for TiO_2 versus Al_2O_3 and Ni; and for Zn versus Ni (within analytical error box); and within the South African and Siberia

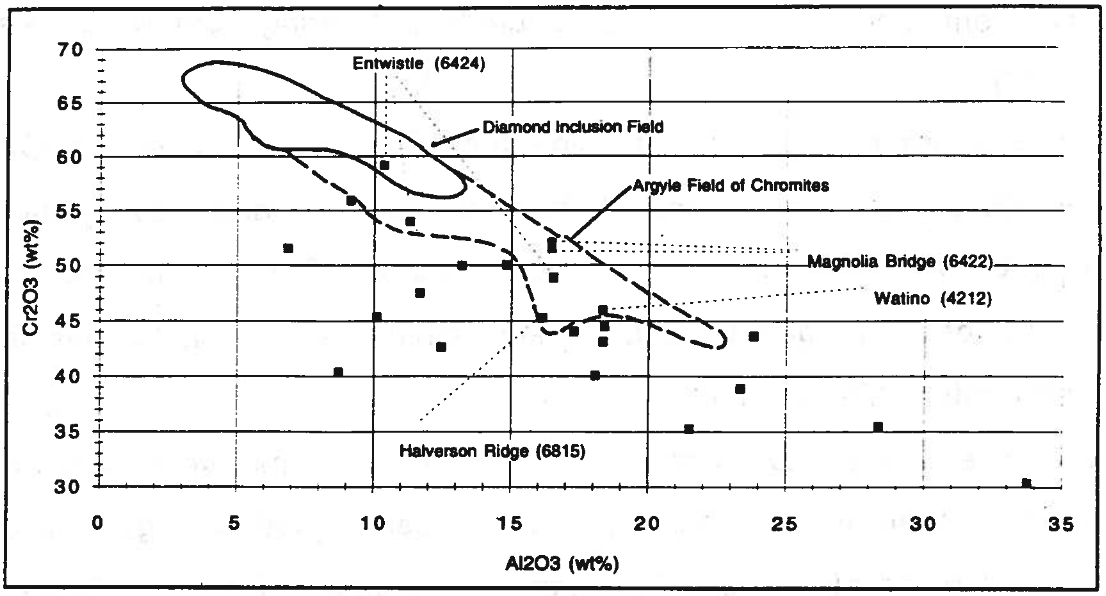

Figure 58. Chromites from preglacial sand and gravel deposits analysed for (a) Al_2O_3 vs Cr_2O_3.

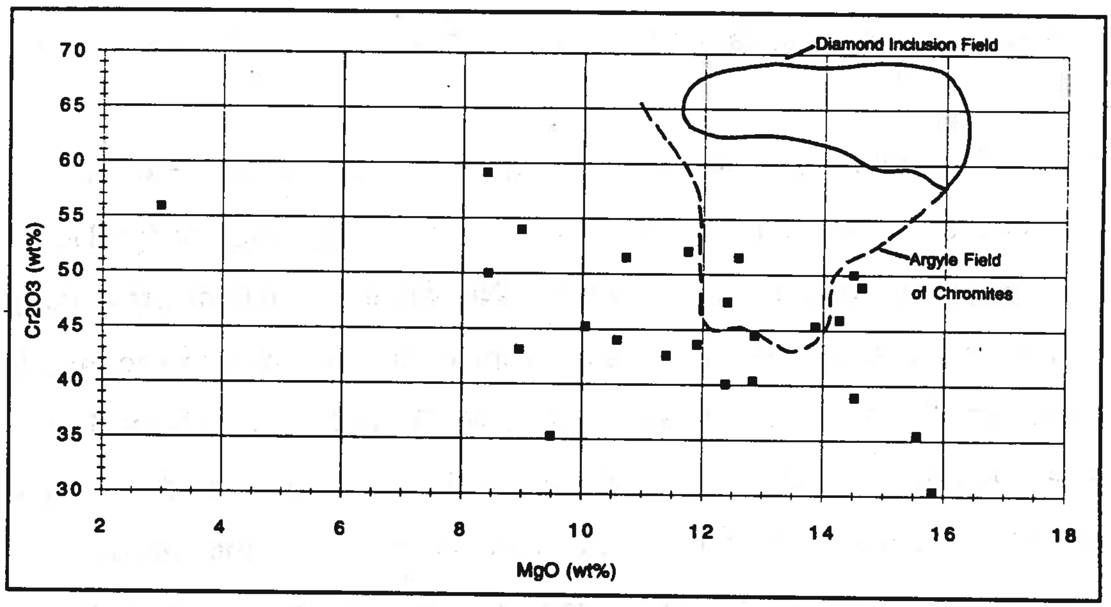

Figure 58. Chromites from preglacial sand and gravel deposits analysed for (b) MgO vs Cr_2O_3.

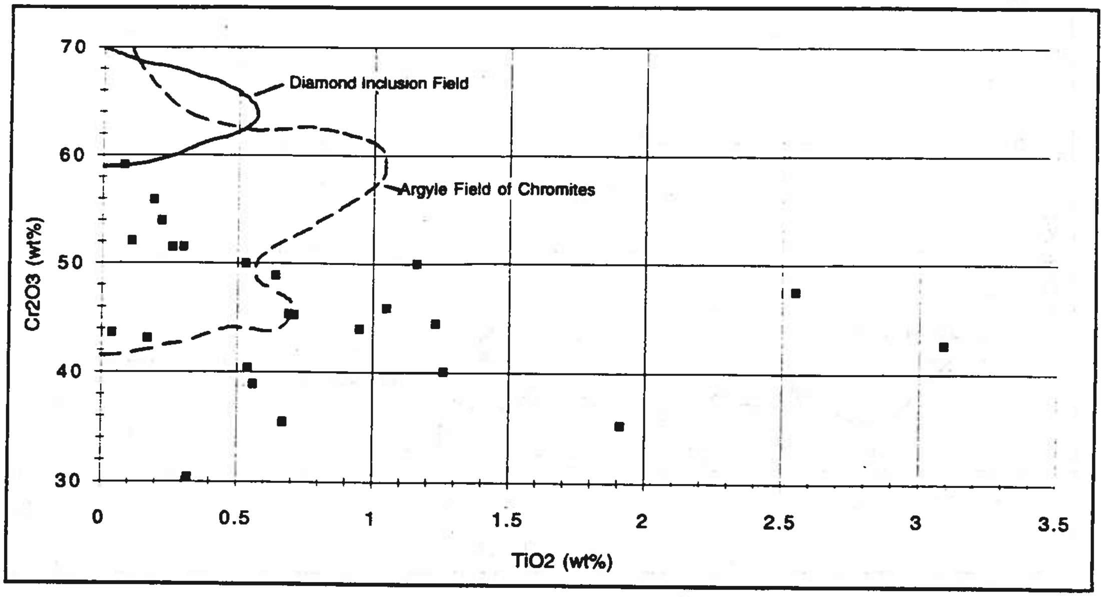

Figure 58. Chromites from preglacial sand and gravel deposits analysed for (c) TiO_2 vs Cr_2O_3.

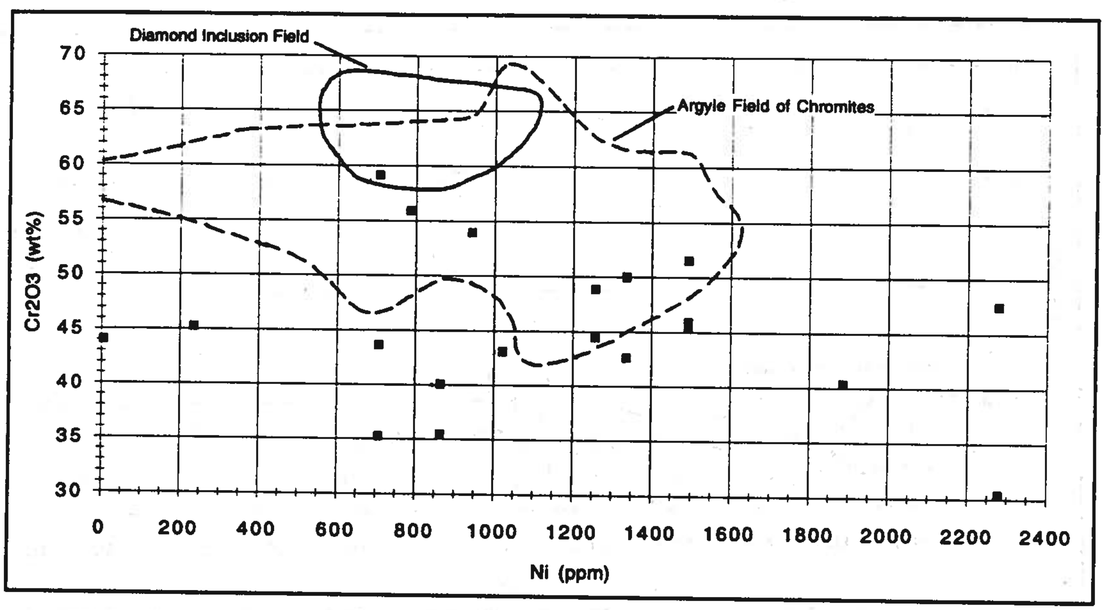

Figure 58. Chromites from preglacial sand and gravel deposits analysed for (d) Ni vs Cr_2O_3.

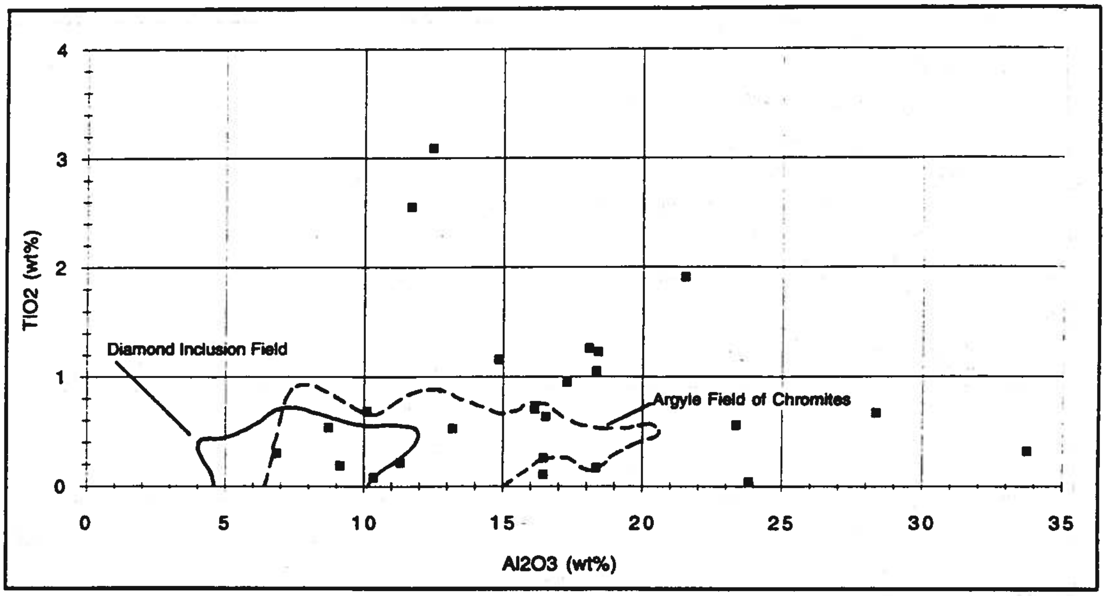

Figure 58. Chromites from preglacial sand and gravel deposits analysed for (e) Al_2O_3 vs TiO_2).

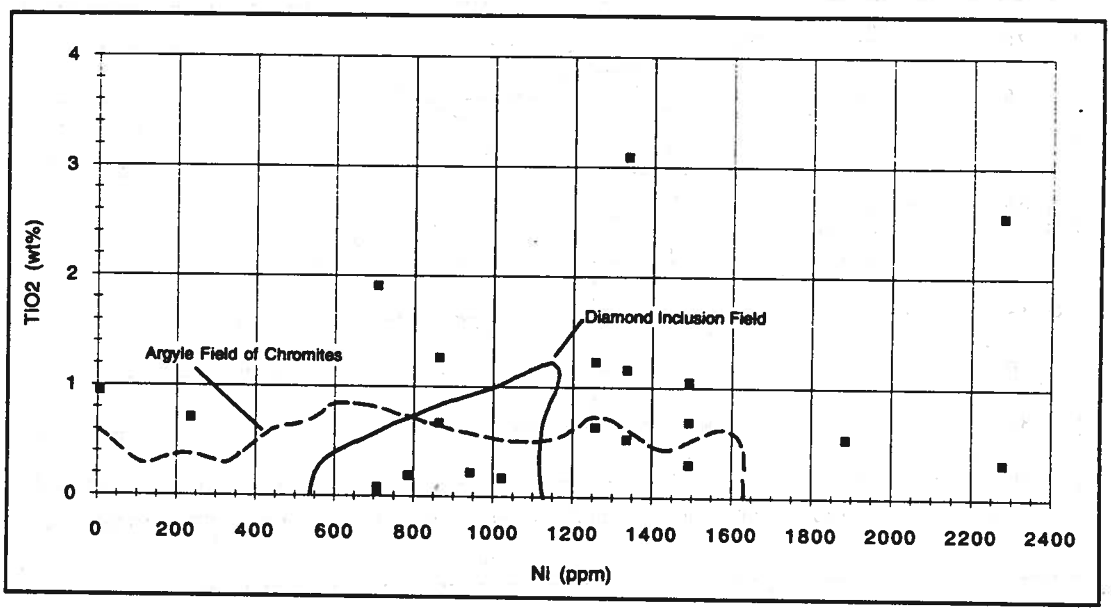

Figure 58. Chromites from preglacial sand and gravel deposits analysed for (f) Ni vs TiO_2.

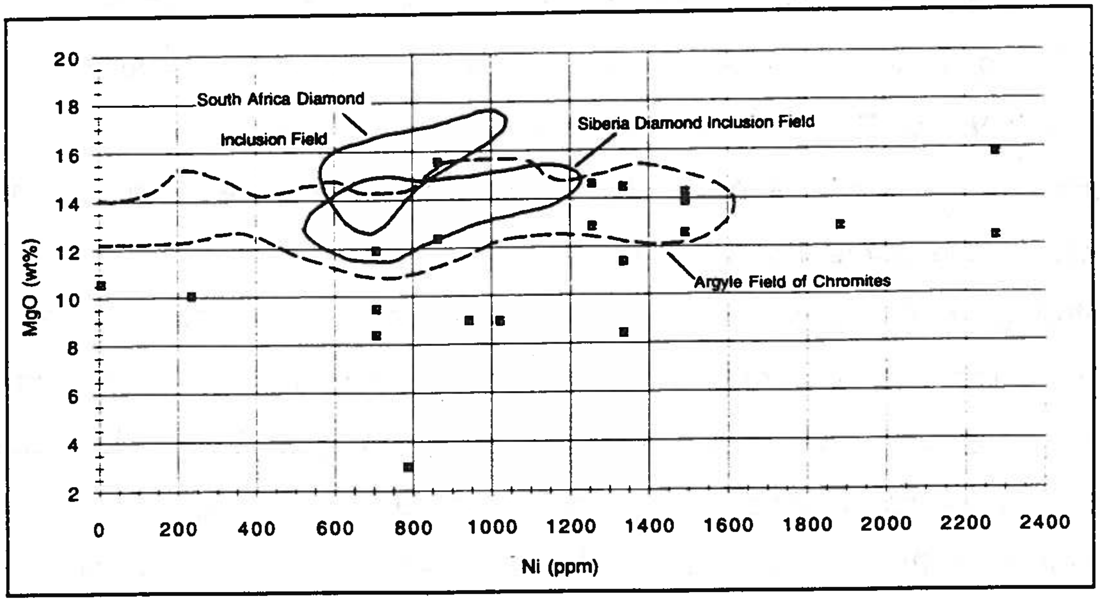

Figure 58. Chromites from preglacial sand and gravel deposits analysed for (g) Ni vs MgO.

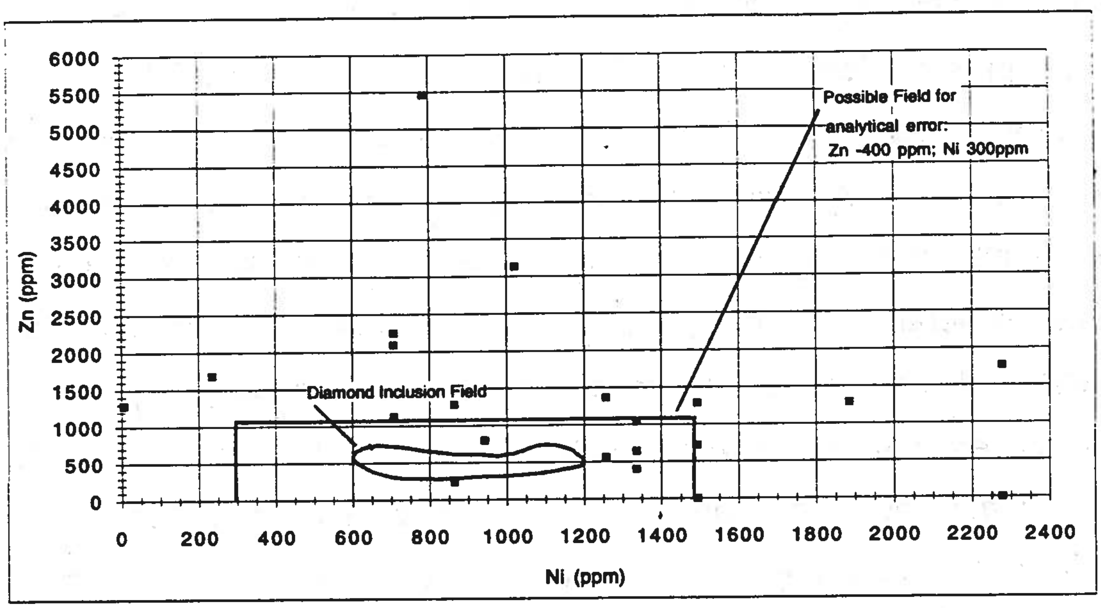

Figure 58. Chromites from preglacial sand and gravel deposits analysed for (h) Ni vs Zn.

diamond inclusion fields for MgO versus Ni (Figure 58e, f, and h). Grains from Group 6 plot in the Argyle field of chromites for Cr_2O_3 versus Al_2O_3, TiO_2, and Ni; for TiO_2 versus Al_2O_3 and Ni; and for MgO versus Ni (Figure 58a, c, d, e, f, and g). As mentioned above three excellent chrome diopsides also come from this region.

Although diamond indicator minerals present in preglacial sands and gravels have a less complicated transport history than minerals that were moved by glacier and recent rivers, a variety of possibilities for source areas and transport histories are still possible. Following is a general discussion of the possibilities and a more specific discussion of Groups 3/4 and 6.

Diatremes in the Main and Front Ranges of the Rocky Mountains (Figure 54) were emplaced before structural deformation and development of the mountains when deep crustal conditions favoured intrusion (also diamond preservation). These diatremes are incorporated into the mountains as part of the formations they intruded and would act like these formations. A sequence of erosion of these formations is shown schematically in Figure 53. Erosion of the diatremes would release indicator minerals into younger bedrock formations (Cretaceous and Tertiary) and into preglacial deposits of any unit (directly or through sequential erosion into younger units). It is possible, but less likely, that diatremes may become exposed at times later than deposition of earlier units (ie Unit 4 or 3 deposits) and could be incorporated only in the youngest units. Indicators from mountain sources should occur as isolated indicator finds. Perhaps the chromite from Arrowwood is such an example.

Diatremes injected into Cretaceous, or older, formations that became involved in Foothills deformation would, if exposed, release indicators into Early Tertiary bedrock or into the preglacial deposits of any unit. Foothills diatremes of Early Tertiary age would penetrate to surface and release mineral indicators directly into deposits of Unit 4 age or younger. Concentrations, in preglacial deposits, of mineral indicators from these younger diatremes would be greater than those of mountain sources but as few preglacial deposits occur in the Foothills (and near Foothills diatremes) downstream transport would dilute the concentrations.

Basement conditions below the Alberta Plains are seen as favourable for the generation of kimberlite or lamproite and at least one kimberlite (Mountain Lake) is known (Figure 54). The age of emplacement of Plains kimberlite is an important factor in the appearance of indicators in the preglacial deposits. Figure 59 shows several possibilities for a western Plains setting. These scenarios may apply to deposits as much as 200 km from the disturbed belt.

A diatreme emplaced in the Early Tertiary (Kimberlite 1 in Figure 59a and b) would release mineral indicators into the oldest preglacial fluvial systems (Unit 4 or 3). Concentrations near the diatreme would be greatest and decrease downstream. Erosion of the oldest gravel deposits (Unit 4) would release indicators into progressively younger deposits (Units 3, 2 or 1) with corresponding decrease in concentrations. If the diatreme remained exposed, erosion and release of indicators would continue directly into the younger units and produce greater concentrations.

A diatreme emplaced in Late Cretaceous (Kimberlite 2 in Figure 59c) would be exposed later in time than the diatreme in scenario 'a' (Figure 59) and would release mineral indicators into younger preglacial fluvial systems (Unit 2 or 1). Concentrations would be greatest near the diatreme and decrease downstream. Erosion of Unit 2 deposits would release indicators into Unit 1 deposits with corresponding decrease in concentrations. If the diatreme remained exposed, erosion and release of indicators would continue directly into Unit 1 and produce greater concentrations.

A diatreme emplaced in Mid to Late Cretaceous (Kimberlite 3 in Figure 59d) would be exposed later in time than either scenarios 'a', 'b' or 'c' (Figure 59) and would release mineral indicators into the youngest preglacial fluvial system (Unit 1). Concentrations would be high near the diatreme and decrease downstream. As the distance eastward onto the Plains increases, older formations are exposed and the differentiation due to age described above becomes less significant.

Some indicators in Group 6 are present in Halverson Ridge (6815), a Unit 3 deposit. This indicates a Mountain or Foothills source or a reasonably young intrusion to the south or west. The indicators from Grimshaw (6692), a Unit 2 deposit, could have a similar source or may have come from the older fluvial system represented by the Halverson Ridge deposit, but upstream from the actual Halverson Ridge deposit. The indicators at Grimshaw could not have come from the gravels equivalent to Watino as these are younger and lower. It is possible the indicators came from the Mountain Lake kimberlite (penetrates at least through the Wapiti Formation) via a system older than Watino, but it appears more likely that the source is to the west or southwest. The presence of numerous chrome diopsides and chromites also indicates a source different from, and perhaps closer than, the Mountain Lake kimberlite. The indicators found at Watino (Unit 1) could have a Mountain or Foothills

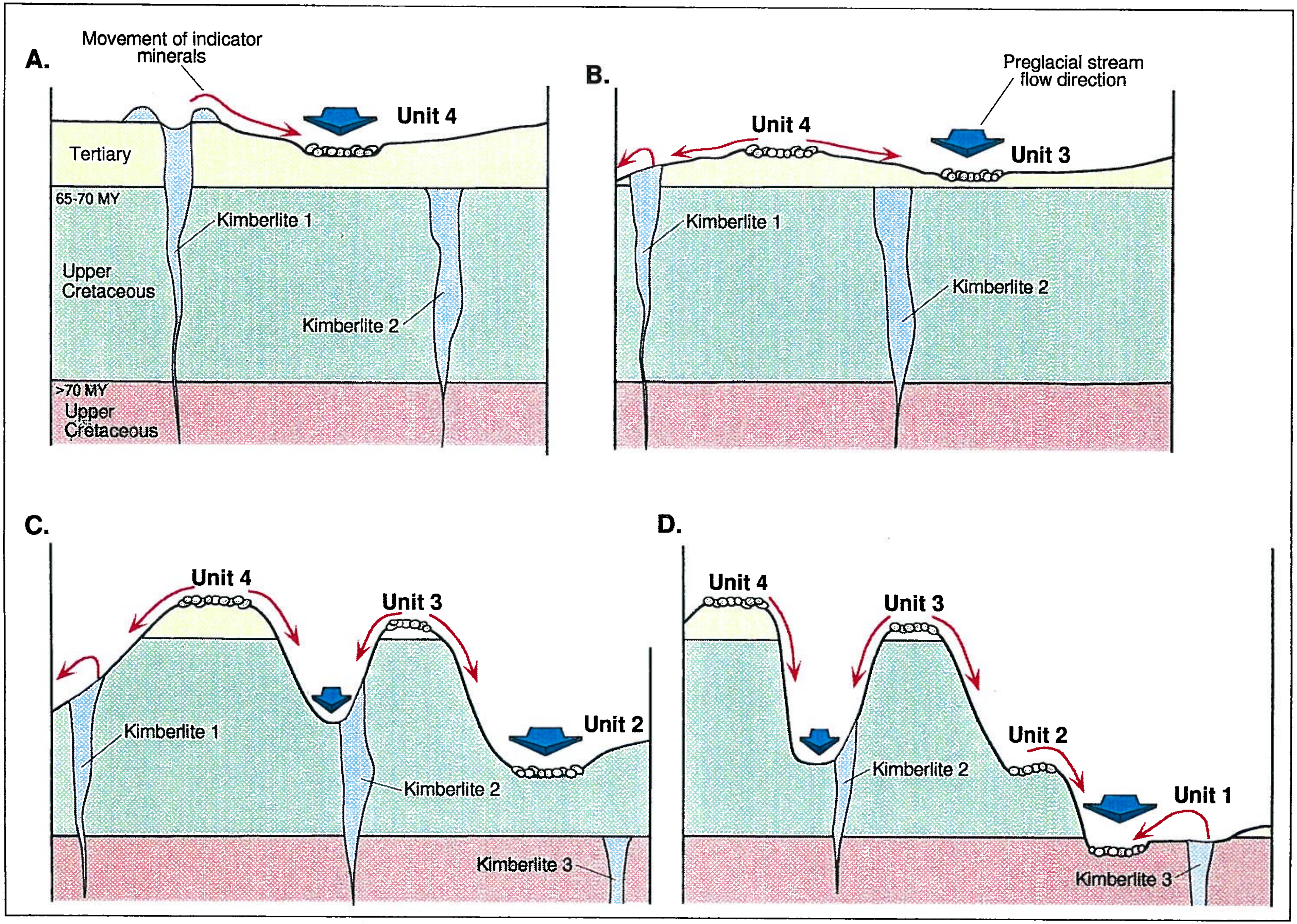

Figure 59. Possible movement of indicator minerals, in Alberta Plains setting, from kimberlites (hypothetical) of various ages.

source or a Plains source of any age less than about 100 million years. The source could have been the Mountain Lake kimberlite or an associated diatreme. The diamonds found northwest of Hinton area (Figure 54) indicate a nearby diatreme. This source could provide indicators to the Watino area if the drainage system developed for Group 6 in Unit 2 and 1 time was on the north side of the drainage divide formed by the remains of the Unit 4 and 3 deposits (Group 5).

All indicators from Group 3/4 deposits are from Unit 2 and Unit 1 deposits just west of Edmonton (Figure 54). A Mountain or Foothills source is possible, but a Tertiary intrusion in the Plains to the west is more likely. The age of the sediment in which the Opdahl diamond was found is not known so it could have been moved by agents younger than preglacial rivers and is of little aid in determining a source. The Hinton area is possible, but unlikely, as it is too far north for the preglacial drainage basin that includes Entwistle and Villeneuve.

The database of indicator minerals (nine deposits and 36 grains) for preglacial deposits is small, but it includes some excellent possibilities for diamondiferous sources and highlights two specific areas, Peace River and Edmonton. Diamond exploration is underway in both these areas and as assessment reports from companies working in these areas become public the amount of information should increase dramatically. The potential for discovery of diatremes in central and northwestern Alberta and along the northern Foothills is good. The data base of diamond indicator minerals in preglacial deposits should be expanded for use in exploration. The data base is also a way to monitor the finds that will be made. We should be able to account for most, if not all, indicators in the preglacial deposits. If we cannot, then there are diatremes still to be found.

Summary

Sand and gravel deposits of Tertiary and Pleistocene age, predating Laurentide continental glaciation, are scattered about Alberta except for the northwest corner (Figures 1 and 2). These deposits were formed in rivers which flowed generally away from the Rocky Mountains (from west or southwest to east or northeast) (Figure 21). Continental uplift gradually increased the elevation of the Plains during this period so that the rivers continued to erode through underlying bedrock, as much as a kilometre in some places.

Mountain building ceased about 50 million years ago and during the Early Tertiary the Mountains were at their highest and most massive (Figure 53a). Boulders and blocks of rock from the Mountains were eroded and swept out onto the plains in the preglacial rivers. The hardest and toughest rocks survived as pebbles and cobbles and in some places were deposited in thick beds (Plate 1b to c, Plate 3c). The rivers swept back and forth laterally gradually eroding the Plains and lowering the base level. In some places the thick gravel beds protected the underlying, generally softer bedrock from erosion (Plate 2a) and these areas gradually rose relative to the surrounding land as it eroded away (Figure 53a to d).

There appears to be at least four distinct levels created by this differential erosion (Figure 46). The first level (Unit 4) marks the level of the earliest rivers or braidplains (Figure 53a). Deposits preserved from this time (Eocene to Miocene) cover the highest hills on the Plains: the Cypress Hills Formation (Plate 3c), the Swan Hills Gravels (Plate 3a), and Obed Mountain (Plate 1b and 2c). The sands and gravels deposited preserve the direction of flow in these ancient rivers through the orientation of the clasts (Plate 1e) and the shape of the beds (Plate 1a and d). This imbrication and bedding was measured and a sense of the direction of flow of rivers was recovered from deposits in all four levels (Figure 21).

The material deposited in the preglacial deposits commonly is coarse gravel (Figure 5). The maximum size of clasts in deposits decreases as distance increases to the east (Figure12). This decrease in size agrees with the streamflow indicators and a west to east flow direction.

Rock formations eroded in the Mountains are reflected in the deposits on the Plains by the lithologies of the pebbles and cobbles (Plate 2d). Clasts were collected and identified (Plates 4 and 5) at ten sites ranging from the U. S. border to north of Peace River (Figure 30). Comparison of the lithologies from the deposits studied resulted in the identification of seven distinct lithologic Groups (Figure 4. These Groups reflect the source formations in the mountains and help define the extent of the river basins. The primary rock types, present in all seven Groups, are quartzites and sandstones.

The Hand Hills (Pliocene age), the Wintering Hills, Whitecourt Tower (Plate 2d), Pelican Mountain, and Halverson Ridge all belong to the second major level (Unit 3). These deposits are characterized by heavy gravel caps on hills or ridges. The topographic high is produced when the gravel armours the area and protects it from erosion, eventually leaving the former river bed as a positive feature (Figure 53b). Unit 2 marks the third erosion surface, about Plains level (Figure 53c), and is represented by deposits at Grimshaw (Plate 1a and d), Entwistle (Plate 2b), Cluny, and Fort Macleod (Plate 1c).

The fourth, and lowest, level (Unit 1) is incised into the Plains and includes deposits at Simonette (Plate 2a), Watino, Villeneuve (Plate 3d), and Kipp. These deposits are dated as Late Wisonsinan and contain faunal remains, ie. mammoth teeth and tusks, which attest to a cold climate and the approaching Laurentide glacier.

The preglacial sands and gravels are not just interesting geological features. They are valuable economic resources. Each year about $50 million worth of sand and gravel is mined from the preglacial deposits for use as mineral aggregate (Plate 3d). Cobbles and large pebbles are common in all Groups so that coarse crushed stone can be manufactured and the hard, resistant rocks result in aggregate which is often above average in quality. The preglacial deposits also contain fine gold. Placer gold concentrations as high as 0.17 g/m^3 with regional averages of 0.02 g/m^3 are present in Groups 3/4 and 6. These values represent a viable by-production during aggregate mining in large volume operations (Villeneuve deposit). Diamond indicator minerals (G10 garnet and diamond inclusion field chromite) are present in deposits near Edmonton and in the Peace country (diamond inclusion field chrome diopside and chromite). It is expected that identification of diamond indicator minerals in conjunction with models of diatreme emplacement and erosion will help to identify diatremes on the Alberta Plains.

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Appendix A

Summary data for all Tertiary and preglacial deposits and sites

Explanation of headings:

Deposit: an accumulation of preglacial sand and gravel over 1 m thick and mappable at a scale of 1:50 000 and identified by a four digit unique number assigned to the deposit

Site: an occurrence of preglacial sand and gravel at surface or in a drill hole

Area: the general area in which the deposit is located

NTS Map Area: the National Topographic System (NTS) map number and name

Elevation (m): the elevation above sea level of the base of the deposit measured in meters

Location: the location of one section wholly or partially within the deposit, given in Dominion Land Survey notation (section-township-range-meridian)

Distance (km) (from foothills): the distance in kilometers to the deposit measured at right angles from the eastern edge of the disturbed belt

Group: the regional group to which the deposit belongs. Grouping is based on common pebble/cobble/boulder lithologies and location

Unit: the stratigraphic unit to which the deposit belongs

References: the primary reference to information on the deposit, see the reference section of this report for the full reference. No reference citation indicates new data published in this report.

Aggregate Potential: one (1) indicates that the aggregate potential of the deposit has been described in the literature, zero (0) indicates that the deposit has not been described or appears to have no economic potential

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
S1197	NE of Onefour	72E/1 Cripple Creek	975	NW002-03-4	215	*7*	*2*	Westgate, 1968	
S1191	E bank Thelma Cr.	72E/8 Thelma Creek	1174	05-25-006-03-4	225	*7*	*3*	Westgate, 1968	
S1195	E bank Thelma Cr.	72E/8 Thelma Creek	1158	SW25-006-03-4	225	*7*	*3*	Westgate, 1968	
4213	Cypress Hills	72E/9 Elkwater Lake	1440	28-007-02-4	253	7	4	Leckie et al, 1989	0
4214	Cypress Hills	72E/9 Elkwater Lake	1340	24-008-01-4	267	7	4	Leckie et al, 1989	0
S1190	Alta-Sask. border	72E/9 Elkwater Lake	1189	09-25-006-01-4	243	*7*	*3*	Westgate, 1968	
S1192	NW of Eagle Butte	72E/9 Elkwater Lake	1264	10-09-008-04-4	215	*7*	*3*	Westgate, 1968	
S1193	Med. Lodge Coulee	72E/9 Elkwater Lake	1325	19-007-03-4	224	*7*	*4*	Westgate, 1968	
S1194	Alta-Sask. border	72E/9 Elkwater Lake	1158	SE36-006-01-4	245	*7*	*3*	Westgate, 1968	
S1200	W bank Mackay Cr.	72E/9 Elkwater Lake	998	06-23-009-01-4	285	*7*	*2*	Westgate, 1968	
1050	Oldman R.-Wolf Island	72E/13 Grassy Lake	731	20-011-14-4	143	1	1	Allong, 1967	0
1100	Oldman R.-Wolf Island	72E/13 Grassy Lake	731	17-011-14-4	141	1	1	Allong, 1967	0
S1198	Bullshead Cr.	72E/15 Seven Persons	891	15-31-009-05-4	240	*1*	*2*	Westgate, 1968	
S1199	Bullshead Cr.	72E/15 Seven Persons	891	16-31-009-05-4	240	*1*	*2*	Westgate, 1968	
5029	Irvine	72E/16 Irvine	800	26-011-02-4	261	1	2	Edwards, 1984	1
5030	Irvine	72E/16 Irvine	800	25-011-02-4	263	1	2	Edwards, 1984	1
S1019	S. Saskatchewan R.	72L/2 Medicine Hat	640	NE32-013-05-4	245	*1*	*1*	Stalker, 1969	
S1020	S. Saskatchewan R.	72L/2 Medicine Hat	655	SW04-014-05-4	245	*1*	*1*	Stalker, 1969	
S1201	N bank S. Sask R.	72L/2 Medicine Hat	670	NE09-013-05-4	245	*1*	*1*	Westgate, 1968	
S1203	E bank S. Sask R.	72L/2 Medicine Hat	632	SE05-014-05-4	245	*1*	*1*	Westgate, 1968	
1041	Red Deer R.-Blindloss	72L Medicine Hat	594	02-023-04-4	266	2	1	Hudson, 1984	1
1042	Red Deer R.-Blindloss	72L Medicine Hat	594	13-023-04-4	272	2	1	Hudson, 1984	1
1043	Red Deer R.-Empress	72L Medicine Hat	587	24-023-01-4	297	2	1	Hudson, 1984	1
1067	Sask. R.-Medicine Hat	72L Medicine Hat	641	05-014-05-4	234	1	1	Hudson, 1984	1
1068	Sask. R.-Medicine Hat	72L Medicine Hat	643	09-013-05-4	231	1	1	Hudson, 1984	1
1069	Sask. R.-Medicine Hat	72L Medicine Hat	641	17-013-05-4	233	1	1	Hudson, 1984	1
4211	Red Deer R.	72L Medicine Hat	701	18-023-15-4	164	2	2	Hudson, 1984	1
S1134	E of Lonebutte	72M/5 Sunnybrook	846	16-36-027-15-4	175	*2*	*2*	Campbell, 1974	
S1022	Castle R.	82G/9 Blairmore	1145	E ctr 27-006-01-5	-10	*1*	*1*	Stalker, 1963a	
1302	Ross Lake	82H/2 Shanks Lake	1364	29-002-22-4	49	1	4	Vonhof, 1969	0

Group and Unit values for Sites are italicized

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
3930	Ross Lake	82H/2 Shanks Lake	1385	12-002-23-4	44	1	3	Vonhof, 1969	0
3931	Ross Lake	82H/2 Shanks Lake	1385	12-002-23-4	44	1	3	Vonhof, 1969	0
3943	Ross Lake	82H/2 Shanks Lake	1385	24-002-23-4	45	1	3	Vonhof, 1969	0
3944	Ross Lake	82H/2 Shanks Lake	1385	19-002-22-4	46	1	3	Vonhof, 1969	0
3945	Ross Lake	82H/2 Shanks Lake	1385	19-002-22-4	47	1	3	Vonhof, 1969	0
3946	North Milk R.	82H/2 Shanks Lake	1323	31-001-21-4	54	1	3	Vonhof, 1969	0
3947	North Milk R.	82H/2 Shanks Lake	1292	31-001-21-4	55	1	3	Vonhof, 1969	0
3948	Reed Lake	82H/2 Shanks Lake	1292	18-002-21-4	56	1	3	Vonhof, 1969	0
3949	Reed Lake	82H/2 Shanks Lake	1292	20-002-21-4	57	1	3	Vonhof, 1969	0
3950	Reed Lake	82H/2 Shanks Lake	1292	28-002-21-4	59	1	3	Vonhof, 1969	0
3951	Shanks L.	82H/2 Shanks Lake	1292	36-001-21-4	63	1	3	Vonhof, 1969	0
3952	Del Bonita	82H/2 Shanks Lake	1292	02-001-21-4	58	1	3	Vonhof, 1969	0
3953	Del Bonita	82H/2 Shanks Lake	1292	06-001-21-4	62	1	3	Vonhof, 1969	0
5560	Milk River Ridge	82H/2 Shanks Lake	1265	17-003-21-4	59	1	3	Shetsen, 1982	1
5566	Peters Ck.	82H/2 Shanks Lake	1387	36-001-23-4	44	1	3	Shetsen, 1982	1
5567	Del Bointa	82H/2 Shanks Lake	1332	15-001-22-4	49	1	3	Shetsen, 1982	1
5568	Del Bonita	82H/2 Shanks Lake	1311	12-001-22-4	53	1	3	Shetsen, 1982	1
5569	Del Bonita	82H/2 Shanks Lake	1290	19-001-21-4	55	1	3	Shetsen, 1982	1
5570	Del Bonita	82H/2 Shanks Lake	1310	17-001-21-4	55	1	3	Shetsen, 1982	1
5571	Del Bonita	82H/2 Shanks Lake	1311	30-001-21-4	55	1	3	Shetsen, 1982	1
5581	Ross Lake	82H/2 Shanks Lake	1387	07-002-22-4	47	1	3	Shetsen, 1982	1
5582	Peters Ck.	82H/2 Shanks Lake	1402	35-001-23-4	43	1	4	Shetsen, 1982	1
5583	North Milk R.	82H/2 Shanks Lake	1265	32-001-23-4	47	1	2	Shetsen, 1982	1
5584	North Milk R.	82H/2 Shanks Lake	1341	20-001-22-4	46	1	3	Shetsen, 1982	1
5585	North Milk R.	82H/2 Shanks Lake	1402	07-001-22-4	44	1	4	Shetsen, 1982	1
5586	North Milk R.	82H/2 Shanks Lake	1410	06-001-22-4	43	1	4	Shetsen, 1982	1
5587	Shanks Ck.	82H/2 Shanks Lake	1341	10-001-22-4	49	1	3	Shetsen, 1982	1
5588	Del Bonita	82H/2 Shanks Lake	1341	02-001-22-4	51	1	3	Shetsen, 1982	1
5589	Del Bonita	82H/2 Shanks Lake	1318	24-001-22-4	53	1	3	Shetsen, 1982	1
5590	Shanks L.	82H/2 Shanks Lake	1295	33-001-21-4	58	1	3	Shetsen, 1982	1

Group and Unit values for Sites are italicized

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
5591	Shanks L.	82H/2 Shanks Lake	1295	24-001-21-4	62	1	3	Shetsen, 1982	1
5592	Del Bonita	82H/2 Shanks Lake	1273	13-001-21-4	62	1	3	Shetsen, 1982	1
3929	Peters Ck.	82H/3 Cardston	1415	27-001-23-4	40	1	4	Vonhof, 1969	0
1303	Whisky Gap	82H/3 Cardston	1415	06-001-23-4	33	1	4	Vonhof, 1969	
3916	Whiskey Gap	82H/3 Cardston	1415	05-001-23-4	35	1	4	Vonhof, 1969	0
3917	Whiskey Gap	82H/3 Cardston	1415	08-001-23-4	36	1	4	Vonhof, 1969	0
3918	Peters Ck.	82H/3 Cardston	1415	28-001-23-4	39	1	4	Vonhof, 1969	0
3919	Peters Ck.	82H/3 Cardston	1415	22-001-23-4	39	1	4	Vonhof, 1969	0
3920	Peters Ck.	82H/3 Cardston	1415	22-001-23-4	39	1	4	Vonhof, 1969	0
3921	Peters Ck.	82H/3 Cardston	1415	21-001-23-4	38	1	4	Vonhof, 1969	0
3922	Whiskey Gap	82H/3 Cardston	1415	16-001-23-4	38	1	4	Vonhof, 1969	0
3923	Jefferson	82H/3 Cardston	1415	33-001-23-4	40	1	4	Vonhof, 1969	0
S1021	St. Mary R.	82H/6 Raley	1050	NE05-005-23-4	30	*1*	*1*	Stalker, 1963a	
5668	St. Mary's R.	82H/7 Raymond	938	23-006-23-4	53	1	1	Shetsen, 1982	1
5669	Magrath	82H/7 Raymond	1105	06-005-21-4	62	1	2	Shetsen, 1982	1
1047	Oldman R.-Lethbridge	82H/10 Lethbridge	834	01-009-22-4	68	1	1	Allong, 1967	0
1048	Oldman R.-Lethbridge	82H/10 Lethbridge	834	01-009-22-4	68	1	1	Allong, 1967	0
1052	Oldman R.-Kipp	82H/10 Lethbridge	887	18-009-22-4	62	1	1	Allong, 1967	0
5695	Oldman R.-Lethbridge	82H/10 Lethbridge	831	13-009-22-4	70	1	1	Shetsen, 1982	1
5696	Oldman R.-Lethbridge	82H/10 Lethbridge	831	12-009-22-4	69	1	1	Shetsen, 1982	1
S1095	W bank Oldman R.	82H/10 Lethbridge	865	02-11-009-22-4	80	*1*	*1*	Horberg, 1952	
5720	Ft. Macleod	82H/11 Fort Macleod	1113	33-007-26-4	23	1	2	Shetsen, 1982	1
5721	Ft. Macleod	82H/11 Fort Macleod	1143	10-007-26-4	22	1	2	Shetsen, 1982	1
S1030	Belly R.	82H/11 Fort Macleod	935	N36-007-25-4	43	*1*	*1*	Stalker 1963b	
S1031	Stand Off	82H/11 Fort Macleod	1035	NW19-007-25-4	40	*1*	*1*	Stalker 1963b	
S1032	Stand Off	82H/11 Fort Macleod	1035	SW30-007-25-4	43	*1*	*1*	Stalker 1963b	
1053	Oldman R.	82H/12 Brocket	991	21-008-27-4	15	1	1	Allong, 1967; Stalker, 1963	0
1054	Oldman R.-Brocket	82H/12 Brocket	1021	35-007-28-4	7	1	1	Allong, 1967; Stalker, 1963	0
S1096	W bank Oldman R.	82H/15 Picture Butte	852	N24-009-22-4	85	*1*	*1*	Horberg, 1952	
S1097	Piyam Coulee	82H/15 Picture Butte	852	E30-009-21-4	85	*1*	*1*	Horberg, 1952	

Group and Unit values for Sites are italicized

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
S1098	E bank Oldman R.	82H/15 Picture Butte	852	SW04-010-21-4	88	*1*	*1*	Horberg, 1952	
S1099	S bank Oldman R.	82H/15 Picture Butte	780	09-35-010-20-4	103	*1*	*1*	Horberg, 1952	
S1139	E of Keho L.	82H/15 Picture Butte	948	NE32-011-22-4	78	*1*	*1*	Campbell & Almadi, 1964	
S1140	Blackspring Ridge	82H/15 Picture Butte	975	NE09-012-22-4	80	*1*	*1*	Campbell & Almadi, 1964	
1051	Oldman R.-Taber	82H/16 Taber	747	19-011-16-4	122	1	1	Stalker, 1963	0
S1024	Oldman R.	82H/16 Taber	755	NW19-011-16-4	133	*1*	*1*	Stalker, 1963a	
S1100	N bank Oldman R.	82H/16 Taber	740	04-012-16-4	138	*1*	*1*	Horberg, 1952	
S1141	Blackspring Ridge	82I/2 Travers	991	NE10-013-22-4	83	*1*	*1*	Campbell & Almadi, 1964	
S1142	E bank Little Bow R.	82I/2 Travers	823	03-014-20-4	103	*1*	*1*	Campbell & Almadi, 1964	
S1143	W bank Little Bow R.	82I/2 Travers	841	18-014-20-4	98	*1*	*1*	Campbell & Almadi, 1964	
S1144	SW of Travers Res.	82I/2 Travers	927	NE07-014-21-4	90	*1*	*1*	Campbell & Almadi, 1964	
S1145	N bank Travers Res.	82I/2 Travers	853	NE33-014-21-4	95	*1*	*1*	Campbell & Almadi, 1964	
S1146	Blackspring Ridge	82I/2 Travers	945	NE11-014-22-4	88	*1*	*1*	Campbell & Almadi, 1964	
5812	Nanton	82I/5 Nanton	1143	31-017-29-4	12	2	2	Shetsen, 1980; Stalker, 1957	0
1056	McGregor L.	82I/6 Vulcan	991	06-018-22-4	79	2	2	Shetsen, 1980; Stalker, 1957	0
S1156	NE of Thigh Hills	82I/6 Vulcan	963	NE34-016-23-4	83	*2*	*2*	Campbell & Almadi, 1964	
S1147	E of McGregor L.	82I/7 McGregor Lake	902	NE35-015-21-4	95	*2*	*1*	Campbell & Almadi, 1964	
S1148	E of McGregor L.	82I/7 McGregor Lake	881	NE12-016-21-4	98	*2*	*1*	Campbell & Almadi, 1964	
S1149	W of McGregor L.	82I/7 McGregor Lake	890	NE19-016-21-4	98	*2*	*1*	Campbell & Almadi, 1964	
S1150	W bank McGregor L.	82I/7 McGregor Lake	869	W33-016-21-4	95	*2*	*1*	Campbell & Almadi, 1964	
S1151	W of McGregor L.	82I/7 McGregor Lake	991	NE10-016-22-4	88	*2*	*2*	Campbell & Almadi, 1964	
S1152	W of McGregor L.	82I/7 McGregor Lake	930	NE12-016-22-4	90	*2*	*1*	Campbell & Almadi, 1964	
S1153	W of McGregor L.	82I/7 McGregor Lake	930	NE21-016-22-4	90	*2*	*1*	Campbell & Almadi, 1964	
S1154	W of McGregor L.	82I/7 McGregor Lake	939	NE34-016-22-4	88	*2*	*1*	Campbell & Almadi, 1964	
S1155	W of McGregor L.	82I/7 McGregor Lake	860	NE36-016-22-4	90	*2*	*1*	Campbell & Almadi, 1964	
S1158	W of McGregor L.	82I/7 McGregor Lake	896	NE33-017-22-4	87	*2*	*1*	Campbell & Almadi, 1964	
S1159	W of McGregor L.	82I/7 McGregor Lake	878	NE35-017-22-4	90	*2*	*1*	Campbell & Almadi, 1964	
S1160	E of McGregor L.	82I/10 Queenstown	917	NE32-018-19-4	115	*2*	*1*	Campbell & Almadi, 1964	
S1161	W of McGregor L.	82I/10 Queenstown	887	NE10-018-22-4	88	*2*	*1*	Campbell & Almadi, 1964	
S1162	W of McGregor L.	82I/10 Queenstown	884	NE32-018-22-4	88	*2*	*1*	Campbell & Almadi, 1964	

Group and Unit values for Sites are italicized

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
S1163	W of canal	82I/10 Queenstown	869	NE34-019-22-4	93	*2*	*1*	Campbell & Almadi, 1964	
S1164	E of canal	82I/10 Queenstown	853	NE36-019-22-4	95	*2*	*1*	Campbell & Almadi, 1964	
S1169	NW of J. Buffalo Hill	82I/10 Queenstown	835	NE31-020-19-4	115	*2*	*1*	Campbell & Almadi, 1964	
S1170	W of Indian L.	82I/10 Queenstown	835	NE20-020-21-4	100	*2*	*1*	Campbell & Almadi, 1964	
S1171	N of Indian L.	82I/10 Queenstown	847	NE31-020-21-4	100	*2*	*1*	Campbell & Almadi, 1964	
S1172	NE of Indian L.	82I/10 Queenstown	841	NE33-020-21-4	102	*2*	*1*	Campbell & Almadi, 1964	
S1173	NE of Indian L.	82I/10 Queenstown	823	NE35-020-21-4	104	*2*	*1*	Campbell & Almadi, 1964	
S1174	E of Shouldice	82I/10 Queenstown	866	NE24-020-22-4	95	*2*	*1*	Campbell & Almadi, 1964	
S1175	NE of Shouldice	82I/10 Queenstown	866	NE35-020-22-4	95	*2*	*1*	Campbell & Almadi, 1964	
5854	Arrowwood	82I/11 Arrowwood	1029	12-020-24-4	71	2	3	Shetsen, 1980; Stalker, 1957	0
5855	Buffalo Hill	82I/11 Arrowwood	1014	16-020-23-4	77	2	3	Shetsen, 1980; Stalker, 1957	0
5856	Buffalo Hill	82I/11 Arrowwood	1014	14-020-23-4	80	2	3	Shetsen, 1980; Stalker, 1957	0
5857	Buffalo Hill	82I/11 Arrowwood	1074	33-019-23-4	75	2	3	Shetsen, 1980; Stalker, 1957	0
5858	Buffalo Hill	82I/11 Arrowwood	1067	03-020-23-4	78	2	3	Shetsen, 1980; Stalker, 1957	0
S1165	Buffalo Hill	82I/11 Arrowwood	1185	08-019-23-4	83	*2*	*3*	Campbell & Almadi, 1964	
S1166	Buffalo Hill	82I/11 Arrowwood	1149	16-019-23-4	83	*2*	*3*	Campbell & Almadi, 1964	
S1167	Buffalo Hill	82I/11 Arrowwood	1149	17-019-23-4	82	*2*	*3*	Campbell & Almadi, 1964	
1055	Bow R.-De Winton	82I/13 Dalemead	975	05-022-28-4	22	2	1	Shetsen, 1980	0
S1028	Oldman R.	82I/13 Dalemead	975	E05-022-28-4	35	*2*	*1*	Stalker, 1963a	
S1180	Bow R.	82I/14 Gleichen	887	09-021-23-4	83	*2*	*1*	Campbell & Almadi, 1964	
S1181	W of Bow R.	82I/14 Gleichen	860	NE23-021-24-4	75	*2*	*1*	Campbell & Almadi, 1964	
3913	Cluny	82I/15 Cluny	960	10-022-21-4	94	2	2		0
S1036	Makepeace	82I/15 Cluny	843	Most 023-19-4	125	*2*	*1*	Stalker, 1973	
S1037	Crowfoot Cr.	82I/15 Cluny	858	Most 023-20-4	110	*2*	*1*	Stalker, 1973	
S1101	NE of Cluny	82I/15 Cluny	893	16-24-022-21-4	108	*2*	*1*	Campbell, 1974	
S1102	NE of Cluny	82I/15 Cluny	945	16-35-022-21-4	110	*2*	*2*	Campbell, 1974	
S1103	E of Crowfoot Cr.	82I/15 Cluny	850	16-22-022-20-4	115	*2*	*1*	Campbell, 1974	
S1104	W of Crowfoot Cr.	82I/15 Cluny	853	16-33-022-20-4	115	*2*	*1*	Campbell, 1974	
S1105	E of Crowfoot Cr.	82I/15 Cluny	851	16-35-022-20-4	117	*2*	*1*	Campbell, 1974	
S1108	Makepeace	82I/15 Cluny	904	16-20-023-19-4	125	*2*	*1*	Campbell, 1974	

Group and Unit values for Sites are italicized

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
S1110	E of Crowfoot Cr.	82I/15 Cluny	913	16-11-023-20-4	118	*2*	*1*	Campbell, 1974	
S1112	S bank Crowfoot Cr.	82I/15 Cluny	843	16-22-023-21-4	108	*2*	*1*	Campbell, 1974	
S1178	SE of Cluny	82I/15 Cluny	869	NE34-021-21-4	105	*2*	*1*	Campbell & Almadi, 1964	
S1179	SE of Cluny	82I/15 Cluny	832	NE36-021-21-4	107	*2*	*1*	Campbell & Almadi, 1964	
S1185	W of Crowfoot Cr.	82I/15 Cluny	826	NE33-022-20-4	110	*2*	*1*	Campbell & Almadi, 1964	
S1186	E of Crowfoot Cr.	82I/15 Cluny	823	NE35-022-20-4	112	*2*	*1*	Campbell & Almadi, 1964	
S1188	NE of Cluny	82I/15 Cluny	896	NE11-022-21-4	108	*2*	*1*	Campbell & Almadi, 1964	
S1189	NE of Cluny	82I/15 Cluny	945	NE35-022-21-4	109	*2*	*2*	Campbell & Almadi, 1964	
S1033	Gem	82I/16 Bassano	744	Most 023-16-4	150	*2*	*1*	Stalker, 1973	
S1034	Crawling Valley	82I/16 Bassano	782	Most 023-17-4	143	*2*	*1*	Stalker, 1973	
S1035	Crawling Valley	82I/16 Bassano	795	Most 023-18-4	138	*2*	*1*	Stalker, 1973	
S1106	E of Crawling V.	82I/16 Bassano	799	16-07-023-17-4	140	*2*	*1*	Campbell, 1974	
S1107	W bank Crawling V.	82I/16 Bassano	792	16-24-023-18-4	138	*2*	*1*	Campbell, 1974	
S1182	Birkenhouse L.	82I/16 Bassano	750	NE31-022-17-4	138	*2*	*1*	Campbell & Almadi, 1964	
S1183	E of Birkenhouse L.	82I/16 Bassano	777	NE33-022-18-4	133	*2*	*1*	Campbell & Almadi, 1964	
S1184	E of Birkenhouse L.	82I/16 Bassano	756	NE35-022-18-4	135	*2*	*1*	Campbell & Almadi, 1964	
6008	Spy Hill	82O/1 Calgary	1288	28-025-03-5	11	2	3	Moran, 1986; Shetsen, 1980	0
6009	Spy Hill	82O/1 Calgary	1257	24-025-03-5	12	2	3	Moran, 1986; Shetsen, 1980	0
6015	Calgary	82O/1 Calgary	1250	35-025-02-5	19	2	3	Moran, 1986; Shetsen, 1980	0
6016	Calgary	82O/1 Calgary	1250	23-025-02-5	20	2	3	Moran, 1986; Shetsen, 1980	0
6017	Nose Hill	82O/1 Calgary	1219	14-025-02-5	21	2	3	Moran, 1986; Shetsen, 1980	0
6018	Nose Hill	82O/1 Calgary	1219	08-025-01-5	22	2	3	Moran, 1986; Shetsen, 1980	0
6034	Big Hill	82O/1 Calgary	1334	06-026-03-5	7	2	3	Moran, 1986; Shetsen, 1980	0
6049	Calgary	82O/1 Calgary	1257	28-024-02-5	12	2	3	Moran, 1986; Shetsen, 1980	0
6050	Olympic Hill	82O/1 Calgary	1234	23-024-02-5	15	2	3	Moran, 1986; Shetsen, 1980	0
S1010	Calgary	82O/1 Calgary	1036	SW11-024-01-5	30	*2*	*2*	Meyboom. 1961	
S1011	Calgary	82O/1 Calgary	1067	28-024-01-5	28	*2*	*2*	Meyboom. 1961	
S1012	Calgary	82O/1 Calgary	1097	31-024-01-5	23	*2*	*2*	Meyboom. 1961	
S1014	Calgary	82O/1 Calgary	1097	01-025-02-5	23	*2*	*2*	Meyboom. 1961	
S1015	Calgary	82O/1 Calgary	1097	02-025-02-5	20	*2*	*2*	Meyboom. 1961	

Group and Unit values for Sites are italicized

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
4023	Crawford Plat.	82O/2 Jumping Pound Cr.	1318	29-025-04-5	0	2	3	Bayrock et al, 1975	1
4024	Crawford Plat.	82O/2 Jumping Pound Cr.	1326	36-025-05-5	0	2	3	Bayrock et al, 1975	1
4025	Crawford Plat.	82O/2 Jumping Pound Cr.	1311	35-025-05-5	0	2	3	Bayrock et al, 1975	1
4026	Crawford Plat.	82O/2 Jumping Pound Cr.	1334	36-025-05-5	0	2	3	Bayrock et al, 1975	1
4027	Radnor Plat.	82O/2 Jumping Pound Cr.	1356	04-026-05-5	0	2	3	Bayrock et al, 1975	1
Note: deposits 4023 to 4026 (Crawford Plateau) and 4027 (Radnor Plateau) are peneplain surfaces with only a covering lag.									
1091	Trochu	82P Drumheller	732	11-034-22-4	122	2	1	Allong, 1967	0
3967	Wintering Hills	82P/1 Finnegan	1029	28-026-18-4	138	2	3		0
3968	Wintering Hills	82P/1 Finnegan	1029	22-026-18-4	140	2	3		0
3969	Wintering Hills	82P/1 Finnegan	1029	22-026-18-4	139	2	3		0
3970	Wintering Hills	82P/1 Finnegan	1029	28-026-18-4	139	2	3		0
3971	Wintering Hills	82P/1 Finnegan	1029	21-026-18-4	138	2	3		0
6810	Wintering Hills	82P/1 Finnegan	1029	21-026-18-4	139	2	3		0
6811	Wintering Hills	82P/1 Finnegan	1029	28-026-18-4	140	2	3		0
S1038	Canalta Slough	82P/1 Finnegan	759	W,NE 024-16-4	153	*2*	*1*	Stalker, 1973	
S1039	S of Red Deer R.	82P/1 Finnegan	814	025-16-4	158	*2*	*1*	Stalker, 1973	
S1040	Wolf L.	82P/1 Finnegan	789	Most 024-17-4	145	*2*	*1*	Stalker, 1973	
S1041	W of Wolf L.	82P/1 Finnegan	873	Most 024-18-4	138	*2*	*1*	Stalker, 1973	
S1043	Selu L.	82P/1 Finnegan	858	Most 025-17-4	148	*2*	*1*	Stalker, 1973	
S1044	Mattoyekiu L.	82P/1 Finnegan	873	Most 025-18-4	139	*2*	*1*	Stalker, 1973	
S1045	S of Red Deer R.	82P/1 Finnegan	858	SE 026-17-4	153	*2*	*1*	Stalker, 1973	
S1046	Finnegan	82P/1 Finnegan	736	025-15-4	165	*2*	*1*	Stalker, 1973	
S1047	S of Red Deer R.	82P/1 Finnegan	797	025-16-4	158	*2*	*1*	Stalker, 1973	
S1048	Homestead Cr.	82P/1 Finnegan	782	026-15-4	170	*2*	*1*	Stalker, 1973	
S1049	N of Red Deer R.	82P/1 Finnegan	782	026-16-4	160	*2*	*1*	Stalker, 1973	
S1055	Wintering Hills	82P/1 Finnegan	1020	20-026-18-4	140	*2*	*3*	Stalker, 1973	
S1057	Wintering Hills	82P/1 Finnegan	1029	29-026-18-4	140	*2*	*3*	Stalker, 1973	
S1115	S of Mattoyekiu L.	82P/1 Finnegan	890	16-34-024-18-4	140	*2*	*1*	Campbell, 1974	
S1116	SW of Mattoyekiu L.	82P/1 Finnegan	891	16-19-024-18-4	135	*2*	*1*	Campbell, 1974	
S1117	E of Crawling V.	82P/1 Finnegan	812	16-21-024-17-4	148	*2*	*1*	Campbell, 1974	

Group and Unit values for Sites are italicized

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Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
S1118	E of Crawling V.	82P/1 Finnegan	823	16-07-025-16-4	155	*2*	*1*	Campbell, 1974	
S1119	E of Crawling V.	82P/1 Finnegan	835	16-20-025-16-4	160	*2*	*1*	Campbell, 1974	
S1120	W of Crawling V.	82P/1 Finnegan	857	16-09-025-17-4	145	*2*	*1*	Campbell, 1974	
S1121	E of Crawling V.	82P/1 Finnegan	835	16-11-025-17-4	148	*2*	*1*	Campbell, 1974	
S1122	E of Seiu L.	82P/1 Finnegan	884	16-20-025-17-4	148	*2*	*1*	Campbell, 1974	
S1123	E of Crawling V.	82P/1 Finnegan	849	16-24-025-17-4	150	*2*	*1*	Campbell, 1974	
S1124	W of Crawling V.	82P/1 Finnegan	872	16-33-025-17-4	150	*2*	*1*	Campbell, 1974	
S1125	SE of Mattoyekiu L.	82P/1 Finnegan	890	16-11-025-18-4	143	*2*	*1*	Campbell, 1974	
S1128	S of R. Deer R.	82P/1 Finnegan	899	16-08-026-17-4	148	*2*	*1*	Campbell, 1974	
S1129	S of R. Deer R.	82P/1 Finnegan	925	16-19-026-17-4	148	*2*	*1*	Campbell, 1974	
S1131	N of Seiu Cr.	82P/1 Finnegan	942	16-08-026-18-4	140	*2*	*1*	Campbell, 1974	
S1042	Deadhorse L.	82P/2 Hussar	896	Most 024-19-4	133	*2*	*1*	Stalker, 1973	
S1109	SE of Hussar	82P/2 Hussar	917	16-31-023-19-4	120	*2*	*1*	Campbell, 1974	
S1111	S of Hussar	82P/2 Hussar	934	16-35-023-20-4	118	*2*	*1*	Campbell, 1974	
S1113	E of Deadhorse L.	82P/2 Hussar	912	16-23-024-19-4	130	*2*	*1*	Campbell, 1974	
S1114	E of Deadhorse L.	82P/2 Hussar	927	16-21-024-19-4	128	*2*	*1*	Campbell, 1974	
3972	Wintering Hills	82P/8 Dorothy	1029	33-026-18-4	139	2	3		0
S1050	Lonebutte	82P/8 Dorothy	841	027-15-4	173	*2*	*1*	Stalker, 1973	
S1051	Clivale	82P/8 Dorothy	843	SE 027-16-4	163	*2*	*1*	Stalker, 1973	
S1052	E of Little Fish L.	82P/8 Dorothy	843	SE 028-15-4	168	*2*	*1*	Stalker, 1973	
S1058	Wintering Hills	82P/8 Dorothy	888	35-026-18-4	148	*2*	*1*	Stalker, 1973	
S1126	E of Clivale	82P/8 Dorothy	818	16-34-026-15-4	173	*2*	*1*	Campbell, 1974	
S1127	E of Clivale	82P/8 Dorothy	837	16-32-026-15-4	170	*2*	*1*	Campbell, 1974	
S1130	E of Dorothy	82P/8 Dorothy	770	16-34-026-17-4	153	*2*	*1*	Campbell, 1974	
S1132	NE of Clivale	82P/8 Dorothy	847	16-08-027-15-4	170	*2*	*1*	Campbell, 1974	
S1133	NE of Clivale	82P/8 Dorothy	829	16-10-027-15-4	173	*2*	*1*	Campbell, 1974	
S1135	NE of Clivale	82P/8 Dorothy	860	16-12-027-16-4	165	*2*	*1*	Campbell, 1974	
S1136	S of Little Fish L.	82P/8 Dorothy	922	16-19-027-16-4	160	*2*	*1*	Campbell, 1974	
S1137	NE of Clivale	82P/8 Dorothy	884	16-23-027-16-4	165	*2*	*1*	Campbell, 1974	
S1138	E of Little Fish L.	82P/8 Dorothy	906	16-11-028-16-4	168	*2*	*1*	Campbell, 1974	

Group and Unit values for Sites are italicized

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Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
3954	Hand Hills L.	82P/9 Craigmyle	992	33-029-15-4	168	2	3	Vonhof, 1969	0
3955	Hand Hills L.	82P/9 Craigmyle	1008	33-029-15-4	168	2	3	Vonhof, 1969	0
3956	Hand Hills	82P/9 Craigmyle	1092	15-030-17-4	156	2	3		0
3957	Hand Hills	82P/9 Craigmyle	1042	21-029-16-4	157	2	3		0
3958	Hand Hills	82P/9 Craigmyle	1100	16-030-17-4	155	2	3		0
3959	Hand Hills	82P/9 Craigmyle	1092	32-029-17-4	150	2	3		0
3960	Hand Hills	82P/9 Craigmyle	1085	10-030-17-4	156	2	3		0
3961	Hand Hills	82P/9 Craigmyle	1103	31-029-16-4	157	2	3		0
3962	Hand Hills L.	82P/9 Craigmyle	1008	32-029-15-4	166	2	3		0
3963	Hand Hills L.	82P/9 Craigmyle	1000	32-029-15-4	166	2	3		0
3964	Hand Hills L.	82P/9 Craigmyle	1011	06-030-15-4	166	2	3		0
3965	Hand Hills L.	82P/9 Craigmyle	1000	07-030-15-4	167	2	3		0
3966	Hand Hills L.	82P/9 Craigmyle	1000	01-030-16-4	165	2	3		0
6808	Hand Hills	82P/9 Craigmyle	1108	32-029-17-4	151	2	3		0
6809	Hand Hills	82P/9 Craigmyle	1085	12-030-17-4	158	2	3		0
S1053	Handhills L.	82P/9 Craigmyle	914	34-029-15-4	178	2	3	Stalker, 1973	
S1059	W of Red Deer R.	82P/10 Munson	762	15-031-21-4	123	*2*	*1*	Stalker, 1973	
S1060	W of Red Deer R.	82P/14 Trochu	838	29-033-22-4	120	*2*	*1*	Stalker, 1973	
S1061	W of Red Deer R.	82P/14 Trochu	838	32-033-22-4	122	*2*	*1*	Stalker, 1973	
S1062	W bank Red Deer R.	82P/14 Trochu	800	02-034-22-4	128	*2*	*1*	Stalker, 1973	
S1063	W of Red Deer R.	82P/14 Trochu	876	06-034-22-4	123	*2*	*1*	Stalker, 1973	
S1064	E bank Red Deer R.	82P/15 Rumsey	800	12-034-22-4	130	*2*	*1*	Stalker, 1973	
1040	Gaetz Ck.	83A/3 Delburne	785	02-038-24-4	119	3	1	Allong, 1967	0
1049	Red Deer	83A/5 Red Deer	876	18-038-27-4	88	3	1	Allong, 1967	0
S1029	Red Deer R.	83A/5 Red Deer	907	SE17-038-27-4	93	*3*	*1*	Stalker, 1963a	
1039	Red Deer R.	83A/6 Alix	770	32-038-23-4	127	3	1	Allong, 1967	0
6106	Lacombe	83A/12 Ponoka	930	04-041-27-4	41	3	2	Sham, 1984	1
6118	Malmo	83A/14 Wetaskiwin	828	20-044-22-4	160	3	2	Sham, 1984	1
6119	Wetaskiwin	83A/14 Wetaskiwin	770	29-045-23-4	63	3	1	Sham, 1984	1
S1072	Ferintosh	83A/14 Wetaskiwin	815	29-044-21-4	170	*3*	*2*	Stalker, 1960	

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Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
1061	Battle R.	83A/15 Ferintosh	701	11-046-21-4	180	3	1	Allong, 1967	0
1070	New Norway	83A/15 Ferintosh	785	22-044-21-4	172	3	1	Allong, 1967	0
1080	New Norway	83A/15 Ferintosh	754	26-044-21-4	174	3	1	Allong, 1967	0
1088	Battle R.	83A/15 Ferintosh	701	06-046-20-4	184	3	1	Allong, 1967	0
1089	Battle R.	83A/15 Ferintosh	732	05-046-20-4	65	3	1	Allong, 1967	0
6125	Driedmeat Ck.	83A/15 Ferintosh	701	14-045-19-4	61	3	1	Sham, 1986	1
6127	Driedmeat Hill	83A/15 Ferintosh	747	17-045-19-4	65	3	1	Sham, 1986	1
6131	Driedmeat L.	83A/15 Ferintosh	701	33-045-20-4	185	3	1	Sham, 1986	1
6134	Battle R.	83A/15 Ferintosh	732	09-046-21-4	179	3	1	Sham, 1986	1
6135	Battle R.	83A/15 Ferintosh	724	10-046-21-4	179	3	1	Sham, 1986	1
6137	Ferintosh	83A/15 Ferintosh	831	18-044-20-4	175	3	1	Sham, 1986	1
6138	New Norway	83A/15 Ferintosh	785	22-044-21-4	172	3	1	Allong, 1967	1
S1068	Driedmeat Cr.	83A/15 Ferintosh	701	15-045-18-4	203	3	1	Stalker, 1960	
S1069	Driedmeat Cr.	83A/15 Ferintosh	701	16-045-18-4	202	3	1	Stalker, 1960	
S1070	Driedmeat Cr.	83A/15 Ferintosh	701	17-045-18-4	201	3	1	Stalker, 1960	
S1071	Driedmeat Cr.	83A/15 Ferintosh	701	18-045-18-4	200	3	1	Stalker, 1960	
S1082	Red Deer. R.	83A/16 Alix	789	31-038-23-4	128	3	1	Rutherford, 1937	
S1065	Rosalind	83A/16 Daysland	716	04-044-17-4	203	3	1	Stalker, 1960	
S1066	Rosalind	83A/16 Daysland	716	05-044-17-4	202	3	1	Stalker, 1960	
S1067	Rosalind	83A/16 Daysland	716	06-044-17-4	200	3	1	Stalker, 1960	
6510	McPherson Ck.	83F/6 Pedley	1372	23-051-24-5	4	3	3	Fox, 1984	1
3915	Obed Mountain	83F/12 Gregg Lake	1585	17-53-24-5	14	5	4		0
6369	Lodgepole	83G/3 Blue Rapids	1006	13-047-11-5	53	4	2	Richardson, 1984	1
6374	N. Sask. R.	83G/7 Tomahawk	732	22-050-06-5	106	4	1	Richardson, 1984	1
6379	Moon L.	83G/7 Tomahawk	823	16-052-07-5	113	4	2	Richardson, 1984	1
6380	Moon L.	83G/7 Tomahawk	831	10-052-07-5	112	4	2	Richardson, 1984	1
1066	Sturgeon R.	83G/9 Onoway	709	12-055-02-5	173	4	1	Edwards, 1984	1
6402	Heatherdown	83G/9 Onoway	748	12-054-02-5	162	4	2	Edwards, 1984	1
6403	Wabamun	83G/9 Onoway	777	18-053-03-5	145	4	2	Edwards, 1984	1
6404	Heatherdown	83G/9 Onoway	777	05-054-01-5	164	4	2	Edwards, 1984	1

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Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
S1079	Wabamun	83G/9 Onoway	755	11-053-04-5	150	*4*	*2*	Rutherford, 1937	
1081	Hoople L.	83G/10 Isle Lake	793	27-052-07-5	115	4	2	Allong, 1967	0
1083	Seba Beach	83G/10 Isle Lake	732	01-053-06-5	128	4	1	Allong, 1967	0
1084	Isle L.	83G/10 Isle Lake	739	36-052-06-5	127	4	1	Allong, 1967	0
1087	Isle L.	83G/10 Isle Lake	770	32-053-05-5	135	4	2	Allong, 1967	0
6411	Whitewood L.	83G/10 Isle Lake	793	21-053-04-5	139	4	2	Richardson, 1984	1
6412	Fallis	83G/10 Isle Lake	793	23-053-05-5	136	4	2	Richardson, 1984	1
6422	Magnolia	83G/10 Isle Lake	762	30-053-06-5	126	4	2	Richardson, 1984	1
6424	Entwhistle	83G/10 Isle Lake	793	21-053-07-5	120	4	2	Richardson, 1984	1
1013	Devon	83H/5 Leduc	648	07-051-25-4	167	4	1	Allong, 1967	0
1014	N. Sask. R.	83H/5 Leduc	648	16-052-25-4	179	4	1	Allong, 1967	0
1020	Ellerslie	83H/5 Leduc	671	08-052-24-4	184	4	1	Allong, 1967	0
1032	Edmonton	83H/5 Leduc	671	17-052-24-4	184	4	1	Allong, 1967	0
1036	Calmar	83H/5 Leduc	709	07-050-26-4	156	4	2	Allong, 1967	0
1074	Devon	83H/5 Leduc	648	06-051-25-4	166	4	1	Allong, 1967	0
1075	Woodbend	83H/5 Leduc	648	29-051-25-4	172	4	1	Allong, 1967	0
1101	Devon	83H/5 Leduc	701	30-050-26-4	159	4	2	Allong, 1967	0
6150	N. Sask. R.	83H/5 Leduc	640	19-050-27-4	148	4	1	Fox, 1984; Allong, 1967	1
1017	Clover Bar	83H/11 Edmonton	617	17-053-23-4	197	4	1	Allong, 1967	0
1021	Clover Bar	83H/11 Edmonton	648	17-053-23-4	198	4	1	Allong, 1967	0
1022	N. Sask. R.	83H/11 Edmonton	663	23-053-23-4	202	4	1	Allong, 1967	0
1023	N. Sask. R.	83H/11 Edmonton	625	22-053-23-4	201	4	1	Allong, 1967	0
1024	Clover Bar	83H/11 Edmonton	655	16-053-23-4	199	4	1	Allong, 1967	0
1025	N. Sask. R.	83H/11 Edmonton	648	26-053-23-4	202	4	1	Allong, 1967	0
1027	N. Sask. R.	83H/11 Edmonton	655	25-053-23-4	206	4	1	Allong, 1967	0
1028	Ft. Saskatchewan	83H/11 Edmonton	610	09-055-22-4	216	4	1	Allong, 1967	0
1030	Edmonton	83H/11 Edmonton	663	36-052-24-4	193	4	1	Allong, 1967	0
1033	N. Sask. R.	83H/11 Edmonton	663	07-053-23-4	195	4	1	Allong, 1967	0
1035	Ardrossan	83H/11 Edmonton	716	36-052-22-4	207	4	2	Allong, 1967	0
1102	Edmonton	83H/11 Edmonton	610	01-053-24-4	193	4	1	Allong, 1967	0

Group and Unit values for Sites are italicized

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
1103	Rundle Park	83H/11 Edmonton	617	12-053-24-4	194	4	1	Allong, 1967	0
1104	Edmonton	83H/11 Edmonton	625	03-053-24-4	190	4	1	Allong, 1967	0
6196	Clover Bar	83H/11 Edmonton	617	18-053-23-4	195	4	1	Fox, 1984; Allong, 1967	1
6197	Clover Bar	83H/11 Edmonton	625	20-053-23-4	198	4	1	Fox, 1984; Allong, 1967	1
6199	Clover Bar	83H/11 Edmonton	617	35-053-23-4	203	4	1	Fox, 1984; Allong, 1967	1
6200	Oliver	83H/11 Edmonton	617	10-054-23-4	205	4	1	Fox, 1984	1
6215	Ft. Saskatchewan	83H/11 Edmonton	655	07-055-22-4	216	4	1	Fox, 1984	1
6216	Clover Bar	83H/11 Edmonton	655	08-053-23-4	196	4	1	Fox, 1984	1
S1081	N. Saskatchewan R.	83H/11 Edmonton	640	30-053-23-4	192	*4*	*1*	Rutherford, 1937	
S1091	Edmonton	83H/11 Edmonton	640	13-053-24-4	188	*4*	*1*	Rutherford, 1936	
1105	Edmonton	83H/12 St. Albert	739	06-054-27-4	182	4	2	Allong, 1967	0
3974	Gladu L.	83H/12 St. Albert	732	09-054-27-4	174	4	2	Edwards, 1984	1
3975	Villeneuve	83H/12 St. Albert	674	20-054-26-4	178	4	1	Edwards, 1984	1
6221	Spruce Grove	83H/12 St. Albert	671	06-053-27-4	164	4	1	Edwards, 1984	1
S1000	Edmonton	83H/12 St. Albert	640	E33-051-26-4	160	*4*	*1*	Carlson, 1967	
S1001	Edmonton	83H/12 St. Albert	649	12-052-27-4	160	*4*	*1*	Carlson, 1967	
S1003	Edmonton	83H/12 St. Albert	632	11-053-25-4	180	*4*	*1*	Carlson, 1967	
S1004	Edmonton	83H/12 St. Albert	647	19-053-25-4	175	*4*	*1*	Carlson, 1967	
S1005	Edmonton	83H/12 St. Albert	606	32-053-25-4	180	*4*	*1*	Carlson, 1967	
S1006	Edmonton	83H/12 St. Albert	632	02-054-26-4	177	*4*	*1*	Carlson, 1967	
S1087	Muir L.	83H/12 St. Albert	754	28-053-27-4	165	*4*	*2*	Rutherford, 1936,1937	
S1088	Muir L.	83H/12 St. Albert	754	32-053-27-4	165	*4*	*2*	Rutherford, 1936,1937	
S1094	N. Saskatchewan R.	83H/12 St. Albert	648	N36-052-25-4	180	*4*	*1*	Rutherford, 1936	
3973	Swan Hills	83J Whitecourt	1326	36-066-10-5	186	5	4	Vonhof, 1969	0
6551	Romeo Ck.	83J/2 Thunder Lake	655	21-058-06-5	161	4	1	Sham, 1984	1
6573	Whitecourt Tower	83J/4 Whitecourt	1158	21-058-12-5	121	5	3	Peterson, 1984	1
6582	Windfall	83K/1 Windfall Creek	899	04-060-15-5	111	5	2	Peterson, 1984	1
3914	Smoky Tower	83L/8 Amundson	1189	31-062-02-6	60	5	3		1
4028	Simonette River	83M/1 Debolt	501	12-071-02-6	117	6	1	Peterson, 1984	1
4212	Watino	83N/12 Watino	379	34-077-24-5	186	6	1	Liverman et al, 1989	0

Group and Unit values for Sites are italicized

Appendix A. Preglacial sand and gravel deposits and sites.

Deposit Site(S)	Area	NTS Map Area	Elevation (m)	Location	Distance to foothills (km)	Group	Unit	References	Aggregate Potential
S1009	Watino	83N/12 Watino	420	15-077-24-5	188	*6*	*1*	Henderson, 1959	
4447	Avenir	83P Pelican	579	16-32-69-15-4	364	5	2	Scafe et al, 1989	1
6819	Pelican Mtn.	83P/11	914	26-076-23-4	349	5	3	Scafe et al, 1987	1
6823	Pelican Mtn.	83P/11	884	22-076-23-4	347	5	3	Scafe et al, 1987	1
6818	Pelican Mtn.	83P/12	884	35-075-25-4	330	5	3	Scafe et al, 1987	1
6820	Pelican Mtn.	83P/12	853	18-076-25-4	329	5	3	Scafe et al, 1987	1
6821	Pelican Mtn.	83P/12	884	31-076-23-4	346	5	3	Scafe et al, 1987	1
6822	Pelican Mtn.	83P/12	884	33-076-23-4	348	5	3	Scafe et al, 1987	1
6824	Pelican Mtn.	83P/12	884	33-075-26-4	320	5	3	Scafe et al, 1987	1
6692	Grimshaw	84C Peace River	633	32-083-23-5	208	6	2	Fox et al, 1987	1
6693	Grimshaw	84C Peace River	610	34-082-24-5	218	6	2	Fox et al, 1987	1
1093	Eureka R.	84D/7 Eureka River	701	29-086-05-6	189	6	2	Allong, 1967	0
6812	Halverson Ridge	84E Chinchaga River	975	08-096-06-6	225	6	3	Scafe et al, 1988	1
6813	Halverson Ridge	84E Chinchaga River	975	22-096-06-6	229	6	3	Scafe et al, 1988	1
6814	Halverson Ridge	84E Chinchaga River	875	01-096-06-6	230	6	3	Scafe et al, 1988	1
6815	Halverson Ridge	84E Chinchaga River	890	07-096-04-6	240	6	3	Scafe et al, 1988	1
6816	Halverson Ridge	84E Chinchaga River	975	36-094-07-6	217	6	3	Scafe et al, 1988	1
S1205	Caribou Mountains	84O Whitesand River	914	06-120-08-5	515	*6*	*3*	Bayrock, 1961	0

Group and Unit values for Sites are italicized

Appendix B

Preglacial sample site descriptions

The deposit Name is the general area name and the Deposit is the unique number. The sample Number/Type refers to the number of trench samples, M denotes a sand matrix sample, and P denotes a panned concentrate. Locations of sample sites given in UTM were obtained from a Global Positioning System, those given in DLS were determined from a topographic map.

Appendix B. Sample site descriptions. The sample number refers to trench samples, M denotes a sand matrix sample, and P denotes a panned concentrate.

Name	Deposit	Number/Type	Location		Site Description
Halverson	6815	1	6352200N	400800E	0.5 m above current mining bench in 6.5 m north face
		2			0.5 m above current mining bench in 6.5 m north face
		3			1.5 m above current mining bench in 6.5 m north face
Grimshaw	6692	1	6231700N	463500E	south face, 1.0 m above base of pit
		2			south face, 1.0 m above base of pit
		3			south face, 1.0 m above base of pit
Grimshaw (Fairview)	6692	M			50 m south of north face, above middle lag, 4.0 m above base of pit
Simonette	4028	1-12	6110850N	425000E	north face, sample 1 below upper sand contact, each sample is a 0.5 m composite
Watino	4212	1	9-34-77-24-W5		north face, main section, 4.0 m above river level
		2			north face, main section, 7.0 m above river level
		3			north face, east section, 10.0 m above river level
Swan Hills	3973	1	6067000N	567800E	north face, 2.75 m above iron stained sand
Pelican	6824	1	6158700N	312000E	2.5 m below till on east face
		2			middle of east face in 1.0 m sand stringer
		3			lowest sample, 3.0 m above pit floor on west face
Smoky Tower	3914	M	6028900N	417400E	from 2.5 m face
Obed	3915	M	5935917N	466723E	upper pit, 2.0 m above base and 4 m below top
Whitecourt	6573	M	5986750N	583500E	3.5 m below till contact
Entwistle S.	6424	M	9-5-53-7-W5		2.0 m above base
Entwistle W.	6424	M	9-17-53-7-W5		5.0 m above base
Entwistle N.	6424	M	8-21-53-7-W5		from 2.0 m exposure above water level
Magnolia	6422	M	1-30-53-6-W5		2.0 m above pit floor
Heatherdown	6402				3.0 m below till
Villeneuve	3975	M			7.0 m below till
Wetaskiwin	6119	1	5864200N	344300E	west face, 1.25 m below till contact
Wetaskiwin	6118	P			
Lacombe	6106	1	5819500N	305500E	lowest sample, 0.5 m above pit base
		2			low-middle sample, 4.0 m below upper contact
		3			highest sample, 2.0 m below upper contact

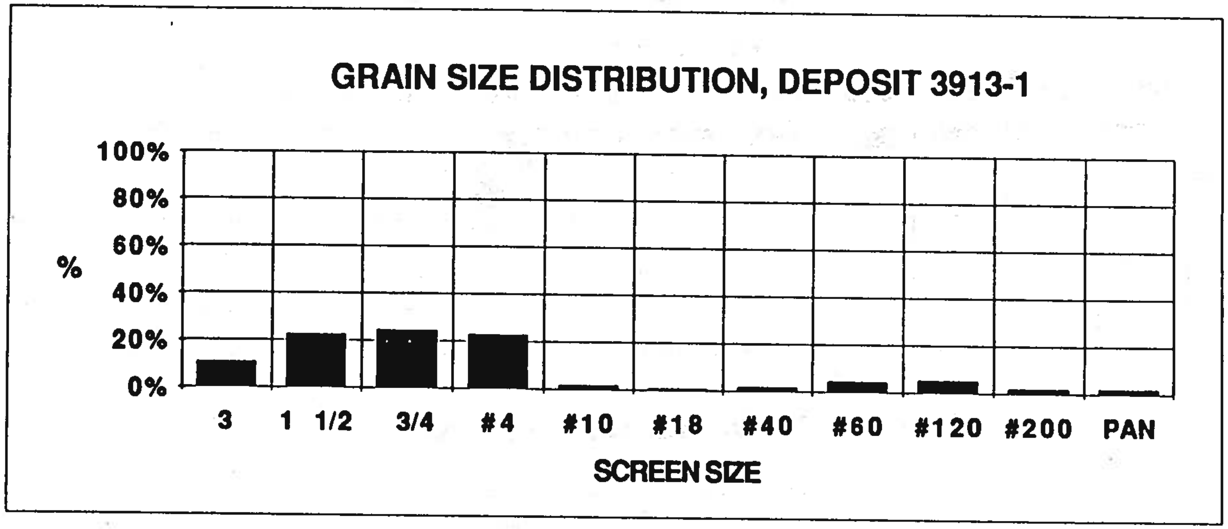
Name	Deposit	Number/Type	Location	Site Description
Hand Hills	3958	1	5709600N 405900E	immediately below widespread sand bed
		2		from sand bed
		3		immediately above pit floor
Wintering Hills	3971	1	5678800N 398500E	immediately above cobble/boulder lag 2.0 m above pit floor
		2		immediately below cobble/boulder lag in center of pit
		3		immediately below cobble/boulder lag in east end of pit
Hand Hills (east)	3964	1	6-6-30-15-W4	1.5 m below till contact
		2		2.5 m below till contact
		3		0.5 m above pit floor
Arrowwood	5855	1	16-17-20-23-W4	2.0 m above pit floor
Calgary	6050	1	5661900N 692800E	lowest sample from horizontal beds 5.0 m below till contact
		2		highest sample 2.0 m below till contact
		3		lowest sample from cross-beds 5.0 m below till contact
Cluny	3913	1	12-11-22-21-W4	highest sample, uncertain if in place
		2		1.5 m below former upper contact
		3		lowest sample collected 2.5 m below former upper contact
Nanton	5812	1	5595600N 289400E	3.0 m below till contact
Del Bonita (west)	5566	1	2-6-2-22-W4	1.5 m below till contact
Del Bonita (east)	5570	1	12-17-1-21-W4	highest sample, 1.0 m below till
		2		1.5 m below till
		3		2 m below till
Magrath	5669	1	5468824N 367537E	3.0 m below till
		M		3.0 m below till
Cypress Hills	4213	M	5-28-7-2-W4	10.5 m section

Appendix C
Grain size distributions for preglacial samples

CLUNY 3913-1

WEIGHT= 244.49 KG

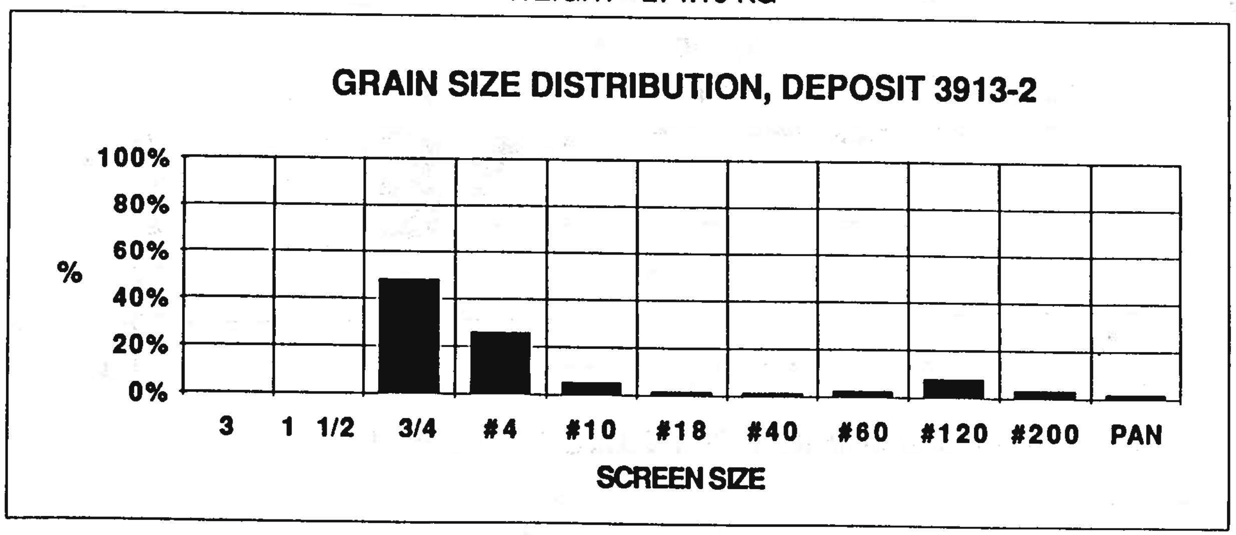
SCREEN	RETAINED
3	11%
1 1/2	23%
3/4	25%
#4	23%
#10	2%
#18	1%
#40	2%
#60	5%
#120	5%
#200	2%
PAN	2%
	100%



CLUNY 3913-2

WEIGHT= 274.10 KG

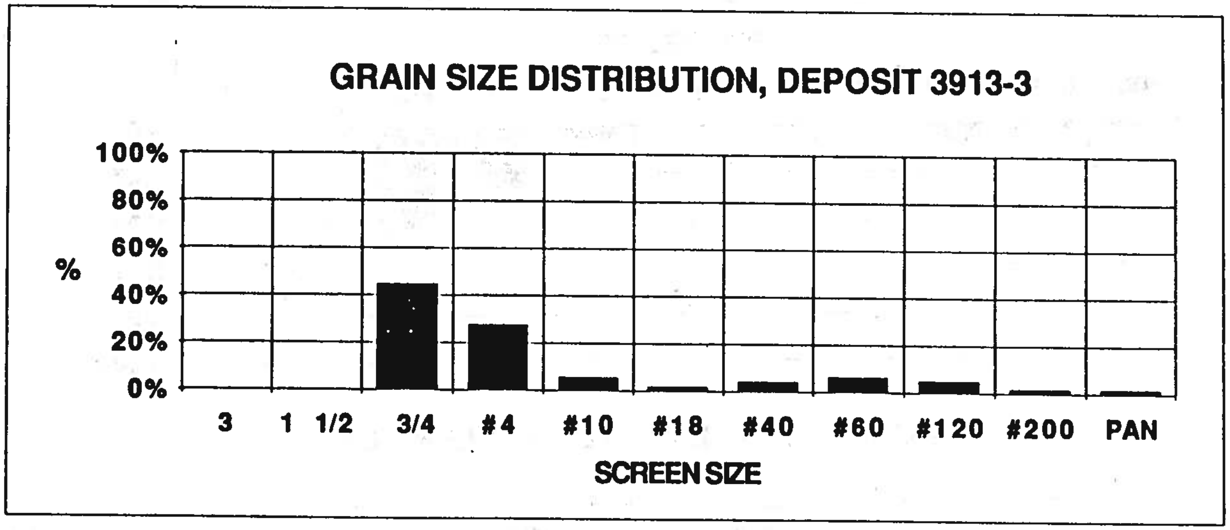
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	48%
#4	26%
#10	6%
#18	2%
#40	1%
#60	3%
#120	8%
#200	3%
PAN	2%
	100%



CLUNY 3913-3

WEIGHT= 267.14 KG

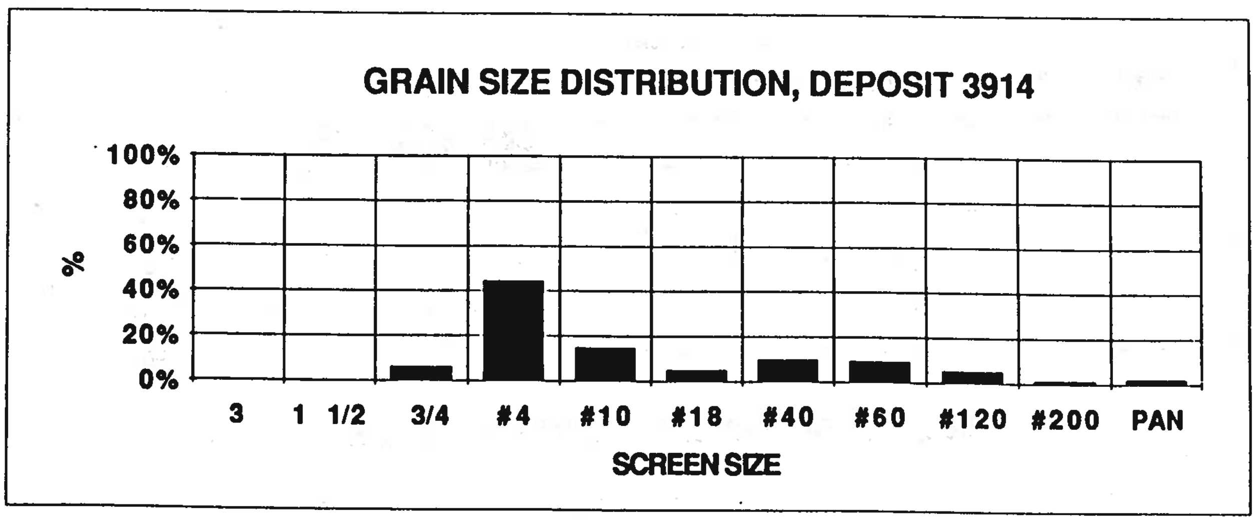
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	45%
#4	28%
#10	6%
#18	2%
#40	4%
#60	6%
#120	5%
#200	2%
PAN	2%
	100%



SMOKY TOWER 3914

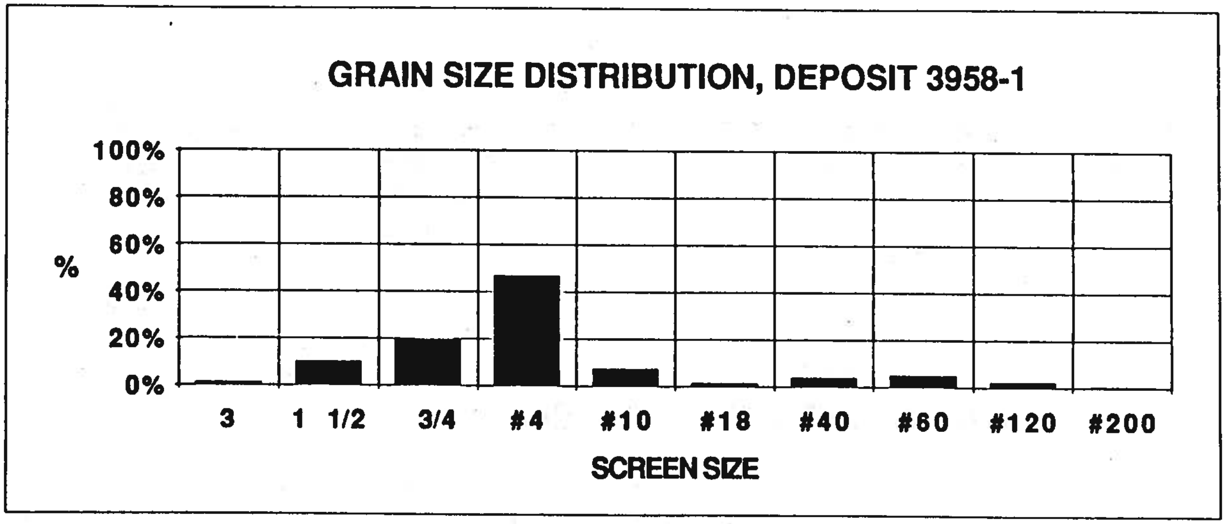
WEIGHT= 18.73 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	6%
#4	45%
#10	15%
#18	5%
#40	10%
#60	10%
#120	5%
#200	2%
PAN	2%
	100%



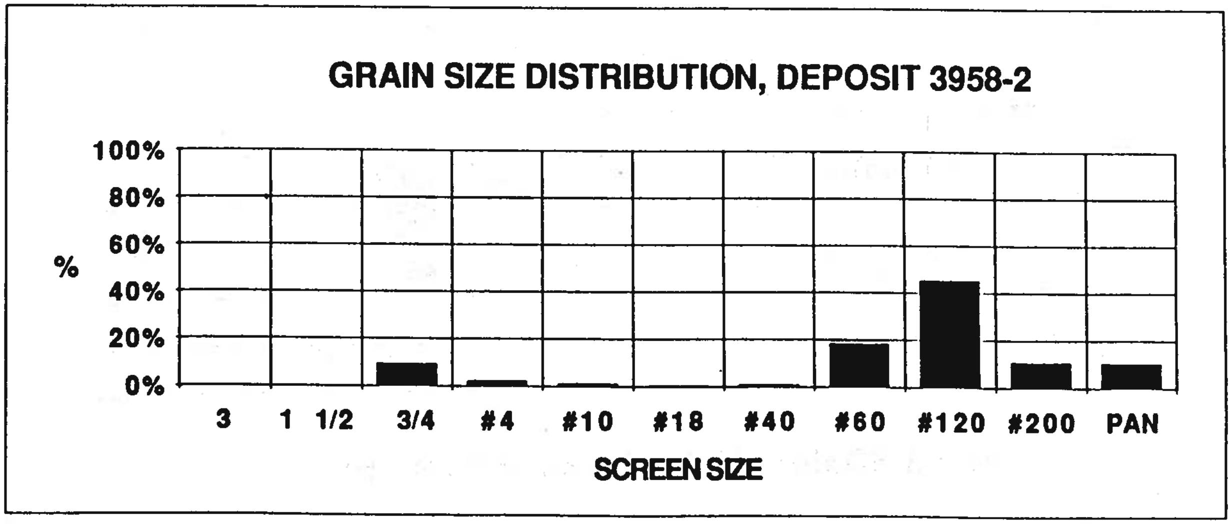
HAND HILLS 3958-1 WEIGHT= 207.65 KG

SCREEN	RETAINED
3	1%
1 1/2	10%
3/4	20%
#4	47%
#10	8%
#18	2%
#40	4%
#60	5%
#120	3%
#200	0%
PAN	0%
	100%



HAND HILLS 3958-2 WEIGHT= 135.88 KG

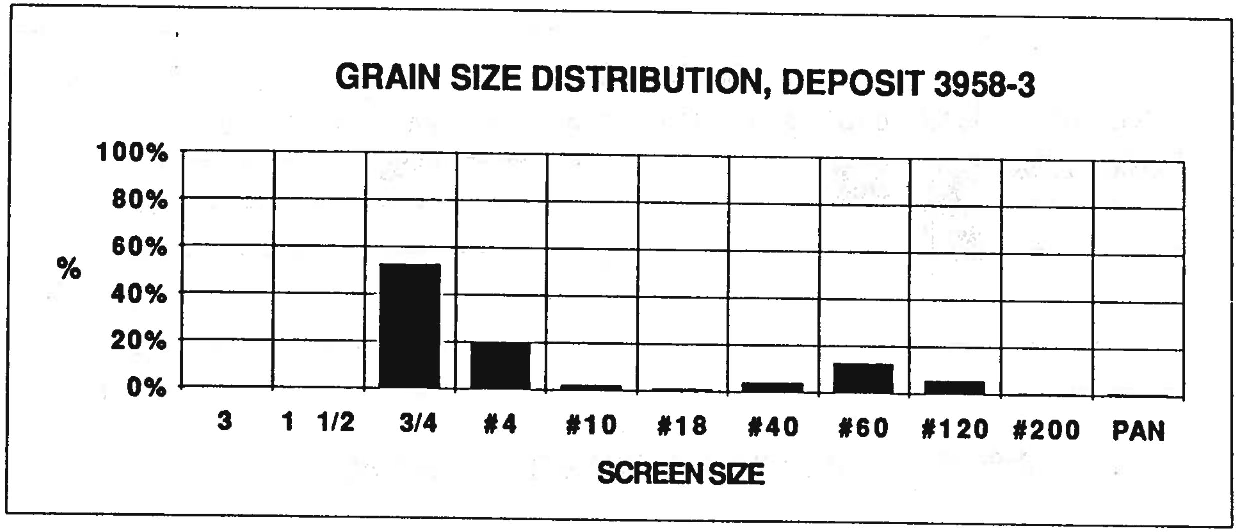
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	10%
#4	3%
#10	1%
#18	0%
#40	1%
#60	18%
#120	45%
#200	11%
PAN	11%
	100%



HAND HILLS 3958-3

WEIGHT= 135.88 KG

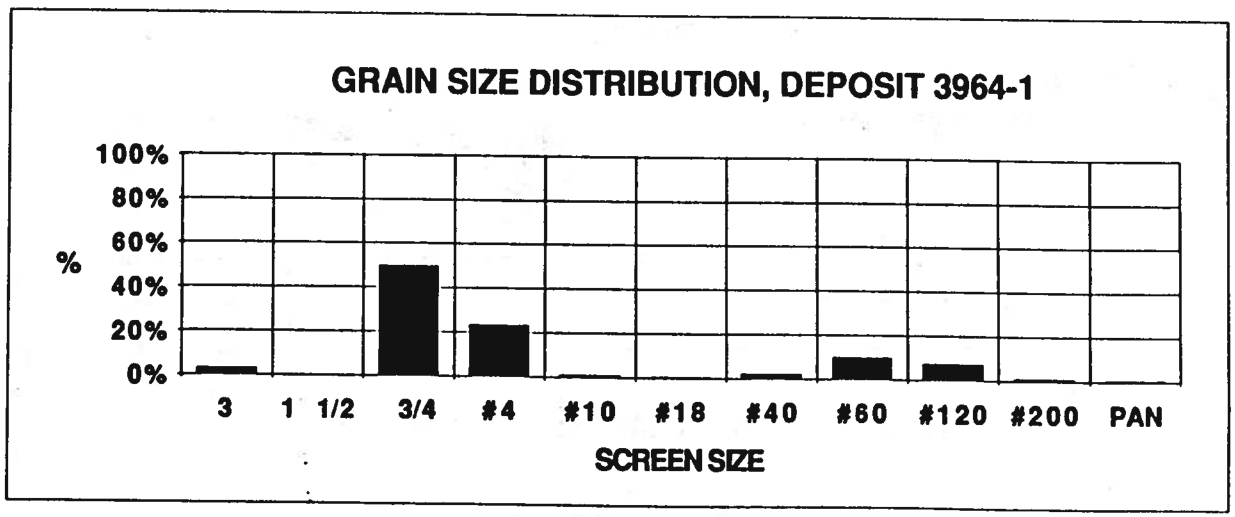
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	53%
#4	20%
#10	2%
#18	1%
#40	4%
#60	13%
#120	6%
#200	1%
PAN	1%
	100%



HAND HILLS LAKE 3964-1

WEIGHT= 191.63 KG

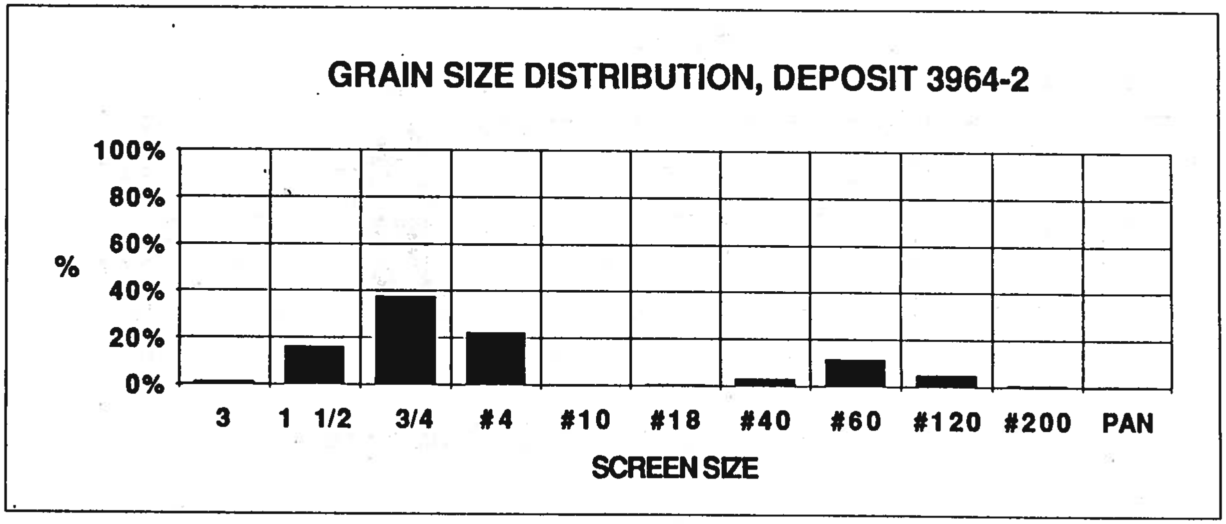
SCREEN	RETAINED
3	3%
1 1/2	0%
3/4	50%
#4	23%
#10	1%
#18	0%
#40	2%
#60	10%
#120	8%
#200	1%
PAN	0%
	100%



HAND HILLS LAKE 3964-2

WEIGHT= 196.98 KG

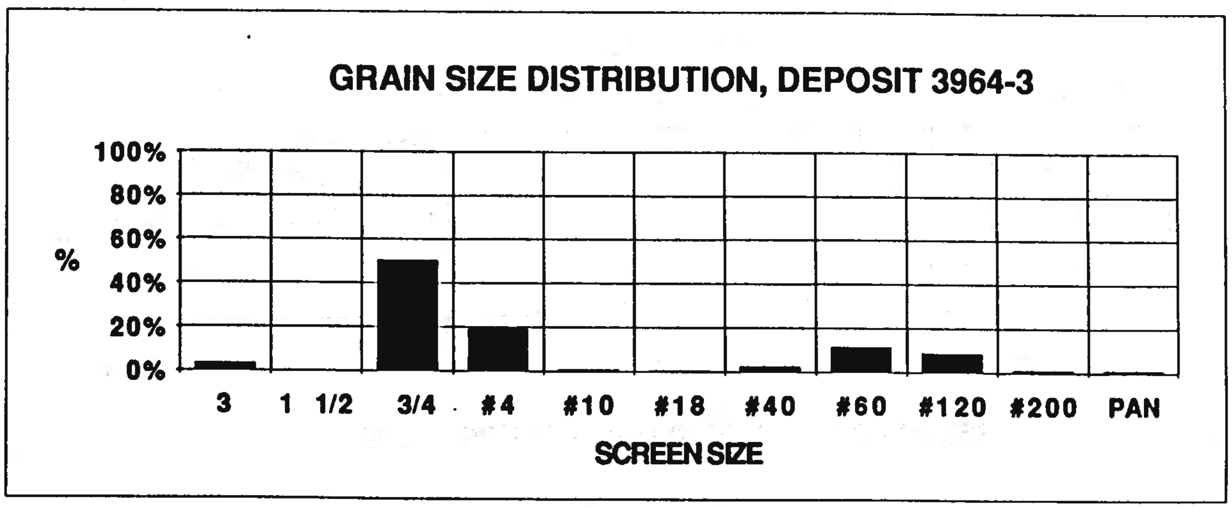
SCREEN	RETAINED
3	1%
1 1/2	17%
3/4	38%
#4	23%
#10	0%
#18	0%
#40	3%
#60	12%
#120	5%
#200	1%
PAN	0%
	100%



HAND HILLS LAKE 3964-3

WEIGHT= 246.50 KG

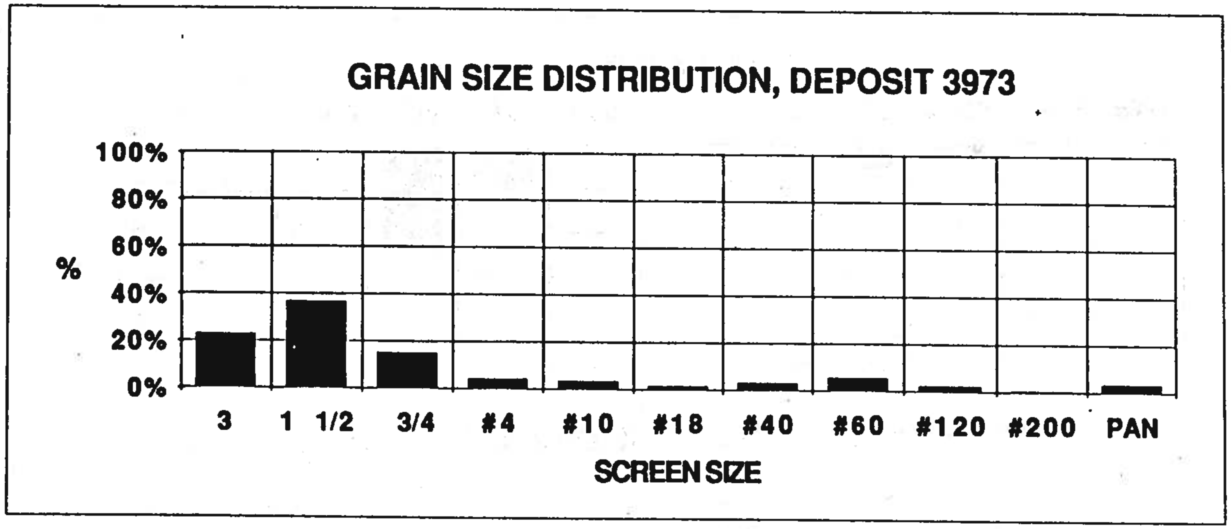
SCREEN	RETAINED
3	4%
1 1/2	0%
3/4	51%
#4	19%
#10	1%
#18	0%
#40	2%
#60	12%
#120	9%
#200	1%
PAN	1%
	100%



SWAN HILLS 3973

WEIGHT= 243.32 KG

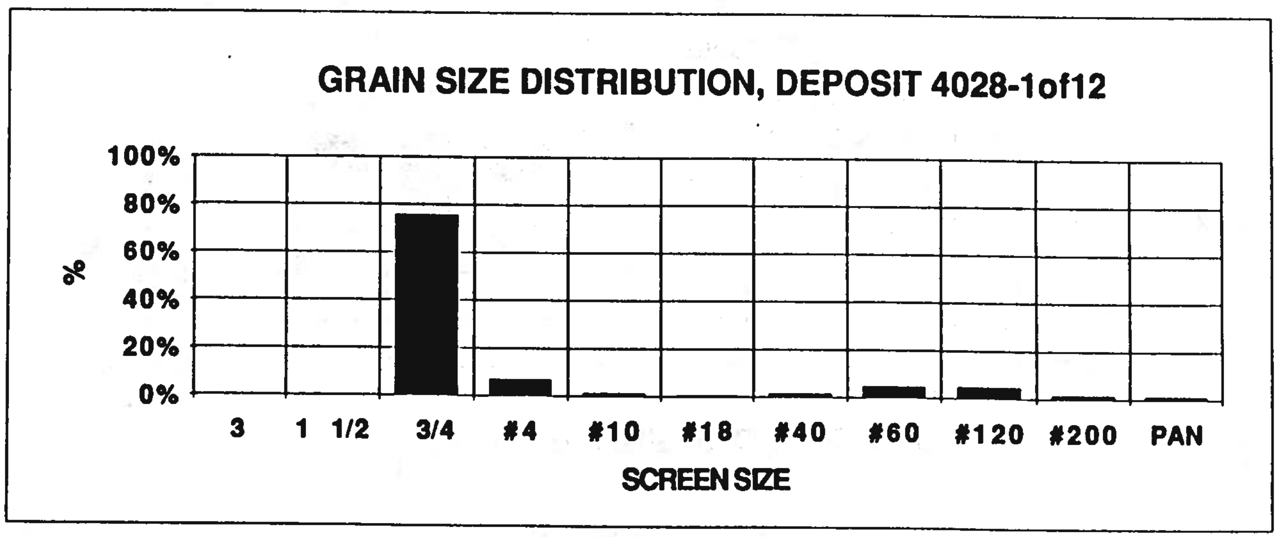
SCREEN	RETAINED
3	23%
1 1/2	37%
3/4	15%
#4	4%
#10	4%
#18	2%
#40	3%
#60	6%
#120	2%
#200	1%
PAN	3%
	100%



SIMONNETTE R. 4028-1 of 12

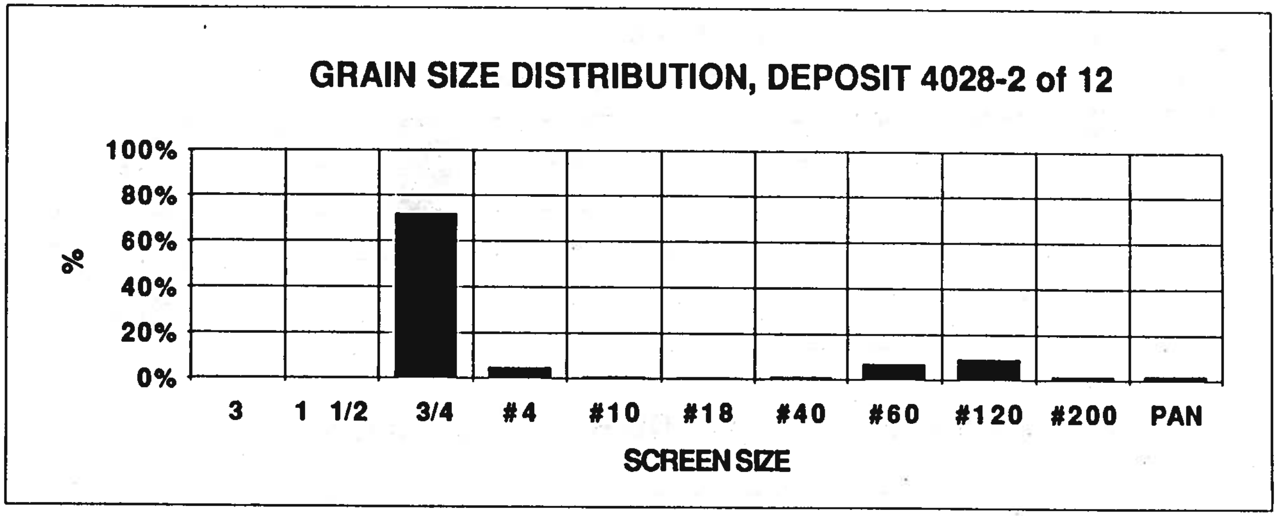
WEIGHT= 20.68 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	76%
#4	7%
#10	1%
#18	0%
#40	2%
#60	5%
#120	5%
#200	2%
PAN	1%
	100%



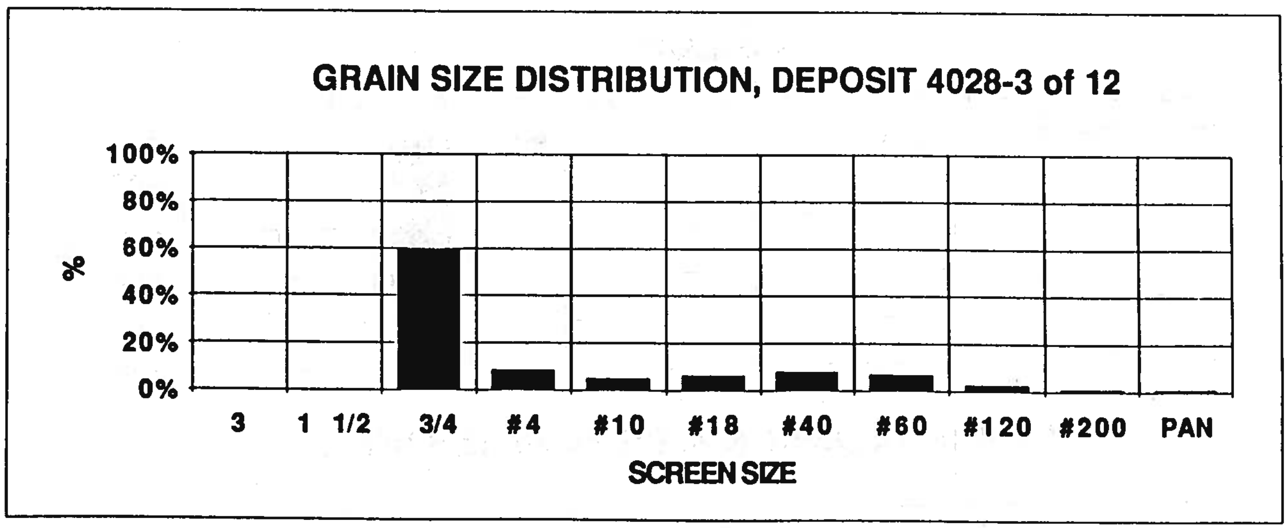
SIMONNETTE R. 4028-2 of 12 WEIGHT= 21.75 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	72%
#4	5%
#10	1%
#18	0%
#40	1%
#60	7%
#120	9%
#200	2%
PAN	2%
	100%



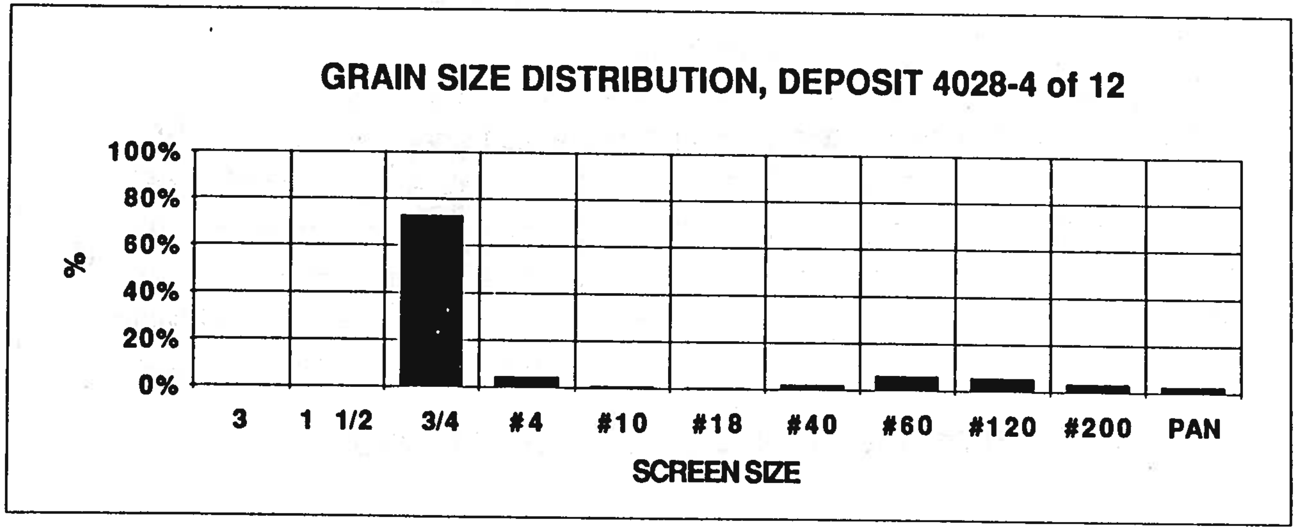
SIMONNETTE R. 4028-3 of 12 WEIGHT= 19.65 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	60%
#4	9%
#10	5%
#18	6%
#40	8%
#60	7%
#120	3%
#200	1%
PAN	1%
	100%



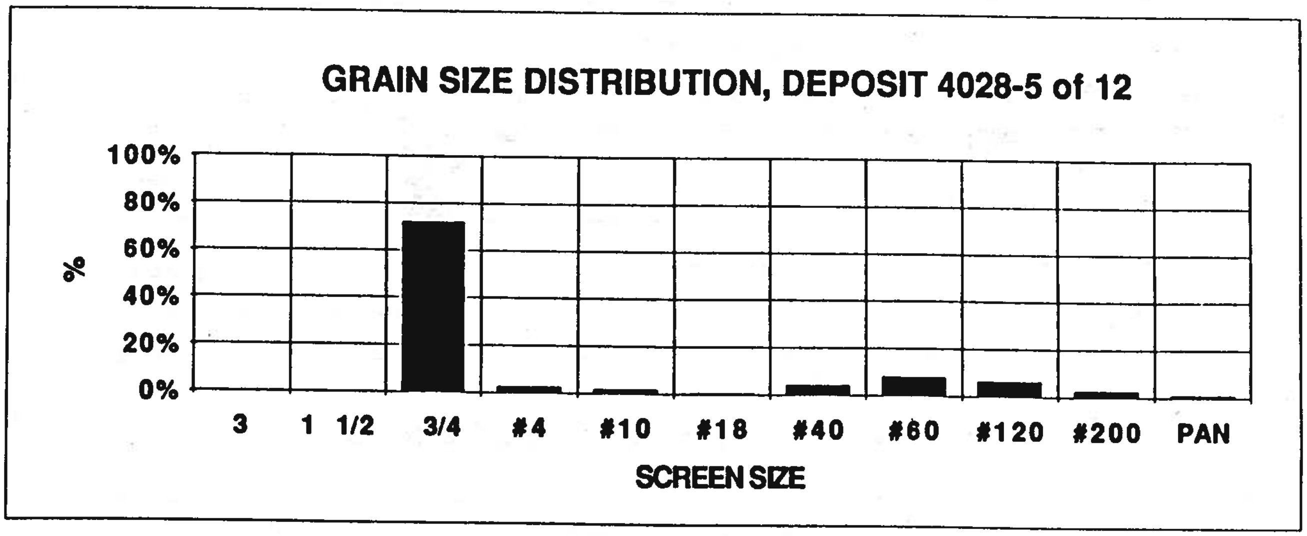
SIMONNETTE R. 4028-4 of 12 WEIGHT= 22.65 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	73%
#4	5%
#10	1%
#18	1%
#40	2%
#60	6%
#120	6%
#200	4%
PAN	3%
	100%



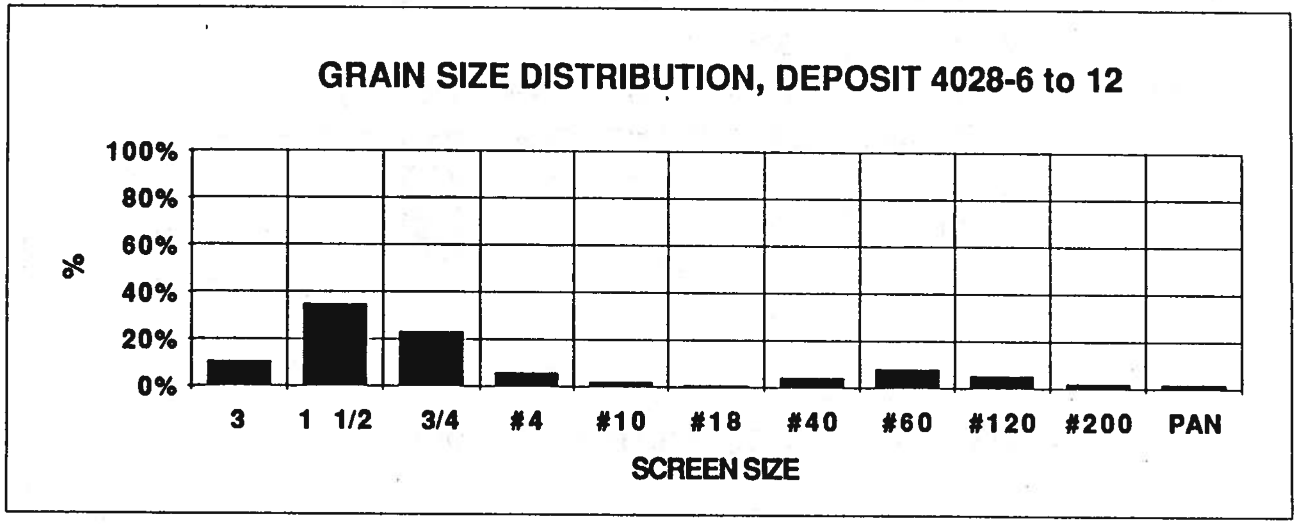
SIMONNETTE R. 4028-5 of 12 WEIGHT= 20.70 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	72%
#4	3%
#10	2%
#18	0%
#40	4%
#60	8%
#120	6%
#200	3%
PAN	1%
	100%



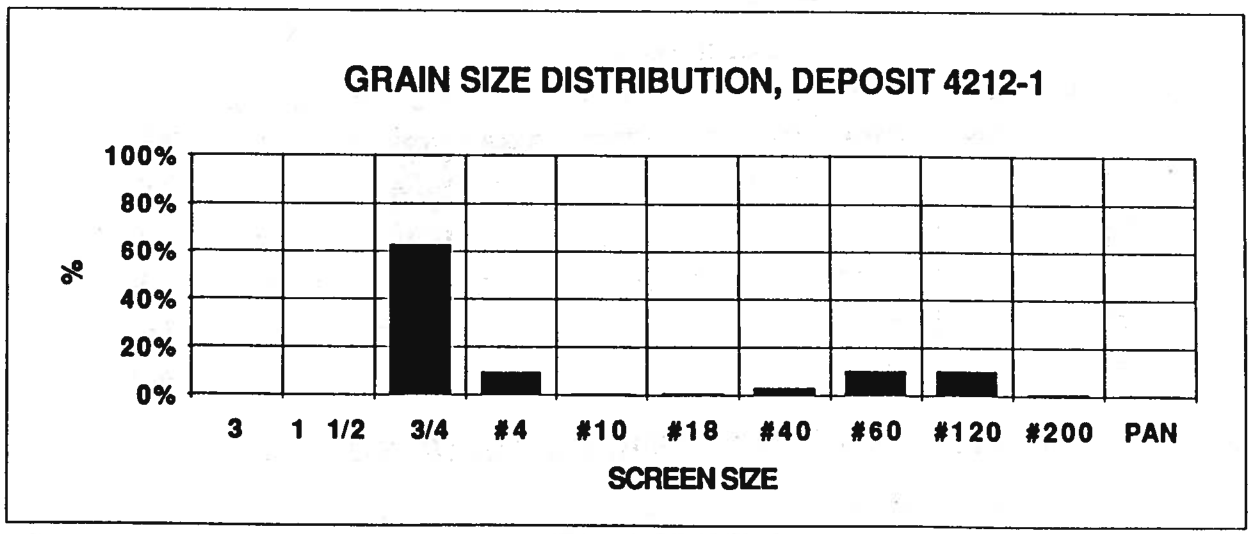
SIMONNETTE R. 4028-6 to 12 WEIGHT= 140.73 KG

SCREEN	RETAINED
3	11%
1 1/2	35%
3/4	23%
#4	6%
#10	2%
#18	1%
#40	4%
#60	8%
#120	5%
#200	2%
PAN	2%
	100%



WATINO 4212-1 WEIGHT= 240.89 KG

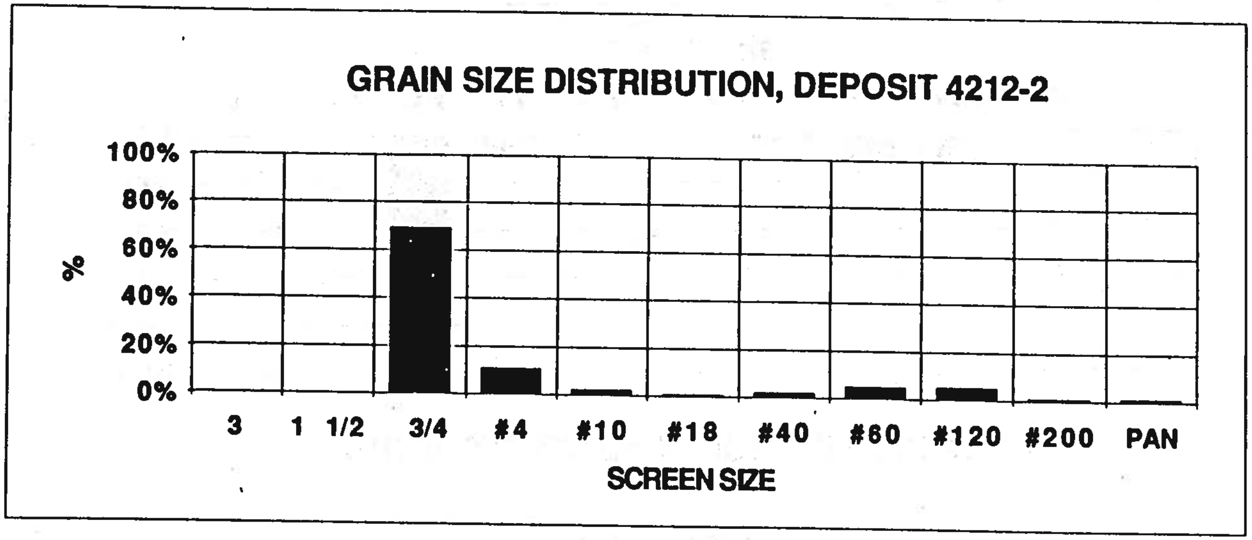
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	63%
#4	10%
#10	1%
#18	1%
#40	3%
#60	11%
#120	11%
#200	1%
PAN	1%
	100%



WATINO 4212-2

WEIGHT= 238.39 KG

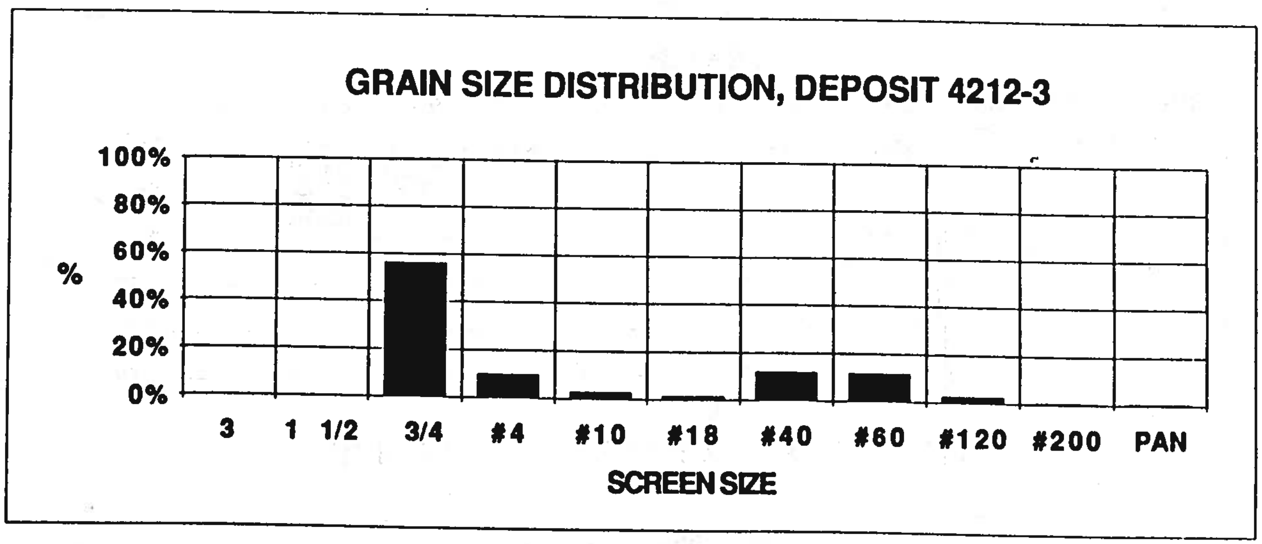
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	70%
#4	11%
#10	3%
#18	1%
#40	2%
#60	5%
#120	6%
#200	1%
PAN	1%
	100%



WATINO 4212-3

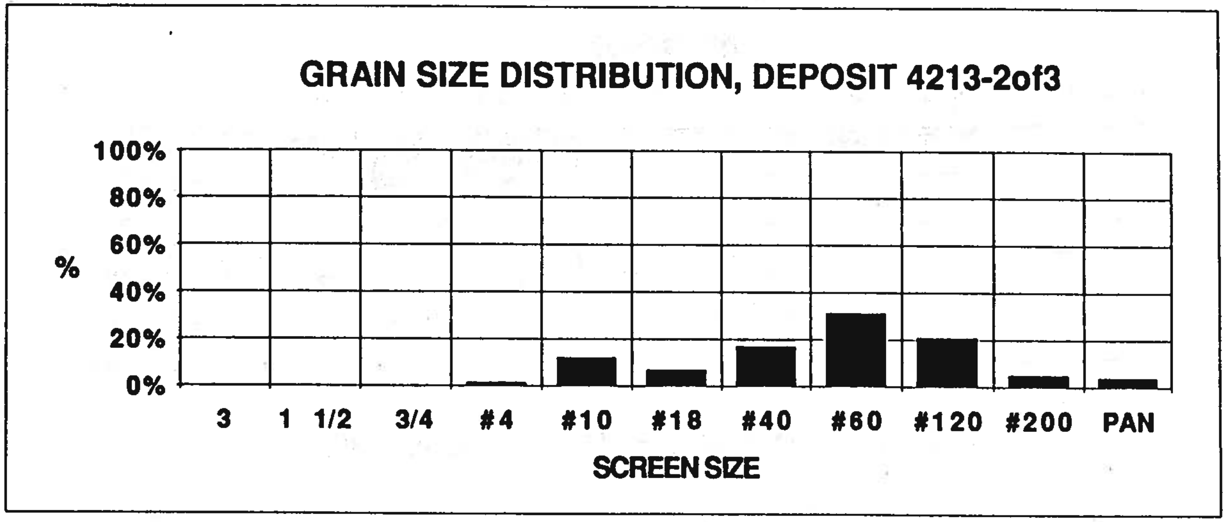
WEIGHT= 233.50 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	56%
#4	10%
#10	3%
#18	2%
#40	12%
#60	12%
#120	3%
#200	1%
PAN	1%
	100%



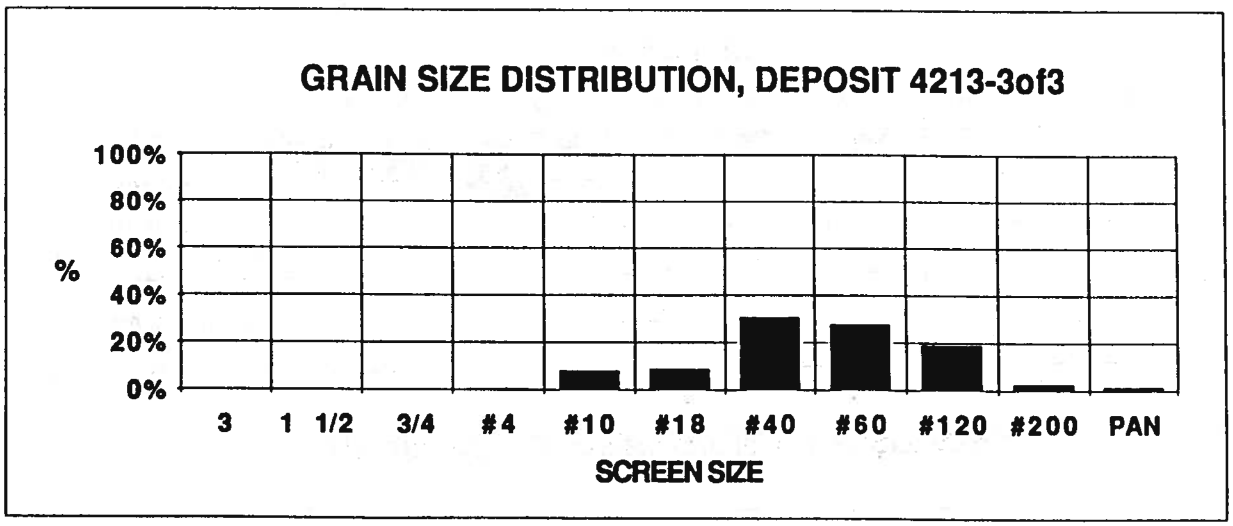
CYPRESS HILLS 4213-2 of 3 WEIGHT= 12.15 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	0%
#4	2%
#10	12%
#18	7%
#40	17%
#60	31%
#120	21%
#200	5%
PAN	4%
	100%



CYPRESS HILLS 4213-3 of 3 WEIGHT= 12.00 KG

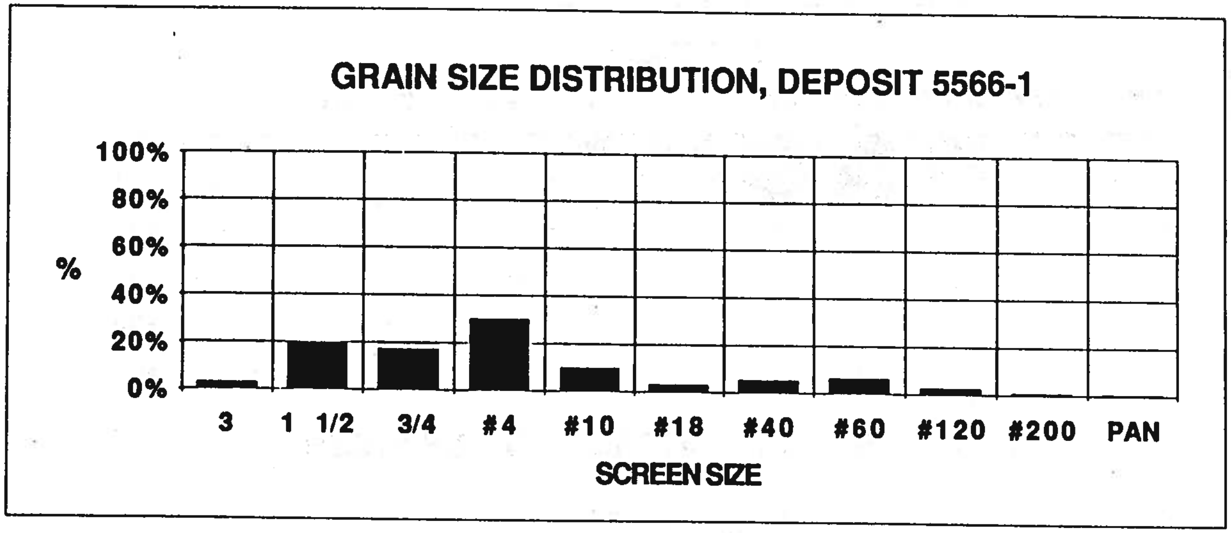
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	0%
#4	0%
#10	8%
#18	9%
#40	31%
#60	28%
#120	19%
#200	3%
PAN	2%
	100%



PETERS CK. 5566-1
DEL BONITA (WEST)

SCREEN	RETAINED
3	3%
1 1/2	20%
3/4	17%
#4	30%
#10	10%
#18	3%
#40	5%
#60	7%
#120	3%
#200	1%
PAN	1%
	100%

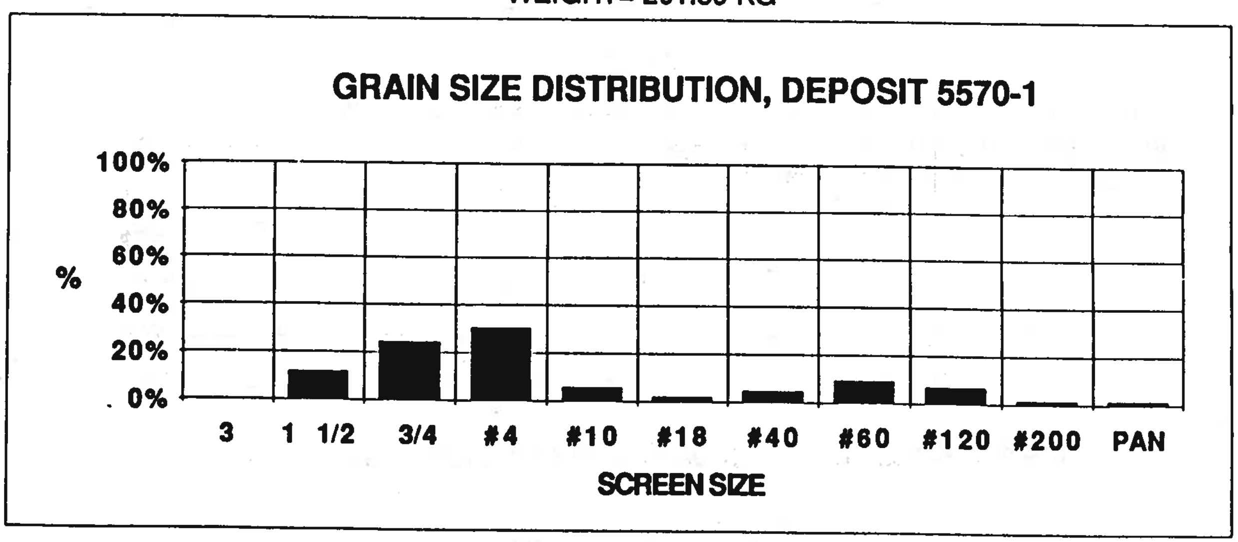
WEIGHT= 263.09 KG



DEL BONITA 5570-1

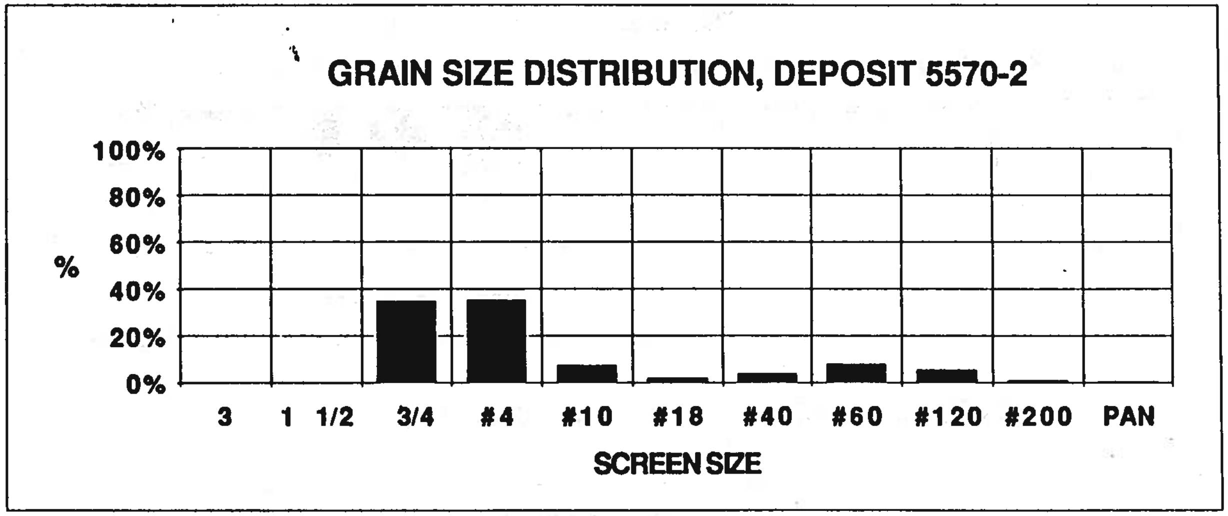
SCREEN	RETAINED
3	0%
1 1/2	12%
3/4	25%
#4	31%
#10	6%
#18	2%
#40	5%
#60	9%
#120	7%
#200	2%
PAN	2%
	100%

WEIGHT= 201.59 KG



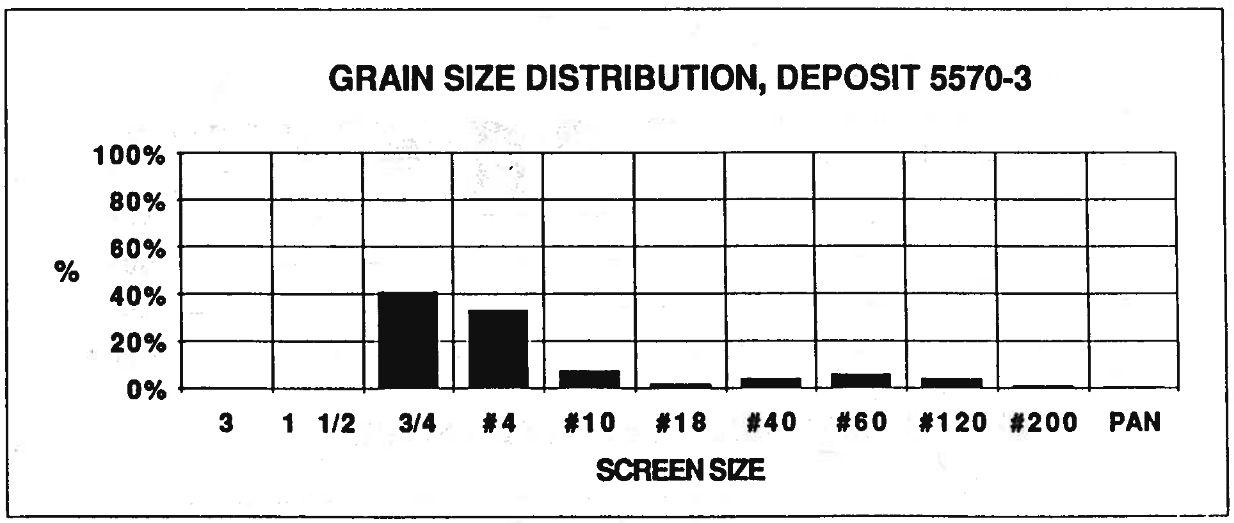
DEL BONITA 5570-2 WEIGHT= 220.81 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	35%
#4	36%
#10	8%
#18	2%
#40	4%
#60	8%
#120	6%
#200	1%
PAN	1%
	100%



DEL BONITA 5570-3 WEIGHT= 211.99 KG

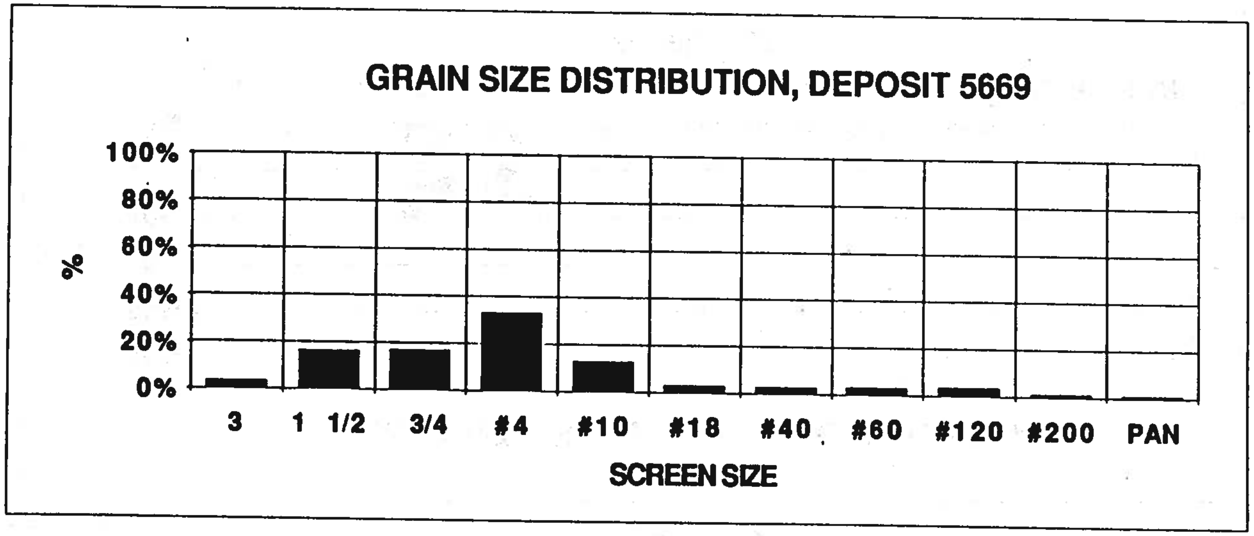
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	41%
#4	33%
#10	8%
#18	2%
#40	4%
#60	6%
#120	4%
#200	1%
PAN	1%
	100%



MAGRATH 5669

WEIGHT= 38.84 KG

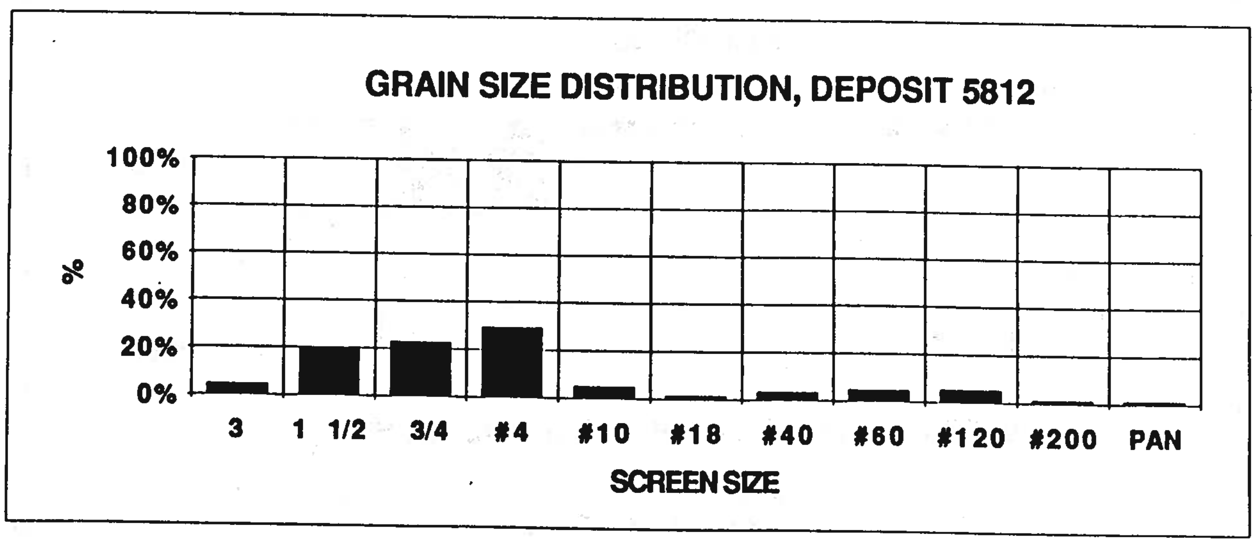
SCREEN	RETAINED
3	3%
1 1/2	17%
3/4	17%
#4	33%
#10	13%
#18	3%
#40	3%
#60	3%
#120	4%
#200	1%
PAN	1%
	100%



NANTON 5812

WEIGHT= 264.15 KG

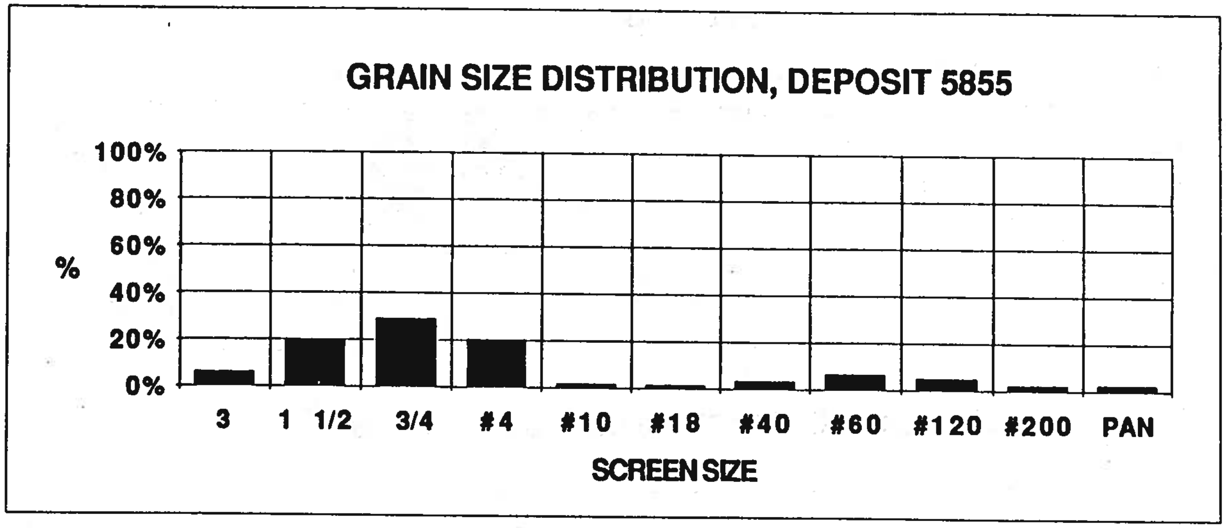
SCREEN	RETAINED
3	5%
1 1/2	19%
3/4	23%
#4	30%
#10	5%
#18	2%
#40	3%
#60	5%
#120	5%
#200	1%
PAN	1%
	100%



BUFFALO HILL 5855

WEIGHT= 269.93 KG

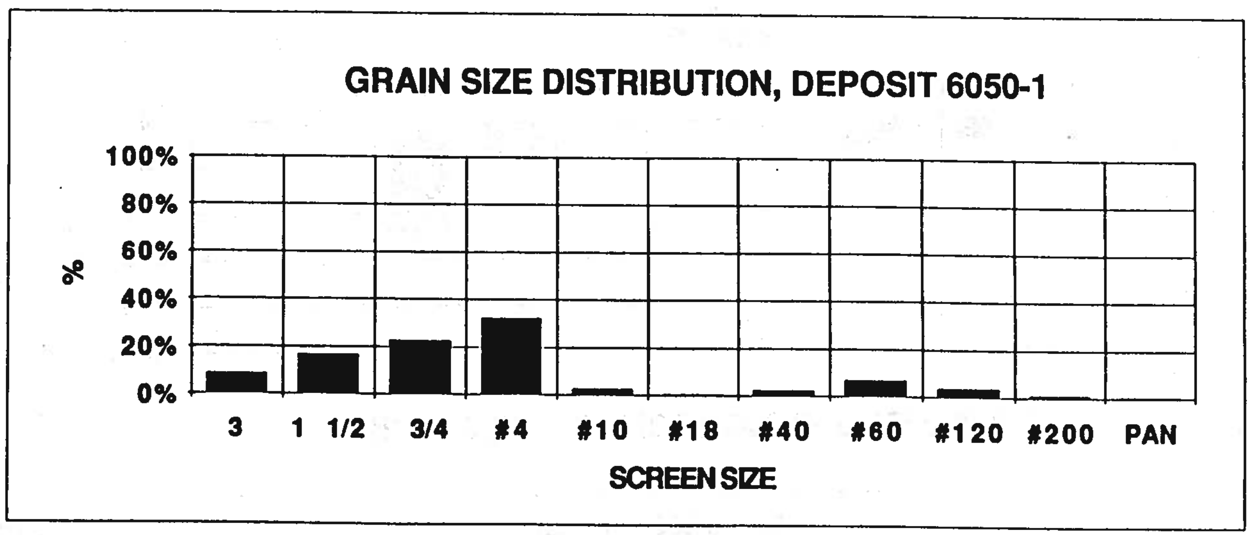
SCREEN	RETAINED
3	6%
1 1/2	20%
3/4	29%
#4	21%
#10	2%
#18	2%
#40	4%
#60	7%
#120	5%
#200	2%
PAN	3%
	100%



OLYMPIC HILL 6050-1

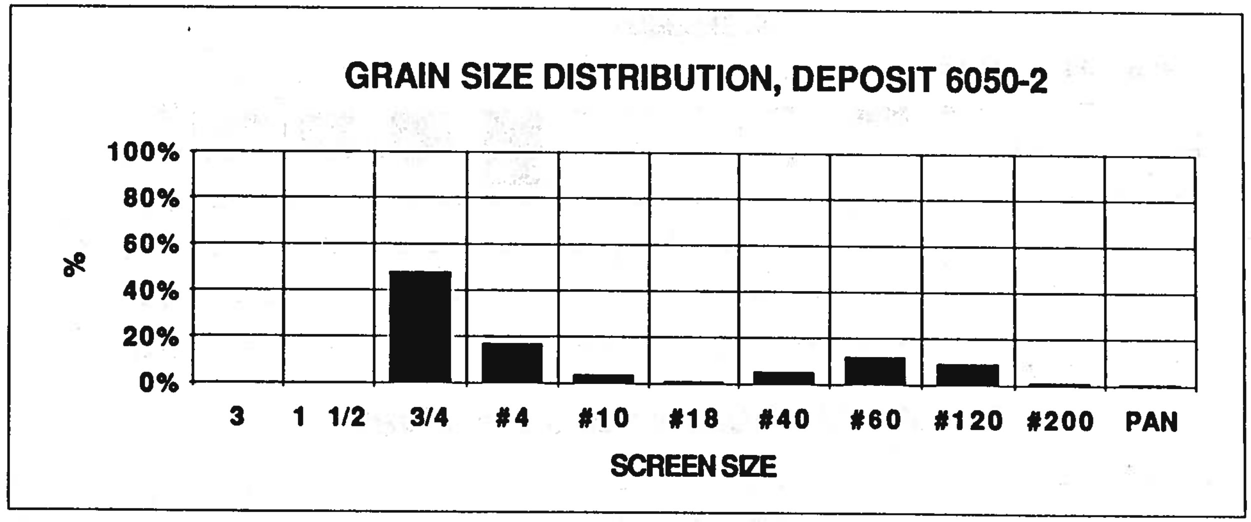
WEIGHT= 276.68 KG

SCREEN	RETAINED
3	9%
1 1/2	17%
3/4	23%
#4	33%
#10	3%
#18	1%
#40	3%
#60	7%
#120	4%
#200	1%
PAN	1%
	100%



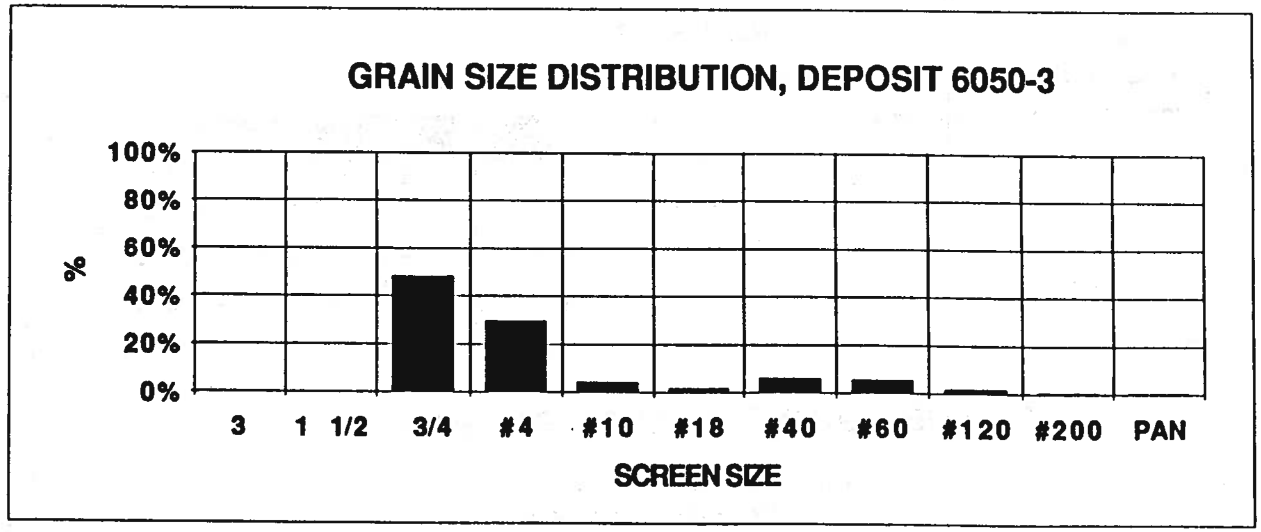
OLYMPIC HILL 6050-2 WEIGHT= 239.87 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	48%
#4	17%
#10	4%
#18	1%
#40	6%
#60	12%
#120	10%
#200	1%
PAN	1%
	100%



OLYMPIC HILL 6050-3 WEIGHT= 270.42 KG

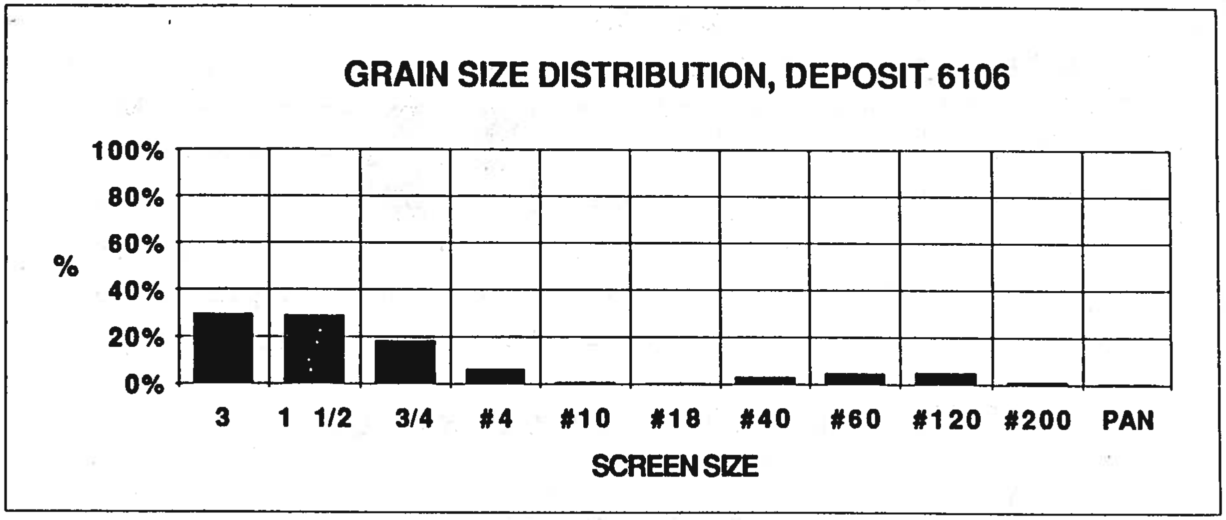
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	48%
#4	30%
#10	4%
#18	2%
#40	6%
#60	6%
#120	2%
#200	1%
PAN	0%
	100%



LACOMBE 6106

WEIGHT= 165.20 KG

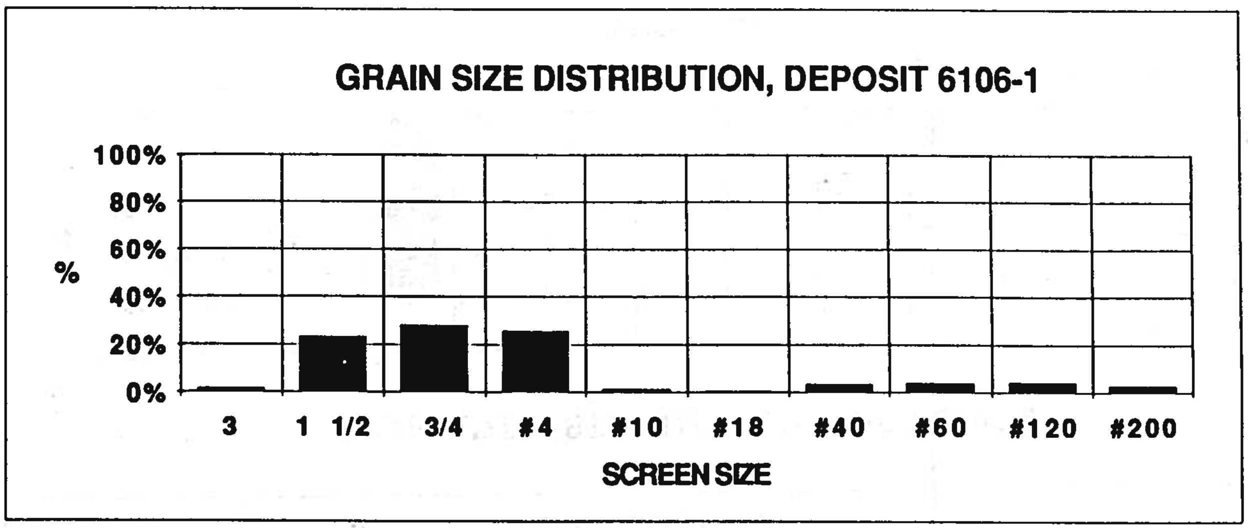
SCREEN	RETAINED
3	30%
1 1/2	29%
3/4	19%
#4	7%
#10	1%
#18	0%
#40	3%
#60	5%
#120	5%
#200	1%
PAN	0%
	100%



LACOMBE 6106-1

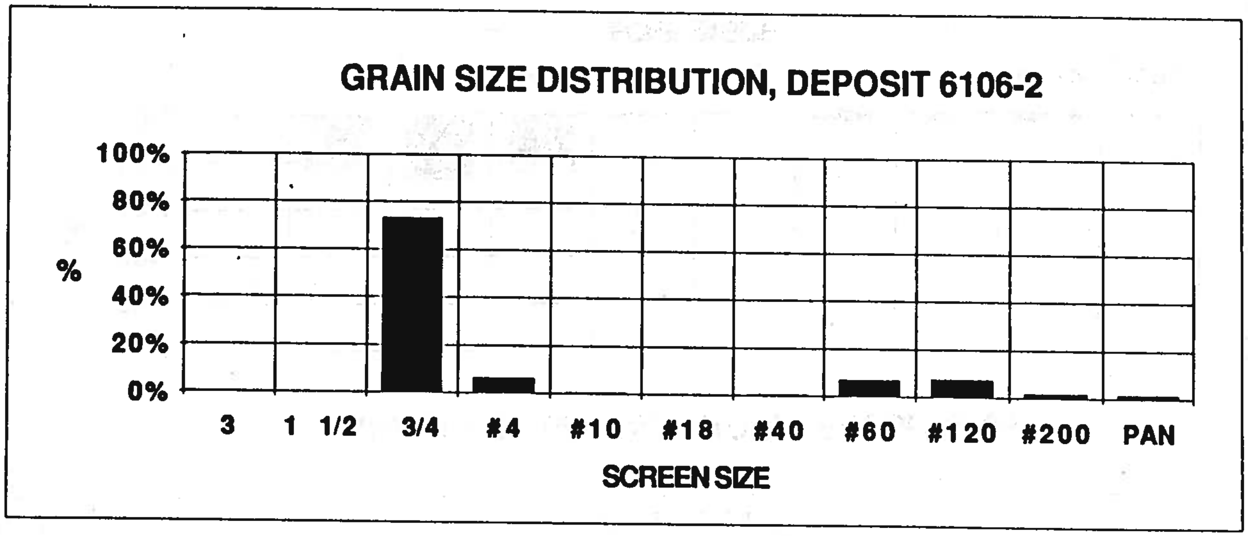
WEIGHT= 212.49 KG

SCREEN	RETAINED
3	2%
1 1/2	24%
3/4	28%
#4	26%
#10	1%
#18	1%
#40	4%
#60	4%
#120	4%
#200	3%
PAN	3%
	100%



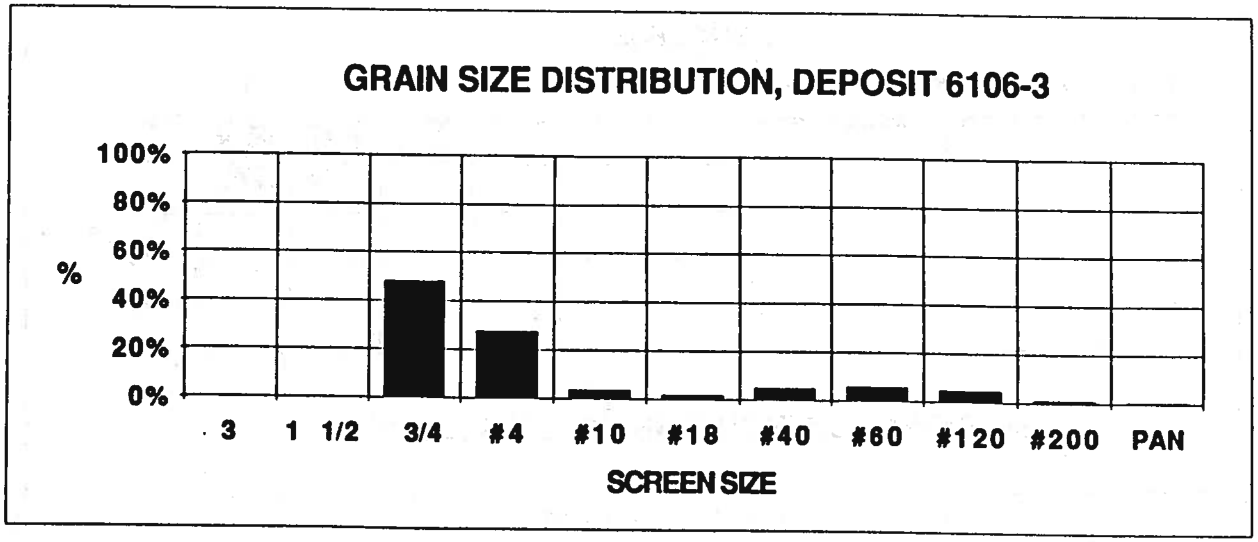
LACOMBE 6106-2 WEIGHT= 213.25 KG

SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	74%
#4	7%
#10	0%
#18	0%
#40	1%
#60	7%
#120	8%
#200	2%
PAN	2%
	100%



LACOMBE 6106-3 WEIGHT= 194.14 KG

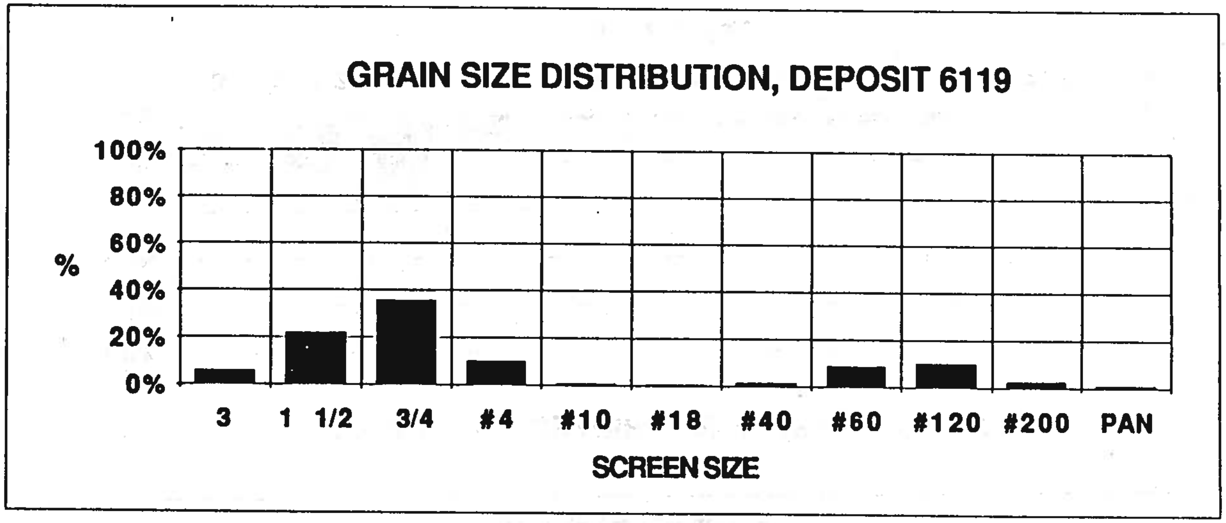
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	48%
#4	28%
#10	4%
#18	2%
#40	5%
#60	6%
#120	5%
#200	1%
PAN	0%
	100%



WETASKIWIN 6119

WEIGHT= 131.30 KG

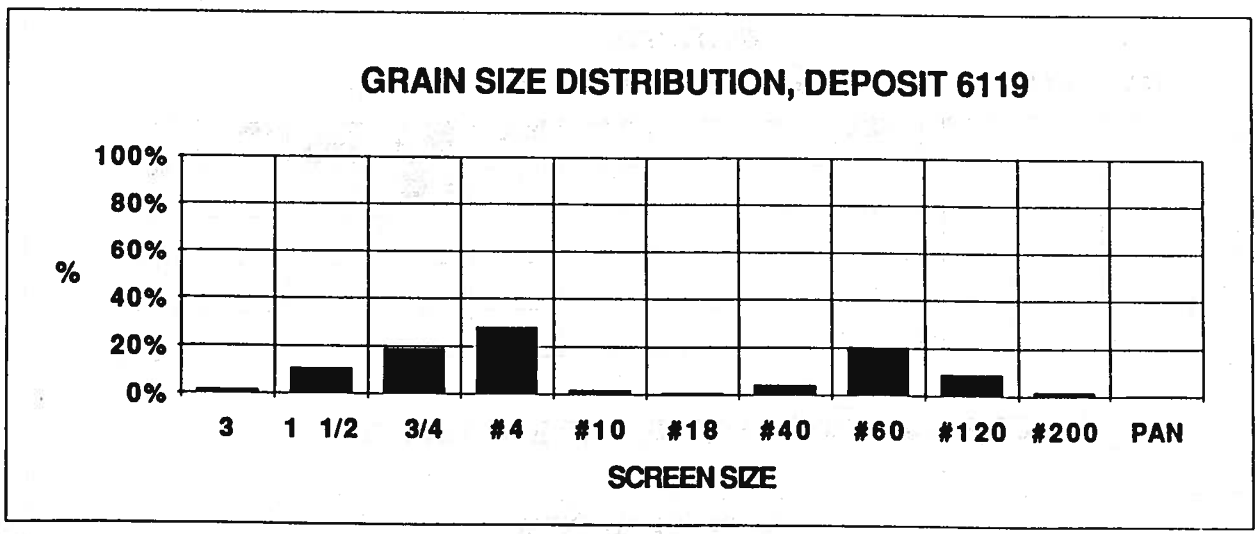
SCREEN	RETAINED
3	6%
1 1/2	22%
3/4	36%
#4	10%
#10	1%
#18	0%
#40	2%
#60	9%
#120	10%
#200	3%
PAN	1%
	100%



WETASKIWIN 6119

WEIGHT= 203.36 KG

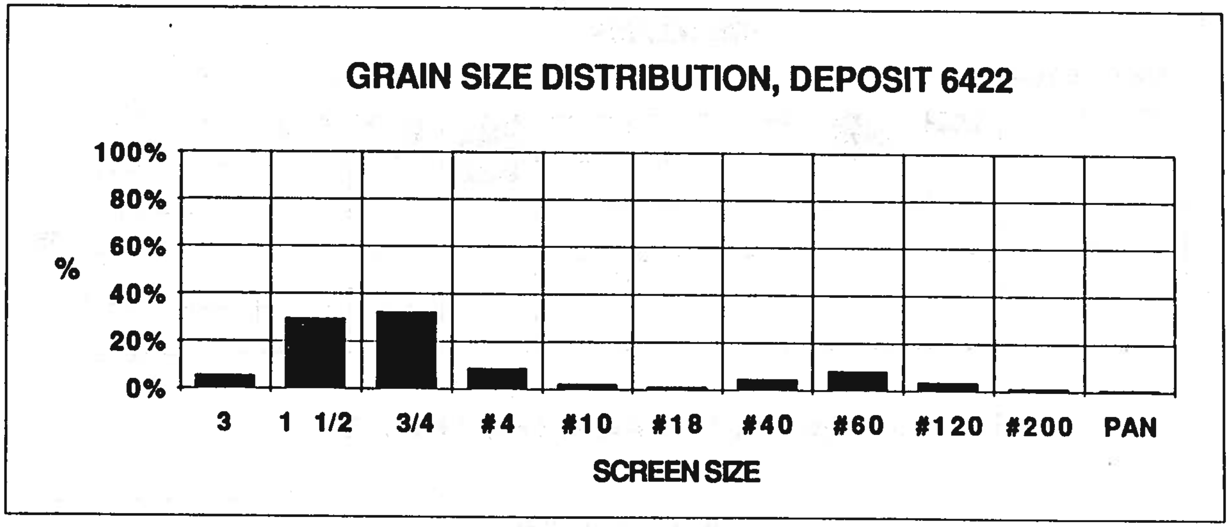
SCREEN	RETAINED
3	2%
1 1/2	11%
3/4	19%
#4	28%
#10	2%
#18	1%
#40	4%
#60	20%
#120	9%
#200	2%
PAN	0%
	100%



MAGNOLIA 6422

WEIGHT= 169.40 KG

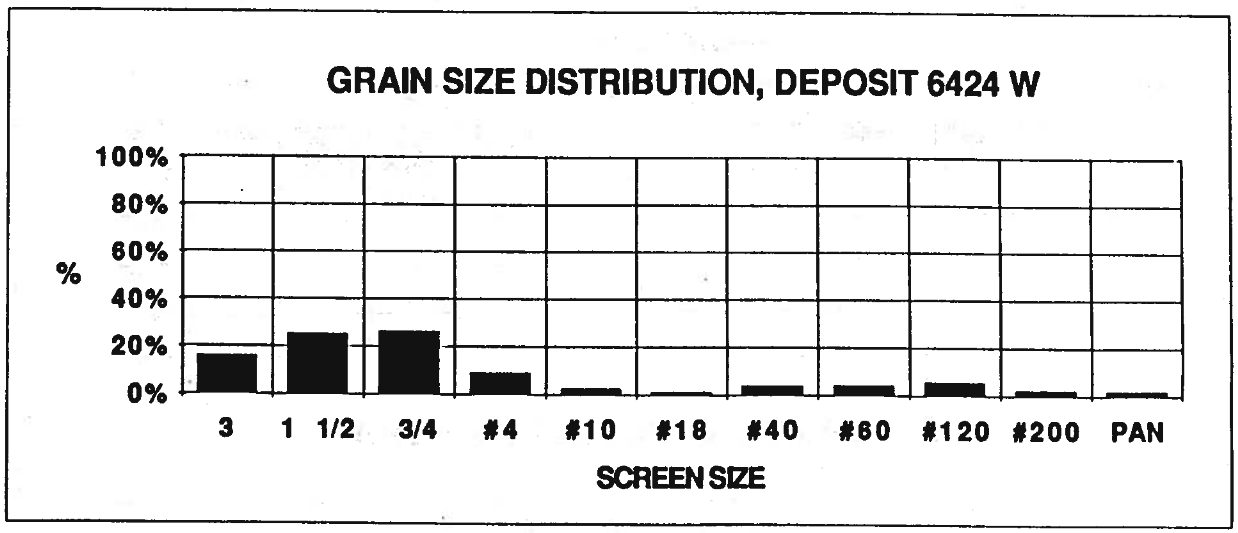
SCREEN	RETAINED
3	6%
1 1/2	30%
3/4	33%
#4	9%
#10	2%
#18	1%
#40	5%
#60	8%
#120	4%
#200	1%
PAN	1%
	100%



ENTWISTLE W. 6424

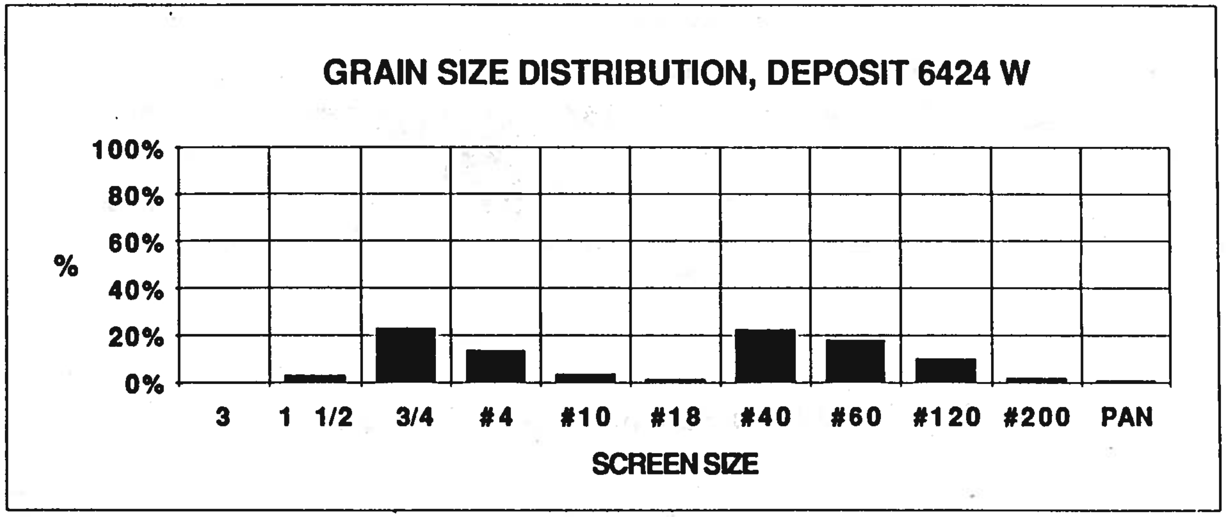
WEIGHT= 145.90 KG

SCREEN	RETAINED
3	16%
1 1/2	25%
3/4	26%
#4	9%
#10	3%
#18	1%
#40	4%
#60	4%
#120	6%
#200	2%
PAN	2%
	100%



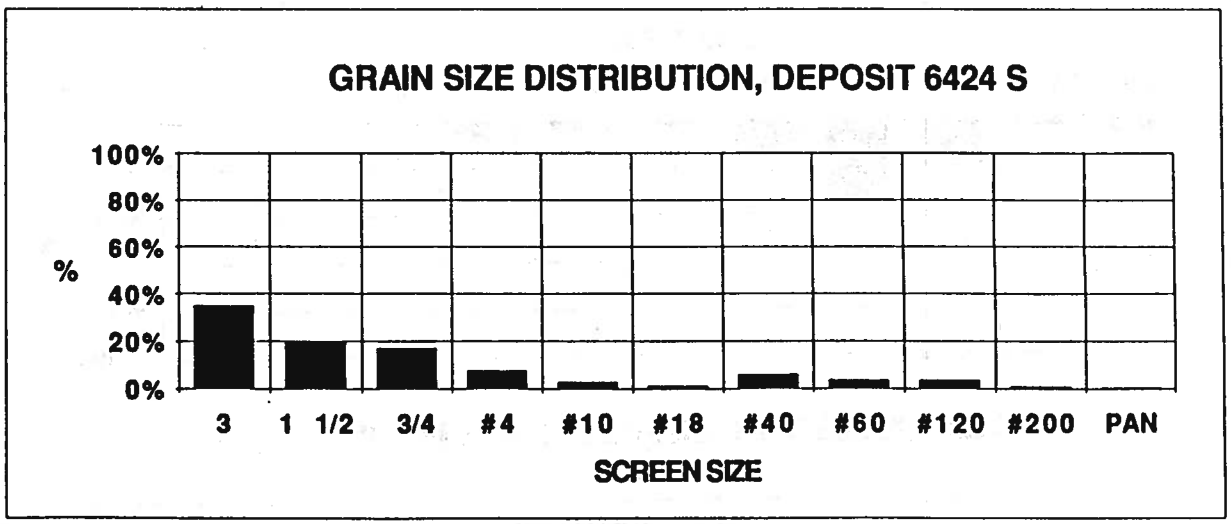
ENTWISTLE W. 6424 WEIGHT= 88.80 KG

SCREEN	RETAINED
3	0%
1 1/2	3%
3/4	23%
#4	14%
#10	4%
#18	2%
#40	23%
#60	18%
#120	10%
#200	2%
PAN	1%
	100%



ENTWISTLE S. 6424 WEIGHT= 210.90 KG

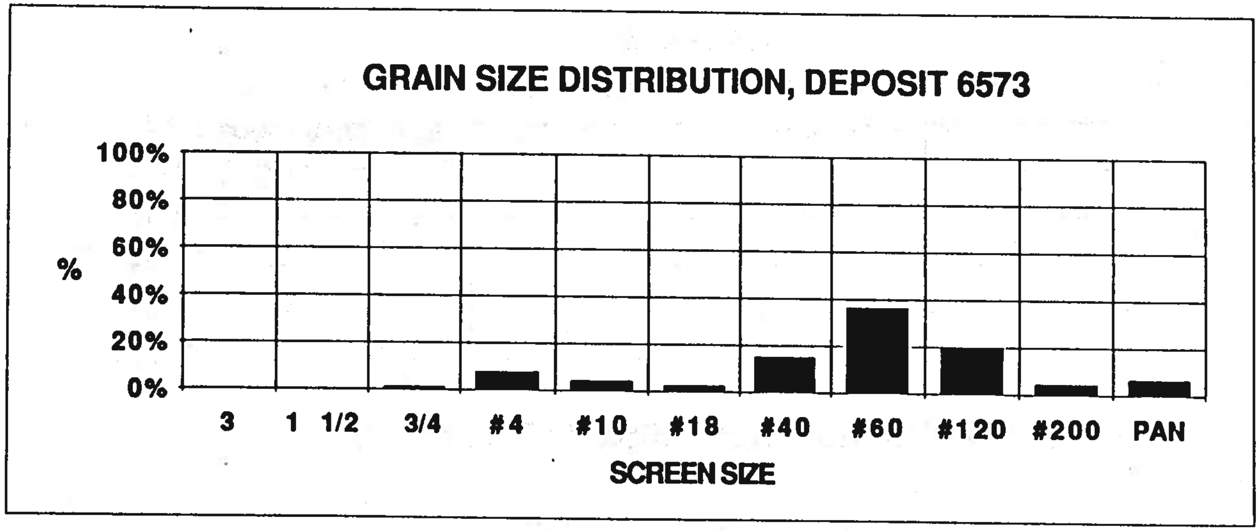
SCREEN	RETAINED
3	35%
1 1/2	20%
3/4	17%
#4	8%
#10	3%
#18	1%
#40	6%
#60	4%
#120	4%
#200	1%
PAN	0%
	100%



WHITECOURT MTN. 6573

WEIGHT= 28.39 KG

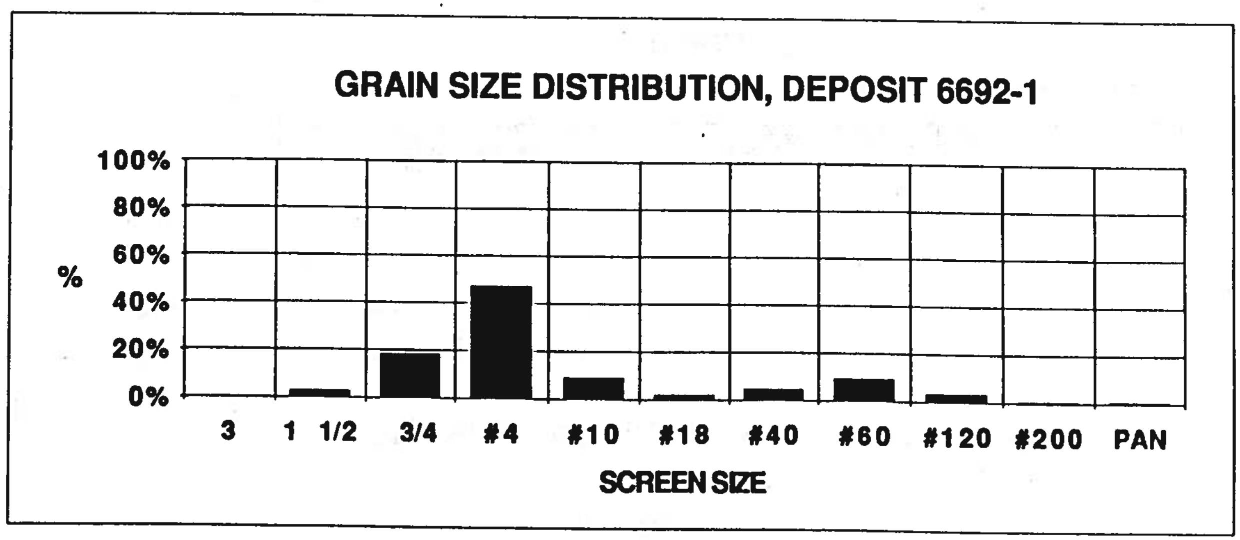
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	1%
#4	8%
#10	4%
#18	3%
#40	15%
#60	37%
#120	20%
#200	5%
PAN	7%
	100%



GRIMSHAW 6692-1

WEIGHT= 187.61 KG

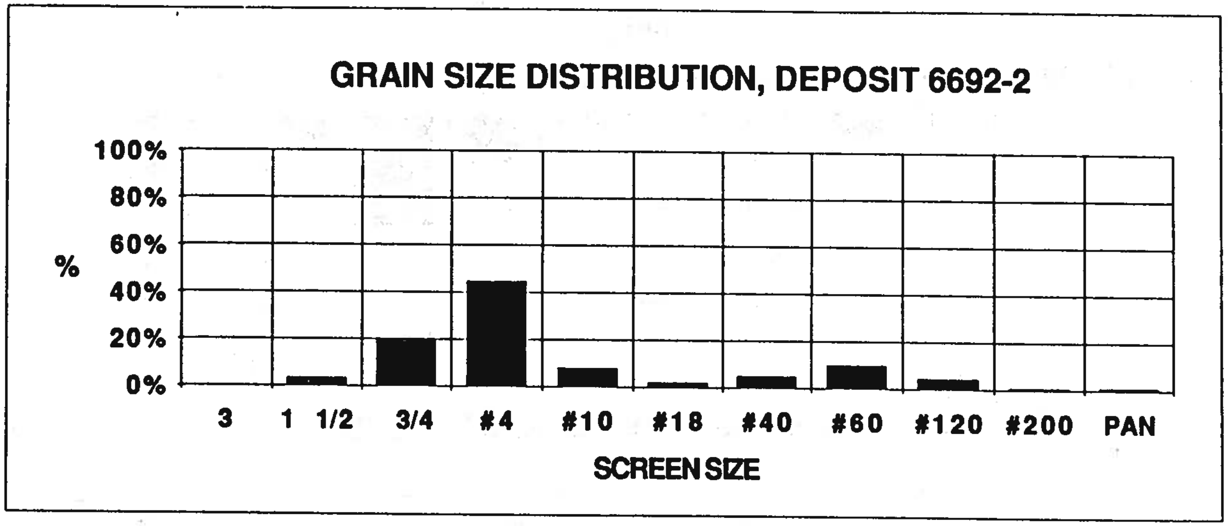
SCREEN	RETAINED
3	0%
1 1/2	3%
3/4	19%
#4	47%
#10	9%
#18	2%
#40	5%
#60	10%
#120	4%
#200	1%
PAN	1%
	100%



GRIMSHAW 6692-2

WEIGHT= 193.07 KG

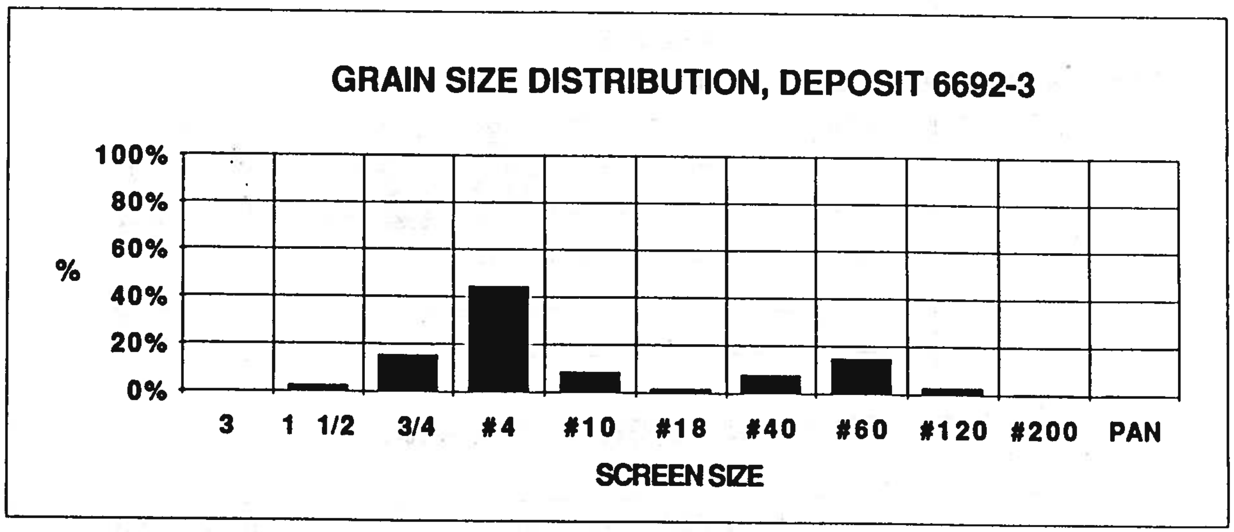
SCREEN	RETAINED
3	0%
1 1/2	4%
3/4	19%
#4	45%
#10	8%
#18	2%
#40	5%
#60	10%
#120	5%
#200	1%
PAN	1%
	100%



GRIMSHAW 6692-3

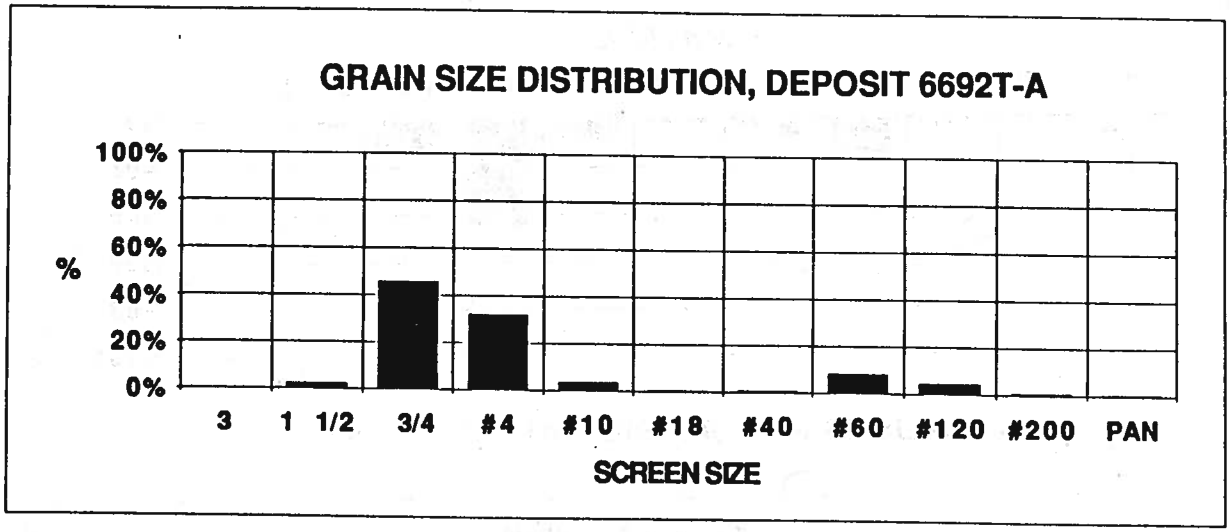
WEIGHT= 196.12 KG

SCREEN	RETAINED
3	0%
1 1/2	3%
3/4	16%
#4	45%
#10	9%
#18	2%
#40	8%
#60	15%
#120	3%
#200	0%
PAN	0%
	100%



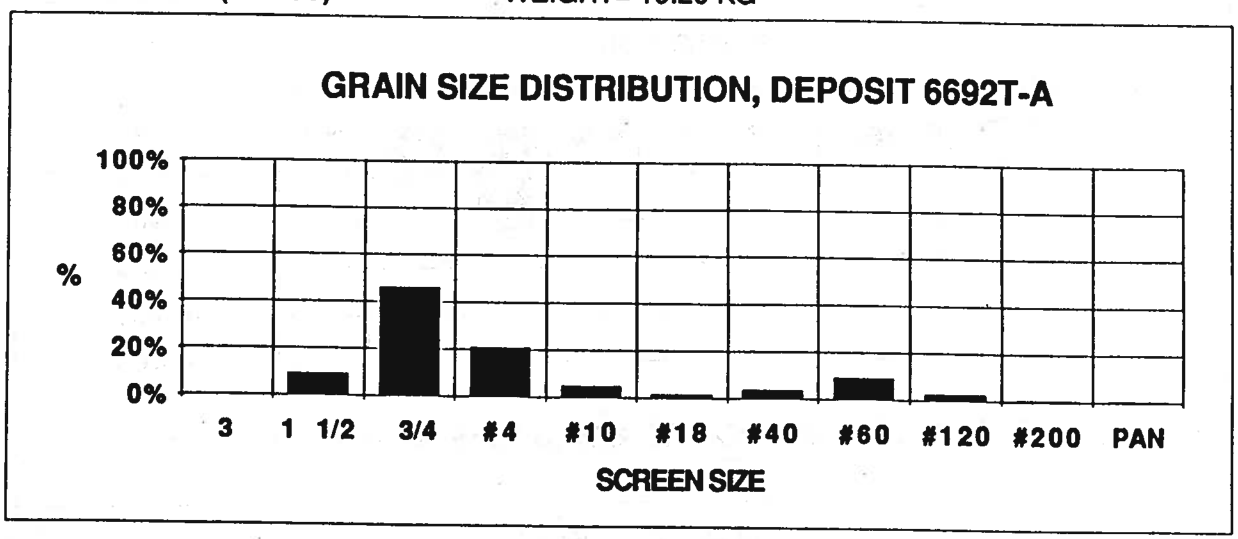
GRIMSHAW (FAIRVIEW) 6692T-A(lower) WEIGHT= 14.08 KG

SCREEN	RETAINED
3	0%
1 1/2	2%
3/4	46%
#4	32%
#10	4%
#18	0%
#40	1%
#60	9%
#120	5%
#200	1%
PAN	0%
	100%



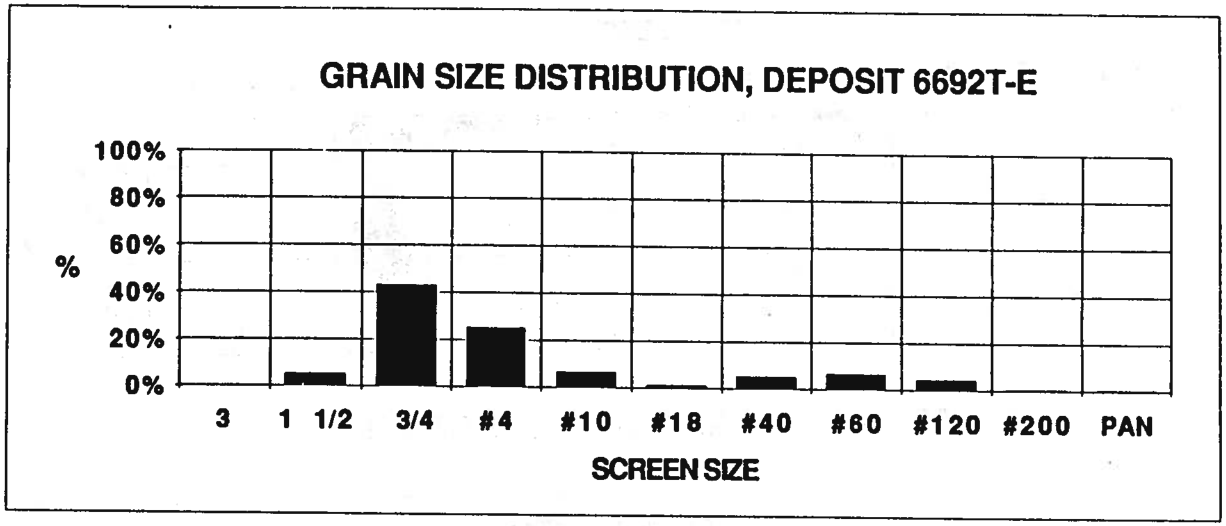
GRIMSHAW (FAIRVIEW) 6692T-A(coarse) WEIGHT= 19.20 KG

SCREEN	RETAINED
3	0%
1 1/2	9%
3/4	46%
#4	21%
#10	5%
#18	2%
#40	4%
#60	9%
#120	3%
#200	1%
PAN	0%
	100%



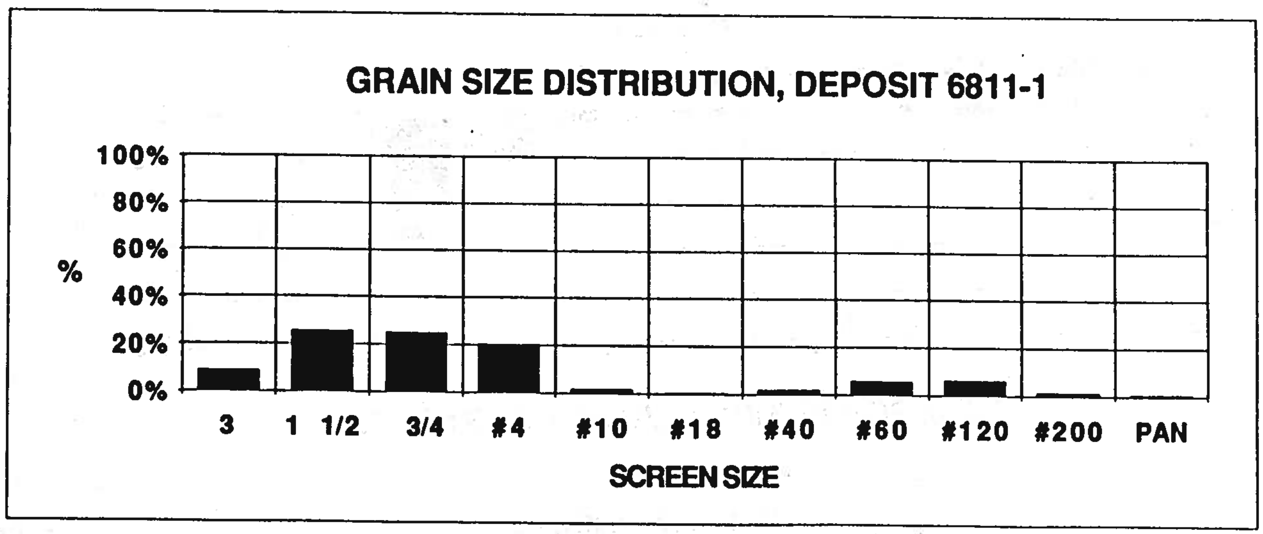
GRIMSHAW (FAIRVIEW) 6692T-E WEIGHT= 23.37 KG

SCREEN	RETAINED
3	0%
1 1/2	5%
3/4	43%
#4	25%
#10	7%
#18	1%
#40	5%
#60	7%
#120	5%
#200	1%
PAN	0%
	100%



WINTERING HILLS 6811-1 WEIGHT= 277.59 KG

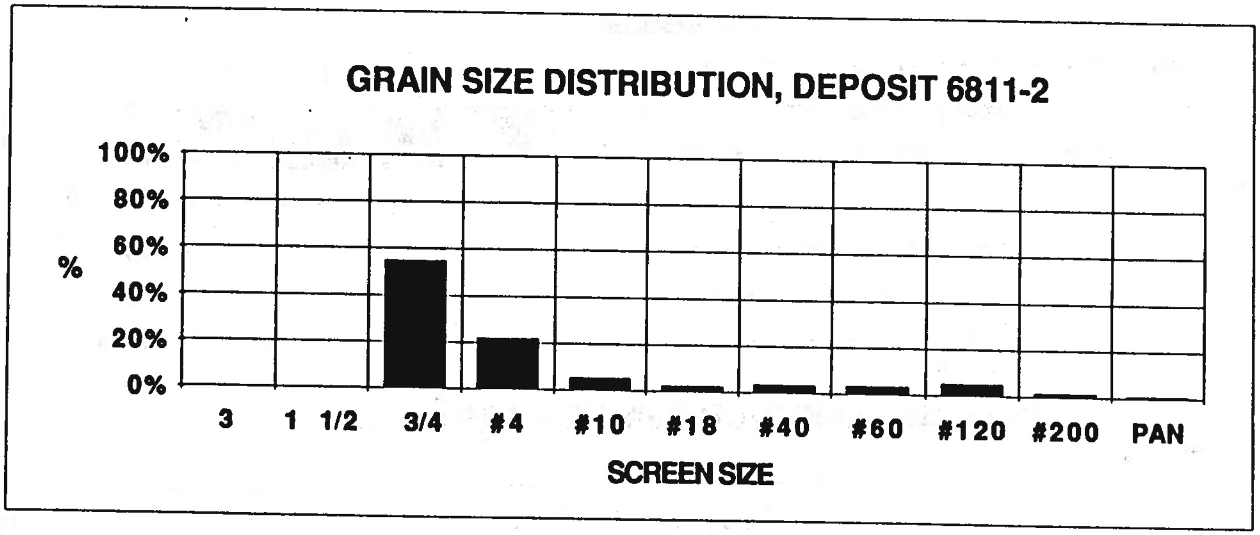
SCREEN	RETAINED
3	9%
1 1/2	26%
3/4	25%
#4	21%
#10	2%
#18	0%
#40	2%
#60	6%
#120	7%
#200	2%
PAN	1%
	100%



WINTERING HILLS 6811-2

WEIGHT= 259.81 KG

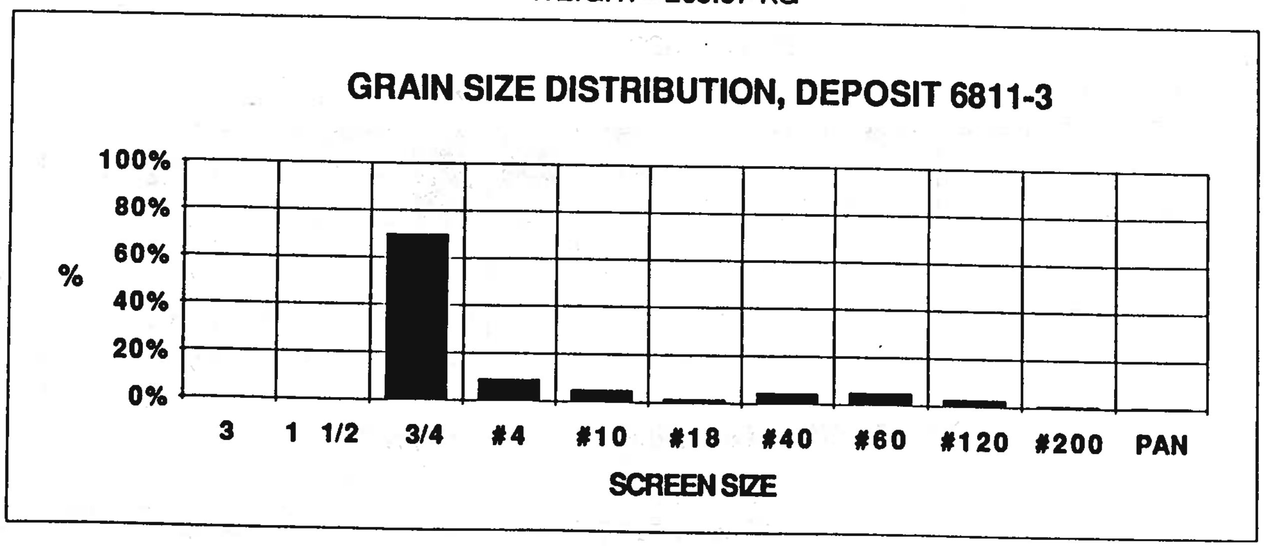
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	55%
#4	22%
#10	5%
#18	2%
#40	3%
#60	4%
#120	5%
#200	2%
PAN	1%
	100%



WINTERING HILLS 6811-3

WEIGHT= 265.57 KG

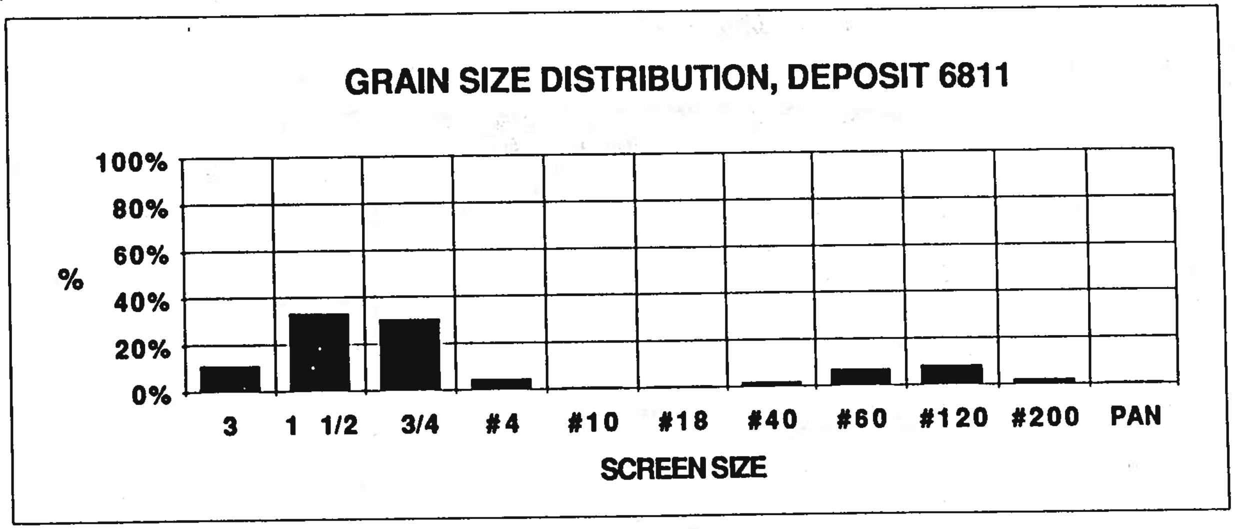
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	70%
#4	9%
#10	5%
#18	2%
#40	5%
#60	5%
#120	3%
#200	1%
PAN	0%
	100%



WINTERING HILLS 6811

WEIGHT= 196.04 KG

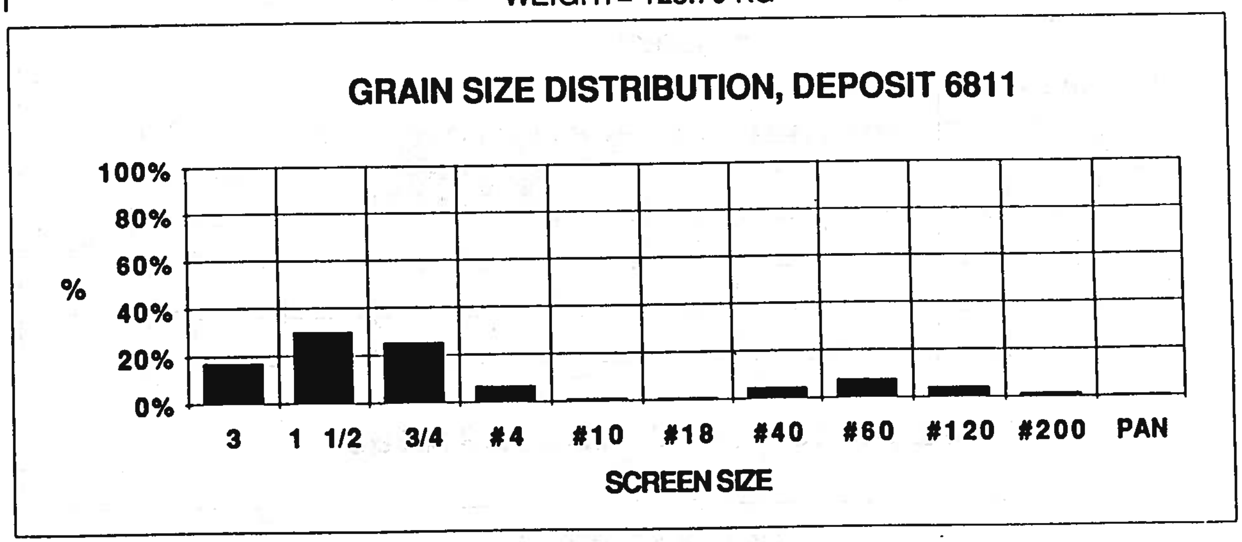
SCREEN	RETAINED
3	11%
1 1/2	33%
3/4	31%
#4	4%
#10	0%
#18	0%
#40	2%
#60	7%
#120	8%
#200	2%
PAN	0%
	100%



WINTERING HILLS 6811

WEIGHT= 123.70 KG

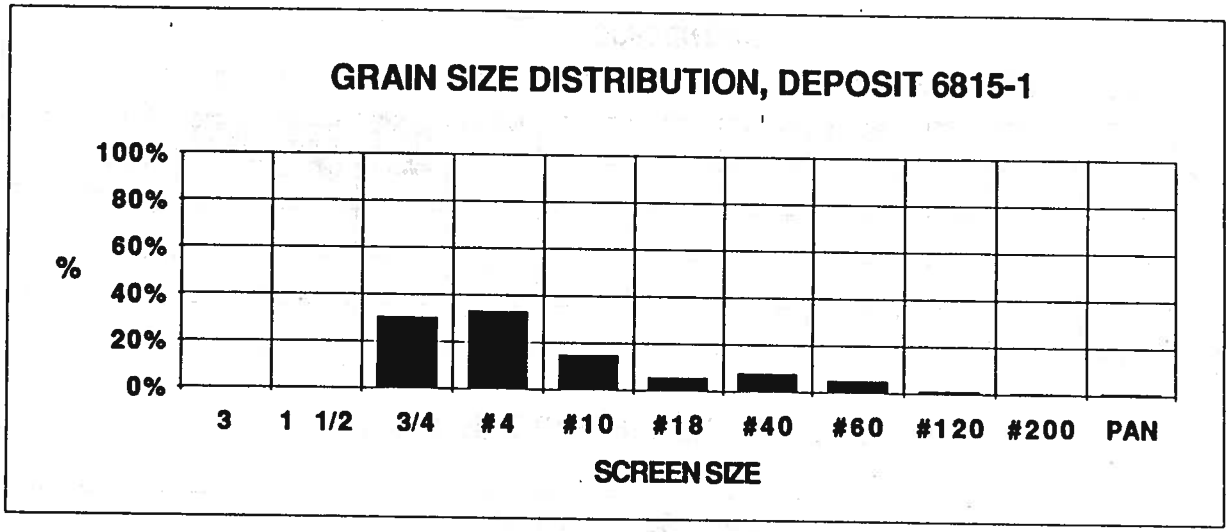
SCREEN	RETAINED
3	17%
1 1/2	30%
3/4	25%
#4	7%
#10	1%
#18	1%
#40	5%
#60	8%
#120	4%
#200	2%
PAN	0%
	100%



HALVERSON RIDGE 6815-1

WEIGHT= 199.98 KG

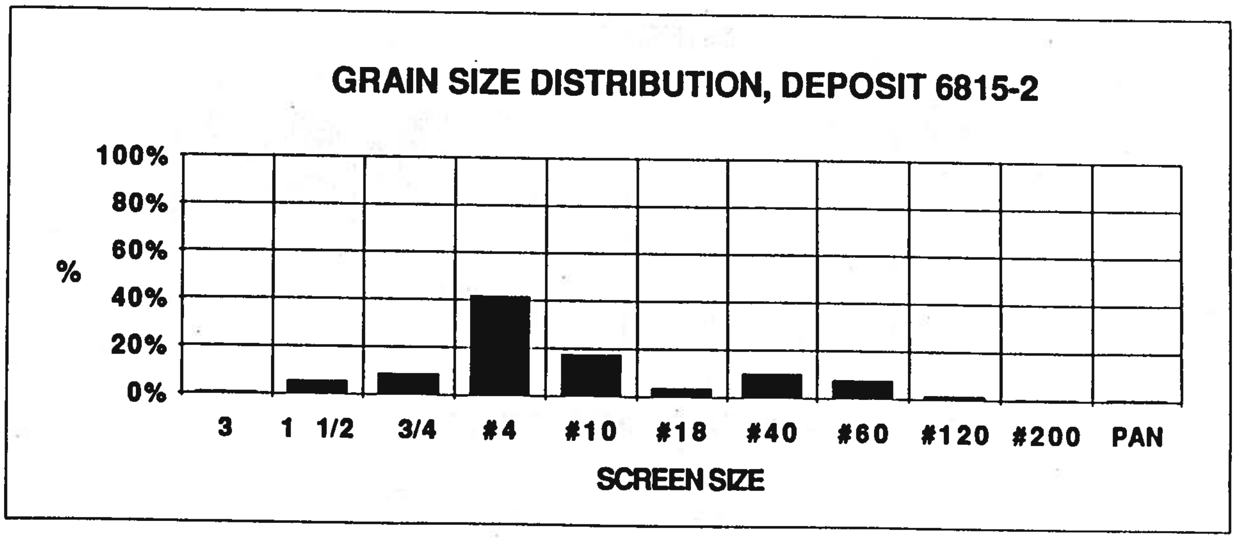
SCREEN	RETAINED
3	0%
1 1/2	0%
3/4	31%
#4	33%
#10	15%
#18	6%
#40	8%
#60	5%
#120	1%
#200	0%
PAN	1%
	100%



HALVERSON RIDGE 6815-2

WEIGHT= 195.72 KG

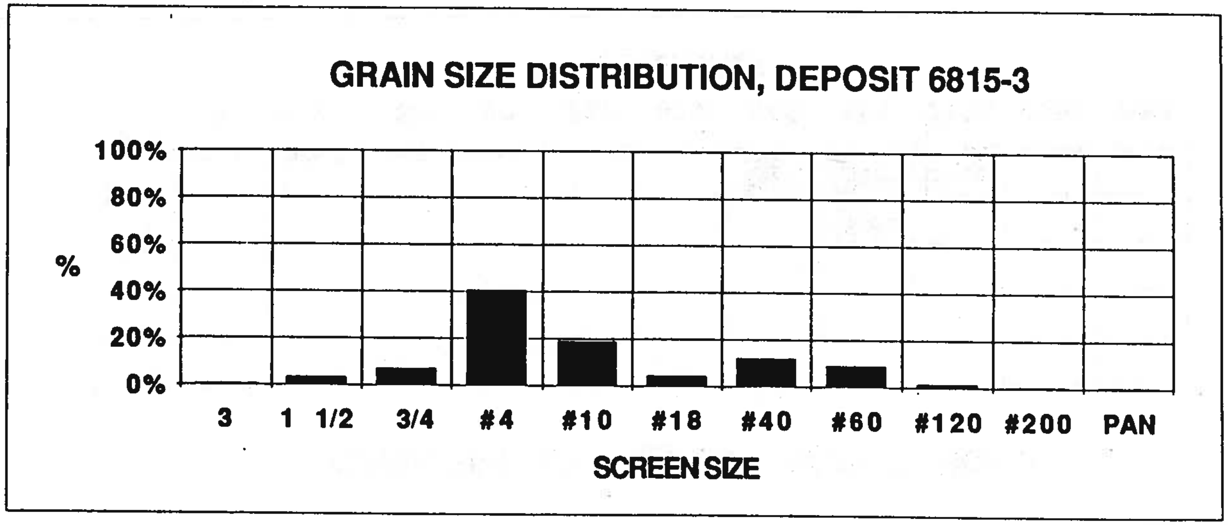
SCREEN	RETAINED
3	1%
1 1/2	6%
3/4	9%
#4	42%
#10	18%
#18	4%
#40	10%
#60	8%
#120	2%
#200	1%
PAN	1%
	100%



HALVERSON RIDGE 6815-3

WEIGHT= 190.16 KG

SCREEN	RETAINED
3	0%
1 1/2	4%
3/4	7%
#4	41%
#10	19%
#18	5%
#40	12%
#60	9%
#120	2%
#200	0%
PAN	1%
	100%



PELICAN MTN. 6824-1

WEIGHT= 201.25 KG

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1 1/2	37%
3/4	26%
#4	5%
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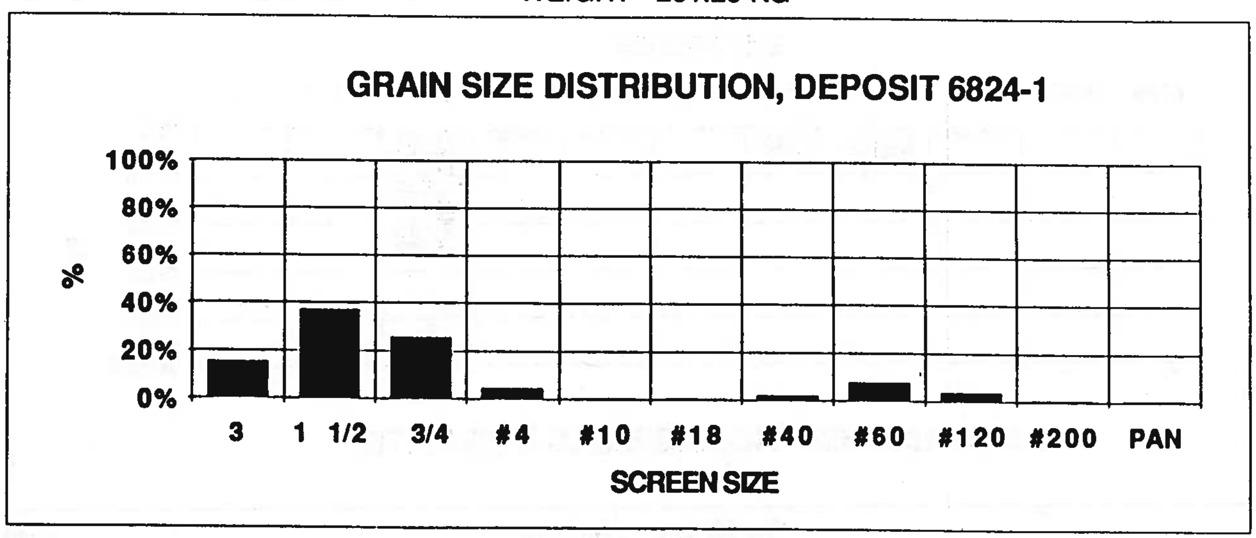
#18	0%
#40	2%
#60	8%
#120	4%
#200	1%
PAN	1%
	100%



PELICAN MTN. 6824-2 WEIGHT= 175.58 KG

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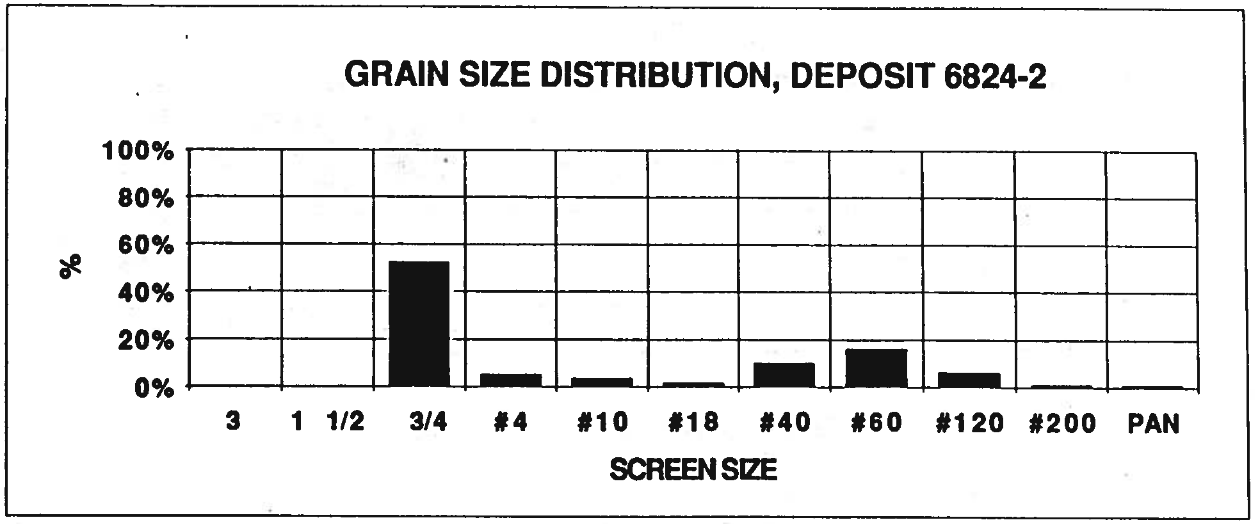
1 1/2	0%
3/4	53%
#4	6%
#10	4%
#18	2%
#40	10%
#60	16%
#120	7%
#200	1%
PAN	1%
	100%



PELICAN MTN. 6824-3 WEIGHT= 185.40 KG

SCREEN	RETAINED
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1 1/2	7%
3/4	3%
#4	4%
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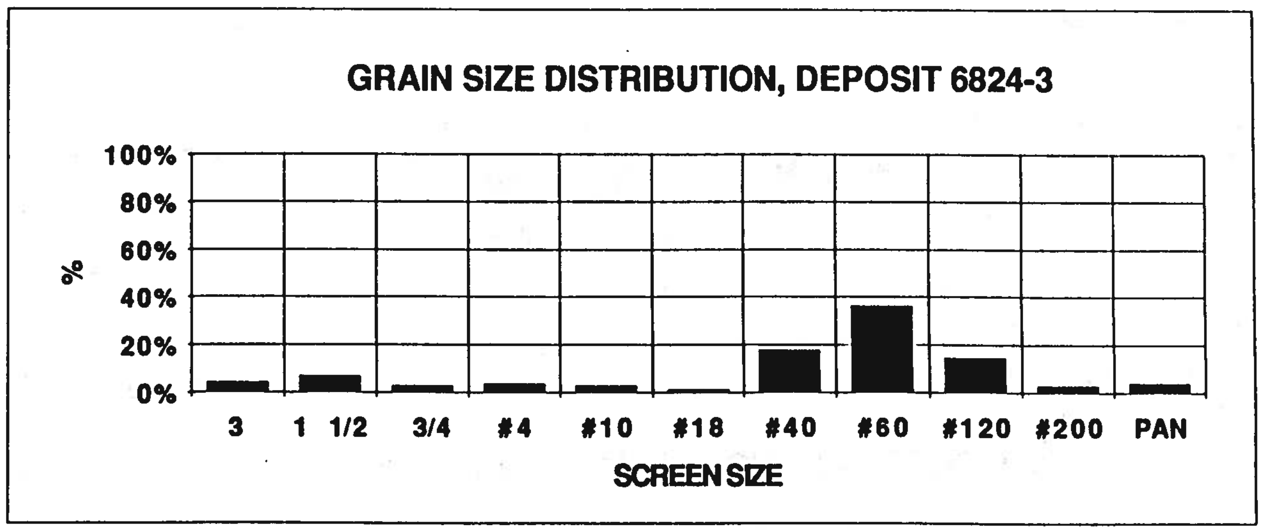
#40	18%
#60	37%
#120	15%
#200	3%
PAN	4%
	100%



Appendix D
Streamflow directions measured from planar cross-beds, trough cross-beds and imbricated gravel fabric

Appendix D. Streamflow directions.

Deposit Name	Number	Planar X-Bedding	Trough X-Bedding	Gravel Fabric
Grimshaw	6692	122[13], 060[13], 115[13] 067[13], 035[13], 070[33] 353[34], 004[34], 011[34] 172[34], 173[35], 225[35]	118[13] 125[33]	022[13], 110[33], 112[33], 323[33]
Simonette	4028	090[31]	040	090[32]
Watino	4212	096, 058[26], 056[27] 068[28], 045[29], 000[30]	056, 056	067[12], 067[16]
Swan Hills	3973	082[1], 085[1], 062		063[1], 010[1], 052[1], 056[1] 071[1], 078[11], 088[1]
Obed Mountain	3915		060	036[14]
Whitecourt Tower	6573			030[15]
Villeneuve	3975	096[17]	117[18]	093[19]
Entwistle	6424	045[15]	045[15]	060[17]
Heatherdown	6402	045	040, 045	120[20]
Wabamun	6411	045[36]		
Hand Hills	3957	054[1]		086[1]
Hand Hills	3958	046[1]		071[1]
Hand Hills	3960	066[1]		
Hand Hills	6809	056[1]		080[1]
Hand Hills	6808	025[1],090	080	044[1], 086[4], 080[15], 071[4]
Hand Hills Lake	3964	064[1]		037[5], 045[1], 095[1], 034[15]
Hand Hills Lake	3965		066[1]	
Hand Hills Lake	3954	050[1]		
Wintering Hills	6811	059[1], 222[1]		047[3], 019[1], 088[1]
Wintering Hills	3971		080	230[2], 085[15]
Calgary	6050	076		069[10]
Calgary	6018	110, 060		
Cluny	3913		020	004[6]
Nanton	5812	138		128[9]
Kipp	1052	125		170[15], 125[15]
Fort Macleod	5721			000[15], 025[15], 355[15]
Magrath	5669		068	077[7], 054
Del Bonita (east)	3950			080[1]
Del Bonita (east)	5571			092[1]
Del Bonita (east)	5570	052[1]		009[1], 071[1], 019[1], 041[1] 035[15], 030[15], 105[15], 065[15]
Del Bonita (east)	5591			078[1]
Del Bonita (west)	5566			010[8]
Del Bonita (west)	3933			070[1]
Del Bonita (west)	3924			056[1]
Del Bonita (west)	3927			010[1]
Del Bonita (west)	5582			085[1]
Del Bonita (west)	5585			003[1]
Cypress Hills	4214	000[25], 015[25], 025[25]		004[24], 030[38]
Cypress Hills	4213	081[1], 050[1]		010[15], 080[15], 050[21], 001[22] 349[23], 067[1], 058[1],079[1] 080[1], 049[1], 060[1], 036[1]

Appendix D. (Continued)

Deposit Name	Number	Planar X-Bedding	Trough X-Bedding	Gravel Fabric
Cypress Hills	4213			072[1], 087[1], 109[1], 031[37]
Cypress Hills	x			347[1]
Cypress Hills	y			003[1]

1 Vonhof, 1969
2 measured in upper beds above boulder bed
3 average of six measurements: 064, 050, 086, 018, 024, 038
4 086 is average of five measurements in lowest beds: 071, 121, 080, 085, 075; 071 is average of five measurements in old Russell pit
5 037 is average of five measurements: 034, 020, 035, 044, 050
6 average of five measurements: 000, 018, 350, 012, 000
7 average of five measurements: 080, 076, 096, 086, 048
8 average of four measurements: 020, 342, 028, 010
9 average of four measurements: 146, 108, 118, 138
10 average of six measurements: 054, 084, 068, 038, 084, 084
11 average of five measurements: 080, 080, 070, 080, 082
12 average of five measurements: 060, 090, 058, 056, 070
13 Grimshaw area measurements, 022 gravel fabric is average of five measurements
14 average of three measurements: 058, 020, 030
15 average of five measurements
16 average of 20 measurements
17 average of 10 measurements
18 average of seven measurements
19 average of 100 measurements
20 average of 12 measurements
21 Leckie and Cheel, 1989, average of 175 measurements
22 Leckie and Cheel, 1989, average of 50 measurements
23 Leckie and Cheel, 1989, average of 48 measurements
24 Leckie and Cheel, 1989, average of 208 measurements, sample site about 2 km east of Alberta-Saskatchewan boundary
25 Leckie and Cheel, 1989, sample site about 2 km east of Alberta-Saskatchewan boundary
26 Liverman et al, 1989, orientations vary from 040 to 075
27 Liverman et al, 1989, orientations vary from 042 to 070
28 Liverman et al, 1989, orientations are E and ENE
29 Liverman et al, 1989, modal direction of ripples is ENE
30 Liverman et al, 1989, dominant direction
31 Liverman et al, 1989, 'eastward current flow'
32 Liverman et al, 1989, imbricated 'to the west'
33 Fairview area measurements, 112 gravel fabric is average of 11 measurements: 090, 120, 110, 155, 105, 130, 125, 095, 105, 110, 090; 110 gravel fabric is average of five measurements: 100, 110, 114, 106, 122; 323 gravel fabric is average of four measurements in cobble lag: 290, 335, 315, 350
34 Tokarsky, 1967, Grimshaw area, cross-bed type not distinguished
35 Tokarsky, 1967, Fairview area, cross-bed type not distinguished
36 trend developed from isopach mapping of gravel units
37 Vonhof, 1969, sample site just east of Alberta-Saskatchewan boundary
38 Vonhof, 1969, sample site about 2 km east of Alberta-Saskatchewan boundary

Appendix E
Lithologies of potential source formations

Aldridge Formation (Middle Proterozoic)

In the Purcell Mountains the lower part consists of rusty weathering, laminated, thinly bedded, light colored, very fine grained quartzite, argillaceous quartzite and siltite, with minor black argillite partings. These grade into the middle part, which is a sequence characterized by light weathering, thin to thick bedded, light colored, fine grained quartzite and argillaceous quartzite interbedded with laminated, rusty weathering, grey siltite and black argillite.

The upper part of the formation consists of rusty weathering, laminated siltite and dark argillite. The formation extends from north of Kimberley, B.C. to south of Missoula MT.

Apekunny Formation (Middle Proterozoic)

Green and red argillite, green quartz sandstone, dolostone and quartz pebble conglomerate and sandy dolostone in eastern Lewis and Clark Ranges in southern Alberta, B.C., and northern Montana; changes southwestward into grey and green laminated argillite with thin beds of green quartz sandstone.

Bad Heart Formation (Upper Cretaceous)

Medium to coarse grained sandstone, weathering dark red in most exposures. Ironstone concretions are common. Some interbedded sandy shale. Marine fossils are numerous and bands of chert pebbles are present. The formation is present in the Peace River area of Alberta.

Blood Reserve Formation (Upper Cretaceous)

Massive, hard to soft, cliff forming to castellated, medium grained, light gray or gray-buff sandstone, weathering to buff, yellow or greenish tinge. Cement varies from calcareous to argillaceous. Cross-bedding and irregular concretions are common. The formation forms a narrow outcrop belt extending northward from the International Boundary to the Oldman River at 31-9-23-W4.

Brewster Limestone Member (Whitehorse Formation) (Upper Triassic)

Resistant cliff forming sequence of pale to medium gray weathering, medium to thick bedded, pelletoid, fossiliferous limestone with local intercalations of slightly silty to sandy dolostone and intraformational limestone breccia. Pale green lenses of chert up to 15 cm long occur in some areas north of Athabasca River.

Confined to the Rocky Mountain Foothills and Front Ranges between the Kakwa and Athabasca Rivers.

Boya Formation (Lower Cambrian)

The Boya Formation consists of clean white sandstone. The Boya is 955 m thick SE of 57°30'N and quartzite increases.

Cadomin Formation (Lower Cretaceous)

Characterized by conglomerate. Average clast size 1-5 cm up to 40 cm. Matrix generally fine to coarse grained sand, and cement is silica. Chert and quartzite are the predominant clast lithologies. More than one bed of conglomerate occurs in some sections, with interbedded sandstone, siltstone and mudstone, often with a high carbonaceous content.

Recognized in the Foothills of Alberta and B.C. between 49°N and about 56°30'N

Cassiar Suite (Middle Cretaceous)

The Cassiar Suite consists of plutons trending NW from ~55°15'N to 64°N in which biotite granite and granodiorite predominate. Muscovite is common in some plutons, and hornblende, generally subordinate to biotite is present in others. Many rocks have a pink color and K-feldspar megacrysts are common.

The Cassiar Batholith, one of the largest plutons in the Canadian Cordillera at about 350 km long and up to 40 km wide, extends NW from ~58°15'N to 60°40'N. Most of the batholith consists of pinkish-gray, medium to coarse grained granite and granodiorite, commonly containing megacrysts of K-feldspar. Biotite is the main mafic mineral; hornblende is locally abundant but generally subordinate to biotite. Muscovite is common in the sheared, western parts of the batholith.

The Mesilinka Pluton is a heterogeneous, biotite granite, quartz monzodiorite, granodiorite and quartz diorite strongly mylonitized on its western margin. The Osilinka Intrusions intrude the Mesilinka and earlier rocks with miarolitic biotite granite and granodiorite containing conspicuous quartz eyes.

Copper Mountain Suite (Lower to Middle Jurassic)

Numerous small alkaline bodies of the Copper Mountain Suite form a roughly linear, northwest-trending belt extending from the International Border to the Stikine Arch (~58°N, 128°W). Most bodies are small, roughly equant stocks, only a few km in diameter. The largest (~30 x 5 km) is probably the northwesterly elongate Middle Jurassic Duckling Creek Syenite Complex, part of the Hogem Batholith. Syenite, monzonite, and monzodiorite are typical of most plutons of the Copper Mountain Suite. Clinopyroxene and biotite are the main mafic minerals. Plutons are characterized by high K_2O/Na_2O ratios up to 24:1.

Cranbrook Formation (Lower Cretaceous)

Type locality midway between Cranbrook and Fort Steele. Predominantly siliceous quartzite, medium to coarse grained, in part containing sporadic quartz pebbles with gritty quartzite and lenticular beds of quartz-pebble conglomerate. White, cream and grey colors prevail, but pale green, rose and pale tan are common. Weathered surfaces are typically smooth and white or yellowish. Exposed near 49°30'N between the Moyie and St. Mary faults in the Purcell Mountains and directly across the Rocky Mountain Trench between the comparable Dibble Creek and Boulder Creek faults in the Hughes Range of the Rocky Mountains.

Dunvegan Formation (Upper Cretaceous)

Light gray to yellowish buff sandstone. Beds may be massive with cross-bedding. Thin beds of shale, shelly limestone and coal are present. Thick arkosic and conglomeratic beds are common in northeastern British Columbia. The formation extends from Fort Nelson and the Liard River over the entire Peace River area and as far south as Wildhay River in the foothills.

Fernie Formation (Jurassic)

Predominantly brownish, medium to dark gray and black laminated shales. Interbedded units include dark phosphatic sandstones and limestones, and black cherty limestones in the lower parts, resistant, well bedded siltstones, sandstones and black oolitic limestones in the middle parts, and glauconitic sands, concretionary bands and brown weathering siltstones and sandstones in the upper part.

Outcrops occur from southeastern British Columbia throughout the Foothills and Front Ranges of Alberta, and into the Foothills north of Peace River in northeastern British Columbia. Thickness can exceed 400 m.

Fantasque Formation (Lower to Upper Permian)

Mainly rhythmically bedded spicular chert 0.3 to 3.0 m thick, shale to 0.1 m, interbedded with chert, and siltstone with thin basal lag deposit of phosphate and chert nodules and pebbles. The chert includes skeletal and other granular material including spicules, pelletoid grains and intraclasts.

Occurs as a thin but laterally persistent unit in the Pine Pass (55°30'N, 122° 30'W) area and northwards on the Interior Platform and southern Mackenzie Fold Belt. The formation varies in thickness from 2.5 to 55 m.

Fort Mountain Formation (Lower Cambrian)

Massive bedded, cliff-forming, purplish, hard, fine grained quartzitic sandstone with bands of siliceous and finely arenaceous shale in lower portion. An arenaceous, quartzitic basal conglomerate occurs in some localities.

Occurs from Mount Assiniboine (50° 52'N, 115° 38'W) to Mount Sedgewick above Siffleur River 52°N 116°W.

Francois Lake Suite (Upper Jurassic to Lower Cretaceous)

Most of these Late Jurassic to Early Cretaceous intrusions between ~53°N, 123°W to 55°N, 125°W, west of Prince George are northwesterly-elongate batholiths with a moderately to strong northwest-trending foliation. Biotite granite to quartz monzonite, commonly with K-feldspar megacrysts, is the dominant lithology.

Gateway Formation (Middle Proterozoic)

In the Galton, MacDonald and Clark Ranges the lower member consists of dark red and purplish red argillite and micaceous siltstone and argillite.

The upper member consists of green and grey micaceous argillite, dolomitic argillite, coarse grained dolomitic sandstone and light grey dolostone and sandy dolostone.

The unit extends from the eastern Purcell Mountains southeastward to near Helena MT along the eastern limit of Purcell-Belt exposures.

Gladstone Formation (Lower Cretaceous)

The lower member is characterized by fine to very fine grained sandstone interbedded with siltstone, mudstone and claystone. Colors are light grey to greenish grey and maroon.

The upper member is characterized by limestone with occasional coquinas of freshwater origin usually subordinate to calcareous mudstone, siltstone and sandstone. Limestone beds are less prominent to the north and are absent north of 53°.

Occurs in the Alberta Foothills between Twp 5 and 54°.

Grinnell Formation (Middle Proterozoic)

Argillite, mainly bright red, but partly mottled and banded with light green; interbedded with white, coarse grained quartz sandstone and red, fine grained sandstone.

The Grinnell Formation extends northward from Glacier National Park MT along both sides of the Clark Range in Alberta and B.C. to near North Kootenay Pass (~49°20'N on Alberta/B.C. border).

Guyet Formation (Devonian-Mississippian)

The Guyet Fm (0-200 m) outcrops at ~52°N 121°W and consists of sandstone-matrix and mudstone-matrix conglomerate and greywacke. Sandstone-matrix conglomerate consists of granule to cobble size clasts of varicolored chert, cherty argillite, pelite, micaceous siltite and quartzite, and minor limestone and basalt. Clasts are subrounded to rounded and are enclosed in a matrix of quartz, chert, siltite and minor feldspar.

Mahto Formation (Lower Cambrian)

Predominantly quartzose sandstone in medium to thick beds, with rare dolostone and sandy dolostone locally, and one or more shale members in western outcrops. The sandstone is nearly pure quartz, consisting of rounded grains of quartz sand welded together by quartz overgrowth. The Mahto outcrops only in the central and western ranges of the Rocky Mountains between Jasper townsite and northward to Pine Pass (55°30'N, 122° 30'W).

McNaughton Formation (Lower Cambrian)

A useful field term between Jasper townsite and Pine Pass (55°30'N, 122° 30'W). A monotonous, thick sequence of bedded quartzose sandstone or quartzite. In the western ranges of the Rocky Mountains a brown weathering unit of interbedded sandstone and shale is designated the Holmes River Member.

Miette (Formation) Group (Upper Proterozoic)

The lower Miette consists of dark grey to black silty phyllite, phyllitic schist and schist, with interspersed units of light brown to tan quartzite and feldspathic quartzite, and tongues of black carbonaceous micritic limestone.

The middle Miette is typified by massive to graded, thick bedded, feldspathic, turbiditic sandstones and conglomeratic sandstones, with intervening units of grey-green to emerald green phyllite, and lesser black pelite

The upper Miette consists of brownish phyllite and slate, with black micritic limestone, calcareous phyllite, sandstone and quartz sandstone.

The Miette crops out from Lake Louise to near Prince George in the Rocky Mountain belt.

Misinchinka Group (Proterozoic and Cambrian)

In the type area in the Pine Pass map area of northeastern B.C. exposures are mainly micaceous and chloritic schists. Adjacent to the type area where metamorphism is less, a lower 2500 m sequence of pebble conglomerates, poorly sorted, graded sandstones, local diamictites and silty mega-shales are overlain by 100 m of banded green and grey and silty argillites. These are overlain by up to 300 m of massive dolostones with minor algal limestone; these overlain by up to 800 m of clastics with increasing grain size higher in the section and including carbonate debris flows in the lower portion.

As currently applied Misinchinka refers to the more highly metamorphosed late Proterozoic strata centered about the Misinchinka River SW of Pine Pass (55°30'N, 122° 30'W).

Mount Wilson Formation (Middle to Upper Ordovician)

Light gray to white, thin to thick bedded and partly cross stratified quartz sandstone, well cemented by clear quartz.

From Mount Wilson (52°00'N 116°45'W northeast of Saskatchewan River south to Bull River northwest of Fernie B.C..

Moyie Suite (Middle Proterozoic)

The Moyie Suite of sills in the Purcell Mountains in southeastern B.C. reach 700 m thickness and intrude all units of the Purcell Supergroup. Many are differentiated and range in composition from gabbro to quartz diorite granophyre.

Palliser Formation (Upper Devonian)

The upper 35 m consists of fine grained, fossiliferous, dark gray to black limestone. The remainder of the formation is composed of massive beds of gray, mottled, dolomitic limestone characterized by irregular branching tracery standing out in relief on weathered surfaces. Front range outcrops form massive cliffs. The Palliser is present throughout the Rocky Mountains and Foothills of Alberta and varies in thickness from ~240-580 m.

Paskapoo Formation (Paleocene)

Prominent thick, massive to cross-bedded, medium to coarse grained, buff weathering sandstone commonly fining upward. Thinner, finer grained, well indurated to unconsolidated sandstones occur throughout the formation. Abundant soft, recessive mudstone to siltstone, usually gray to greenish gray. Minor coal beds are locally economic. Limestone beds are thin and argillaceous but sometimes very fossiliferous. Conglomerate or conglomeratic sandstone is a minor but conspicuous component of some sections. The formation is confined to a crescent with its base along the Foothills, the bottom near 50°N, the top near 55°N and its outer edge extending out to 112°N at its most easterly limit.

Phillips Formation (Middle Proterozoic)

Thin to very thin bedded, dark purple and red, fine to coarse grained quartz sandstone and siltstone. Argillite and micaceous argillite occur as partings and thin interbeds that commonly grade laterally into intraformational conglomerate. Type section in Galton Range, southeastern B.C., extends from the eastern Purcell Mountains southeastward to near Helena MT along the eastern limit of Purcell-Belt exposures in the Rocky Mountains.

Ranger Canyon Formation (Lower to Upper Permian)

Diagenetic complex of chert, sandstone and siltstone, with associated dolostone, gypsum, phosphate pellets and ooliths, floating sand grains in blue gray chert with sponge spicules, disseminated organic material, fracturing with mosaic breccias and zebra chert and thin basal phosphatic chert conglomerate. 8.5 to 30 m thick.

Type section on Mount Ishbel, Sawback Range, Banff National Park (51°16'N, 115°47'W). Very widespread in Front Ranges of Rocky Mountains from Idaho and grades into Fantasque Formation near Pine Pass (55°30'N, 122° 30'W).

Rock Creek Member (Fernie Formation) (Middle Jurassic)

Resistant gray to gray-brown quartzose siltstone and sandstones.

From Frank to Jasper areas.

Roosville Formation (Middle Proterozoic)

Green and greenish grey argillite, dolomitic argillite, siltstone and sandstone, with less abundant white and grey quartz sandstone, light grey and yellow argillaceous dolostone and stromatolitic dolostone and red argillite. Micaceous partings are common in the siltstone and sandstone.

The northern limit is in the Clark Range from near North Kootenay Pass (~49°20'N on

Alberta/B.C. border) and the formation continues across the international boundary.

Scollard Formation (Upper Cretaceous and Paleocene)

Mainly an interbedded, interfingering sequence of argillaceous sandstone, siltstone, mudstone and shale. Thick coal seams are present in the upper part of the unit, associated with carbonaceous to coaly shale and laterally persistent bentonite beds. Fine grained, quartzose, smectitic, often calcareous. light gray to buff sandstone units are interbedded with light greenish gray, smectitic, sandy to silty mudstone, argillaceous siltstone and dark purplish gray, smectitic, sandy to silty claystone and shale. The formation is recognized from the Fox Creek and Swan Hills area in the north to the Delia and Rosebud area near Drumheller in the south.

Sheppard Formation (Middle Proterozoic)

Light colored dolostone and stromatolitic dolostone, light yellow, gray and dark red sandstone and siltstone, light green dolostone, sandstone, dolomitic argillite, argillite, and in the southern Clark Range one chloritized basic lava flow.

The formation extends from North Kootenay Pass (~49°20'N on Alberta/B.C. border) to south of Helena MT along the eastern limit of Purcell-Belt exposures.

Siyeh Formation (Middle Proterozoic)

The lower member consists of green, grey and black argillites, green and grey argillaceous and arenaceous dolostones and dolomitic quartz sandstones.

The middle member consists mainly of thick bedded, argillaceous grey limestone and dolostone, interbedded algal stromatolites, and thin interbeds and partings of grey and black argillite, with minor sandy dolostone, intraformational conglomerate and oolitic limestone.

The upper member consists mainly of green argillite and dolostone with subordinate red argillite.

The formation is exposed from North Kootenay Pass (~49°20'N on Alberta/B.C. border) to Marias Pass MT.

Slide Mountain Assemblage (Carboniferous-Permian)

The Slide Mountain Assemblage consists mainly of mafic volcanics with related ultramafic, mafic and rarely granitic bodies, and predominantly fine grained clastic rocks and chert. It forms a discontinuous belt that extends along the Omineca Belt for approximately 2000 km, from 49°30' N near Kootenay Lake to 65°N in the western Yukon.

The Slide Mountain Assemblage rocks in the Omineca Mountains at 56°N comprise a succession of cherty argillite, with local thin Lower Permian carbonate beds and thick gabbro and diabase sills as much as 100 m thick. The upper, mainly volcanic part comprises massive, variolitic, locally pillowed basalt, interbedded fine grained, calcareous lithic tuff in places with Early Permian conodonts, and small fault-bounded bodies of sheared serpentinized peridotite.

Starlight Evaporite Member (Whitehorse Formation) (Upper Triassic)

Buff, yellow, light gray to reddish brown weathering sequence of interbedded carbonates, sandstones, siltstones, intraformational and/or solution breccias, with locally intercalated beds and lenses of gypsum. A well indurated cliff forming buff to yellow weathering slightly dolomitic quartz sandstone, with locally intercalated beds of sandy dolostone forms a distinctive lithofacies between the Athabasca and Bow rivers and is named the Olympus Sandstone Lentil.

Occurs throughout the Rocky Mountain Foothills and Front Ranges and southwestern and west-central Alberta and northeastern B.C. to Sukunka River (E of Pine Pass 55°30'N, 122° 30'W).

St. Piran Formation (Lower Cambrian)

A sandstone formation with some greenish, siliceous and arenaceous shales in its upper portion. The sandstones vary in color from light gray to dirty gray, brownish, purplish and pink.

Occurs from Mount Assiniboine (50° 52'N, 115° 38'W) to Mount Sedgewick (52°N 116°W) above Siffleur River.

Stelkuz Formation (Lower Cambrian)

Dark gray siltstone and interbedded very fine grained quartzite in the upper Stelkuz and overlying Boya formations. In the Cassiar and Omenica Mountains the upper part of the Stelkuz Formation, up to 600 m thick, comprises mudstone and sandstone, the latter more abundant upward in the section. The upper contact generally is marked by the appearance of clean white sandstone of the Boya Formation.

Tipperary Quartzite (Lower Ordovician)

Type locality is just east of Tipperary Lake in southeastern B.C. (50°40'N, 115°21'W). Thickly bedded, cross-laminated quartzites with very minor dolomitic quartz sandstones, silica-rich dolostones and shaly mudstones. Observed thicknesses range from 33 to 175 m. The Tipperary, Monkman and Mount Wilson quartzites all have very similar lithologies and probably represent transport of sand from a similar source to different areas of the carbonate shelf at various times during the Ordovician.

Restricted to a small area in the carbonate facies of the southern Rocky Mountains (Kananaskis 82I).

Wapiti Formation (Upper Cretaceous)

Medium to coarse grained, gray, feldspathic, calcareous, buff weathering, smectitic sandstone which is thin bedded to massive. Gray smectitic mudstone and bentonite. Some thin conglomerate and minor coal seams are present in the region of the Liard River. The formation is present in a crescent from Edmonton to northeastern British Columbia with outliers in the Pelican Mountain area, Clear Hills and Halverson Ridge.

Whitehorse Formation (Upper Triassic)

Light weathering, variegated, locally sandy limestone and dolostone, with small amount of calcareous and dolomitic sandstone and solution or intraformational breccia.

Present in the Rocky Mountain Foothills and eastern Front Ranges between the U.S. border and the Sukunka River (E of Pine Pass 55°30'N, 122° 30'W) area of northeastern B.C..

Yanks Peak Formation (Lower Cambrian)

In the Cariboo Mountains (~54°N, 120°W) the Yanks Peak Fm averages 400 m thick and is mainly light colored quartzite.

Appendix F

Petrographic analyses for crushed gravel samples from preglacial deposits

Appendix F-1. Location of crushed gravel samples

Deposit Number	Source	Locality	Location
6815	Alberta Forest Service	Halverson Ridge	16-1-96-5-W6
6692	Team Aggregate (Fairview)	Grimshaw	SE5-82-1-W6
3915	Obed Mountain Coal	Obed Mountain	17-53-24-W5
6424	Valley Concrete (Entwistle south)	Entwistle	9-5-53-7-W4
6402	TBG Pit 84 stockpile	Heatherdown	N11-54-2-W5
3975	Consolidated Concrete	Villeneuve	8-54-26-W4
6106	Lafarge	Lacombe	4-5-41-27-W4
3971	Richardson pit (?)	Wintering Hills	4-28-26-18-W4
6050	Burnco Springbank	Olympic Hill	7-29-24-2-W5
5855	County of Vulcan	Arrowwood	16-17-20-23-W4
3913	County of Wheatland	Cluny	12-11-22-21-W4
5812	(?)	Nanton	4-36-17-30-W4
5570	M.D. Cardston	Del Bonita (east)	12-17-1-21-W4
4213	(?)	Cypress Hills	5-28-7-2-W4

Appendix F-2. Petrographic Number analyses for crushed gravel samples collected from deposits shown.

	Deposit Number						
	6811	6424	3915	6402	3975	6815	6692
Rock Type	%	%	%	%	%	%	%
Sandstone, good, fair	48.3	70.1	89.6	59.4	50.9	37.7	34.0
Sandstone, poor	2.8	4.4	3.4	3.9	2.6	1.6	0.9
Sandstone, deleterious	1.2	1.2	2.9	1.1	2.4	0.7	0.8
Iron concretion, poor	.	.	.	.	0.5	.	.
Iron concretion, deleterious	.	.	.	0.1	1.0	T	.
*Gr.-Di.-Ga., good	.	.	.	0.6	.	.	1.8
*Gr.-Di.-Ga., poor	.	.	.	.	.	.	T
Quartz, crystalline, good	.	0.1	.	T	0.2	10.1	3.2
Chert/cherty carbonate, fair	8.8	.	.	.	.	.	.
Chert/cherty carbonate, poor	1.0	.	.	.	.	.	.
Chert, fair	6.7	1.8	0.2	2.9	14.1	0.8	3.1
Chert, poor	7.0	2.4	.	3.1	2.3	0.9	.
Quartzite, good	23.6	18.6	3.5	28.2	23.7	43.9	52.8
Carbonate, good, fair	.	1.1	.	.	0.7	.	.
Clay/silt, deleterious	0.5	0.1	0.4	0.1	0.2	1.6	0.1
**Sand	.	.	.	.	.	2.5	.
Argillite, poor	.	.	.	.	.	.	0.1
Volcanic, good, fair	.	.	.	0.6	1.4	.	3.1
Total	99.9	99.8	100.0	100.0	100.0	99.9	99.9
Hardness (compared to Alberta average)	above	average	above	above	above	above	above

*Gr.-Di.-Ga.= granite-diorite-gabbro
**Sand= sand left on 80 mesh sieve after washing, from inside clay coatings

Appendix F-2 (cont'd). Petrographic Number analyses for crushed gravel samples collected from deposits shown.

	Deposit Number						
Rock Type	3913 %	4213 %	5570 %	5812 %	5855 %	6050 %	6106 %
Sandstone, good, fair	66.6	56.1	82.0	50.8	67.0	57.0	70.6
Sandstone, poor	3.9	1.6	2.3	2.5	2.2	1.4	3.6
Sandstone, deleterious	1.5	1.3	1.3	2.9	1.1	0.1	2.1
Iron concretion, poor	.	.	.	.	.	.	.
Iron concretion, deleterious	.	.	.	.	.	.	.
*Gr.-Di.-Ga., good	.	.	.	.	.	.	.
*Gr.-Di.-Ga., poor	.	.	.	.	.	.	.
Quartz, crystalline, good	.	0.6	.	.	.	.	.
Chert/cherty carbonate, fair	1.3	.	.	10.5	.	.	.
Chert/cherty carbonate, poor	.	.	.	0.1	.	.	.
Chert, fair	1.9	8.2	.	.	2.5	1.7	7.4
Chert, poor	3.0	7.6	.	.	3.9	2.9	2.0
Quartzite, good	6.2	15.4	5.1	0.9	7.4	12.3	11.8
Carbonate, good, fair	12.5	.	.	31.2	14.6	23.9	1.9
Carbonate, poor	.	.	.	0.1	.	.	0.2
Carbonate, deleterious	.	.	.	0.1	.	.	.
Siltstone, good, fair	.	.	.	.	.	.	0.1
Siltstone, poor	.	.	.	0.4	.	.	.
Clay/silt, deleterious	0.4	0.9	0.3	0.6	1.1	0.3	0.1
**Sand	0.2	.	.	.	.	.	.
Argillite, good, fair	.	.	8.6	.	.	.	.
Argillite, poor	.	.	.	.	.	.	.
Volcanic, good, fair	1.4	.	.	.	.	.	0.4
Cementation, poor	0.8	8.3	.	.	.	0.4	.
Total	99.8	100.0	99.8	100.1	100.0	99.9	100.2
Hardness (compared to Alberta average)	above	average	average	average	average	above	average

*Gr.-Di.-Ga.= granite-diorite-gabbro
**Sand= sand left on 80 mesh sieve after washing, from inside clay coatings

Appendix G

Sand size heavy mineral data for preglacial samples from Allong (1967) and Leckie and Cheel (1989)

Appendix D Sand size heavy mineral data for preglacial samples from Allong (1967). Numerical values in %. T is trace.

Unique	Garn	Spin	Tour	Rut	Mon	Ti	Sta	Epid	Horn	Ac/Tr	Aug	Enst	Diop	Chltd	Chl	Biot	Ky/Zr	Alt	Unid	Mag	Ilm	H/L/P/G
6412	16		T	T	1	T	1	52	2		T	1	1	5	T	T	2	4	T	12	T	1
6411	17	T			3	1	T	44	1		T	1	3	3	2	1	1	7	2	11	T	1
6402	10	T	1		1			60	T		T			2	2	1	4	8	2	4		3
6402	15		T	T	2		T	41	1		T		2	3	2		3	8	2	12	2	
6402	19		1		4	T	1	35	1		T	T	3	3	2	T	2	8	3	14	1	2
1005	20		T		4	1	T	54	1	T	T	1	2	3	1		2	4	1	6	T	2
6223	17		2	T	2	T	1	55	T	T	T	T	1	2			T	4	T	13		T
6222	17		1	T	3	T	1	34	5	T	T	1	1	1	T		1	T	T	31	T	1
1101	16		T	1	2		T	31	T			T	T	2	T		T	3	1	41	T	
1073	7	T	1	T	2	T	T	59	2	T	T		4	2	T	T	1	8	T	7	T	T
1074	15		1	T	3	T	1	54	T				2	2	T	1	1	6	T	9	T	1
6216	12	T	T	T	6	T	1	32	1			1	T	T	T	T	1	7	T	34	T	T
6216	8		T		3	T	T	67	1		T	T	2	3	T		1	5	T	5	T	T
6116	10	T	T		1		1	60	2	T	T	1	1	3	T	1	1	8	1	5		T
1025	13	T	1		3	T	1	38	5		T	T	2	3	T		1	5	T	23		T
1022	10		T	1	3	T	1	44	3		T		2	3	1		T	5	1	23	T	T
6196	14		T		3		T	63	T				2	2	2		2	5	1	6	T	
6197	10	T	1		3	1	1	57	1	T		T	3	3	1	T	2	3	1	9	2	
1024	9	T	1	1	2	T	T	60	6	T			3	1	2	T	2		1	9	T	
1027	11	T	T	T	T		T	38	T	T	T	T	T	3		T	T	4	1	36	2	T
6199	26	1	T		5		2	35	2			T	T	1	T	1	1	6	7	14	1	T
1035	19	10	T	T	3		T	30	1	T		1	1	2	1	T	2	3	T	25	T	T
6422	10		T		T	T	T	51	T		T	T	6	1	4	5	1	10	1	5	T	2
1035	10		2		3		T	52	T	T			2	2	3	7	T	6	1	7	1	6
1049	19	T	T		2	T	T	58	1		T	T	T	2	2	T	2	4	1	6	2	
1049	18		T	T	2		1	44				2	T	1	3		T	5	3	14	3	2
6106	6	T			2			54	1	T	T	1	3	5	2		T	8	3	16	3	2
1080	10	T	1	T	1	T	2	49	T	T	T	T	T	4	T	T	1	6	T	16	2	1
6127	14	T	T		2	T		65				T	T	1	T		1	7	T	4	1	1
1061	10	T	1	T	2	T	T	66				T	1	3	T	T	T	8	3	2	1	T
6134	10	T	T		T		T	53	T		T	T	3	2	3	T	2	10	1	8	T	3
1055	7		1		T	T		35	5		1	T	4	2	2	2	6	8	T	10	T	15

Appendix D Heavy minerals (continued)

Unique	Garn	Spin	Tour	Rut	Mon	Ti	Sta	Epid	Horn	Ac/Tr	Aug	Enst	Diop	Chltd	Chl	Biot	Ky/Zr	Alt	Unid	Mag	Ilm	H/L/P/G
5857	8	T	T	T	1		1	24	T				T	T	2	T	T	44	2	12	1	2
1056	3	17	T	T	2			22	2			T	2		3	T	2	T	2	21	2	8
1042	7	4	T		1		1	31	2	T	T	1	T	1	3	T	1	6	2	35	T	4
1041	21	2	T	T	2		T	35	3		T	T	2	1		T	1	39	2	20	T	1
1052	T	5	T		T		T	46	T	T	5		5		T	1		27	T	5	1	1
1047	1	19	T	T	1		T	22	1	T	T	T	T	T	T	T	2	46	3	2	T	1
1051	2	14	T		T	T	T	36		T	T	T	T		T	T	2	28	3	4	T	8
1100	18	T	T	T	5	T	T	51	2	T	T	T	2	T	1			2	T	11		1
1067	24	20	4		4	T	2	10	3	2	T	2	2	T	1		2	6		17	1	1
1068	4	T	3		1		T	32	20	9	T	3	2	T	T	1	3	8	T	5		1

Explanatory Notes: Garn = garnet, Spin = spinel, Tour = tourmaline, Rut = rutile, Mon = monazite, Ti = titanite, Sta = staurolite, Epid = epidote, Horn = hornblende, Ac/Tr = actinolite or tremolite, Aug = augite, Enst = enstatite, Diop = diopside, Chltd = chloritoid, Chl = chlorite, Biot = biotite, Ky/Zr = Kyanite or zircon, Alt = altered, Unid = unidentified, Mag = magnetite, Ilm = ilmenite, H/L/P/G = hematite, leucoxene, pyrite, or goethite.

Appendix H
Pebble lithologies

(in pocket)

Appendix I
Gold analyses from preglacial deposits

Appendix I. Preglacial placer gold values.

Deposit Number	Name	Sample	Gold Analyses		Sand and Gravel Sample				Gold Values per Total Sample						Values in Sand		Concentrate	
			Assay (ppb)	Amal. (mg)	Weight (kg)	Gravel %	Sand %	Con. (gm)	gm/ tonne	oz/ ton	oz/ 1000t	oz/ 100 000t	gm/ cu.m.	oz/ cu. yd.	gm/ tonne	oz/ ton	gm/ tonne	oz/ ton
6815	Halverson Ridge	#1		.8820	199.98	0.64	0.36	28.71	.0044	.0001	0.129	12.86	.0107	.0003	.0123	.0004	143.56	5.06
		#2		.2580	195.72	0.58	0.42	21.29	.0013	.0000	0.038	3.79	.0031	.0001	.0031	.0001	108.78	3.84
		#3		.5770	190.16	0.52	0.48	36.59	.0030	.0001	0.088	8.85	.0070	.0002	.0063	.0002	192.42	6.79
		Total		1.7170	585.86	0.58	0.42	86.59	.0029	.0001	0.085	8.55	.0069	.0002	.0070	.0002	147.80	5.21
6692	Grimshaw	#1		.2310	187.61	0.66	0.34	28.28	.0012	.0000	0.036	3.59	.0028	.0001	.0036	.0001	150.74	5.32
		#2		.3990	193.07	0.70	0.30	22.73	.0021	.0001	0.060	6.03	.1723	.0042	.0069	.0002	117.73	4.15
		#3		.9100	196.12	0.64	0.36	21.01	.0046	.0001	0.135	13.53	.0110	.0003	.0129	.0004	107.13	3.78
		Total		1.5400	576.80	0.67	0.33	72.02	.0027	.0001	0.078	7.79	.0062	.0002	.0080	.0002	124.86	4.40
4028	Simonette	#1		.0070	20.68	0.83	0.17	1.05	.0003	.0000	0.010	0.99			.0020	.0001	50.77	1.79
		#2		.0110	21.75	0.77	0.23	0.59	.0005	.0000	0.015	1.48			.0022	.0001	27.13	0.96
		#3		.1155	19.65	0.69	0.31	2.61	.0059	.0002	0.171	17.14			.0190	.0006	132.82	4.69
		#4		.1520	22.65	0.78	0.22	2.73	.0067	.0002	0.196	19.57			.0305	.0009	120.53	4.25
		#6-12		2.7800	140.73	0.75	0.25	6.29	.0198	.0006	0.576	57.62	.0578	.0014	.0790	.0023	44.70	1.58
		Total		3.0655	225.46	0.76	0.24	13.27	.0136	.0004	0.397	39.66	.0124	.0003	.0560	.0016	58.86	2.08
4212	Watino	#1		.6210	240.89	0.73	0.27	27.71	.0026	.0001	0.075	7.52	.0075	.0002	.0095	.0003	115.03	4.06
		#2		.7800	238.39	0.81	0.19	19.55	.0033	.0001	0.095	9.54	.0095	.0002	.0172	.0005	82.01	2.89
		#3		2.3420	233.50	0.66	0.34	12.13	.0100	.0003	0.293	29.25	.0284	.0007	.0295	.0009	51.95	1.83
		Total		3.7430	712.78	0.73	0.27	59.39	.0053	.0002	0.153	15.32	.0151	.0004	.0197	.0006	83.32	2.94
	Group 6			10.0655	2100.90			231.27	.0048	.0001	0.140	13.97	.0102	.0010			110.08	3.88
3973	Swan Hills	#1		.0320	243.32	0.79	0.21	43.31	.0001	.0000	0.004	0.38	.0004	.0000	.0006	.0000	178.00	6.28
6824	Pelican Mountain	#1		.2410	201.25	0.84	0.16	36.54	.0012	.0000	0.035	3.49	.0029	.0001	.0075	.0002	181.57	6.40
		#2		.2370	175.58	0.59	0.41	34.49	.0013	.0000	0.039	3.94	.0029	.0001	.0033	.0001	196.43	6.93
		#3		.5070	185.40	0.19	0.81	89.76	0027	.0001	0.080	7.98	.0061	.0002	.0034	.0001	484.14	17.08
		Total		.9850	562.23	0.55	0.32	160.79	.0018	.0001	0.051	5.11	.0040	.0001	.0054	.0002	285.99	10.09
3914	Smoky Tower	#1		.0030	18.73	0.51	0.49	0.86	.0002	.0000	0.005	0.47	.0006		.0003	.0000	45.92	1.62
3915	Obed Mountain	screened		.0170	90.00	0.60	0.40	1.16	.0002	.0000	0.006	0.55	.0006		.0005	.0000	12.89	0.45
	Group 5			1.0370	914.28			206.12	.0011	.0000	0.033	3.31	.0025	.0001			225.45	7.95
6573	Whitecourt	screened		.2010	28.39	0.90	0.91	17.67	.0071	.0002	0.206	20.65	.0387		.0078	.0002	622.40	21.95
6424	Entwistle W.	screened		.7140	40.00	0.75	0.25	10.11	.0179	.0005	0.521	52.06	.0687	.0038	.0714	.0021	252.75	8.92
6424	Entwistle N.	pan conc.		.5530	40.00	0.75	0.25	1.90	.0138	.0004	0.403	40.32	.0532	.0029	.0553	.0016	47.50	1.68
6422	Magnolia	pan conc.		.0140	40.00	0.78	0.22	1.36	.0004	.0000	0.010	1.02	.0013	.0001	.0016	.0000	34.00	1.20
6119	Wetaskiwin	#1		2.9610	203.36	0.60	0.40	21.61	.0146	.0004	0.425	42.47	.0359	.0009	.0364	.0011	106.26	3.75
6118	Wetaskiwin	#2		.1460	40.00	0.60	0.40	3.71	.0037	.0001	0.106	10.65	.0140	.0000	.0091	.0003	92.75	3.27
6106	Lacombe	#1		.9630	212.49	0.80	0.20	10.52	.0045	.0001	0.132	13.22	.0117	.0003	.0227	.0007	49.51	1.75
		#2		.3810	213.25	0.81	0.19	6.43	.0018	.0001	0.052	5.21	.0046	.0001	.0094	.0003	30.15	1.06
		#3		.3240	194.14	0.76	0.24	6.28	.0017	.0000	0.049	4.87	.0039	.0001	.0070	.0002	32.35	1.14
		Total		1.6680	619.88	0.79	0.21	23.23	.0027	.0001	0.078	7.85	.0067	.0002	.0129	.0004	37.47	1.32
	Group 3/4			6.2570	1011.63			79.59	.0062	.0002	0.180	18.04	.0166	.0006			78.68	2.78
3958	Hand Hills	#1		.0760	207.65	0.78	0.22	8.56	.0004	.0000	0.011	1.07	.0009	.0000	.0017	.0000	41.22	1.45
		#2		.0020	135.88	0.13	0.87	3.87	.0000	.0000	0.000	0.04			.0000	.0000	28.48	1.00

Appendix I. Preglacial placer gold values.

		#3		.0380	135.88	0.73	0.27	4.43	.0003	.0000	0.008	0.82	.0008	.0000	.0010	.0000	32.60	1.15
		Total		.1160	479.41	0.54	0.17	16.86	.0002	.0000	0.007	0.71	.0009	.0000	.0014	.0000	35.17	1.24
6811	Wintering Hills	#1		.1920	277.59	0.81	0.19	9.13	.0007	.0000	0.020	2.02	.0017	.0001	.0036	.0001	32.89	1.16
		#2		.1440	259.81	0.77	0.23	8.44	.0006	.0000	0.016	1.62	.0013	.0000	.0024	.0001	32.49	1.15
		#3		.0150	265.79	0.79	0.21	6.37	.0001	.0000	0.002	0.16	.0001	.0000	.0003	.0000	23.97	0.85
		Total		.3510	803.19	0.79	0.21	23.94	.0004	.0000	0.013	1.27	.0011	.0000	.0021	.0001	29.81	1.05
3964	Hand Hills Lake	#1		.0450	191.63	0.76	0.24	19.58	.0002	.0000	0.007	0.68	.0005	.0000	.0010	.0000	102.18	3.60
		#2		.0540	196.98	0.79	0.21	14.49	.0003	.0000	0.008	0.80	.0007	.0000	.0013	.0000	73.56	2.59
		#3		.0810	246.50	0.74	0.26	21.00	.0003	.0000	0.010	0.96	.0010	.0000	.0013	.0000	85.19	3.01
		Total		.1800	635.11	0.76	0.24	55.07	.0003	.0000	0.008	0.83	.0007	.0000	.0012	.0000	86.71	3.06
5855	Arrowwood	#1		.0290	269.93	0.76	0.24	6.85	.0001	.0000	0.003	0.31	.0004	.0000	.0004	.0000	25.38	0.90
6050	Calgary	#1		.0120	276.68	0.82	0.18	6.72	.0000	.0000	0.001	0.13	.0001	.0000	.0002	.0000	24.29	0.86
		#2		.0360	239.87	0.65	0.35	2.66	.0002	.0000	0.004	0.44	.0003	.0000	.0004	.0000	11.09	0.39
		#3		.0220	270.42	0.78	0.22	3.05	.0001	.0000	0.002	0.24	.0002	.0000	.0004	.0000	11.28	0.40
		Total		.0700	786.97	0.75	0.25	12.43	.0001	.0000	0.003	0.26	.0002	.0000	.0004	.0000	15.79	0.56
3913	Cluny	#1		.0950	244.49	0.82	0.18	5.84	.0004	.0000	0.011	1.13	.0012	.0000	.0022	.0001	23.89	0.84
		#2		.0720	274.10	0.74	0.26	5.74	.0003	.0000	0.008	0.77	.0009	.0000	.0010	.0000	20.94	0.74
		#3		.0480	267.14	0.73	0.27	4.09	.0002	.0000	0.005	0.52	.0006	.0000	.0007	.0000	15.31	0.54
		Total		.2150	785.73	0.76	0.24	15.67	.0003	.0000	0.008	0.80	.0009	.0000	.0011	.0000	19.94	0.70
5812	Nanton	#1		.0510	264.15	0.77	0.23	17.42	.0002	.0000	0.006	0.56	.0006	.0000	.0008	.0000	65.95	2.33
	Group 2			1.0120	4024.49			148.24	.0003	.0000	0.007	0.73	.0007	.0001			36.83	1.30
5566	Del B. (west)	#1		.1380	263.09	0.70	0.30	12.06	.0005	.0000	0.015	1.53	.0017	.0000	.0017	.0001	45.84	1.62
5570	Del B. (east)	#1		.0580	201.59	0.68	0.32	10.88	.0003	.0000	0.008	0.84	.0007	.0000	.0009	.0000	53.97	1.90
		#2		.1230	220.81	0.71	0.39	8.06	.0006	.0000	0.016	1.62	.0015	.0000	.0014	.0000	36.50	1.29
		#3		.0830	211.99	0.74	0.26	4.35	.0004	.0000	0.011	1.14	.0010	.0000	.0015	.0000	20.52	0.72
		Total		.2640	634.39	0.71	0.32	23.29	.0004	.0000	0.012	1.21	.0011	.0000	.0013	.0000	36.71	1.29
5669	Magrath	#1		.0210	38.84	0.70	0.30	1.76	.0005	.0000	0.016	1.58	.0001		.0018	.0001	45.31	1.60
	Group 1			.4230	936.32			37.11	.0005	.0000	0.013	1.32	.0012	.0000			39.63	1.40
4213	Cypress Hills	screened		.0097	54.00	0.75	0.25	9.31	.0002	.0000	0.005	0.52	.0009		.0007	.0000	172.41	6.08

Appendix J
Diamond indicator mineral electron microprobe analyses

Appendix J. Diamond indicator mineral electron probe analyses

Deposit #	Grain #	Site #	Mineral (MIN ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% Si2O	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn
5570	38	411	G_03_CALCIC_PYROPE_ALMANDINE	0.09	0.00	22.35	7.86	9.39	39.34	22.54	0.03	0.29	n/a	101.89	n/a	n/a
6424	a	412	PICRO_CHROMITE	0.64	48.88	18.23	14.64	0.00	0.16	16.53	0.00	0.31	n/a	99.62	1257	562
6424	b	412	PICRO_CHROMITE	0.22	53.96	25.66	8.98	0.00	0.05	11.31	0.00	0.43	n/a	100.83	943	803
6424	d	412	PICRO_CHROMITE	1.16	50.03	19.53	14.50	0.00	0.23	14.83	0.00	0.28	n/a	100.78	1336	402
6424	f	412	PICRO_CHROMITE	0.08	59.15	22.10	8.40	0.00	0.05	10.36	0.00	0.51	n/a	101.00	707	2089
6422	a	417	PICRO_CHROMITE	0.30	51.55	27.65	12.59	0.00	0.17	6.86	0.00	0.33	n/a	99.64	1493	0
6422	c	417	PICRO_CHROMITE	0.69	45.35	30.08	13.87	0.00	0.15	10.11	0.00	0.23	n/a	100.76	1493	723
6422	d	417	PICRO_CHROMITE	0.26	51.49	18.91	10.72	0.03	0.00	16.46	0.00	0.31	n/a	98.18	n/a	n/a
6422	e	417	PICRO_CHROMITE	0.11	52.05	18.93	11.75	0.00	0.00	16.46	0.00	0.35	n/a	99.65	n/a	n/a
3975	a	426	G_01_TITANIAN_PYROPE	0.72	4.10	7.91	21.27	5.02	42.31	19.68	0.03	0.00	n/a	101.04	n/a	n/a
3975	e	426	G_02_HIGH_TITANIUM_PYROPE	1.16	5.07	7.53	19.89	6.44	41.23	18.30	0.00	0.25	n/a	99.87	n/a	n/a
3975	c	426	G_09_CHROME_PYROPE	0.28	6.12	6.56	20.78	5.67	41.82	18.76	0.00	0.31	n/a	100.30	n/a	n/a
3975	b	426	G_10_LOW_CALCIUM_CHROME_PYROPE	0.01	5.96	7.08	20.07	5.86	41.14	19.04	0.00	0.48	n/a	99.64	n/a	n/a
3975	d	426	G_10_LOW_CALCIUM_CHROME_PYROPE	0.06	6.54	5.87	23.10	2.36	42.63	18.83	0.00	0.31	n/a	99.70	n/a	n/a
3975	f	426	SUB_PICRO_CHROMITE	0.56	38.91	21.37	14.53	0.00	0.24	23.36	0.00	0.07	n/a	99.04	n/a	n/a
6424	h	430	G_10_LOW_CALCIUM_CHROME_PYROPE	0.00	7.96	7.03	18.66	7.00	40.74	17.89	0.05	0.43	n/a	99.76	n/a	n/a
3958	8	499	UNKNOWN (G4 Garnet)	2.78	0.08	26.96	0.24	32.07	34.05	2.57	0.17	2.20	n/a	101.12	n/a	n/a
3964	16	500	PICRO_CHROMITE	0.95	44.01	26.55	10.58	n/a	0.19	17.29	n/a	0.31	n/a	100.12	6	1285
5855	47	501	PICRO_CHROMITE	2.55	47.52	25.54	12.41	n/a	0.11	11.67	n/a	0.17	n/a	100.48	2279	1767
6692	a	413	CPX_03_UNKNOWN	0.55	0.78	2.99	14.93	19.59	50.99	7.09	2.08	0.06	n/a	99.06	n/a	n/a
6692	d	413	CPX_03_UNKNOWN	0.52	1.07	2.79	14.73	19.50	51.24	6.63	2.07	0.04	n/a	98.61	n/a	n/a
6692	h	413	CPX_05_CHROME_DIOPSIDE	0.14	1.03	2.30	15.18	19.94	52.39	5.85	2.11	0.06	n/a	99.00	n/a	n/a
6692	75	413	PICRO_CHROMITE	0.17	43.10	27.52	8.95	n/a	0.05	18.35	n/a	0.41	n/a	99.07	1022	3133
6692	74	413	SUB_PICRO_CHROMITE	1.91	35.26	30.84	9.48	n/a	0.08	21.51	n/a	0.40	n/a	99.85	707	2250
6692	76	413	SUB_PICRO_CHROMITE	0.67	35.49	19.86	15.56	n/a	0.16	28.37	n/a	0.24	n/a	100.49	864	241
6815	86	414	CHROMITE	0.19	55.90	27.90	2.97	n/a	0.13	9.15	n/a	1.35	n/a	98.37	786	5463
6815	85	414	PICRO_CHROMITE	0.71	45.25	27.17	10.05	n/a	0.08	16.14	n/a	0.30	n/a	99.94	236	1687
6815	87	414	PICRO_CHROMITE	0.63	50.02	25.62	8.43	n/a	0.08	13.20	n/a	0.34	n/a	98.52	1336	1044
4212	23	427	G_03_CALCIC_PYROPE_ALMANDINE	0.08	0.00	22.15	9.12	8.81	37.94	24.33	0.01	0.53	n/a	102.97	n/a	n/a
4212	27	427	PICRO_CHROMITE	1.23	44.50	23.23	12.86	n/a	0.08	18.40	n/a	0.29	n/a	100.92	1257	1366
4212	30	427	PICRO_CHROMITE	0.04	43.65	20.20	11.91	n/a	0.08	23.83	n/a	0.41	n/a	100.35	707	1125
4212	31	427	PICRO_CHROMITE	0.54	40.37	36.20	12.84	n/a	0.08	8.72	n/a	0.29	n/a	99.44	1886	1285
4212	32	427	PICRO_CHROMITE	1.05	45.93	20.11	14.27	n/a	0.09	18.34	n/a	0.31	n/a	100.45	1493	1285
4212	33	427	PICRO_CHROMITE	1.26	40.09	22.88	12.39	n/a	0.11	18.07	n/a	0.25	n/a	95.32	864	1285
4212	34	427	PICRO_CHROMITE	3.09	42.64	29.96	11.40	n/a	0.16	12.46	n/a	0.31	n/a	100.27	1336	643
4212	35	427	UNKNOWN (Chromite)	0.32	30.40	16.81	15.82	n/a	0.14	33.75	n/a	0.21	n/a	97.74	2279	0

Deposit#- this study
Grain#- Dufresne et al, 1996
Site#- Dufresne et al, 1996

[boxed] =grain chemistry falls within diamond inclusion field

[shaded] =grain chemistry falls within Argyle field of chromites

Note: some oxides are used in several plots, if any plot involving the oxide falls within the diamond inclusion or Argyle fields that oxide value is highlighted (above) as anomalous

PLATE 1 KEY

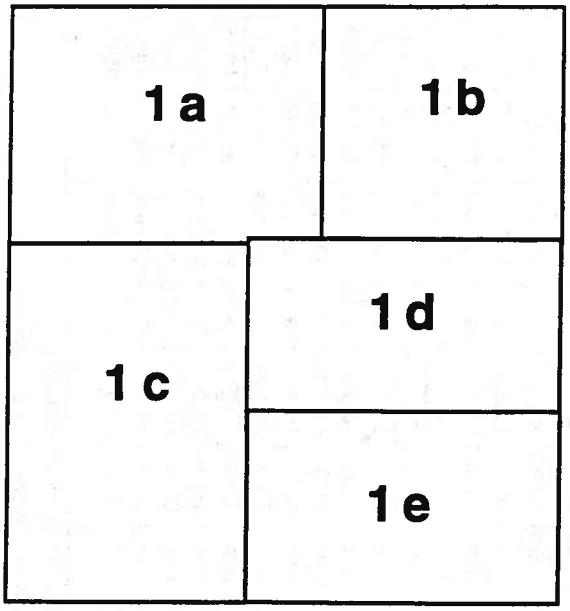


Plate 1a. Photograph of pit face in the Grimshaw Gravels (deposit 6692) at the Grimshaw end. Deposit is in Unit 2 (Plains level) and in Group 6 (northwestern Alberta). Volumetric samples were taken from the three trenches near the base of the section. Note the trough cross-bedding. The deposit contains thick gravel beds (section is >6 m) and a huge volume of granular material exploitable as mineral aggregate. The deposit is finer than Obed Mountain (Plate 1b) but suitable for almost all aggregate purposes.

Plate 1b. Photograph of pit face in the Obed Mountain deposit (3915) next to the Obed coal mine. Deposit is in Unit 4 (highest level, see Plate 2c) and in Group 5 (northcentral Alberta). Note the massive, cobbly gravel. The cobbles can be oversize for mineral aggregate processing. The deposit is equivalent (Unit) to the Cypress Hills Formation.

Plate 1c. Photograph of pit face in the Fort Macleod deposit (5721). Deposit is in Unit 2 (Plains level) and in Group 2 (southcentral Alberta). Note the thick, massive beds (section ~3 m) and thin till overburden.

Plate 1d. Photograph of pit face in the Grimshaw Gravels (deposit 6692) at the Fairview end. Deposit is in Unit 2 (Plains level) and in Group 6 (northwestern Alberta). Note the planar beds (upper) and planar cross-beds (lower). The deposit contains thick gravel beds (~15 m) and a huge volume of granular material exploitable as mineral aggregate. The lag surface, at knee level of field assistant, marks a change in streamflow conditions.

Plate 1e. Photograph from deposit 4028 on the Simonette River. Deposit is in Unit 1 (below Plains level, see Plate 2a) and in Group 6 (northwestern Alberta). The pebbles and cobbles display imbricate fabric (flow from right to left). The tabular rocks are local sandstones.

PLATE 2 KEY

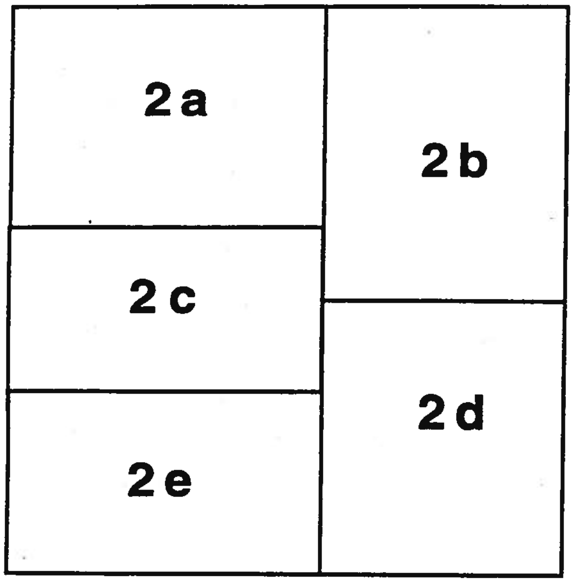


Plate 2a. Photograph of section on the Simonette River (deposit 4028). Deposit is in Unit 1 (below Plains level) and in Group 6 (northwestern Alberta). The deposit rests on bedrock (Wapiti Formation is the dark material in the lower third of section). The preglacial gravels (middle third of section) protected the soft bedrock from erosion. The upper third of the section is glaciolacustrine sands and silts. The steep section and thick overburden would prohibit this location for exploitation for mineral aggregate.

Plate 2b. Photograph of pit face at the south end of the Entwistle deposit (6424). Deposit is in Unit 2 (Plains level) and in Group 3/4 (central Alberta). The gravel is coarse and the bedding massive. The boulder is in the till overlying the deposit. The till overburden on this east side of the deposit is almost as thick as the gravel (~3 m) and adds expense to the cost of aggregate extraction.

Plate 2c. Photograph from the top of the Obed Mountain pit (deposit 3915) looking west towards the Rocky Mountain Front Ranges. Deposit is in Unit 4 (highest level) and in Group 5 (northcentral Alberta). Note the huge boulder (~3 m) of local sandstone which was probably moved and deposited by glacier on top of the deposit. The deposit is 14 km from the edge of the disturbed belt (about 40 km from mountain front in photo).

Plate 2d. Photograph from the top of Whitecourt Mountain (deposit 6573) looking north past the town of Whitecourt. Deposit is in Unit 3 (hills and ridges) and in Group 5 (northwestern Alberta). Note the quartzite cobbles from the deposit scattered about the slope (a ski run in winter).

Plate 2e. Photograph of pebbles at deposit 5566 (Del Bonita). Deposit is in Unit 3 (high plateau) and in Group 1 (southern Alberta). The pebbles are primarily argillite (red and green), quartzite (white and purple) and conglomerate with red argillite clasts.

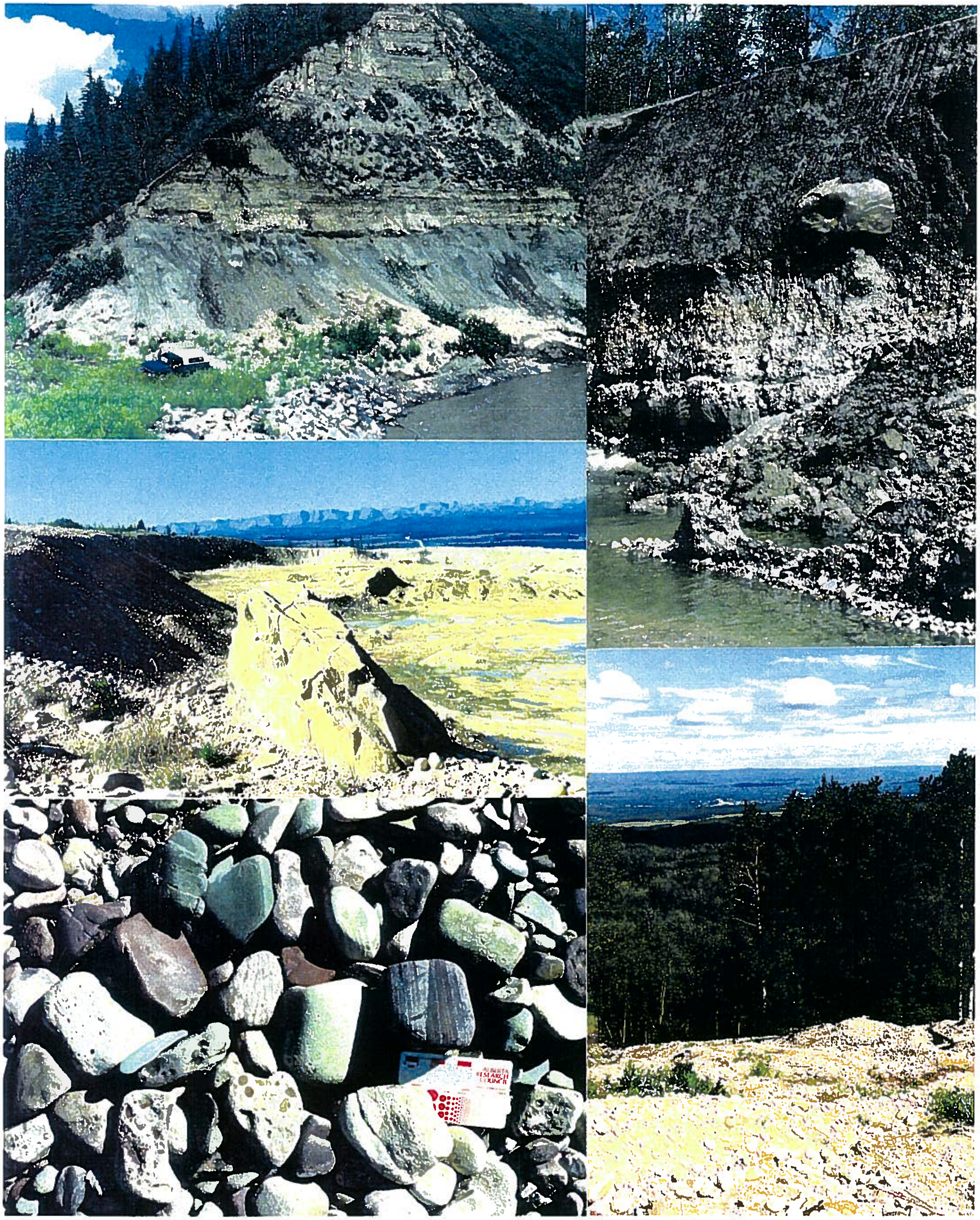


PLATE 3 KEY

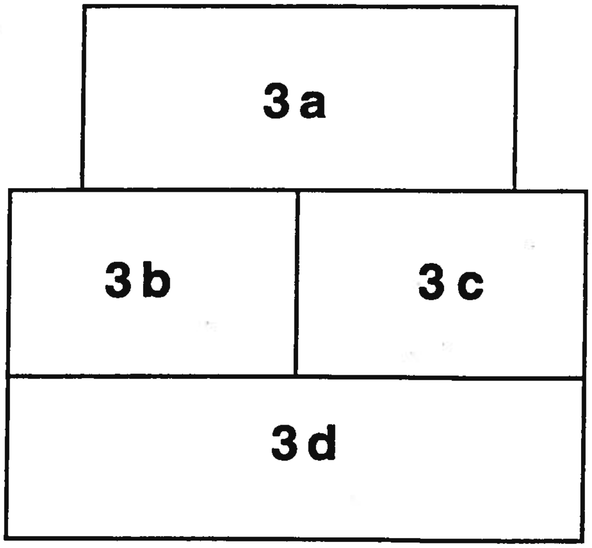


Plate 3a. Photograph of pit in the Swan Hills Gravels (deposit 3973). Deposit is in Unit 4 (highest hills) and in Group 5 (northcentral Alberta). The deposit is extremely coarse (cobbly gravel), and contains huge reserves of aggregate. The section in the background is ~10 m. Edwards, in the foreground, pans sand matrix from the deposit in a pond in the pit floor.

Plate 3b. Photograph from deposit 4028 on the Simonette River. Deposit is in Unit 1 (below Plains level, see Plate 2a) and in Group 6 (northwestern Alberta). The tabular boulder (1 m) is a local sandstone resting (as does the deposit) on Wapiti Formation bedrock. The boulder is an example of a large clast which moved a short distance from its source but which would not survive a long distance of transport as did the hard quartzites. A series of boulders are at the basal contact of this preglacial deposit and form a lag surface.

Plate 3c. Photograph of the Cypress Hills Formation (deposit 4213). Deposit is in Unit 4 (highest level) and in Group 7 (southeastern Alberta). The Cypress Hills Formation is the oldest preglacial deposit in Alberta (Eocene-Oligocene). The deposit caps the highest hill on the Plains. Note the cementation which makes this part of the deposit a conglomerate. Not all gravels in the deposit are cemented.

Plate 3d. Photograph of a working face in a pit in the Villeneuve deposit (3975). Deposit is in Unit 1 (below Plains level) and in Group 3/4 (central Alberta). The deposit contains thick gravel beds (>10 m) and a huge volume of granular material exploitable as mineral aggregate. This deposit is the primary source of concrete quality aggregate for Edmonton. The deposit is finer than some of the Unit 2 deposits in the region (see Plate 2b) but is suitable for almost all aggregate purposes. The gravels are covered by fine preglacial sand, till, and glaciolacustrine silts and clays. This overburden is about the thickness of the exploitable gravel. The lower part of the deposit is an aquifer and requires pumping (see water at bottom left). By-product gold is recovered from this operation.

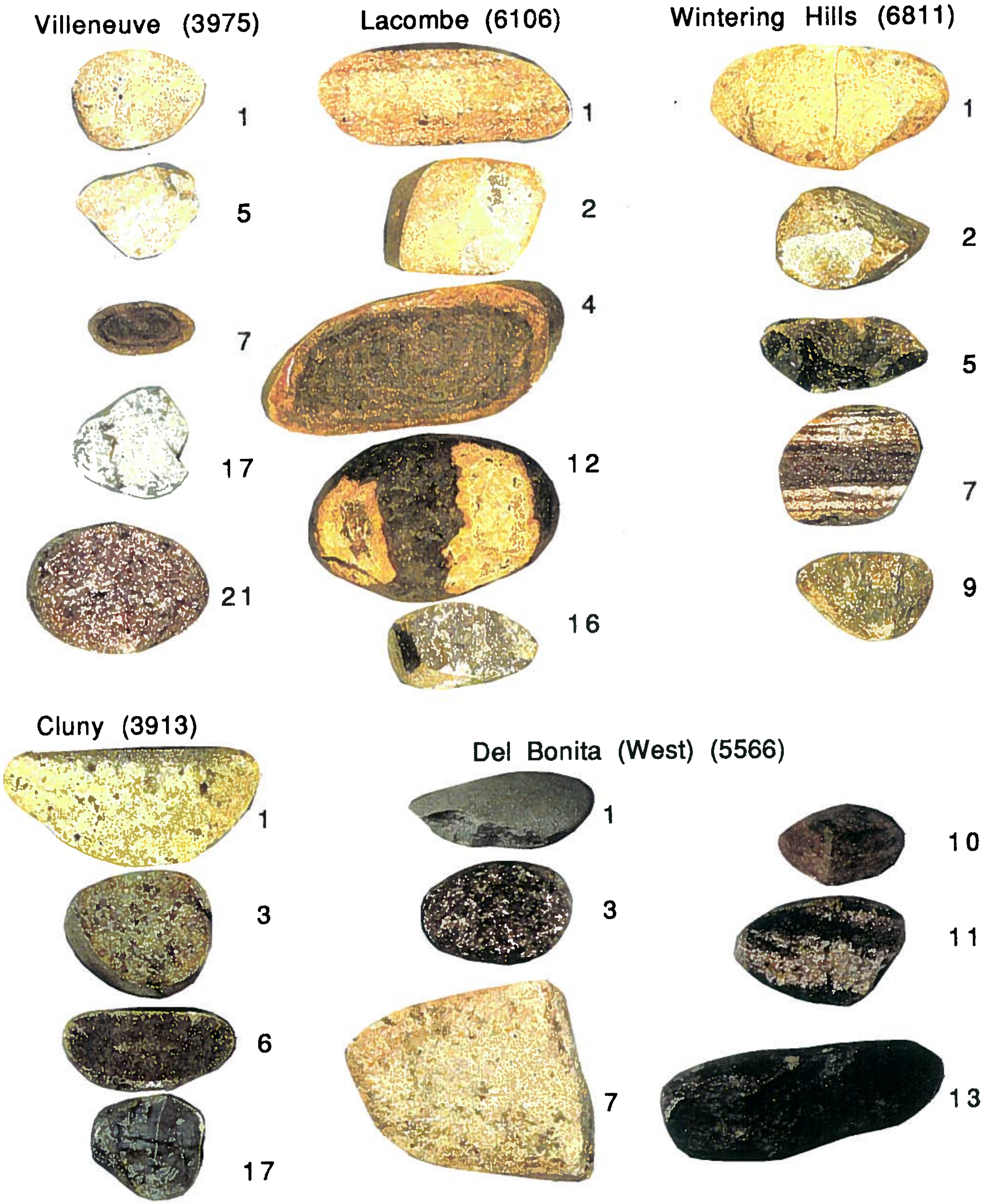


Plate 4 Examples of rock types from deposits in Groups 1, 2 and 3/4. True scale. See Appendix H for lithologic descriptions.

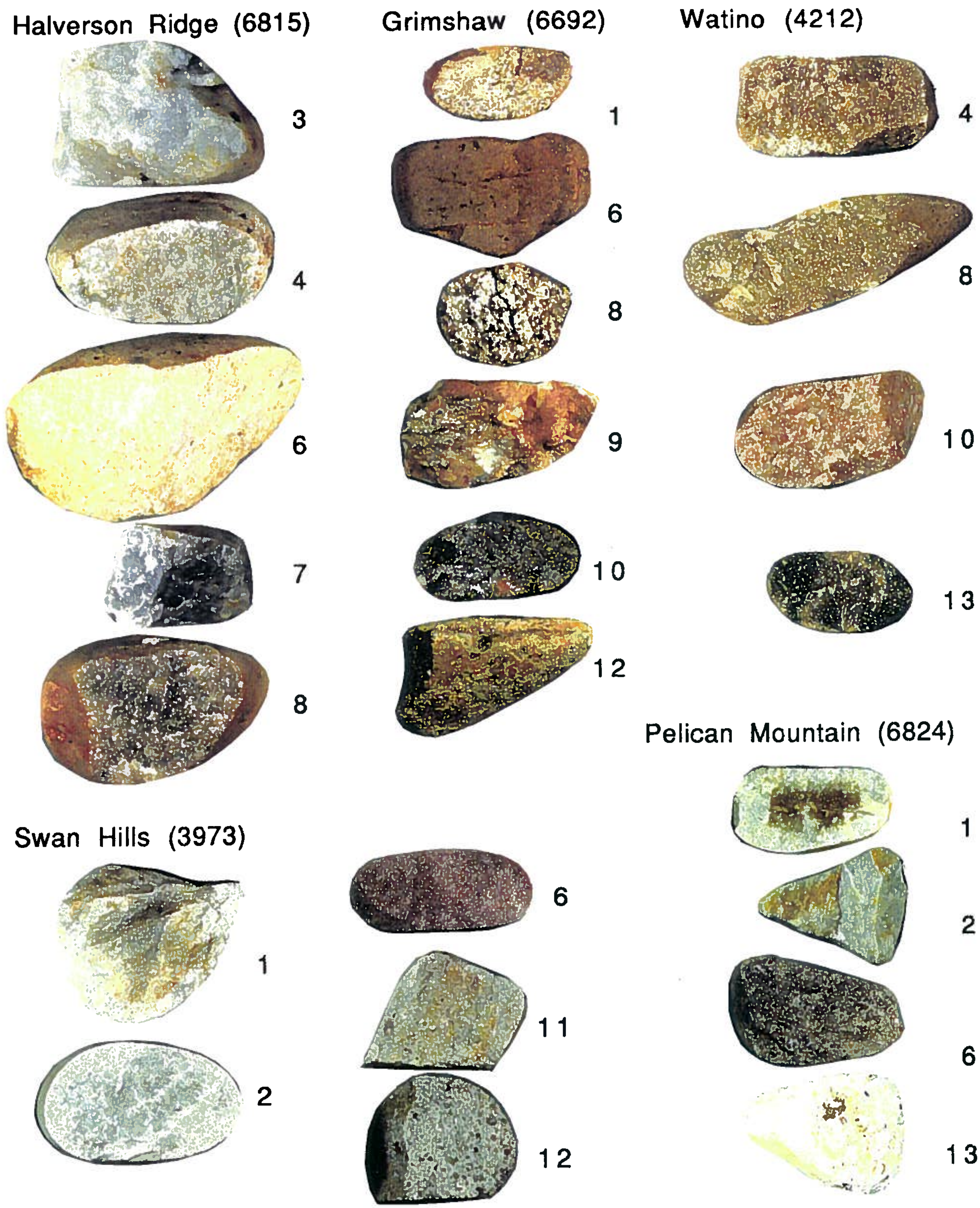


Plate 5. Examples of rock types from deposits in Groups 5 and 6. True scale. See Appendix H for lithologic descriptions.

Appendix H. Pebble lithology descriptions.

Deposit #6824 (Pelican)	Potential Source Formation	Clast Counts			Fresh color	Fresh color code	Weathered color	Weathered color code	Texture		Rnd	Shape	Additional comments
Sample #1 and 3		0.75"-1.5"	1.5"-3.0"	>3.0"	(Munsell System)	(Munsell System)	(Munsell System)	(Munsell System)	Int.	Ext.			
		%	%	%									
Quartzite													
1-gray quartzite	McNaughton, Yanks Peak	7.08%	10.74%	12.50%	light gray	N7	yellowish gray	5Y8/1	glsy	sm	sr	eqt-el	some pits and fractures
5-gray quartzite	McNaughton, Yanks Peak	11.87%	33.05%	28.10%	medium to light gray	N6-N7	medium bluish gray	5B6/1	vis	vsm	wr	f-eqt	flakes, glassy; med.-crs. grains (.1-4 mm)
8-mottled bluish gray quartzite	McNaughton, Yanks Peak	2.94%	8.54%	3.13%	light bluish gray	5B6/1	light bluish gray	5B6/1	vis	slr	wr	f-eqt	bedded; elongate grain texture, grains .1 mm, pits, weathers white
10-gray quartzite	McNaughton, Yanks Peak	2.48%	0.83%	0.00%	mottled medium to light gray	N6-N7	light gray	N7		vsm	wr	eqt-f	glassy, fractured appearance, polished
11-gray quartzite	McNaughton, Yanks Peak	3.78%	0.83%	0.00%	light gray	N7	light to very light gray	N7-N8		sm	wr	eqt	olive gray (5Y4/1) core; iron staining (10YR7/4),flaked
1-13-white quartzite	McNaughton, Yanks Peak	0.07%	0.00%	0.00%	v. lt. gray-white	N8-N9	v. lt. gray-white	N8-N9	c	vsm	wr	eqt	coarse almost crystalline
Sandstone													
2-medium, gray sandstone	Gladstone, Mahto	23.68%	5.23%	3.13%	very light gray	N8	very light gray	N8	mg	slr	wr	eqt	often rusty stained, grains .1-1 mm
3-medium, yellow brown sandstone	Starlight	12.00%	13.22%	6.25%	pale yellowish brown	10YR7/2	grayish orange	10YR7/4	mg	r	sr-r	eqt	weathers very deeply, pits, grains .2-1 mm
4-medium to coarse, gray sandstone	Gladstone, Mahto	12.20%	14.33%	22.22%	light to very light gray	N7-N8	grayish orange	10YR7/4	mg-cg	slr	sr-wr	eqt-f	bedded, clear crs qtz grains (.1-2 mm), fairly hard
6-coarse, purple quartzite/sandstone	Gladstone	5.41%	0.55%	0.00%	pale red purple	5RP	pale red purple	5RP	m-crs	sm	sr-r	eqt-f	some banding, grains .1-2 mm
7-coarse to fine, pale pink sandstone	Gladstone	9.92%	4.41%	25.00%	pale pink	5RP8/2	pale pink	5RP8/2	cg	fsm	r-wr	eqt-f	rusty stains; laminae of variable size grains (.5-2 mm)
9-medium, gray sandstone	Gladstone, Mahto	6.46%	5.79%	3.13%	medium light gray	N6	medium light gray	N6	m-f	sm	sr-r	el-eqt	hard, grains .1-1 mm
12-micaceous sandstone	Wapiti	0.13%	0.00%	0.00%	lt. gray-dk. y. orange	N7-10YR6/6	lt. gray-dk. y. orange	N7-10YR6/6	crs	vr	wr	f	very deeply weathered, grains .5-1 mm, sericite, schist?
15-fine, gray sandstone	Gladstone, Mahto	0.13%	0.00%	0.00%	lt. gray	N7	gray. orange	10YR7/4	f-m	r	r	eqt-f	weathered, grains .1-.5 mm
17-fine, quartzite/sandstone	Gladstone, Mahto	0.07%	0.00%	0.00%	pale yellowish brown.	10YR6/2	lt. olive gray	5Y6/1	vis	sm	wr	eqt	brown core, flakey, grains .1-.5 mm
1-12-gray sandstone	Gladstone, Mahto	0.00%	2.20%	3.13%	olive gray	5Y5/1	med. lt. gray-mod. y. brown	N6-10YR5/4	f	sm	wr	eqt	impure, weathers gradationally to browner core, grains <.2 mm
1-19-cherty sandstone	Gladstone, Mahto	0.07%	0.00%	0.00%	mottled medium gray	N5	mottled medium gray	N5	m	sm	wr	f-eqt	grains .1-1 mm, hard
Siltstone													
13-white claystone	Wapiti	0.78%	0.00%	0.00%	white-gray. orange	N9-10YR7/4	white-gray. orange	N9-10YR7/4		vr	r	f-eqt	very soft clay clasts, easily disintegrates in water
1-17-siltstone	Wapiti	0.07%	0.00%	0.00%	medium light gray	N6	light gray	N7		sm	r-wr	eqt	banded (laminae)
Conglomerate													
18-qtz pebble conglomerate	Gladstone, Mahto	0.07%	0.00%	0.00%	light gray	N7	light gray	N7	vcg	slr	sr	eqt	grains to 3 mm
Chert													
14-gray chert	Bad Heart	0.13%	0.28%	3.13%	dark to very light gray	N3, N8	mod. y. brown	10YR5/4		var	wr	el	hard, mottled
16-brown chert	Bad Heart	0.33%	0.00%	0.00%	mod. yellowish brown	10YR5/4	v. lt. gray	N8		vsm	wr	eqt	white weathering, conchoidal
1-15-black chert	Bad Heart	0.33%	0.00%	0.00%	grayish black	N2	grayish black	N2		vsm	wr	f-eqt	polished
Total number clasts		1533	363	32									

Deposit #3975 (Villeneuve)	Potential Source Formation	Clast Counts			Fresh color	Fresh color code	Weathered color	Weathered color code	Texture		Rnd	Shape	Additional comments
		0.75"-1.5"	1.5"-3.0"	>3.0"	(Munsell System)	(Munsell System)	(Munsell System)	(Munsell System)	Int.	Ext.			
Quartzite													
5-tan quartzite	Miette	6.96%	N	N	v. lt. gray-pale yell. orange	N8-10YR8/6	dk. yell. orange	10YR6/6			sa-sr	eqt	v. hard
9-orange quartzite	Miette	0.99%	O	O	mod. reddish orange	10R6/6	lt. brown	5YR5/6	vis	vsm	r	eqt-f	v. hard, grains .2-.5 mm
10-green quartzite	Miette	0.18%	T	T	grayish olive	10Y4/2	lt. olive brown	5Y5/6	vis	vsm	r	eqt	impure with pink/white eyes, grains .2-1 mm
11-pink quartzite	McNaughton	0.18%			pale red purple	5RP6/2	mod. orange pink	5YR8/4	vis	sm	sa-sr	eqt	fresh surface hard, weathers loose, grains .2-1 mm
13-purple quartzite	McNaughton	1.99%	A	A	grayish red	10R4/2	mod. yell. brown	10YR5/4		vsm	wr	eqt	hard, breaks across grains
22-quartz	Mahto	1.99%	N	N	white	N9	v. pale yell. orange	10YR8/2		sm	sr	eqt	quartz or true quartzite?
			A	A									
			L	L									
Sandstone													
1-medium, tan sandstone	Miette	24.86%	Y	Y	gray. orange	10YR7/4	mod. yell. brown	10YR5/4	m-crs	sm	r	eqt-f	hard, .5-2 mm
2-fine, gray to brown sandstone	Miette	22.87%	S	S	v. lt. gray-mod. yell. brown	N8-10YR5/4	lt. ol. gray-mod. yell. brown	5Y6/1-10YR5/4	vf	sm	sr-r	eqt-f	hard, <.1 mm, sometimes zoned weathering, some pits
3-coarse, tan sandstone	Miette	1.99%	E	E	mod. yell. brown	10YR5/4	mod. yell. brown	10YR5/4	crs	slr	sr	eqt	.5-2 mm
4-fine, gray brown sandstone	Miette	5.97%	D	D	dk. yell. brown	10YR4/2	dk. yell. brown	10YR4/2	f-vf	sm-slr	r-wr	eqt	.1+<.1 mm, hard, some iron stained, weathered, pitted; impure
6-fine, salt and pepper sandstone	Gladstone	3.98%			olive gray	5Y4/1	dk. yell. brown	10YR4/2	f	slr	wr	eqt-f	.2 mm, hard, black chert grains
7-fine, yell. brown sandstone	Paskapoo	1.99%			pale yell. brown	10YR5/2	pale-mod. yell. brown	10YR6/2-5/4	vf	r	sr	f-eqt	<.1 mm, fairly soft (local), weathered core, musky
12-fine, gray brown sandstone	Miette	3.98%			pale yell. brown	10YR6/2	grayish orange	10YR7/4	vf	sm	sr	f-eqt	<.1 mm, hard (silicified), brittle
14-coarse, tan sandstone	Miette	0.99%			gray. orange	10YR7/4	gray. orange	10YR7/4	crs	sm	wr	eqt	.5-1.5 mm, to 5 mm elongated dark grains, hard, impure
Siltstone/Shale													
8-gray siltstone	Miette	0.99%			olive gray	5Y4/1	olive gray	5Y4/1	vf	sm	sr-r	f	<.1 mm, hard, metamorphic? earthy
16-gray shale	Miette	1.99%			dk. yell. brown	10YR4/2	dusky yell. brown	10YR2/2	vf	vsm	sa-sr	eqt	<.1 mm, hard, weathered surface
Conglomerate													
20-red conglomerate	Guyet, Cadomin	1.99%			grayish red	5R4/2	grayish red	10R4/2	vcg	r	wr	eqt-f	.5-5 mm, mod. hard, some grains weather loose
21-chert conglomerate	Guyet, Cadomin	3.98%			mod. yell. brown	10YR5/4	mod. yell. brown	10YR5/4	vcg	slr	r-wr	eqt-f	.2-7 mm, cherty (salt and pepper)
Chert													
15-gray chert	Guyet, Ranger Canyon	1.99%			med. lt. gray	N6	mod. yell. brown	10YR5/4	vf	sm	sr-r	eqt	v. hard; some pits, flakey not glassy (siliceous)
17-white chert	Guyet, Ranger Canyon	5.97%			lt. gray	N7	yell. gray	5YR8/1	vf	sm	sa	eqt	v. hard; one has fizz, pitted, siliceous (not glassy)
18-gray chert	Guyet, Ranger Canyon	2.98%			med. lt. gray	N6	lt. olive gray	5Y5/2	glsy	vsm	sa	el-eqt	polished, glassy, conchoidal
19-dark gray chert	Guyet, Ranger Canyon	0.99%			olive gray	5Y3/2	olive gray	5Y3/2	vf	pol	sa	eqt	conchoidal, extremely fine
Igneous/Metamorphic													
23-meta-sediment?	Gladstone	0.18%			olive gray-mod. orange pink	5Y3/2-5YR8/4	dk. yell. brown	10YR4/2		vsm	sa-sr	eqt	banded? hard, vf with large (3 mm) feldspar crystals? (orange)
Total number clasts		544											

Appendix H. Pebble lithology descriptions.

Deposit #6106 (Lacombe)	Potential Source Formation	Clast Counts			Fresh color	Fresh color code	Weathered color	Weathered color code	Texture		Rnd	Shape	Additional comments
Sample #2		0.75"-1.5"	1.5"-3.0"	>3.0"	(Munsell System)	(Munsell System)	(Munsell System)	(Munsell System)	Int.	Ext.			
		%	%	%									
Quartzite													
2-tan sandstone/quartzite	Miette	25.58%	9.32%	11.54%	light gray	N7	mod. yellowish brown	10YR5/4	vis	sm	r-wr	eqt-f	grains .1-.2 mm, weathers deeply and yellowish; hard
3-tan sandstone/quartzite	Miette	3.94%	2.47%	0.00%	v. light gray	N8	yell. gray	5Y7/2	vis	sm	r	eqt	grains <.1mm; flakes, white grains in clear qtz; pitted
5-brown quartzite	Miette	1.97%	0.00%	0.00%	gray. orange	10YR7/4	gray. orange	10YR7/4	glsy	vsm	wr-r	eqt	qtz grains .4-.7 mm
6-purple quartzite	Miette	0.98%	1.64%	0.00%	pale red-gray. red	5R6/2-4/2	pale red-gray. red	5R6/2-4/2	vis	sm	wr	eqt	variable color and grain size (.1-1 mm), banded
11-brown sandstone/quartzite	Miette	0.98%	5.21%	0.00%	dark yell. brown	10YR4/2	dark yell. brown	10YR4/2	vis	vsm	wr	el	grains <.1 mm
21-white quartzite	Miette	0.20%	0.27%	0.00%	white-mod. red	N1-5R5/4	lt. brown-v. pale orange	5YR6/4-10YR8/2	vis	pol	wr	eqt	grains .5-1 mm, visible in clear cement
22-gray quartzite	Miette	0.20%	0.00%	0.00%	gray. red	10R4/2	pale yellowish brown	10YR6/2		vsm	wr	eqt	grains <.1 mm, v. hard
10-brown quartzite	Miette	0.98%	0.27%	0.00%	mod. yellowish brown	10YR5/4	mod. yellowish brown	10YR5/4	flk	vsm	r	eqt	grains .5-1.5 mm, waxy appearance
Sandstone													
1-coarse, tan sandstone	Paskapoo	17.71%	12.60%	7.69%	yell. gray	5Y6/2	grayish orange	10YR7/4	mg-vcg	sm	r-wr	eqt-f	grains .5-2 mm, bedded
4-v. fine, brown sandstone	Paskapoo	8.86%	0.55%	3.85%	lt. brown-dusky yell. brown	5YR6/4-10YR2/2	mod. yellowish brown	10YR5/4	vfg	fsm	wr	f-eqt	grains <.1 mm, concentric weathering; some soft
7-medium, tan sandstone	Miette, Starlight	3.94%	0.00%	0.00%	gray. orange	10YR7/4	mod. yellowish brown	10YR5/4	mg	fsm	wr	f-eqt	variable grain size <.1-1 mm
8-coarse, tan sandstone	Paskapoo	16.73%	61.92%	76.92%	v. pale orange	10YR8/2	gray. orange	10YR7/4	cg	sm	wr	eqt	grains .5-1.5 mm, cleaner than #1
9-medium, pepper sandstone	Miette, Starlight	1.97%	1.92%	0.00%	mod. yellowish brown	10YR5/4	mod. yellowish brown	10YR5/4	mg	fsm	wr-r	eqt	grains .5 mm, small pits; 1 with spericules, not as impure as 3975-6
Shale													
12-ironstone/mudstone	Paskapoo	2.95%	2.19%	0.00%	dark yell. brown	10YR4/2	dark yell. orange	10YR6/6	vfg	r	r-wr	eqt	grains <.1 mm, v. soft, some rind, HCl fizz
Conglomerate													
19-chert pebble conglomerate	Cadomin	1.00%	0.00%	0.00%	pale yellowish brown	10YR6/2	mod. yellowish brown	10YR5/4	vcg	fsm	r	eqt	grains to 1 cm
Carbonate													
15-cherty dolomite	Devonian, Carboniferous	1.97%	0.27%	0.00%	mod. yell. brown-lt. bluish gray	10YR5/4-5B7/1	mod. yellowish brown	10YR5/4	aph	vsm	sr	eqt	hard, some vugs, slow HCl fizz, conchoidal fracture
16-brown limestone	Devonian, Carboniferous	1.97%	0.00%	0.00%	dark yell. brown	10YR4/2	pale yellowish brown	10YR6/2	aph	sm	wr	f-eqt	HCl fizz, crystals <.1 mm; conchoidal fracture
17-gray limestone	Devonian, Carboniferous	0.98%	0.00%	0.00%	olive gray	5Y3/2	dusky yellow	5Y6/4	vfg	sm	r	vf	HCl fizz, crystals <.1 mm
18-black limestone	Devonian, Carboniferous	2.95%	0.00%	0.00%	olive black	5Y2/1	olive black	5Y2/1	vfg	sm	r-wr	eqt-f	HCl fizz, crystals <.1 mm (extremely fine)
Chert													
13-brown chert	Devonian, Ranger Canyon	0.98%	0.82%	0.00%	mod. yellowish brown	10YR5/4	mod. yellowish brown	10YR5/4	aph	vsm	r	eqt	hard, some pits; extremely fine grained (not glassy)
14-black chert	Devonian, Ranger Canyon	2.95%	0.55%	0.00%	olive black	5Y2/1	olive gray	5Y3/2	aph	vsm	sr	eqt	hard, some pits, one elongate; extremely fine grained (not glassy)
Argillite													
20-red argillite	?	0.20%	0.00%	0.00%	dk. red. brown	10R3/4	mod. brown	5YR3/4	aph	pol	wr	eqt	cherty?, red and black bands
Total number clasts		498	365	26									

Deposit #6811 (Wintering Hills)	Potential Source Formation	Clast Counts			Fresh color	Fresh color code	Weathered color	Weathered color code	Texture		Rnd	Shape	Additional comments
Samle #2		0.75"-1.5"	1.5"-3.0"	>3.0"	(Munsell System)	(Munsell System)	(Munsell System)	(Munsell System)	Int.	Ext.			
Quartzite													
2-tan quartzite	Miette, Tipperary	23.70%	21.43%	20.00%	dark yell. brown	10YR6/6	mod. yellowish brown	10YR5/4	vis	sm	r-wr	eqt-f	grains <.1 mm
6-orange quartzite	Miette, Tipperary	0.99%	0.00%	0.00%	dark yell. orange	10YR6/6	dark yell. orange	10YR6/6	flk	vsm	sr	eqt	one meta. conglomerate, grains to 3 mm; mottled coloring
7-purple quartzite	Miette, Tipperary	0.99%	3.17%	10.00%	pale red. purple	5RP6/2	m. yell. brown-gray. red purple	10YR5/4-5RP4/2	vis	sm	wr	eqt	grains .3-.7 mm, hard, some banded
20- tan quartzite	Miette, Tipperary	0.12%	0.00%	0.00%	gray. orange	10YR7/4	mod. yellowish brown	10YR5/4	glsy	sm	sr	eqt-el	one meta. qtz pebble (to 2 mm) cgl. (breaks across clasts)
22- orange (pink) quartzite	Miette, Tipperary	0.06%	0.00%	0.00%	pale reddish brown	10R5/4	lt. brown	5YR5/6	vis	vsm	wr	eqt	grains <.1 mm
Sandstone													
1-medium, tan sandstone	Paskapoo	29.62%	31.75%	50.00%	dark yell. orange	10YR6/6	dusky yellow	5Y6/4	m.-cg	fsm	r-wr	eqt	grains .2-1 mm, some deeply weathered, friable, pitted
3-v. fine, brown sandstone	Paskapoo	9.87%	4.76%	0.00%	mod. yellowish brown	10YR5/4	mod. yellowish brown	10YR5/4	vfg	fsm	r-wr	f	grains <.1 mm, weathered, oxidized
4-v. fine, gray sandstone	Gladstone, Mount Wilson, Rock Creek	2.96%	1.59%	0.00%	lt. olive gray	5Y5/2	lt. olive gray	5Y5/2	vfg	sm	wr	eqt-f	grains <.1 mm, dirtier and harder than #3
Shale/Siltstone													
13-mudstone	Paskapoo	0.99%	1.59%	0.00%	pale yell. orange	10YR8/6	pale yell. orange	10YR8/6	slty	vr	r	eqt	silty, v. soft, HCl fizz, core of ironstone?
14-siltstone	Fernie	0.42%	1.59%	0.00%	olive gray	5Y4/1	lt. olive gray	5Y5/2	slty	sm	r	eqt-el	laminated, calcareous; splits readily on bedding
15-siltstone	Fernie	0.12%	0.00%	0.00%	dk.-mod. yell. brown	10YR4/2-5/4	gray. orange	10YR7/4	slty	sm	r	eqt-f	hard; silt to v. f. sand (quartz)
Conglomerate													
19-chert pebble conglomerate	Cadomin	0.06%	0.00%	0.00%	mod. yellowish brown	10YR5/4	mod. yellowish brown	10YR5/4	vcg	sm	sr	eqt	lt. brown (#16) & black (#17) chert clasts > 1 cm; ; irreg. surface
Carbonate													
5-chert/cherty dolomite	Devonian, Carboniferous, Whitehorse	11.85%	14.29%	0.00%	pale yellowish brown	10YR6/2	mod. yellowish brown	10YR5/4	aph	vsm	sr	eqt	hard, some vugs and gray chert, slow HCl fizz, cryptocrystalline
8-speckled, gray limestone	Devonian, Ranger Canyon	1.97%	0.79%	0.00%	med. gray	N5	gray. orange	10YR7/4	cryst	slr	r-sr	eqt-f	HCl fizz, crystals .5-2 mm
9-brown limestone	Devonian, Ranger Canyon	2.96%	0.00%	0.00%	pale yellowish brown	10YR6/2	dk. yell. orange	10YR6/6	cryst	sm	r	eqt	HCl fizz, conchoidal, cryptocrystalline
10-dk. gray limestone	Devonian, Ranger Canyon, Paskapoo	9.87%	9.52%	20.00%	olive black	5Y2/1	olive gray	5Y4/1	vfg	vsm	sr-r	eqt-f	HCl fizz, crystals <.1 mm, some chert, some fossiliferous
11-gray dolomite	Devonian, Carboniferous, Whitehorse	0.99%	0.00%	0.00%	dark yell. brown	10YR4/2	mod. yellowish brown	10YR5/4	aph	sm	wr	eqt	slow HCl fizz, cryptocrystalline
12-lt. gray limestone	Devonian, Ranger Canyon	0.99%	1.59%	0.00%	dark yell. brown	10YR4/2	dark yell. brown	10YR4/2	aph	sm	wr	eqt-f	HCl fizz, conchoidal fracture
Chert													
16-lt. brown chert	Devonian, Ranger Canyon	0.99%	7.94%	0.00%	mod. yellowish brown	10YR5/4	mod. yellowish brown	10YR5/4	aph	pol	sr	eqt	conchoidal fracture; slight weathering rind, glassy
17-black chert	Devonian, Ranger Canyon	0.24%	0.00%	0.00%	gray black	N2	gray black	N2	aph	pol	sr	eqt	conchoidal fracture; glassy
18-fossil wood/chalcedony	Devonian, Ranger Canyon	0.12%	0.00%	0.00%	dk. gray-lt. bluishish gray	N3-5B7/1	mod. yellow. brown-dark yell. orange	10YR5/4-6/6	aph	pol	sr	f	
Igneous													
21-white quartz	Miette, Tipperary	0.06%	0.00%	0.00%	bluish white	5B9/1	pale yell. orange	10YR8/6	cg	vsm	r	eqt	xls > 2 mm; some xl terminated in vug
Total number clasts		1677	277	10									

Appendix H. Pebble lithology descriptions.

Deposit #4212 (Watino) Sample #1	Potential Source Formation	Clast Counts 0.75"-1.5"	1.5"-3.0"	>3.0"	Fresh color (Munsell System)	Fresh color code (Munsell System)	Weathered color (Munsell System)	Weathered color code (Munsell System)	Texture Int.	Ext.	Rnd	Shape	Additional comments
Quartzite													
1-gray quartzite	McNaughton, Stelkuz, Boya, Monkman	3.97%	1.09%	0.00%	dark gray	N3	mod. yellowish brown	10YR5/4		sm	sr-r	f-eqt	flakes, fine texture
2-gray quartzite	McNaughton, Stelkuz, Boya, Monkman	7.94%	19.13%	22.22%	light gray	N7	mod. yell. brown/dk. yell. orange	10YR5/4/10YR6/6		sm	sr	eqt	weathers grainy on rind, glassy in center
3-brown quartzite	Mahto	0.99%	0.00%	0.00%	dusky yellowish brown	10YR2/2	dusky yellowish brown	10YR2/2		sm	wr	eqt	flakes, very fine texture, impure
4-brown quartzite	Mahto	8.94%	6.01%	0.00%	lt. brown	5YR6/4	mod. yellowish brown	10YR5/4		sm	sa-sr	f-eqt	flakes, fine texture
5-brown quartzite	Mahto	1.99%	0.55%	0.00%	dk. yellow brown	10YR4/2	dk. yellow brown	10YR4/2	vis	sm	r-wr	f-eqt	grains <.1-.2 mm
Sandstone													
7-cherty sandstone	Mahto	0.99%	1.91%	0.00%	pale yellowish brown	10YR5/2	pale yellowish brown	10YR5/2	fg-mg	slr	wr	eqt	salt and pepper, grains .2-.5 mm
8-medium, brown sandstone	Starlight	65.54%	68.31%	77.78%	mod. yell. brown-dk. y-orange	10YR5/4-10YR6/6	mod. yell. brown-dk. y-orange	10YR5/4-10YR6/6	mg-fg	sm	r-wr	f-el	smooth;, grains .3 mm
18-v. fine, brown sandstone	Starlight	0.05%	0.00%	0.00%	dk. red. brown-lt. brown	10R3/4-5YR6/4	grayish red	10R4/2	vfg	slr	sr	eqt	colored bands, grains <.1 mm
4-pink sandstone	Mahto	0.99%	1.09%	0.00%	grayish orange	10YR7/4	grayish orange	10YR7/4	fg	sm	wr	eqt	deeply weathered, grains .1 mm
Conglomerate													
6-qtz pebble congl.	Misinchinka Gp.	3.97%	0.82%	0.00%	mod. yell. brown-lt. olive gray	10YR5/4-10Y5/2	mod. yell. brown	10YR5/4	cg	ptd	wr	eqt	grains to 5 mm, impure mix
Chert													
9-brown chert	Fantasque	1.99%	0.55%	0.00%	mod. yell. brown/dusky yell. brown	10YR5/4/10YR2/2	mod. yell. brown/dk. yell. brown	10YR5/4/10YR4/2		vsm	sr	eqt	polished
13-chalcedony-gray chert	Fantasque	0.23%	0.27%	0.00%	light gray-mod. yell. brown	N6-10YR5/4	light gray-mod. yell. brown	N6-10YR5/4		vsm	r-wr	f-eqt	mottled, patterned, polished
14-black chert	Fantasque	0.09%	0.27%	0.00%	black	N1	black	N1		pol	sr	eqt	conchoidal, breaks sharp, polished
15-chalcedony?	Fantasque	0.09%	0.00%	0.00%	mod. reddish brown	10R4/6	pale reddish brown	10R5/4		sm	wr	eqt	mottled, patterned, chatter marks
Shale													
16-reddish brown shale	Bad Heart	0.05%	0.00%	0.00%	mod. reddish brown	10R4/6	mod. reddish brown	10R4/6		r	r	vf	soft
17-ironstone	Bad Heart	0.05%	0.00%	0.00%	brownish gray	5YR4/1 (core)	dk. yellow brown	10YR4/2 (rind)	vf	r	sr	f	soft, has rind
Igneous													
10-vein quartz	Cassiar Suite	0.99%	0.00%	0.00%	mod. orange pink	5YR8/4	pale yellowish orange	10YR8/6		vsm	sa, wr	eqt	polished; quartz?, feldspar?
11-smoky quartz	Cassiar Suite	0.99%	0.00%	0.00%	med. gray	N5	dk. yellow brown	10YR4/2		vsm	wr	eqt	glassy
12-meta-volcanic?	Fantasque	0.14%	0.00%	0.00%	grayish black	N2	dusky yellowish brown	10YR2/2		vsm	r-wr	eqt	hard, polished, some rectangular x'ls
Total number clasts		2165	366	9									

Deposit #3973 (Swan Hills)	Potential Source Formation	Clast Counts 0.75"-1.5"	1.5"-3.0"	>3.0"	Fresh color (Munsell System)	Fresh color code (Munsell System)	Weathered color (Munsell System)	Weathered color code (Munsell System)	Texture Int.	Ext.	Rnd	Shape	Additional comments
Quartzite													
1-gray sandstone/quartzite	Gladstone, Mahto	27.73%	34.80%	52.63%	light-med. gray	N7-N6	lt. olive gray-yellowish gray	5Y6/1-10YR7/4	vis	sm	wr	eqt-f	generally flaked, grainy as weathers (.1-1 mm)
2-gray quartzite	McNaughton, Yanks Peak	16.84%	29.96%	42.11%	lt. olive-med. lt. gray	5Y6/1-N6	lt-med. lt. gray	N6-N7	vis	sm	r	f-eqt	flakes, glassy; flat to concave surface (percussed?), grains .1-.5 mm
4-gray quartzite	McNaughton, Yanks Peak	6.93%	10.13%	0.00%	lt-med. lt. gray	N6-N7	lt-med. lt. gray	N6-N7		sm	r	el	stretched' fabric, elong. pits, hard
7-grayish blue quartzite	McNaughton, Yanks Peak	0.99%	0.00%	0.00%	lt. brown gray	5YR6/1	light gray- pale blue	N6-5PB7/2		sm	wr	el	elongate grain texture, flat & smooth, pits on edges, hard
8-gray quartzite	McNaughton, Yanks Peak	0.99%	4.85%	0.00%	lt. gray-lt. olive gray	N7-5Y5/2	lt. gray-lt. olive gray	N7-5Y5/2		vsm	wr	eqt	mottled,very hard, conchoidal fract., sharp, glassy
19-white quartzite	McNaughton, Yanks Peak	0.19%	0.00%	0.00%	lt. gray	N7	lt. gray-pale yell. orange	N7-10YR7/6		vsm	sr	el	milky white (dry), orange weathering, pits (sulphides)
Sandstone													
3-fine, gray quartzite/sandstone	Gladstone, Mahto	5.94%	5.29%	0.00%	lt. brownish-med. light gray	5YR6/1-N6	pinkish-lt. brownish gray	5YR8/1-5YR6/1	f-m	slr	r-wr	eqt	hard, some pits, grains .1-.5 mm
5-medium, gray quartzite/sandstone	Gladstone	4.95%	4.85%	0.00%	yell. gray-gray. orange	5Y7/2-10YR7/4	gray. orange-dk. yell. orange	10YR7/4-10YR6/6	m-crs	ptd	r-sr	eqt	fresh surfaces flaked, subtle laminae, grains .2-1 mm
6-red quartzitic sandstone	Gladstone	3.96%	4.85%	0.00%	pale red-grayish red	5R6/2-5R4/2	pale red	5R6/2	f-m	sm	wr	el-eqt	hard, crs eyes, med-crs well-r qtz grains (.1-.7 mm) in f matrix
9-schistose sandstone	Gladstone	3.96%	0.00%	0.00%	lt. gray-lt. olive gray	N7-5Y6/1	lt. olive gray-v. lt. gray	5Y5/2-N8	m-crs	ptd	wr	el-eqt	lighter gray as qtz content increases, grains .1-1.5 mm; schist?
10-medium, white sandstone	Yanks Peak	2.97%	4.85%	0.00%	yell. gray	5Y8/1	yell.-lt. gray	5Y8/1-N7	mg	sm	wr	eqt	very solid, grains .1-1 mm
11-coarse sandstone	Gladstone	12.88%	0.00%	0.00%	lt. olive gray-lt. gray	5Y6/1-N7	lt. olive gray-lt. gray	5Y6/1-N7	crs	fsm	sr-r	f-eqt	some pitting, qtz grains to 2 mm, hard
18-very fine, gray sandstone	Gladstone	0.10%	0.00%	0.00%	lt. gray	N7	med. lt. gray-lt. brn. gray	N6-5YR6/1	vf	sm	wr	el	thinly laminated, minor pitting, hard, grains .1 mm
20-purple, banded sandstone	Gladstone	0.19%	0.00%	0.00%	pale red purple-lt. gray	5RP6/2-N6	pale red purple-lt. gray	5RP6/2-N6	vcrs	vsm	wr	f-eqt	bands purple and gray, grains to 4 mm
Siltstone/Shale													
14-brown mudstone	Scollard	0.10%	0.00%	0.00%	mod. yell. brown	10YR5/4	pale yell. brown	10YR6/2		sm	wr	el-eqt	weathering rind
15-gray shale	Scollard	0.10%	0.00%	0.00%	dk. gray	N3	med. gray	N5		sm	wr	vf	splits into thin laminae easily, soft
Conglomerate													
12-qtz conglomerate	Miette, Cadomin	8.91%	0.00%	0.00%	lt. gray-v. lt. gray	N7-N8	yellowish gray	5Y7/2	vcg	slr	r-wr	eqt	dk.-lt. qtz grains (wr,4 mm), fairly hard to v. soft
13-qtz conglomerate	Miette, Cadomin	1.98%	0.00%	0.00%	v. lt. gray-med. lt. gray	N8-N6	v. lt. gray-med. lt. gray	N8-N6	vcg		sr-r	eqt	qtzite texture but some crs grains (5 mm) visible
Chert													
16-mottled black chert	Miette, Cadomin	0.10%	0.00%	0.00%	gray. black	N2	gray. black	N2		vsm	r	eqt	hard, polished, v. lt. gray strings (N8)
17-gray chert	Miette, Cadomin	0.10%	0.44%	0.00%	olive gray	5Y4/1	mod. yell. brown	10YR5/4		vsm	r-wr	el-eqt	hard
21-orangish chert	Miette, Cadomin	0.10%	0.00%	5.26%	gray. orange	10YR7/4	dk. yell. orange	10YR4/2		vsm	wr	eqt	v. hard, some etching, light colored blebs
Total number clasts		1041	376	19									

Deposit #6815 (Halverson Ridge)	Potential Source Formation	Clast Counts			Fresh color	Fresh color code	Weathered color	Weathered color code	Texture		Rnd	Shape	Additional comments
Site #2		0.75"-1.5"	1.5"-3.0"	>3.0"	(Munsell System)	(Munsell System)	(Munsell System)	(Munsell System)	Int.	Ext.			
Quartzite													
3-white quartz	Misinchinka Gp., Mahto, Stelkuz, Boya	25.1%	32.8%	0.0%	white-pale	N9-10YR8-6/6	dark yellowish orange	10YR8-6/6	glsy	var	sr-r	eqt	stains yellowish; pitted, pits iron/manganese stained, fractured
4-gray sandstone/ quartzite	Misinchinka Gp., Mahto, Stelkuz, Boya	7.7%	22.4%	100.0%	light gray-olive gray	N7-5Y6/1	light gray-olive gray	N7-5Y6/1	vis	sm	wr	eqt	minor staining, grains .2 mm
5-gray quartzite with quartz vein	Misinchinka Gp., Mahto, Stelkuz, Boya	1.9%	5.2%	0.0%	light gray-olive gray/white	N7-5Y6/1//N9	lt. gray-olive gray/dk. yell. orange	N7-5Y6/1/10YR8/6	vis	sm	wr	eqt-f	quartz vein cuts pebble,grains .1-.7 mm
8-gray sandstone/quartzite	Misinchinka Gp., Mahto, Stelkuz, Boya	1.9%	5.2%	0.0%	brownish to olive gray	5YR4/1-5Y4/1	light/moderate brown	5YR4/4-5/6		sm	r	f-eqt	fine textured
9-yellowish brown quartzite	Misinchinka Gp., Mahto, Stelkuz, Boya	2.9%	8.6%	0.0%	dark/pale yellowish brown	10YR4-6/2	dark yellowish orange	10YR6/6		vsm	wr	el	sharp edges, flaked appearance,very fine texture
11-orange sandstone/quartzite	McNaughton	4.8%	10.3%	0.0%	light bluish gray-dk. yell. orange	5B7/1//10YR6/6	dark yellowish orange	10YR6/6	vis	sm	wr-r	f-eqt	speckled and mottled, pitted, grains .1 mm
12-gray quartzite	Misinchinka Gp., Mahto, Stelkuz, Boya	5.8%	0.0%	0.0%	medium/medium dark gray	N4-6	medium/medium dark gray	N4-6	glsy	vsm	sr-r	eqt	quartzite to quartz
15-fine, olive gray quartzite	Misinchinka Gp., Mahto, Stelkuz, Boya	1.0%	0.0%	0.0%	light olive gray	5Y6/1	dark yellowish orange	10YR6/6		sm	wr	vf	
Sandstone													
1-medium, pinkish gray sandstone	McNaughton	1.9%	1.7%	0.0%	grayish pink to lt. brownish gray	5R8/2 to 5YR6/1	grayish pink to grayish orange	10YR7/4	mg	sm	wr	eqt	grains .1-.8 mm
2-fine, purple sandstone	McNaughton	1.9%	0.0%	0.0%	pale red purple	5RP6/2	pale red purple-mod. yell. brown	5RP6/2-10YR5/4	fg	sm	r-wr	el-eqt	some banding, grains .1 mm
6-medium, gray sandstone	McNaughton	31.9%	0.0%	0.0%	very light-light gray gray	N7-8	v. pale orange-dark yellowish orange	10YR6/6-8/2	mg	fsm	wr	eqt-f	granular, weathers deeply, some pits, grains .3 mm
14-fine, brownish gray sandstone	Dunvegan	1.0%	0.0%	0.0%	brownish gray	5YR4/1	moderate brown	5YR4/4	vfg	r	sa	f	local?, grains <1 mm
17-arkose- sandstone	McNaughton	0.3%	0.0%	0.0%	lt. bluish to olive gray	5B5/1-5Y6/1	mod. y. brown	10YR5/4	m-f	slr	sr-r	eqt	impure sandstone or arkose?, grains .1-.5 mm
18-soft gray sandstone	Dunvegan	0.5%	0.0%	0.0%	light gray	N7	pale yellowish orange	10YR8/6	vf	r	sa-sr	el	moderately hard to soft (local), grains <1 mm
Chert													
7-bluish gray chalcedony	Fantasque	6.8%	13.8%	0.0%	md/lt bluish gray-lt. olive gray	5B5-7/1,5Y6/1	md/lt bluish gray-lt. olive gray	5B5-7/1,5Y6/1	wxy	vsm	r-wr	f-eqt	mottled coloring, polished
13-brownish black chert	Fantasque	1.0%	0.0%	0.0%	brownish black	5YR2/1	brownish black	5YR2/1		sm	wr	eqt	sharp corners, brittle, conchoidal, no weathering
19-brown chert	Fantasque	1.3%	0.0%	0.0%	pale y. brown	10YR6/2	dk. y. brown	10YR4/2		vsm	sr	eqt	
16-black chert	Fantasque	1.3%	0.0%	0.0%	olive black	5Y2/1	black	N1	vfg	vsm	r-sr	f-eqt	conchoidal fracture; iradescent blue-black
Argillite													
10-cherty argillite	Fantasque	1.0%	0.0%	0.0%	light olive gray	5Y6/1	light olive gray	5Y6/1		sm	r	eqt	siltstone?, hard (cherty?)
Total number clasts		625	58	1									

Deposit #6692 (Grimshaw)	Potential Source Formation	Clast Counts			Fresh color	Fresh color code	Weathered color	Weathered color code	Texture		Rnd	Shape	Additional comments
Sample #2		0.75"-1.5"	1.5"-3.0"	>3.0"	(Munsell System)	(Munsell System)	(Munsell System)	(Munsell System)	Int.	Ext.			
Quartzite													
3-coarse, purple sandstone/quartzite	McNaughton	1.0%	0.0%	0.0%	dusky red purple-light gray	5RP3/2-N7	gray-mod. yellowish brown	N5-10YR5/4	vis	sm	wr	eqt	bedded, grains .1-1.5 mm
4-yellow brown quartzite	McNaughton	5.9%	37.2%	0.0%	pale yellow brown	10YR6/2	mod. yellowish brown	10YR5/4	vis	vsm	sr-r	el	flakes, grains visible (.1 mm)
7-brown quartzite	McNaughton	6.9%	14.0%	0.0%	dark to mod. brown	10YR4/2-5/4	dark to mod. brown	10YR4/2-5/4		sm	sr	eqt-f	hard, fine texture
15-black quartzite	McNaughton	2.0%	2.3%	0.0%	greenish black	5GY2/1	greenish black	5GY2/1		sm	r	eqt	fine texture, resembles volcanic
17-coarse, red to brown meta-arkose	McNaughton	10.8%	0.0%	0.0%	mod. yellowish brown	10YR5/4	mod. yellowish brown	10YR5/4	cg	ptd	r	eqt	some micaceous (oxidized) bands, crs chert/feld. x'ls/grains (5 mm)
23-gray quartzite	McNaughton	0.1%	0.0%	0.0%	medium gray	N5	mod. yellowish brown	10YR5/4		sm	wr	f-eqt	subtle banding, glassy
Sandstone													
1-coarse, yellow brown sandstone	Starlight	6.9%	25.6%	0.0%	dark yellowish orange	10YR6/6	mod. yellow brown	10YR5/4	cg	sm	r	eqt-f	smooth, grains .5-1.5 mm
2-medium, gray orange sandstone	McNaughton	11.8%	0.0%	0.0%	gray orange	10YR7/4	dark yellowish orange	10YR6/6	m	sm	wr	eqt-el	minor pitting, grains.1-.7 mm
5-medium to coarse, brown sandstone	Starlight	2.9%	0.0%	0.0%	mod. yell. brown-pale y-orange	10YR5/4-10YR8/6	mod. yell. brown-pale y-orange	10YR5/4-10YR8/6	mg-cg	fsm	sr	eqt	differential weathering (ss and qtz vein), some pits, grains .3-2 mm
6-fine, orange sandstone	Bad Heart	2.9%	2.3%	0.0%	dark yellowish orange	10YR6/6	dark yellowish orange	10YR6/6	vfg	r	sa	f	local source, irregular shapes, grains <1 mm
11-fine, dark brown sandstone	Starlight	2.0%	4.7%	0.0%	dusky yellowish brown	10YR2/2	dusky yellowish brown	10YR2/2	f-vf	sm	r-wr	el	hard, smoother and rounder than #7, grains .1 mm, impure
14-medium, brown sandstone	Starlight	2.0%	0.0%	0.0%	mod. yellowish brown	10YR5/4	mod. yellowish brown	10YR5/4	mg		wr	el	weathered, remnant x'ls(oxidized),shaped as bulbs, resembles volcanic
Conglomerate													
10-chert pebble conglomerate	Fantasque	5.9%	2.3%	0.0%	medium gray	N5	mod. yellowish brown	10YR5/4	vcg-cg	sm	sr	eqt	minor pits, clasts to 1.5 cm
Chert													
16-mottled gray chalcedony	Fantasque	6.9%	2.3%	0.0%	lt. bluish gray to lt. olive gray	5B7/1-5Y6/1	dusky yellow	5Y6/4	glsy	vsm	sr-wr	eqt-f	mottled, some white mica
19-black chert	Fantasque	4.9%	2.3%	0.0%	black	N1	olive black	5Y2/1		vsm	sr-r	eqt	hard, conchoidal, sharp, polished
Argillite													
18-reddish brown argillite	Slide Mountain Assemblage	1.0%	0.0%	0.0%	dark reddish brown	10R3/4	dark reddish brown	10R3/4		vsm	sa	f	hard, sharp
22-black argillite	Slide Mountain Assemblage	0.0%	0.0%	0.0%	dk. y. brown	10YR4/2	black	N1		sm	sa	vf	
Igneous													
8-white granite	Cassiar Suite	5.9%	2.3%	0.0%	light brown-med. orange pink	5YR5/6-5YR8/4	dark yellowish orange	10YR6/6	cg	r	wr	eqt	speckled, deep, white weathering, xls .5-5 mm; feld/qtz/mica?
9-quartz	Cassiar Suite	13.7%	4.7%	0.0%	bluish white- v. pale orange	5B9/1-10YR8/2	dark yellowish orange	10YR6/6		sm	sr-r	eqt-el	glassy, vein quartz, with white mica
13-black basalt?	Slide Mountain Assemblage	1.0%	0.0%	0.0%	black	N1	olive gray-brown gray	5YR4/1-5Y4/1	vfg	sm	r	vf	hard, may be vf sandstone?
12-green basalt	Slide Mountain Assemblage	3.9%	0.0%	0.0%	grayish green-olive gray	10GY5/2-5Y4/1	lt. olive brown?-mod. y-brown	5Y5/6-10YR5/4	vcg-vf	r	wr-r	f	soft, deeply weathered
20-pink granite	Cassiar Suite	0.2%	0.0%	0.0%	pale y. orange	10YR7/6	dk. y. orange	10YR6/6	vcg-cg	r	wr-r	eqt	v. deeply weathered, mostly feld?
21-orange schist	Slide Mountain Assemblage	1.5%	0.0%	0.0%	y. orange	10YR7/6	y. orange	10YR7/6	cg	r	sa	f-eqt	xls 3 mm
24-volcanic	Slide Mountain Assemblage	0.0%	0.0%	0.0%	med. gray/gray. olive/mod. brown	N5/10Y4/2/5YR3/4	same as fresh		cg	sm	sr-wr	eqt	phenocrysts to 4 mm
25-vesicularbasalt	?												found in other sample, no comparable rock in sample
Total number clasts		1426	43	0									

Appendix H. Pebble lithology descriptions.

Deposit #3913 (Cluny)	Potential Source Formation	Clast Counts			Fresh color	Fresh color code	Weathered color	Weathered color code	Texture		Rnd	Shape	Additional comments
Sample #1		0.75"-1.5'	1.5"-3.0"	>3.0"	(Munsell System)	(Munsell System)	(Munsell System)	(Munsell System)	Int.	Ext.			
Quartzite													
1-brown sandstone/quartzite	Paskapoo	6.96%	31.37%	61.11%	gray. orange	10YR7/4	gray. orange	10YR7/4	vis	sm	wr	eqt	iron specks, grains .2-.5 mm
2-gray quartzite	Mount Wilson, Tipperary	8.95%	26.67%	5.56%	very light gray	N8	yellowish gray	5Y7/2	glsy	vsm	wr	eqt-f	clear qtz grains/xls
4-purple quartzite	Rock Creek, St. Piran	0.99%	1.18%	5.56%	pale yell. brown-gray. red	10YR6/2-5R4/2	pink. gray-gray. red	5YR8/1-5R4/2	vis	sm	wr	eqt	banded, grains .1 mm
5-brown quartzite	Rock Creek, St. Piran	1.99%	0.00%	0.00%	dk. yellowish brown	10YR4/2	mod. yellowish brown	10YR5/4	vis	r	wr	eqt	earthy smell, resinous lust[illegible], grains .5 mm; impure
6-v. fine, sandstone/quartzite	Paskapoo	37.78%	6.67%	16.67%	mod. yellowish brown	10YR5/4	grayish orange	10YR7/4		fsm	wr	eqt-el	vf texture
7- pink quartzite	Mount Wilson, Tipperary	0.05%	0.00%	0.00%	gray. pink	5R8/2	mod. orange pink	5YR8/4	vis	vsm	wr	eqt	grains .1-.3 mm
8- red speckled quartzite	Mount Wilson, Tipperary	0.11%	0.00%	0.00%	gray. orange pink	5YR7/2	gray. orange pink	5YR7/2		vsm	wr	eqt-f	f texture; red staining and bands
9-white quartz	Mount Wilson, Tipperary	1.99%	0.00%	0.00%	white	N9	v. pale orange	10YR8/2	glsy	vsm	sr	eqt	irregular surface
Sandstone													
14-fine, orange sandstone	Paskapoo	0.99%	0.00%	0.00%	grayish orange	10YR7/4	grayish orange	10YR7/4	vf	vr	r	eqt	local, soft, v deeply weathered, grains <.1 mm
15-peppery sandstone/arkose	Rock Creek, St. Piran	2.98%	1.96%	0.00%	dk. yellowish brown	10YR4/2	pale yellowish brown	10YR6/2	m	r	wr	eqt-el	grains .2-.6 mm
Siltstone													
11-laminated sandstone/siltstone	Rock Creek, St. Piran	0.11%	0.00%	0.00%	dk. yellowish brown	10YR5/6	dk. yellowish brown-pale olive	10YR5/6-10Y6/2		slr	wr	eqt	bands .5-1cm, silt-vf sand
Conglomerate													
3-qtz pebble conglomerate/gritstone	Fort Mountain, Cadomin, Paskapoo	5.96%	27.45%	11.11%	light olive gray	5Y6/1	mod. yellowish brown	10YR5/4	vcg	slr	wr	eqt	frosted to pink wr qtz grit, impure, grains .2-5 mm
10-chert pebble conglomerate	Fort Mountain, Cadomin	0.11%	0.00%	0.00%	dk. yellowish brown	10YR5/4	dk. yellowish brown	10YR5/4	peb	sm	wr	eqt-f	pebbles to 1.5cm
Carbonate													
12-gray limestone	Devonian, Carboniferous	16.90%	2.35%	0.00%	olive gray	5Y5/2	olive gray	5Y5/2	vf	sm	sr-r	eqt-f	effervesces
13-foss. limestone	Devonian, Carboniferous	0.99%	0.39%	0.00%	brown. black	5YR2/1	brown. gray	5YR4/1	vf	vr	sr	f-eqt	crinoid pieces, matrix vf, effervesces
16-gray dolomite	Devonian, Carboniferous, Whitehorse	1.99%	0.00%	0.00%	brown. gray	5YR4/1	dk. yellowish brown	10YR4/2	vf	r	sa	f-eqt	slow effervesces
21-mottled, cherty dolomite?	Devonian, Carboniferous	4.97%	0.00%	0.00%	lt. bluish gray	5B7/1	dusky yellow	5Y6/4		sm	sr	eqt	vugs (.1mm), xls not visible
22-brown limestone	Devonian, Carboniferous	0.05%	1.18%	0.00%	mod. yellowish brown	10YR5/4	dk. yellowish brown	10YR2/2	vf	vsm	wr	eqt	conchoidal fracture
20-cherty limestone	Devonian, Carboniferous	0.05%	0.00%	0.00%	v. light gray	N8	yell. gray	5Y7/2	crs	fsm	r	eqt	crs texture, pitted
Chert													
17-gray chert	Devonian, Carboniferous	2.98%	0.00%	0.00%	light gray	N7	pale yell. orange	10YR8/6		vsm	sr	eqt	sharp, conchoidal, yell. rin[illegible]
18-mottled brown chert	Devonian, Carboniferous	2.98%	0.00%	0.00%	pale yellowish brown	10YR6/2	gray. orange	10YR7/4		r	sr	eqt	staining of colors, one w/ [illegible]. red (5R6/6) and white filling
19-black chert	Devonian, Carboniferous	0.11%	0.78%	0.00%	black	N1	black	N1		vsm	wr	eqt	polished, glassy
Total number clasts		1861	255	18									

Deposit #5566 (Del Bonita west)	Potential Source Formation	Clast Counts			Fresh color	Fresh color code	Weathered color	Weathered color code	Texture		Rnd	Shape	Additional comments
Sample #1		0.75"-1.5'	1.5"-3.0"	>3.0"	(Munsell System)	(Munsell System)	(Munsell System)	(Munsell System)	Int.	Ext.			
		%	%	%									
Quartzite													
5-greenish gray quartzite	Grinnell	3.98%	0.40%	0.00%	mod. olive brown	5Y4/4	dk. y. brown	10YR4/2	vis	slr	wr	eqt	glassy, grains <1 mm
7-sandstone/quartzite	Aldridge, Rock Creek, Blood Reserve	6.97%	25.90%	44.44%	gray. orange	10YR7/4	mod. y. brown	10YR5/4	vis	sm	sr-r	eqt-f	glassy, grains .1-.3 mm, whitish to yellowish,pink-brown dry hue
8-purplish gray sandstone	Phillips	1.99%	8.37%	11.11%	pale red purple	5RP6/2	mod. y. brown	10YR5/4	vis	sm	r	eqt	glassy, grains 2 mm, impure (speckled), some purple banding
9-purple banded quartzite	Phillips	4.98%	10.36%	11.11%	red purple	5RP4/2	red purple	5RP4/2	vis	r	r	eqt	glassy, grains .2-1 mm, faint laminae deeper gray, one shale piece
10-sandstone/quartzite	Grinnell, Sheppard, Phillips	8.96%	12.35%	11.11%	mod. red	5R5/4	grayish red	10R4/2	vis	slr	sr-r	eqt-f	glassy, grains .1-1 mm, very impure, some feldspar + shale
15-white quartzite	Grinnell	3.98%	0.40%	0.00%	v. lt. gray-dusky y. green	N8-5GY5/2	pinkish gray-dusky y. green	5YR8/1-5GY5/2	vis	fsm	sr	eqt	glassy, clean, weathers white/tan and green hue, green shale clasts
21-gray quartzite	Grinnell	0.08%	0.00%	0.00%	med. lt. gray	N5	med. lt. gray	N5	vis	vsm	sr-sa	eqt	glassy, hard, grains .5 mm
26-bluish gray quartzite		0.08%	0.00%	0.00%	gray. red purple	5RP3/2	v. dusky red	10R2/2		vsm	sa-sr	eqt	glassy, conchoidal
Sandstone													
4-fine, gray sandstone	Roosville, Sheppard, Blood Reserve	5.97%	15.54%	11.11%	pale olive	10Y6/2	dusky yellow	5Y6/4	vf	sm	r-sr	f-eqt	scratches, grains <1mm
12-very fine, gray sandstone	Roosville, Sheppard	10.95%	0.00%	0.00%	mod. olive brown	5Y4/4	lt. olive gray	5Y5/2	vf	sm	wr	vf	thinly laminated, grains <.1 mm
14-very fine sandstone	Roosville, Sheppard	3.98%	0.40%	0.00%	mod. brown	5YR3/4	mod. brown	5YR3/4	vf	sm	wr	vf	scratches, grains <.1 mm
16-quartzite/very fine sandstone	Phillips	6.97%	3.19%	0.00%	pale olive	10Y6/2	olive black	5Y2/1	vf	sm	wr	f-eqt	scratches, similar to #14 but gray, flakey, grains <.1 mm
17-fine, gray sandstone	Roosville, Sheppard	1.99%	0.00%	0.00%	pale olive	10Y6/2	dusky yellow	5Y6/4	vf	sm	r-sr	f-eqt	scratches, grains <.1mm
25-brown quartzite	Roosville, Sheppard	0.16%	0.00%	0.00%	dusky yellow. brown	10YR2/2	mod. y. brown	10YR5/4	f	sm	sa	el	rectangular blocks, glassy, grains visible (.1 mm)
Siltstone													
2-siltstone	Roosville, Sheppard	1.00%	0.00%	0.00%	yell. gray	5Y7/2	yell. gray-dusky yellow	5Y7/2-5Y6/4		sm	r	eqt	thinly laminated
Conglomerate													
6-gritstone/arkose	Roosville, Sheppard	1.99%	0.00%	0.00%	dk. greenish gray	5GY4/1	olive black	5Y2/1	mg-cg	slr	r	f-eqt	very impure, grains to 2 mm
11-sandstone/conglomerate	Apekunny, Grinnell, Cranbrook, Siyeh	11.94%	15.14%	11.11%	pale red-gray. orange-med. gray	5R6/2-5YR7/2-N5	mod. y. brown	10YR5/4	mg-cg	slr	r-sr	eqt-f	grains (weathered) glassy (fresh), red shale, black bands (carbon)
Chert													
20-brown chert	Apekunny, Grinnell, Cranbrook, Siyeh	0.16%	0.00%	0.00%	mod. olive brown	5Y4/4	mod. y. brown	10YR5/4		vsm	sr-sa	eqt	v hard, conchoidal, glassy-flakey, polished
Argillite													
1-green argillite	Apekunny, Gateway, Roosville, Siyeh	14.93%	7.17%	0.00%	green. gray	5G6/1	green. gray	5G6/1	vf	sm	wr-r	vf	some qtz eyes (<.1 mm), some thinly laminated
18-quartzite/argillite	Apekunny, Gateway, Grinnell, Phillips Roosville, Siyeh	3.98%	0.40%	0.00%	blackish red	5R2/2	gray. red	5R4/2	vf	sm	sr	eqt-el	faint laminae, glassy, grains <.1 mm, one shale clast
19-sandstone/argillite	Apekunny, Gateway, Grinnell, Phillips Roosville, Siyeh	3.98%	0.40%	0.00%	gray. red	5R4/2	gray. red	5R4/2	vf	vsm	sr	f-eqt	hard, grains <.1 mm
Igneous													
3-diorite	Moyie Suite	1.00%	0.00%	0.00%	black/white mottled		dusky y. brown	10YR2/2	mg-cg	r	wr	eqt	all wr, xls .1-2 mm, rough, deeply weathered
13-basalt	Moyie Suite	0.16%	0.00%	0.00%	olive gray	5Y3/2	olive gray	5Y3/2	f-m	sm	sr	eqt	scratches, xls .5-1 mm
Total number clasts		1224	251	9									

Abbreviations describing internal (Int) pebble texture: vis= grains visible, aph=aphanitic, cryst=crystalline; glsy= glassy; wxy= waxy; flk=flakes; v= very; f, m, c= fine, medium, coarse; g= grained; slty=silty; peb=pebbly

Abbreviations describing external (Ext) pebble texture: sm= smooth; r= rough; var= variable; v= very; f= fairly; sl= slightly; f= fairly; ptd=pitted; pol=polished

Roundness (Rnd) is estimated for all pebbles of this type, abbreviations used to describe pebble roundness: wr= well rounded; r= rounded; sr= subrounded; sa= subangular

Shape is estimated for all pebbles of this type, abbreviations used to describe pebble shape: eqt= equant; el= elongate; f= flat; modifiers: v= very

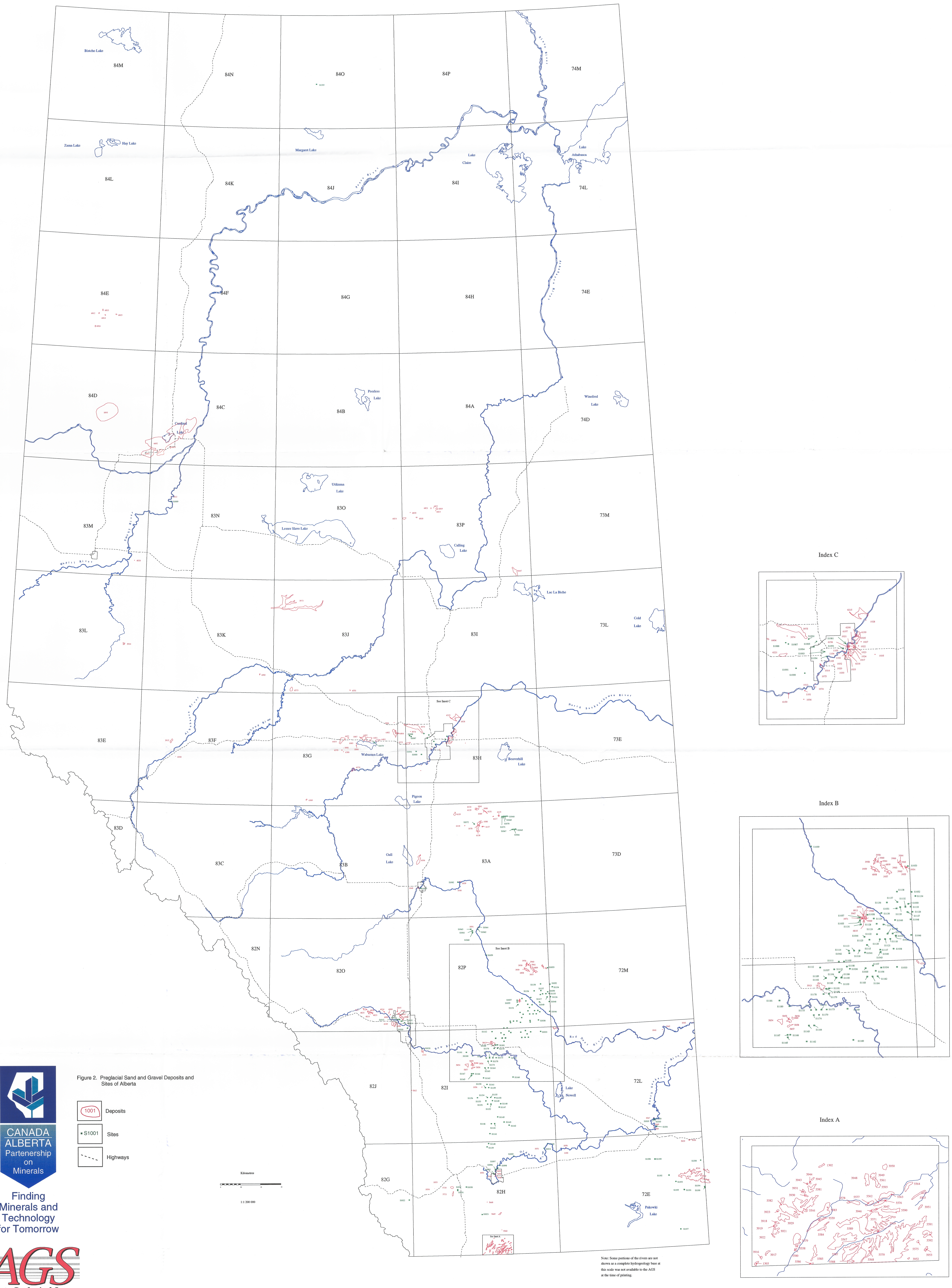


Figure 2. Preglacial Sand and Gravel Deposits and Sites of Alberta

1001	Deposits
S1001	Sites
- - -	Highways

Note: Some portions of the rivers are not shown as a complete hydrogeology base at this scale was not available to the AGS at the time of printing.

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