THE PROVENANCE OF DIAMOND INDICATOR MINERALS IN BEDROCK OF THE HINTON AREA, ALBERTA FOOTHILLS

C. Willem Langenberg and Andrew Skupinski*

Alberta Geological Survey
6th Floor, 9945-108 Street
Edmonton, Alberta, T5K 2G6

*Tatra Mineralogical
228 Ranchlands Court NW
Calgary, Alberta, T3G 1N9

Alberta Geological Survey
Open File Report 1996-09

ACKNOWLEDGEMENTS

This study was conducted on contract to Cameco Corporation of Saskatoon (Saskatchewan). An earlier version of this report forms part of an assessment report (Alberta Department of Energy, Index No.19950005), that was submitted by Cameco to the Alberta government in June 1995 and that was released for public viewing on June 9th, 1996. The management of Cameco is thanked for permission to publish this report as an Alberta Geological Survey Open File Report. Shaun O'Connell is thanked for measuring most of the paleocurrent directions and Roy Eccles for reviewing an earlier version of this report. Garth Drever is thanked for stimulating discussions and companionship in the field. Discussions with Jim Marlatt, Vlad Sopick and Mike Whitehead are very much appreciated. However, the conclusions are our own.

CONTENTS

ABSTRACT

Bedrock sampling confirmed that diamond indicator minerals are present in Cretaceous and Tertiary rocks of the Hinton area, Alberta. A major find is the presence of olivines (including diamond inclusion olivines) in these sediments. Another find is that sediments, which are older than Maastrichtian, contain diamond indicator minerals in the Cadomin area. This might indicate that there were 2 periods of ultramafic, and possibly kimberlite or lamproite, intrusions: one in the Maastrichtian around 70 Million years ago and an older one possibly in the Aptian around 110 Million years ago.

Four anomalous areas including the Entrance, Cadomin, Ruby Creek and Coal Valley areas can be delineated. These areas could contain ultramafic diatremes. Based on bedrock samples, the Entrance and Cadomin areas rank highest in terms of diamond exploration potential.

A study of thin sections from the bedrock samples show that chromite, ilmenite and garnet can be recognized and microprobed. A layer with 20 ilmenite grains may provide additional support for a local source of the grains.

Paleocurrent analysis shows preferred directions between azimuths N010^0 East and N160^0 East for Late Cretaceous and Tertiary sediments, with a few deviating directions towards N325^0 East. These directions may reflect local current directions during deposition that can be used to find local source areas and possibly local ultramafic diatremes.

INTRODUCTION

Micro diamonds have been found recently in stream samples north of the Hinton area (Dufresne et al., 1996). The purpose of this study was to determine if diamond indicator minerals, which are present in stream samples (Cameco, 1995), are present in the bedrock. Heavy minerals have been reported in Cretaceous and Tertiary clastic sediments of the Hinton area (Rahmani and Lerbekmo, 1975; Mellon, 1967).

METHODOLOGY

For the purpose of this study, 62 large bedrock samples with a weight of about 25 kg were collected from Cretaceous and Tertiary horizons. The different horizons sampled are shown in Table 1, together with the number of samples per horizon. Each outcrop was described and observations were made on the sedimentary environment and the possible presence of current indications. A small representative sample was also retained as a source for a thin section. Diamond indicator minerals, present in these thin sections, were analyzed by microprobe at the University of Calgary.

Table 1. Stratigraphic horizons sampled for this study

Horizon	Number of samples
Miette Fm.	1
Gog Fm.	1
Nikanassin Fm.	1
Cadomin Fm.	2
Gladstone Fm.	1
Mountain Park Mb.	1
Cardium Fm.	2
Wapiabi Fm.	2
Chungo Mb.	3
Brazeau Congl.	5
Brazeau Fm.	22
Entrance Congl.	5
Coalspur Fm.	6
Paskapoo Fm	8
High Divide Congl.	2
Total	62

The 25 kg samples were shipped to CF Minerals' Laboratory, where the pebbles from conglomerates were segregated and weighed. The remaining fraction was crushed to particles smaller in size than 6mm. Using the shaker table, the heavy minerals (>2.8 SG) were obtained. The iron magnetic fractions were removed and the remaining heavies were separated in a fine fraction (100-177 microns) and a bit coarser fraction (177-850 microns). These size fractions were then separated in a light (2.8-2.95 SG), mid (2.95-3.2 SG) and heavy (>3.2 SG) fraction using tetrabromoethane and methylene iodide fluids.

The heavy fraction were separated with the Franz Separator in an Upper (more paramagnetic) and Lower (less paramagnetic) fraction. The Upper fraction includes regional ilmenites and almandines and the Lower contains orange and purple garnets (pyropes and eclogitic garnets), green Cr-diopsides, green olivines, brown dravitic tourmalines, opaque picroilmenite and opaque chromites. These diamond indicator minerals were picked by CF Minerals and their composition verified with their SEM microscope. The garnets were classified according to Dawson and Stephens (1975) and the pyroxenes according to Stephens and Dawson (1977). G3 and G4 were classified as Group 1 or Group 2 (McCandless and Gurney, 1986) for grains that were analyzed by microprobe for sodium. The compositions of the chromites were plotted to see if they fall in the diamond inclusion field (Fipke et al., 1995). Chromites in the diamond inclusion field are informally refered to as diamond inclusion chromites (DIC's). Olivines were classified as olivines in the diamond inclusion field (informally called diamond inclusion olivines or DIO's) according to their plot of Cr_2O_3 against the MgO number (Fipke et al., 1995, p.67).

Plugs with diamond inclusion olivines and diamond inclusion chromites were used for observations on morphology.

Ten of these outcrops proved to be suitable to obtain reliable current directions of fluvial systems. Trough cross-stratification is the most accurate paleocurrent-direction indicator in fluvial deposits and, consequently, this was the structure generally used. The methodology by DeCelles et al. (1983) was used to determine these current directions. Because of deformation most sections have dipping bedding planes. The bedding was rotated to horizontal, using standard stereonet techniques (see Marshak and Mitra, 1988), to obtain the corrected original paleocurrent directions.

GENERAL GEOLOGY

Cretaceous and Tertiary strata are known from outcrop in the northeast part of the Hinton area, while older rocks are present in the southwest and in the subsurface as known from oil and gas wells (Langenberg, 1993). The major structures are, from northeast to southwest: the Pedley Thrust, Coalspur Triangle Zone (formerly called Coalspur Anticline), Entrance Syncline, Mercoal Thrust, Brazeau Flats, Brazeau Thrust, Brazeau Syncline, Grave Flats Thrust, Cadomin Syncline, Nikanassin Thrust and McConnell Thrust. The Pedley Thrust defines the Coalspur Triangle Zone. The Mercoal Thrust has southwest directed displacement and defines a triangle zone that probably formed before the Coalspur Triangle Zone. The Brazeau Thrust shows northeast directed movements and places Blackstone shales on top of the Brazeau Formation. The Brazeau Syncline has an overturned southwest limb and is a tight fold. The Nikanassin Thrust forms the boundary with the Front Ranges in the northwestern part of the area, while in the southeast the McConnell Thrust forms the boundary with the Front Ranges.

STRATIGRAPHY AND SEDIMENTARY ENVIRONMENTS

Some 4500 m of Jurassic, Cretaceous and Tertiary strata are present in the area, overlying Paleozoic and Triassic rocks. The stratigraphic units are discussed separately from oldest to youngest.

PALEOZOIC AND TRIASSIC ROCKS

Paleozoic and Triassic rocks are known from the subsurface and from the Front Ranges above the Nikanassin and McConnell thrusts. A sample was taken from the Cambrian Gog Formation near Jasper, but it did not contain any diamond indicator minerals.

FERNIE AND NIKANASSIN FORMATIONS

The Jurassic Fernie Formation largely consists of marine shales. The overlying, largely Jurassic Nikanassin Formation consists of marine and non-marine sandstones and shales. The upper Nikanassin Formation is probably lower Cretaceous in age. It is uncomformably overlain by the Cadomin Formation of the Luscar Group. Sample ABD30-8 (for sample locations see Figure 1 - notice that prefix ABD30 is omitted on Figure 1) was collected from the upper Nikanassin Formation in the Railroad exposure near Cadomin and contains diamond inclusion olivines (Table 2).

LUSCAR GROUP

The largely Albian (about 96-106 Ma) Luscar Group consists of the Cadomin, Gladstone, Moosebar and Gates formations (Langenberg and McMechan, 1985). This group, which is equivalent to the Mannville Group of central Alberta, shows both marine and non-marine sedimentary environments and is about 600m thick.

CADOMIN FORMATION

The 10 m thick Cadomin Formation consists of chert pebble conglomerates, deposited in alluvial fans and on braided river pediment plains, and unconformably overlies the Nikanassin Formation. The Cadomin likely represents a major drop in sea level and a major sequence boundary. The Cadomin Formation is an excellent marker horizon, both at the surface and in the subsurface. The 2 samples collected from the Cadomin Formation contain several diamond inclusion olivines (Table 2).

GLADSTONE FORMATION

The Lower Cretaceous (Aptian-Albian) Gladstone Formation is equivalent to the coal-bearing Gething Formation in northeastern British Columbia and the oilsands-bearing McMurray Formation in northeastern Alberta. The formation lies conformably on the Cadomin Conglomerate with no apparent major stratigraphic break. The section at Cadomin shows a transition from well drained alluvial plain deposits with thin coals near the base, to coastal plain deposits with thicker coals near the top; the section is 125 m thick. Sample ABD30-10 was collected from the Gladstone Formation in the Railroad exposure near Cadomin and contains many diamond inclusion olivines (Table 2).

MOOSEBAR FORMATION

The Moosebar consists of marine shales and sandstones and is about 75 m thick. Several marine cycles can be recognized in the Albian Moosebar/lower Gates succession (Macdonald et al., 1988). The Moosebar is lower Albian in age (about 104 Ma old).

The lower Moosebar Formation consists of a series of shales interbedded with sharp based siltstones and thin sandstones. It is interpreted to have formed in an offshore environment in which storm events periodically deposited thin sand units.

In the upper Moosebar more sandstones (often with hummocky cross stratification) are found. The hummocky cross stratification supports the storm deposited origin and has been found in other locations of the Moosebar to Gates transition. A glauconitic pebble conglomerate bed with a sharp base is found in the upper Moosebar and is interpreted as an offshore transgressive deposit. It may in part represent very slow deposition of a condensed section. The boundary between Moosebar and Gates is gradational in a coarsening-up succession.

GATES FORMATION

The Albian Gates Formation consists of the Torrens, Grande Cache and Mountain Park members and is about 400 m thick. Both shallow marine and non-marine sedimentary environments are present.

Torrens Member

The offshore/transgressive deposits of the Moosebar give way upsection to lower shoreface and finally foreshore sediments of the Torrens Member. The trace fossil assemblage is consistent with this interpretation.

The Torrens member consists of massive (though occasionally thinly bedded), fine to very fine-grained sandstone. Faint parallel laminations are the predominant structures, with some trough cross bedding and hummocky cross stratification also present. Scour surfaces, with pebble lag deposits, are also common in the unit. Mudstone is a minor lithology in this cycle and is usually associated with the hummocky cross stratification. Trace fossils may be present. The Torrens is interpreted to be a succession of prograding shoreline deposits, with upper shoreface to foreshore environment transitions being present.

Grande Cache Member

The base of the Grande Cache Member in the Cadomin area is the 10 m thick Jewel coal seam. The sandstones of the lower part of the Grande Cache Member are often brackish until the first major fluvial sandstones are encountered. A brackish water interpretation is based on the presence of trace fossils and the presence of lenticular bedding throughout this interval. Foraminifera in this member indicate a shallow brackish (not normal marine) marine environment. The upper part of the Grande Cache member is largely non-marine and contains fining-upward sequences.

Mountain Park Member

The base of the Mountain Park Member is generally defined at the base of the first major greenish coloured sandstone encountered going upsection from the major coal seams. These sandstones are interpreted to be large scale fluvial deposits and may occur at various stratigraphic levels, making this field mapping criteria somewhat arbitrary if only limited exposure is available. Sample ABD30-11 was collected from this member near Cadomin and contains some diamond indicator minerals (Table 2).

The contact between the Mountain Park Member and the overlying dark grey shales of the Blackstone Formation is generally sharp. The Mountain Park Member is largely Middle Albian in age (about 100 Ma old).

BLACKSTONE FORMATION

The formation consists largely of dark marine shale and siltstone, with minor beds of sandstone, bentonite and some ironstone concretions. Some 500 m of Blackstone sediments may be present in the Brazeau Thrust sheet, although there may be structural repeats present. Its age is late Albian to late Turonian. Stott (1963) distinguishes 4 members in this formation, but they are not easily mappable in this poorly exposed area. Fish scales are found near the base of the formation near Cadomin and are probably equivalent to the Fish Scale Zone of the Western Canadian Basin, which is about 96 Ma old.

CARDIUM FORMATION

The Cardium Formation consists of marine sandstone, siltstones and shale. It forms a useful marker horizon for mapping purposes, because it is relatively thin (about 80 m) and the sandstones forms ridges, that are easy recognizable on aerial photographs. The marine sandstones often contain hummocky cross beds and trace fossils. The Blackstone and Cardium formations form a coarsening upwards succession, indicative of a fall in relative sea-level.

Four members can be recognized in outcrop (Stott, 1963), but are too thin to be mappable on a 1:50 000 scale. The age of the Cardium Formation is late Turonian to early Coniacian. Two samples were collected from the Cardium Formation.

WAPIABI FORMATION

The Wapiabi Formation includes all the beds between the Cardium Formation and the greenish sandstones of the Brazeau Formation and is about 600 m thick. The age of the formation is Turonian to Campanian. Stott(1963) distinguishes 7 members in the Wapiabi Formation. However, the only easily mappable unit on a 1:50 000 scale is formed by the marine sandstones of the Chungo Member. For this reason the Wapiabi Formation is divided into the Upper and Lower Wapiabi members, whereby the base of the Chungo Member can be used as marker horizon.

Lower Wapiabi members

The lower members are the Muskiki, Marshybank, Dowling, Thistle and Hanson members, which are dark grey, marine shales and siltstones. The Marshybank Member contains a larger percentage of siltstones and the Thistle Member consists of calcareous shales (Stott, 1963), but these members could not be mapped separately. One sample was collected from a possible outcrop of the Marshybank Member along the Brazeau River (ABD30-31) and another from possibly the Dowling Member along the Pembina River (ABD30-52).

Upper Wapiabi members

The upper members are the Chungo and Nomad members. The Chungo consists of about 70 m of fine grained, often reddish-brown weathering sandstones and minor siltstone. Hummocky cross-stratification and trace fossils, such as *Planolites* sp. and *Skolithos* sp., indicate that these sandstones are largely marine and clearly distinctive from the younger alluvial sandstones of the Brazeau, Coalspur and Paskapoo formations. Marine bivalves can be found in the Chungo sandstones. Three samples from the Chungo Member were collected, of which sample ABD30-15 from Wampus Creek contains many diamond inclusion olivines and 2 G11's (Table 2).

The Nomad Member consists of dark grey marine shales in between the Chungo sandstones and the greenish sandstones of the Brazeau Formation. This member is about 30 m thick.

BRAZEAU FORMATION

The Brazeau Formation, together with the Coalspur and Paskapoo formations forms part of the continental Saunders Group of alluvial plain origin (Jerzykiewicz, 1985a and in press). The Brazeau Formation consists of about 1200 m of sandstones, shales and some coal seams deposited by fluvial systems, above the marine shales of the Wapiabi Formation and below the basal Entrance Conglomerate of the Coalspur Formation. Along the Blackstone River, Jerzykiewicz (1985a) distinguished 4 cyclothems in the Brazeau

Formation. Each cyclothem consists of two parts: a lower one containing thick and numerous channel sandstone layers, and an upper one composed mainly of overbank deposits. It is uncertain if these cyclothems can be recognized in the Hinton area, because of the lack of a complete section through the Brazeau Formation. The age of the Brazeau Formation is Campanian-Maastrichtian.

A total of 27 samples were collected from the Brazeau Formation, because earlier work (Cameco confidential data) had shown the presence of diamond inclusion chromites (DIC's). These DIC's were confirmed by the present sampling, in addition to some olivines in the diamond inclusion field (Table 2). Several samples of the Brazeau Formation are described in the petrography section.

Conglomerates with a thickness of several tens of meters occur near the base of the formation, which might correspond to the lower part of Cyclothem #1 of Jerzykiewicz (1985). The pebbles average 1-2 cm in diameter, with maximum clast size of about 5 cm. Conglomerates are found in stratigraphically higher parts of the formation, but are not as extensive as the lower ones. Five of the 27 Brazeau samples were taken from these conglomerates.

COALSPUR FORMATION

The Coalspur Formation is equivalent to Cyclothem #5 (Jerzykiewicz, 1985) and contains a 600 m thick continental succession of interbedded sandstones, mudstones and thick economic coal seams. The base of the Coalspur Formation is the Entrance Conglomerate. Thick coal seams interbedded with coaly shales and numerous bentonites occur in the upper part of the formation. This interval is known as the Coalspur Coal Zone. The Val d'Or Coal Seam is at the top of the interval and the Mynheer coal seam is at the bottom. These seams (plus other coal seams) are recognizable in the whole area between Hinton and Coal Valley. The Cretaceous-Tertiary boundary (66.5 Ma ago) is at the base of the Mynheer coal seam (Jerzykiewicz and Sweet, 1986). The Coalspur Formation represents a nonmarine, fluvially dominated environment of deposition.

Six samples were collected from the Coalspur Formation, in which only a few chromites were found (Table 2).

Entrance Conglomerate

The base of Cyclothem #5 is formed by the Entrance Conglomerate (Jerzykiewicz, 1985a and b). Near Hinton the Entrance Conglomerate is generally well sorted and forms a layer 12 m thick composed of closely packed, well rounded pebbles averaging 5-8 cm in diameter. Maximum clast size reaches 20 cm. The Entrance is interpreted to be an alluvial fan. Away from its type section near Entrance, the thickness of the conglomerate decreases and it is gradually replaced by channel sandstones, which do not form a mappable unit.

Five samples from the Entrance Conglomerate were collected, which showed many diamond inclusion olivines south and west of Hinton (ABD30-1 and 4) and some diamond inclusion chromites (DIC's) in the Highway 40 section southeast of Hinton (ABD30-54). A conglomerate sample is described in the petrography section, together with an igneous pebble.

The conglomerate is massive to crudely horizontally bedded, but does contain irregular lenses of sandstone up to 5 m thick, which represent channels and exhibit trough cross stratification. Current directions were obtained from these sandstones.

PASKAPOO FORMATION

The Paleocene Paskapoo Formation consists of at least 1500 m of thick alluvial sandstones and mudstones above the uppermost coal seam of the Coalspur Formation, which is the Val d'Or Seam in the Hinton area. The base of the Paskapoo Formation is the first major sandstone above the Val d'Or Coal seam in the Hinton area. The High Divide Ridge Conglomerate forms part of the Paskapoo Formation and is stratigraphically about 1000 m above the base of the Paskapoo Formation. A detailed stratigraphy has not yet been established for the Paskapoo Formation because of limited exposure. Work on the stratigraphy is in progress by the GSC, using oil well data and some good exposures along the North Saskatchewan and Brazeau rivers (T. Jerzykiewicz, pers. comm., 1993).

Ten samples were collected from the Paskapoo, which include two from the High Divide Conglomerate. These samples contained some diamond inclusion chromites (DIC's, see Table 2).

High Divide Ridge Conglomerate

The High Divide Ridge Conglomerate is loosely consolidated and solid outcrops are rare. The total thickness can be estimated at about 300 m. The lithology is very similar to the Entrance Conglomerate. The only difference is the size of the clasts, which are considerably larger in the High Divide conglomerate, with cobble-size clasts predominating in some layers. The maximum clast size reaches 40 cm (Jerzykiewicz, 1985b). A mid-Paleocene age (P3) has been established by palynology (T. Jerzykiewicz, pers. comm., 1993). Some chromites were recovered from these conglomerates (Table 2).

DIAMOND INDICATOR MINERALS

The diamond indicator minerals present in the bedrock samples are listed in Table 2. The chemical analyses of selected heavy minerals are listed in spread sheets and are available from the author on request. The most frequent and consequently most interesting indicator is diamond inclusion olivine, followed by diamond inclusion chromite. Some G3, G4, G9 and G11 garnets were also found. In addition, some chrome-diopside should be noted.

OLIVINE

Olivine has never been described from sediments in the Foothills (J. Lerbekmo, University of Alberta, pers. comm., 1994), and is the most important discovery of the present exploration. Olivine has been used as a diamond indicator mineral in Siberia, but has not yet been used in western Canada (R. Morton, University of Alberta, pers. comm., 1994). The olivines of the Hinton area have high MgO contents (up to 53%) and intermediate FeO contents (around 8%), which indicates that they are mantle olivines or at least of ultramafic origin (T. Chacko, University of Alberta, pers. comm., 1994). Bergman (1987) lists analyses of olivines from different basic rocks. There is a difference in Mg numbers and CaO and NiO contents between groundmass olivine phenocrysts in kimberlites, lamprophyres and lamproites, compared to alkali basalts and related rocks, but not between the xenocryst/xenolith phases. This makes the differentiation of olivines difficult. Nevertheless, Diamond Inclusion Olivines (DIO's) can be tentatively differentiated based on a plot of Cr_2O_3 content against MgO number (Fipke et al., 1995).

The spatial distribution of the DIO's is very distinct (see Figure 1). They are concentrated in 2 areas, the first one around Entrance (near Hinton) in Maastrichtian-Paleocene (around 65 Ma old) sediments, the second one near Cadomin in Aptian-Albian (around 100 Ma old) sediments. This second anomalous area is somewhat surprising, because diamond indicator minerals have not yet been reported from streams that drain Lower Cretaceous rocks, nor in Lower Cretaceous bedrock. Other samples with anomalous DIO's is ABD30-15, from the Chungo Member along Wampus Creek and ABD30-32 of the Cadomin Conglomerate near Ruby Creek.

Mitchell (1986) has observed that olivines in kimberlites are either rounded macrocrysts or euhedral-to-subhedral microphenocrysts. Our grains could be either disaggregated macrocrysts or microphenocrysts. A cursory look at the grains mounted in the plugs shows that the DIO's are very angular and can not have been transported much farther than about 100 km by fluvial systems (Afanasev et al., 1984). Olivine is very unstable in supergene conditions and in Siberia it was not found in Jurassic sediments that contain pyrope and picroilmenite (Afanasev et al., 1984). Olivine might have been present after deposition of these Siberian sediments, but it was probably subsequently altered to serpentine, because olivine is very susceptible to the effects of low-grade metamorphism and hydrothermal alteration (Deer et al., 1966).

TABLE 2. NUMBER OF DIAMOND INDICATOR MINERAL GRAINS IN BEDROCK SAMPLES OF THE HINTON AREA

						Clinopyroxene			Garnets				Group 1	Eclogitic	Tour-
Sample	Strat. Unit	Olivine	DIO	Chromite	DIC	Group 2	Group 5	Group 6	G3	G4	G9	G11	G3	Almandine	maline
ABD3O-1	Entrance Congl.	33	30	5						1					
ABD3O-2	Entrance Congl.			3											
ABD3O-3	Brazeau Fm	7	5	6						1					
ABD3O-4	Entrance Congl.	38	34	6							2				
ABD3O-5	High Divide Congl.	2	1	13	1				1		2		1		
ABD3O-6	Brazeau Fm	1		9	1				4			1	1		
ABD3O-7	Brazeau Fm	3	2	33	5										1
ABD3O-8	Nikanassin Fm	13	11	4	1	2	1					1			1
ABD3O-9	Cadomin Congl.	7	5	10											
ABD3O-10	Gladstone Fm	38	36	1							1	2			
ABD3O-11	Mountain Park Fm	2	2	19	2										
ABD3O-12	Cardium Fm														
ABD3O-13	Chungo Mb			2											
ABD3O-14	Brazeau Congl.			14	1										
ABD3O-15	Chungo Member	34	26	1		4	1	1				2			
ABD3O-16	Brazeau Congl.	4	4	8	1					1					
ABD3O-17	Brazeau Fm	3	3	22	4										1
ABD3O-18	Entrance Congl.			5	1					1					
ABD3O-19	Paskapoo Fm			2											
ABD3O-20	Coalspur Fm	2	2	4											
ABD3O-21	Brazeau Fm			5						1					
ABD3O-22	Brazeau Fm			9											
ABD3O-23	Paskapoo Fm	1	1	1											
ABD3O-24	Paskapoo Fm			2					1		1				
ABD3O-25	Brazeau Fm			7											
ABD3O-26	Brazeau Fm			16	2				2	2					
ABD3O-27	Brazeau Fm.	6	4	6	1										
ABD3O-28	Paskapoo Fm			24	3										
ABD3O-29	Coalspur Fm														
ABD3O-30	Brazeau Fm			11	2				1						1
ABD3O-31	Marshybank Mb.	3	2												
ABD3O-32	Cadomin Congl.	16	13									1			
ABD3O-33	Cardium Fm			10											
ABD3O-34	Brazeau Fm			7	1							1			
ABD3O-35	Brazeau Fm			11	3				1						
ABD3O-36	Brazeau Fm	3	1				1								
ABD3O-37	Brazeau Fm			3	1										
ABD3O-38	Brazeau Fm			14					1						
ABD3O-39	Brazeau Fm			2	1				3	1			1		
ABD3O-40	Brazeau Fm	1		9	1										
ABD3O-41	Brazeau Fm			8					1	3				1	
ABD3O-42	Brazeau Fm			5											
ABD3O-43	Coalspur Fm			5											
ABD3O-44	Brazeau Fm			11	1										
ABD3O-45	Brazeau Fm	1	1	21	2										
ABD3O-46	Brazeau Fm			4	1										
ABD3O-47	Coalspur Fm?			6											
ABD3O-48	Coalspur Fm	2	1	3						1					
ABD3O-49	Brazeau Congl.			13	3				1					2	
ABD3O-50	Brazeau Congl.			11	1										
ABD3O-51	Brazeau Congl.			19	1										
ABD3O-52	Wapiabi Fm			5					1					1	
ABD3O-53	Chungo Mb			9											
ABD3O-54	Entrance Congl.			22	6										
ABD3O-55	Coalspur Fm			5											
ABD3O-56	High Divide Congl.			1											
ABD3O-57	Paskapoo Fm			9	1					1				1	
ABD3O-58	Paskapoo Fm														
ABD3O-59	Brazeau Fm														
ABD3O-60	Brazeau Fm			9					2						
ABD3O-61	Gog Formation														
ABD3O-62	Miette Fm.														

Abbreviations:

DIC - Diamond Inclusion Chromite

DIO - Diamond Inclusion Olivine

G3, G4, G9 and G11 - Garnet groups from Dawson and Stephens (1975).

Clinopyroxene groups from Stephens and Dawson (1976). Group 5 is chrome-diopside.

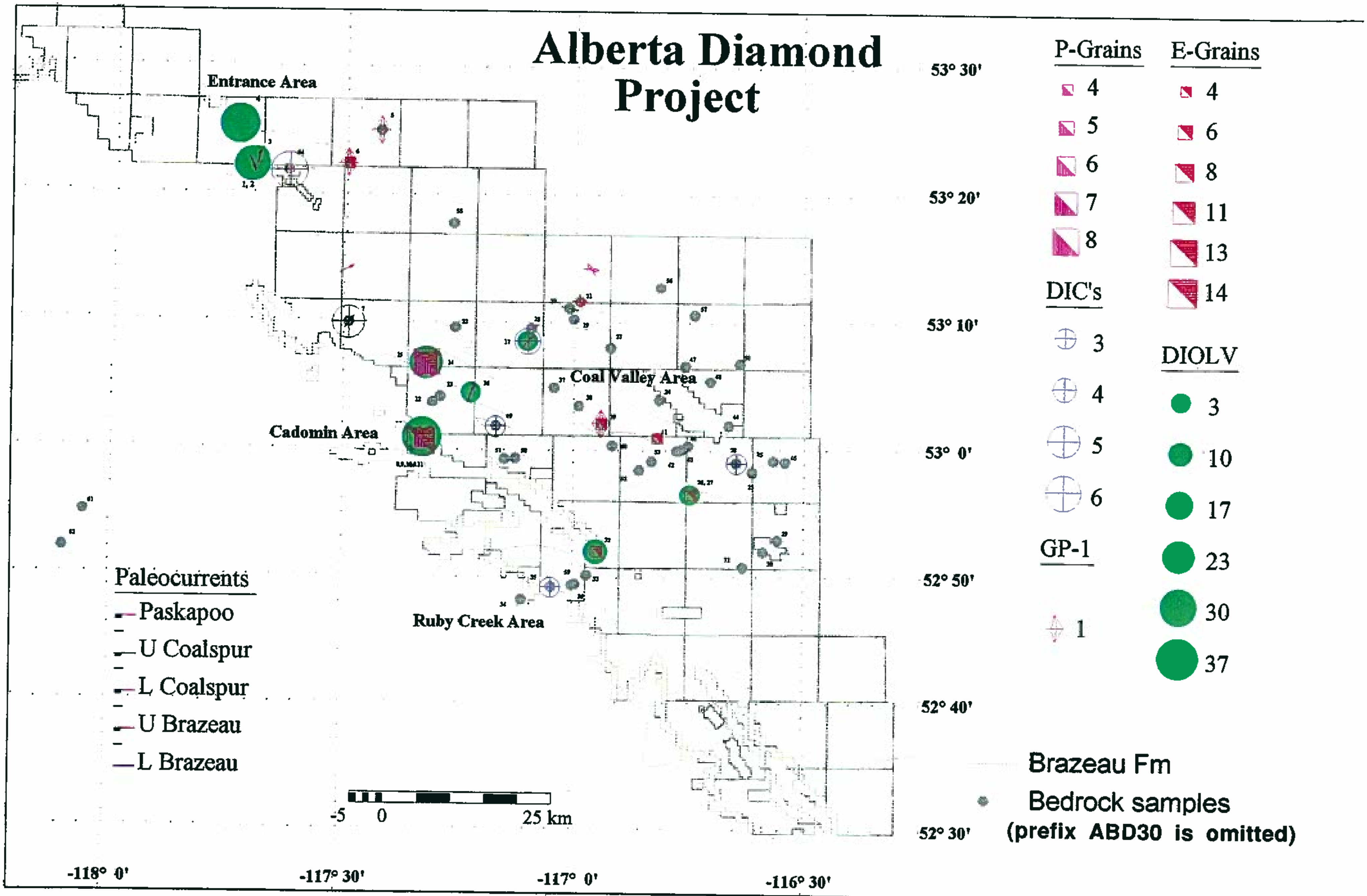


Figure 1. Map of the study area with the location of samples with diamond indicator minerals and paleocurrent directions.

The rank of coal in the Hinton area is high volatile bituminous for Brazeau and Coalspur coals and low to medium volatile for lower Cretaceous coals (Macdonald et al, 1989). These ranks indicate at least a zeolite grade of metamorphism (about 170° C and 1.6 kbar for the lower Cretaceous). Under these conditions and in the presence of water, olivine will alter to serpentine (Tracy and Frost, 1991). The fact that olivine is still around in fairly large numbers (Table 2) indicates that it might have been present in even larger numbers after deposition. Combined with the preferred location of DIO's in 2 areas, these data appear to indicate a relatively local source for the olivines.

Another indication for local sources is the fact that the olivines in a sample from the marine Chungo Member (ABD30-15) are not more abraded than olivines from the alluvial formations. Afanasev et al. (1984) show that kimberlite minerals show maximal mechanical wear in nearshore marine environments. The little amount of abrasion in olivines in the Chungo sample may be another indication of a local source. The expected distance has to be further investigated, but it could be in the range from several kilometers to several 10's of kilometers. If these olivines came from ultrabasic (or basic) source rocks in British Columbia, we would expect to see them in more different locations.

CHROMITE

Several diamond inclusion chromites (DIC's) are present in the bedrock samples. The distribution of DIC's seems to be less concentrated than diamond inclusion olivines. Some DIC's were found in the same area as the DIO's, others were found in the Ruby Creek area, where stream samples indicate a diamond inclusion chromite anomaly. Some were also found in the Coal Valley area. The number of DIC's in the bedrock samples of the Ruby Creek area is less than in the stream samples. The fact that chromites (and garnets) are found in many places along the Foothills might indicate that a large percentage of these minerals come from sources in British Columbia, although no DIC's were found in the BC diatremes (Fipke et al., 1995).

GARNET

Garnets are classified according to Dawson and Stephens (1975). G3 and G4 garnets were further classified as Group 1 or Group 2 eclogitic, based on their sodium contents (McCandless and Gurney, 1986). Three eclogitic Group 1 garnets (G3 and G4) were found. Both the Entrance and Cadomin areas (DIO anomalous areas) contain some G9 and G11 garnets.

PYROXENE

Pyroxenes are classified according to Stephens and Dawson (1977). Chrome-diopside (Group 5 clinopyroxene) does not show a preferred location.

PETROGRAPHY OF SELECTED SAMPLES

The provenance of diamond indicator minerals is further investigated by the study of thin sections, with an emphasis on finding ultramafic source rocks. Data from Mack and Jerzykiewicz (1989) indicate that a large percentage of the detrital grains in post-Wapiabi (Late Cretaceous and Tertiary) sandstones is from volcanic source rock, which could include diatremes.

Several samples were selected before the CF Minerals Laboratory analyses were available. Additional samples were investigated after the laboratory results were obtained. Two to three thin sections were made from each sample. The thin sections were polished and examined both in transmitted and reflected light. All thin sections were checked in reflected light with Differential Interference Contrast in intervals of 0.3 mm (this is a good method for finding the opaque Chromites).

The Cr-bearing Spinels are named according to the following criteria:
Picotite - all Spinels which are light brown in colour.
Mg-Chromite - all Spinels which are dark reddish-brown.
Chromite - all opaques and semi-opaques grains.

The locations of grains and particles of interest were registered on the mechanical stage and marked for microprobing. The microprobe analyses performed at the University of Calgary (Samples: ABD30-7, ABD30-35 and ABD30-41) are listed in Appendix 1. Spinels that were microprobed, are named according to the Winchell (1951) nomenclature (see Appendix 2). This classification conforms to the base of the Spinel prism (see Mitchell, 1986, p.220). For the description of sandstones, the classification of Pettijohn (1975) is used.

SAMPLE ABD30-1 (THIN SECTIONS: A, B, C)

The sample is a lithic wacke from a thin sandstone layer in-between conglomerates of the Entrance Conglomerate.

MACROSCOPIC DESCRIPTION

The rock is a fine-grained sandstone of greenish-grey colour. The coarser particles, up to 3 mm in size, are randomly disseminated in a fine-grained matrix. The rock is well sorted and bedding can not be observed in hand specimen. Except quartz grains, minerals are not determinable with the hand-lens. The cement matrix appears to be rich in clay minerals.

MICROSCOPIC DESCRIPTION

Texture

The rock consists of moderately packed detrital grains in a clay matrix. The grains are well sorted, subrounded to subangular in shape. The majority of grains are almost equant, but some clasts display a moderate elongation.

Elongated grains are parallel to bedding. Rare plagioclase crystals display euhedral shape.

The grain size falls in the range 0.1-0.5 mm. Cherts and quartz display higher angularity than other particles. Mica flakes are commonly deformed between other clasts. Clay cement is vermiculite. It has been crystallized in voids after deposition of the clasts. Some interstices are partly filled with vermiculite, and pores occur.

Modal Content:

Lithic particles	~ 55%
Quartz	~ 20%
Feldspars	~ 8%
Other	~ 2%
Matrix	~ 15%

Lithic particles:

Cherts (very common)
Intermediate to felsic volcanics (common)
Quartz-mica Schists (less common)
Carbonaceous particles (less common)
Quartzites (less common)
Calcarenites (rare)
Granitoids (very rare)

Mineral particles:

Quartz (very common)
Plagioclase (An 25-40%)(common)
Microcline (uncommon)
Perthite (rare)
Muscovite (rare)
Phlogopite (very rare)
Chlorite (uncommon)
Dolomite (uncommon)

HEAVY MINERALS

Epidote (common)
Rutile (common)
Anatase (common)
Zircon (less common)
Tourmaline-Schorl (very rare)
Sphene (rare)
Vesuvianite (one grain)
Olivine (Forsterite) (one grain ?)
Garnet (8 grains)
Clinopyroxene (2 grain)
Picotite (Cr-Spinel) (5 grains)

Semi-opaques:

Mg-Chromite (3 grains)

Opaques:

Chromite (7 grains)
Magnetite (Ulvospinel ?) (6 grains)
Ilmenite (3 grains)

Reflected Light Examination

Chromite (totally opaque) occur as subhedral grains, up to 0.1 mm in size. The low reflectivity power is the main discriminating feature.

Mg-Chromite occurs as subhedral or euhedral grains. The size of the grains falls in the range 0.05-0.15 mm. In reflected light they display a typical very low reflectivity. In transmitted light, grains are very dark with a red-brown colour.

Picotite (Cr-spinel) displays a bit lower reflectivity than other Chrome-bearing spinels, but is distinctly transparent in transmitted light. Its colour is brown or dark brown rather than reddish.

Magnetite (ulvospinel ?) displays a distinctive pinkish tint in linear polarized light. The pinkish colour may indicate a titanium content typical for ulvospinels.

Ilmenite occurs in two varieties. The first variety displays a reflectivity a bit higher than that of magnetite (indicating possible ulvospinel admixture), white colour and hardly noticeable reflection pleochroism. The second one shows less reflection, with a light brownish tint and a distinctive reflection pleochroism. Both varieties are very strongly anisotropic under crossed polarized light. The majority of ilmenite has been altered to anatase, which is common.

COMMENTS

The majority of quartz and feldspar is probably of plutonic origin. However, some subhedral quartz grains which are unstrained or with only a weak wavy extinction may be of volcanic origin. In some grains, solid needle-like inclusions of rutile occur. Plagioclase is oligoclase or andesine with anorthite content of 25-40%. A lot of plagioclase grains are strongly sericitized, but unaltered grains occur as well.

Some volcanic particles contain lath-shaped feldspars, displaying a parallel arrangement, which indicates that these fragments might be trachytes.

The ultrabasic rock remnants are represented mainly by the spinel group minerals which are very resistant to weathering. One grain of olivine, displaying optical properties of forsterite (+ve), a possible large 2V angle (65-80°), and one grain of clinopyroxene should be microprobed together with all garnets.

SAMPLE ABD30-2 (THIN SECTIONS: A, B, C)

This sample is a polymictic Entrance conglomerate.

MACROSCOPIC DESCRIPTION

The coarse pebbles are well rounded and range from 5 mm to several centimetres in size. The pebbles are of varied lithology, consisting mainly of cherts and quartzites, less commonly of volcanics and granitic rocks. Interstitial cementing material consists of medium-grained angular quartz and lithic grains, very fine-grained greenish clay minerals and calcite.

MICROSCOPIC DESCRIPTION

Texture

The rock consists of clastic, volcanic and plutonic framework pebbles and crushed fragments of pebbles. The pebble contacts are locally squashed and commonly cataclasis has been developed. Quartzites appear to be more resistant to tectonic stress than cherts.

The conglomerate is cemented by a combination of fine- to medium-grained material consisting of subangular particles of quartz, plagioclase, lithic fragments, clay minerals and calcite. Grain size of mineral and lithic particles of the cement ranges from 0.1 to 0.5 mm. The volume of cement is about 5%. Locally, cement is mixed with crushed cataclastic material.

A large percentage of the quartzite pebbles are well rounded. Other sedimentary types display subrounded to subangular shapes. Due to tectonic stress, many pebbles are fractured. Fractures are commonly impregnated with calcite and less commonly with chalcedony. The quartzite pebbles are generally ellipsoidal.

Pebbles

The following rocks were found:

Quartzites (very common)
Cherts (common)
Lithic wackes (less common)
Arkosic arenites (rare)
Rhyolite (one pebble)
Quartz Monzogabbro (rare, see 2A description)

Cement

The cementing material is heterogeneous. It consists of clastic particles (including lithic and mineral particles), interstitial authigenic clay and calcite.

Lithic particles:

Cherts (dominant)
Arenites (not common)
Carbonaceous clusters (rare)

Metamorphic schists (not common)
Volcanics (rare)

Mineral particles:

Quartz is dominant. A majority of the grains contains fluid inclusions. Grains with solid (rutile) inclusions are less common. Quartz displays almost entirely a moderate wavy extinction.

Feldspar is mainly of albite composition. Sericitization and saussuritization of plagioclase is common.

Phyllosilicates are represented mainly by muscovite, and less commonly by chlorite and biotite. One flake of red-orange phlogopite has been observed. All phyllosilicates are commonly strained or crushed. Clusters of **serpentine** locally occur in the cement.

Clay is present as poorly crystallized interstitial chlorite and illite.

Heavy Minerals

Epidote (very common)
Anatase (common)
Sphene (rare)
Rutile (rare)
Dravite-Tourmaline (rare)

In reflected light only fine-grained pyrite has been observed.

COMMENTS

Diamond indicator minerals have not been found in the rock. Except Epidote, heavy minerals are rare in the cement. Magnesium-bearing tourmaline (dravite), occurring in the sample, is typical for a metasomatized basic and ultrabasic rock assemblage. The clusters of serpentine occasionally occurring in the cement may be the product of alteration of some ultramafic components, e.g. olivine.

SAMPLE ABD30-2A

This sample is a quartz monzogabbro pebble in the Entrance conglomerate.

MACROSCOPIC DESCRIPTION

The analyzed rock is a fragment of a pebble with a diametre of about 8 cm. The rock is semiphaneritic and greenish grey in colour. The medium-grained feldspar crystals are the main rock-forming components. Dark green chloritized biotite is disseminated among feldspars.

MICROSCOPIC DESCRIPTION

Mineral Content:

Plagioclase (An 53-58%)	~ 86%
Quartz	~ 8%
Chlorite	~ 3.5%
Calcite	~ 0.5%
Magnetite	~ 2%

Texture

The texture is subhedral granular. Plagioclase is hypidiomorphic, with the size of the grains in the range of 0.5-2.0 mm. Zonal textures are common. Polysynthetic albite twinning is always developed in plagioclase. The cores of the grains are usually slightly sericitized due to a higher content of anorthite.

Quartz is interstitial. It is commonly unstrained. Totally chloritized biotite is commonly present in the rock. The pseudomorphic chlorite is commonly impregnated with fine-grained calcite.

Reflected Light Examination

Magnetite is the only original opaque mineral preserved in the rock. It is sometimes adjoined by leucoxene clusters, which are the product of Ilmenite alteration. No other opaques were detected.

SAMPLE ABD30-4 (THIN SECTIONS: A, B, C)

The sample is largely of the matrix of the Entrance Conglomerate, which is lithic arenite.

MACROSCOPIC DESCRIPTION

The rock is a medium-grained sandstone, grey-yellow in colour, with random rounded pebbles of rocks. The examined specimen contains one pebble of dark chert. The rock consists of dark and white particles. Only the quartz grains are determinable macroscopically. Bedding is not visible.

MICROSCOPIC DESCRIPTION

Texture

The rock fabric is typical of arenite. The framework consists of moderately packed detrital grains cemented by a clay matrix, which is not voluminous. The grains are well sorted, subrounded to subangular in shape. About 50% of detrital grains is equant, but another 50% are moderately elongated. The elongated grains are parallel to bedding. The cementing clay coates individual grains. Some grains are loosely packed leaving interstitial fissures. Pores between grains are not completely filled with vermiculite and voids are common. Some of the voids are filled with secondary calcite.

The detrital grain size is 0.3-0.8 mm. Quartz and cherts are usually bigger and more angular than other grains.

Modal Content:

Lithic particles	~ 65%
Quartz	~ 20%
Feldspar	~ 5%
Other	~ 5%
Cement	~ 5%

Lithic particles:

Cherts (very common)
Quartzites (uncommon)
Fine-grained Sandstones (uncommon)
Mudstones (uncommon)
Intermediate to felsic volcanics (uncommon)
Quartz-mica Schists (rare)
Micrites (rare)
Calcarenites (rare)
Agat (one particle)
Granitoids (very rare)

Mineral particles:

Quartz (very common)
Plagioclase (An 0-(?)%)(uncommon)
Perthite (rare)
Dolomite (rare)
Chlorite (rare)
Muscovite (very rare)
Biotite (very rare)

Heavy Minerals:
Picotite (Cr-spinel) (1 grain)

Opaques:
Chromite (2 grains)
Magnetite (1 grains)

COMMENTS

The quartz grains, most commonly, display a straight extinction. Strained grains with a strong wavy extinction are uncommon. Solid and fluid inclusions are rare.

Optically determined plagioclase grains were albite (An 0%). Due to strong sericitization, other grains were not determined. Quartz and the majority of feldspar probably come from plutonic and metamorphic sources.

Heavy minerals are very rare in the rock. One grain of Cr-spinel (picotite), 0.3 mm in size, and light brown in colour has been found in transmitted light. In reflected light examination, some rare opaque chromite and magnetite was detected.

SAMPLE ABD30-7 (THIN SECTIONS: A, B, C)

This sample is a lithic arenite of the Brazeau Formation.

MACROSCOPIC DESCRIPTION

The rock is fine-grained, well sorted and dark grey-yellowish in colour. The bedding is not noticeable in hand specimen. Among clastic grains only quartz, feldspars and dark siltstone can be identified under hand-lens magnification. The clay cement is not voluminous. It contains some calcite, as indicated by HCl.

MICROSCOPIC DESCRIPTION

Texture

The texture is typical for lithic arenite, with a framework of detrital grains in a clay matrix. The grains are generally well sorted and moderate to tightly packed. The majority of clasts are almost equant, so parallel orientation is not well visible. Nevertheless, random mica flakes and some elongated clasts display preferred shape orientation.

The average grain size varies between 0.10-0.25 mm. The framework grains are subangular to angular in shape. Rounded clasts have not been observed. The quartz and plagioclase grains display higher angularity than lithic particles.

Modal Content:

Lithic particles	~ 48%
Quartz	~ 23%
Feldspars	~ 16%
Carbonate clasts	~ 4%
Other	~ 4%
Matrix	~ 5%

Lithic particles

Lithic fragments are dominantly cherts and silicified siltstones. Less commonly intermediate to felsic volcanics occur. Metamorphic quartz-muscovite schists, quartzites and plutonic granite fragments are uncommon.

Mineral particles:

Quartz (predominant)
Plagioclase (very common)
K-feldspars (common)
Calcite (less common)
Epidote (common heavy mineral)
Biotite (rare)
Muscovite (rare)
Chlorite (rare)
Celadonite (rare)

Chalcedony (rare)
Heavy Minerals (rare)
Serpentine (very rare)

The majority of quartz and feldspars is most probably of a plutonic origin. Detrital quartz grains are usually unstrained or display only a weak wavy extinction. Fluid inclusions in quartz are not abundant. In some grains, solid needle-like inclusions of rutile occur predominantly. Plagioclase is oligoclase or andesine. The majority of plagioclase is unaltered, but totally sericitized grains occur as well.

Mica is almost all muscovitized or chloritized biotite. Many flakes are crushed and bent between other particles. Aggregating celadonite occurs randomly as a detrital grain. Some celadonite has been also observed as part of the cement.

Cement

The cement, between tightly packed detrital grains, is not voluminous. It is predominantly a very fine-grained authigenic clay. It displays aggregating texture and colour resembling vermiculite. Randomly authigenic silica has been crystallized within clay cement.

HEAVY MINERALS

Two varieties of spinel, which might be diamond indicators, have been found: **picotite and beresovskite (Mg-chromite)**. They were initially distinguished using colour difference, which was confirmed by microprobing. The grains which are brown in colour, optically isotropic and transparent are picotite (Figure 2a). The grains displaying very dark brown-reddish colour and optically isotropic are varieties of Mg-chromite. This type of spinel occurs as transparent, semi-opaque (Figure 2b) and also as totally opaque grains (see Reflected light examination). Later, after the microprobing, a more precise mineralogical classification was applied (Appendix 2). Their composition is close to the "Diamond Inclusion Field" (Appendix 3). The dark red and semi-opaque grains were renamed as beresovskite according to the Winchell (1951) classification. One grain of light green-olive Spinel was determined as **pleonast**.

Other Heavy Minerals:
- Fe-Epidote (very common, pleochroic)
- Rutile (less common)
- Zircon (less common)
- Xenotime (uncommon)
- Sphene (uncommon)
- Dravite (tourmaline) (common, brown-yellow pleochroism)
- Catapleite $Na_2Zr(Si_3O_9)\ 2H_2O$ (rare)
- Garnet (uncommon, broken and sericitized)

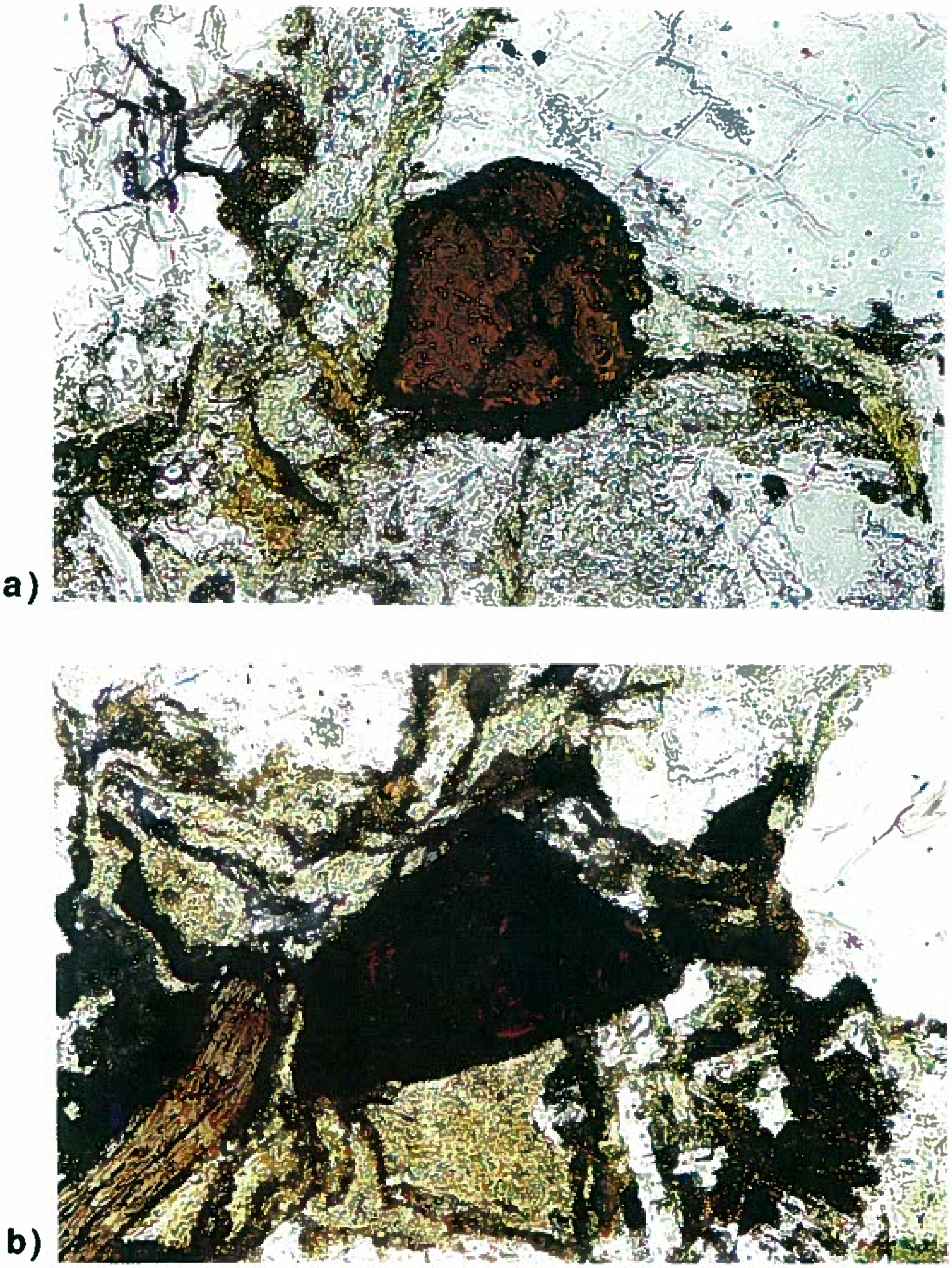


Figure 2. Photomicrographs of possible diamond indicator minerals in sample ABD30-7.
a) Picotite, b) Berosovskite (Mg-Chromite)

Reflected Light Examination

Opaque heavy minerals are predominantly magnetite and anatase, pseudomorphic after Ilmenite. Unaltered ilmenite uncommonly occurs as well. Reddish iridescent spot reflections may indicate locally increased magnesium contents (over 2%, see ABD30-7B3). About 90% of the original ilmenite has been altered. Besides semi-opaque Mg-chromite, totally opaque grains occur.

Very fine-grained (0.01 mm) pyrite occurs randomly in the rock.

COMMENTS

The rock contains two diamond indicator minerals: chrome-bearing spinels (**picotite** and **beresovskite**) and **ilmenite**. Together with a small cluster of serpentine, the above minerals are remnants of eroded ultrabasic rocks (possibly kimberlites). Some other heavy minerals: rutile, zircon, garnet and dravite may be ubiquitous in different paragenesis.

Catapleite (one grain detected) is typical of alkaline rocks both, plutonic and volcanic.

SAMPLE ABD30-8 (THIN SECTIONS A, B, C)

The sample is a lithic (ankerite) arenite of the Nikanassin Formation.

MACROSCOPIC DESCRIPTION

The rock is a medium-grained sandstone. It is dark-grey in colour on a cut surface, and rusty when weathered. A bedding is very pronounced by darker and lighter laminations.

MICROSCOPIC DESCRIPTION

Texture

The detrital grains are tightly packed and moderately well sorted. They are subangular to angular in shape, and 0.1-0.4 mm in size. The majority of grains is equant. The flattened grains of chert and softer carbonaceous particles are oriented parallel to the bedding plane. There are laminar domains enriched in carbonaceous material, which are interlayered with domains where quartz and chert is more abundant. Ankerite grains are evenly disseminated among other particles. They are monocrystalline and fine-grained polycrystalline (micritic). Ankerite grains are commonly coated by limonite and clay matter. Particles of ankerite are subrounded to subangular and are generally equant.

The quartz grains and cherts are partly cemented by silica and also clay-limonitic matter which is not voluminous. As indicated by HCl, some invisible calcite occurs in limonitized matter between cemented grains.

Modal Content:

Quartz	~ 40%
Chert	~ 25%
Siltstone	~ 3%
Carbonaceous particles	~ 15%
Ankerite	~ 15%
Limonite cement	~ 2%
Heavy Minerals	trace

Heavy Minerals:

The following heavy minerals were identified:

Transparent:	Rutile (7 grains) Zircon (4 grains) Tourmaline-Dravite (1 grain) Monazite (1 grain)
Opaques:	Magnetite (1 grain) **Chromite** (1 grain)

SAMPLE ABD30-10

The sample is a lithic (ankerite) arenite of the Gladstone Formation.

MACROSCOPIC DESCRIPTION

The rock is a very fine-grained sandstone. It is dark-grey in colour on a fresh surface, and rusty when weathered. A bedding is very well pronounced by alternating darker and lighter laminations. Fracture cleavage parallel to bedding is visible in the sample. Thin carbonate veinlets discordant to the bedding occur.

MICROSCOPIC DESCRIPTION

Texture

The rock displays a laminar fabric. The laminar domains consist of moderately packed and well sorted detrital grains of ankerite and quartz, 0.05-0.1 mm in size. They are interlayered with domains enriched in fine-grained chert. Limonitized clay-carbonaceous particles commonly occur in both parts. The grains are cemented by clay-limonite matter which is not voluminous. As indicated by HCl, some invisible calcite occurs in limonitized matter between cemented grains.

The quartz grains are subangular to angular in shape, and commonly elongated in bedding. Particles of ankerite are subrounded to subangular and more frequently are equant. Very thin flakes of muscovite randomly occur in the rock. A very fine-grained aggregating glauconite is present amongst the detrital particles in trace amounts.

Modal Content:

Ankerite	~ 60%
Quartz	20-35%
Cherts	2-5%
Muscovite	trace
Carbonaceous matter	5-10%
Limonite cement	~ 2%
Glauconite	trace
Heavy Minerals	trace

Heavy Minerals:

Heavy mineral grains are only sporadically encountered in thin section. The following minerals were identified:

Transparent:	Rutile (5 grains)
	Tourmaline-Dravite (1 grain)
Opaques:	Magnetite (1 grain)
	Chromite (1 grain)
	Ilmenite (1 grain)

SAMPLE ABD30-15 (THIN SECTIONS: A AND B)

The sample is a lithic (Ankerite) arenite of the Chungo Member of the Wapiabi Formation.

MACROSCOPIC DESCRIPTION

The rock is a fine-grained equigranular sandstone. It is massive and grey in colour. The weathered surface is grey-yellow. Except very fine-grained muscovite flakes, other minerals are not determinable in the sample. A bedding is not visible.

MICROSCOPIC DESCRIPTION

Texture

The rock framework consists of tightly packed detrital grains of quartz, chert and ankerite, up to 0.1 mm in size. The grains are well sorted and equant. The shape of grains varies from subrounded to subangular. The lithic cherts and Ankerite particles are cemented with a limonitized clay matter, which is not voluminous. The quartz grains are commonly cemented with recrystallized silica. The grains of ankerite are coated by limonite. Other mineral particles: feldspar, muscovite and heavy minerals are less voluminous in the rock.

Modal Content:

Quartz		60-70%
Lithic particles:		
Cherts	20-25%	
Siltstones	minor	
Ankerite		5-10%

Feldspar	rare
Muscovite	rare
Glauconite	trace
Heavy minerals	>1%
Limonitized cement	1-2%

Heavy Minerals:

The heavy minerals are much more common in this sample than in mineralogically consanguineous samples ABD30-8 and ABD30-10. Their size is comparable to those of the main detrital particles. The contributions of heavy minerals (counted in 2 thin sections) are as follow:

Transparent:	Rutile (23 grains)
	Zircon (7 grains + cluster of 20 grains)
	Tourmaline-Schorlite (4 grains)
	Tourmaline-Dravite (3 grains)
	Picotite (5 grains)
Opaques:	**Ilmenite** (3 grains)
	Chromite (8 grains)
Semi-opaques:	**Mg-Chromite** (2 grains)

COMMENTS

An excellent sorting of the clastic material and the occurrence of glauconite indicate a marine sedimentation. A high angularity of detrital grains suggests a short-distance transport. The presence of Cr-bearing spinels indicate a ultrabasic provenance.

SAMPLE ABD30-17 (THIN SECTIONS: A AND B)

The sample is a lithic wacke of the Brazeau Formation.

MACROSCOPIC DESCRIPTION

The rock is a medium-grained sandstone of grey-yellowish colour. The detrital particles, light and dark in colour, are up to 1 mm in size. Only quartz grains are easily determinable. The rock is well sorted and bedding is not noticeable. The detrital grains are weakly cemented by a carbonate matrix. Interstitial porosity is noticeable.

MICROSCOPIC DESCRIPTION

Texture

The framework consists of loosely packed detrital grains cemented by primary carbonate (protomatrix). The grain size varies in the range 0.25-0.8 mm. The particles are well sorted. They are subrounded to angular in shape. The grains are almost equant, but some of them are moderately elongated. Some feldspar crystals display euhedral shapes. There is no bedding noticeable in the grain arrangement. The pore system is extensive. The voids are connected by interstitial channels, up to 0.01 mm in width. Some pores are up to 0.5 mm in size.

Modal Content:

Lithic particles	45-50%
Quartz	~25%
Feldspars	>5%
Cementing carbonate	15-20%

Lithic particles:

Sedimentary:	Cherts (very common)
	Carbonaceous Schists (common)
	Siltstones (uncommon)
	Sandstones (uncommon)
	Micrite (rare)
Metamorphic:	Mica Schists (common)
	Quartz-Sericite Schists (uncommon)
	Quartzites (uncommon)
	Chlorite Schists (rare)
Volcanic:	Intermediate to felsic volcanics (rare)

Mineral Particles:

Quartz (very common)
Plagioclase (common)
Microcline (uncommon)
Perthite (uncommon)
Biotite (uncommon)
Muscovite (rare)

Heavy Minerals:

Transparent:	**Garnet** (4 grains)
	Rutile (3 grains)
	Anatase (2 grains with Ilmenite relicts)
	Olivine (?) (1 grain 0.06 mm in size)
	Sphene (1 grain)
Opaques:	**Chromite** (2 grains)
	Ilmenite (2 grains)

COMMENTS

Provenance of Clasts:

The detrital grains represent three sources: Sedimentary, Metamorphic/Plutonic and Volcanic.

Ultrabasic rock sources are represented by two grains of totally opaque chromite and one grain of possible olivine. The last one displays (+ve) optical character and straight extinction to the cleavage. Its birefrigence is similar to olivine. However, due to the very small size, microprobing is essential for the correct diagnosis.

SAMPLE ABD30-27

The sample is a siltstone of the Brazeau Formation.

MACROSCOPIC DESCRIPTION

A very fine-grained and compact rock, which is dark grey-greenish in colour. The sample displays a tendency to angular cracking. The fractures are in places coated with limonite.

MICROSCOPIC DESCRIPTION

Texture

The grain size of the clastic particles fall in the range of 0.1-0.5 mm. The clasts are cemented by cryptocrystalline green-brownish clay matter. The clasts make up about 40% of the rock volume. The mineral particles are very well sorted and display angular shapes. The determinable clastic minerals are:

Plagioclase (25% An)
Quartz
Biotite
Muscovite
Chlorite
Chalcedony
Glauconite
Epidote
Ilmenite, Magnetite, Hematite

The largest Plagioclase grains, up to 0.2 mm in size, were determined as oligoclase (An 25%). Zonal texture and corrosion of some plagioclase crystals indicate a probable volcanic origin.

Parts rich in clay cement form part of this siltstone. Both siltstone and clay display microfolding with development of small tensional voids in the clay parts. The voids are filled with crystalline clusters of a mineral that looks like Kaolinite, but is probably boehmite (gamma-AlO(OH)). The clusters are vermicular in shape, and up to 3 mm in length. The single crystals of boehmite (?) are about 0.2 mm in size. They display birefringence and refractive indexes a bit higher than quartz and a very good cleavage (010). Their optical sign is (+ve), and symmetry is orthorhombic. The optical determination of boehmite is difficult and could be checked by XRD.

Reflected Light Examination

Ilmenite is a common opaque in the rock. The largest grains, up to 0.03 mm in size, display a strong anisotropy. Magnetite is less common than Ilmenite. Its size is comparable to Ilmenite. Very fine-grained chromite (smaller than 0.03 mm) may be present, but is not optically determinable. Fine-grained hematite randomly occurs.

COMMENTS

Diamond indicators have not been determined. However, some very fine-grained chromite may be present in the rock.

SAMPLE ADB30-34 (THIN SECTIONS: A, B, C)

The sample is a lithic arenite of the Brazeau Formation.

MACROSCOPIC DESCRIPTION

The arenite is a medium- to coarse-grained rock consisting of subangular to subrounded particles of siltstones, grains of quartz and rare feldspar. The rock is light grey in colour. The bedding plane is marked by coarse-grained intercalations containing rare pebble-sized particles of quartzite. The cement is not voluminous. It is enriched in calcite as indicated by HCl.

MICROSCOPIC DESCRIPTION

Texture

The rock is structurally supported by a detrital framework consisting of strongly sillicified siltstones, cherts, quartz and feldspar fragments, uncommon volcanics and metamorphic mica schists. Clastic particles of ferruginous **serpentine**, up to 0.3 mm in size, occasionally occur.

Clasts are tightly packed. They are 0.3-1.5 mm in size. Within coarse-grained intercalations some lithic fragments reach pebble size. The shapes are subangular to subrounded. Roundness of particles is higher in the coarse-grained parts.

The arenite is cemented by a mixture of fine-grained clay minerals and limonite. Occasionally, carbonate (dolomite at the centre of voids and calcite around it) occurs in the cement. The volume of the cement is well below 5%.

Clasts

Lithic fragments:

Cherts (very common)
Quartzites (common)
Quartz siltstones (common)
Quartz sandstones (minor)
Volcanics (minor)
Mica schists (rare)
Carbonaceous clusters (rare)

Mineral particles:

Quartz (predominant)
Plagioclase (common)
Microcline (minor)
Serpentine (minor)

Biotite (rare)

Quartz is predominant over other minerals. Two varieties of quartz are present: unstrained grains with a lot of fluid inclusions are most likely of volcanic origin. All grains displaying strong wavy extinction and strain structures belong to the metamorphic category. A few grains of quartz display a ribbon texture, characteristic of high temperature deformation.

Plagioclase is mainly andesine, possibly from a volcanic source. Polysynthetic twinning is common in the plagioclase. Some grains display a zonal texture. All grains are predominantly fresh. Some slightly sericitized grains occur. Uncommon microcline and perthitic K-feldspar is of probable plutonic origin. In reflected light, only a few grains of altered Ilmenite have been detected.

HEAVY MINERALS

Fe-Epidote (common)
(1) Tourmaline Dravite (uncommon)
(2) Tourmaline Schorlite (rare)
Xenotime (rare)
Apatite (rare)

COMMENTS

Typical diamond indicator minerals have not been found in the rock. Except for epidote, heavy minerals are only sporadically present. Magnesium-bearing tourmaline (dravite) is typical of metasomatized basic and ultrabasic assemblages. The clusters of serpentine, locally occurring in the cement, may be an alteration-product of ultrabasic rocks.

Volcanic fragments with feldspar phenocrysts point to intermediate to felsic extrusive source rocks in the West.

SAMPLE ABD30-35 (THIN SECTIONS: A AND B)

The sample is a calcite cemented lithic wacke of the Brazeau Formation.

MACROSCOPIC DESCRIPTION

The rock is a medium-grained sandstone with a greenish-grey colour. It is well sorted and bedding is not noticeable macroscopically. Besides quartz grains, very fine-grained flakes of mica are distinguishable in the sample. The cement is calcareous as indicated by HCl.

MICROSCOPIC DESCRIPTION

Texture

The rock consists of loosely packed detrital grains cemented by calcite. The grains are well sorted. They are chiefly subrounded to subangular in shape, but minor perfectly rounded and very angular grains of quartz randomly occur as well. The grains are equant or display a moderate elongation. However, elongated grains are randomly oriented and bedding is not noticeable. The average detrital grain size is 0.5 mm.

Detrital **serpentine** grains, which are 0.3 mm in size, occur in the rock. One of these is antigorite as indicated by the microprobe (see Appendix 1). The other is probably chrysotile-lizardite (not microprobed). Three additional clusters of possible serpentine have been observed.

Grains are cemented by very fine-grained polycrystalline calcite, which is very voluminous. Some clay impurities are disseminated in calcite, while larger twinned crystals of calcite are present in the cement.

Modal Content:

Lithic particles	~ 25%
Quartz	~ 12%
Feldspars	~ 8%
Other	~ 5%
Calcite Cement	~ 50%

Lithic particles:

- Cherts (very common)
- Quartzites (uncommon)
- Quartz-mica Schists (uncommon)
- Carbonaceous particles (uncommon)
- Volcanics (uncommon)
- Metavolcanics (rare)
- **Serpentinites** (2 clasts)

Mineral particles:

- Quartz (very common)
- Plagioclase (An 20-40%)(common)
- Perthite (uncommon)
- Microcline (minor)
- Celadonite (minor)
- Epidote (minor)
- Biotite (rare)
- Muscovite (rare)
- Phlogopite (very rare)

Heavy Minerals:

Heavy minerals are not abundant in the rock. However, one thin layer distinctly enriched in heavy minerals is present. The most common heavy mineral in this layer is Ilmenite. However, it is not picro-ilmenite as indicated by relatively low Mg and Cr contents (Appendix 1). **Cr-spinels** occur less commonly (3 grains). Their composition is close to the "Diamond Inclusion Field" (Appendix 3). One grain of possible **olivine**, optically (+ve) and with straight extinction, occurs as well (microprobing has not been made yet). The following heavy minerals were detected:

Opaques:	Ilmenite (over 20 grains)
	Magnetite (14 grains)
	Beresovskite (1 grain)
	Cr-Picotite (2 grains)
Transparent:	Tourmaline-Schorl (1 grain)
	Sphene (2 grains)
	Olivine (1 grain)
	Apatite (1 grain)

COMMENTS

The majority of detrital grains come from sedimentary or igneous sources.

Detrital material from ultrabasic rocks (possibly kimberlites) include: 2 grains of **serpentine**, 1 grain of **olivine** (microprobing is necessary) and 3 grains of **Cr-bearing spinels**. The occurrence of ilmenite and magnetite, together with the above mentioned grains, will be of interest to diamond explorers.

SAMPLE ABD30-41 (THIN SECTIONS: A, B, C)

The sample is a lithic wacke of the Brazeau Formation.

MACROSCOPIC DESCRIPTION

The rock sample is dark grey with a yellow-green tint. It is fine-grained and well sorted. Only quartz and feldspars can be identified macroscopically under hand-lens magnification. The cement matrix is not voluminous, and does not contain calcite as indicated by HCl.

MICROSCOPIC DESCRIPTION

Texture

The texture is typical for lithic wackes, with a framework of detrital grains in a clay matrix. The grains are generally well sorted and moderate to tightly packed. The majority of clasts are almost equant. Some larger grains, mostly lithic fragments and mica flakes display preferred orientation.

The average grain size varies between 0.10-0.25 mm. The framework grains are subangular to angular in shape. Rounded clasts have not been observed. The quartz and plagioclase display higher angularity than lithic particles.

Modal Content:

Lithic particles	~ 48%
Quartz	~ 20%
Feldspars	~ 20%
Other	~ 3%
Matrix	~ 15%

Lithic particles

Lithic fragments are mostly cherts, while siltstones are less common. Clusters of carbonaceous matter have been occasionally observed as well. Volcanics are less common. Quartz-muscovite schists, quartzites and granite fragments are uncommonly present.

Mineral particles:

Quartz (very common)
Plagioclase (An 36-48%)(very common)
K-feldspars (uncommon)
Epidote (common as heavy mineral)
Biotite (rare)
Muscovite (rare)
Chlorite (rare)
Heavy Minerals (rare)

The majority of quartz and feldspars is probably of igneous origin. Quartz detrital grains are usually unstrained or display only a weak wavy extinction. The fluid inclusions in quartz are not abundant. In some grains, solid needle-like inclusions of Rutile occur. Plagioclase is andesine (An 36-48%). The majority of plagioclase is unaltered, but sericitized grains occur as well.

Micas are muscovite and biotite. Mica flakes are frequently deformed. Chlorite randomly occurs as alteration product.

Cement

Between detrital grains, the volume of cement occupies about 15%. It is predominantly a very fine-grained authigenic clay. It resembles palagonite or vermiculite. A very fine-grained aggregating Chlorite uncommonly occurs in the cement.

HEAVY MINERALS

Heavy minerals were examined both under transmitted and reflected light. Heavy minerals are unevenly distributed in the rock. For example in thin section 41(C), heavy minerals (including opaques) are less common than in 41(A) and 41(B).

Two varieties of spinel have been found, which may be diamond indicators: **picotite and beresovskite**. These grains are subangular and are 0.05-0.2 mm in size. Their composition is close to the "Diamond Inclusion Field" (Appendix 3).

Other Heavy Minerals:
- Fe-Epidote (very common, pleochroic)
- Rutile (less common)
- Zircon (less common)
- Dravite-Tourmaline (common, brown-yellow pleochroism)
- Staurotite (rare)
- Garnet (rare, broken and sericitized)

Reflected Light Examination

Opaque heavy minerals are rare. Anatase, pseudomorphic after ilmenite, is most common. Unaltered Ilmenite randomly occurs as well. About 90% of the original Ilmenite has been altered. Picroilmenite displaying internal red-brown reflections has not been found. Magnetite is much less common than ilmenite.

Beside semi-opaque Mg-chromite, also totally opaque chromite occurs.

COMMENTS

Chrome-bearing spinel could be diamond indicators. The microprobe analyses classify them as: **beresovskite** (semi-opaque and dark reddish brown grains), **Cr-picotite** (brown grains) and **picotite** (light brown grains). On the diagram of Cr_2O_3 versus MgO no grain is located within the "Diamond Inclusion Field", but one is close (Appendix 3). Other heavy minerals: rutile, zircon, garnet and dravite could also occur in assemblages unrelated to diamond-bearing rocks.

SAMPLE ABD30-54 (THIN SECTIONS: A AND B)

The thin section is largely from the cement of the Entrance Conglomerate and is a lithic wacke.

MACROSCOPIC DESCRIPTION

The rock is a conglomerate with well rounded pebbles and a lithic wacke cement. The size of the pebbles is up to 5 cm. Only one pebble of a reddish quartzite and two small pebbles of volcanic rocks occur in the sample. The pebbles are loosely packed.

The cement is a medium-grained sandstone with a greenish-grey colour. The coarser particles up to 1 mm in size are randomly disseminated in the medium-grained matrix. The rock is moderately well sorted and bedding is not noticeable. Except the quartz grains, other minerals are not determinable in the sample. The cementing sandstone is rich in calcite, as indicated by HCl.

The microscopic description is related to the cementing sandstone only.

MICROSCOPIC DESCRIPTION

Texture

The rock consists of moderately packed detrital grains cemented by calcite. The grains are moderately sorted, chiefly subangular in shape. Some well rounded particles of quartz and angular quartzites occur as well. The majority of grains are almost equant. The grain size is in the range 0.5-1.2 mm. Some larger cherts up to 2.2 mm in size are present.

The calcite cement crystallized within interclastic voids, filling the voids almost totally and resulting in low intergranular porosity.

Modal Content:

Lithic particles	~ 60%
Quartz	> 15%
Feldspars	~ 10%
Cement	< 15%

Lithic particles:

Cherts (very common)
Quartzites (less common)
Dolomicrites (less common)
Quartz-mica Schists (less common)
Arkosic Sandstone (minor)
Volcanics (minor, includes at least 1 andesite grain)
Calcarenites (rare)
Serpentinite (1 grain)

Mineral particles:

Quartz (very common)
Plagioclase (common)
Microcline (uncommon)
Orthoclase (rare)
Muscovite (rare)
Dolomite (uncommon)

Heavy Minerals:

Epidote (common)
Rutile (1 grain)
Xenotime (1 grain)
Apatite (2 grains)
Sphene (1 grain)
Anatase (rare)
Garnet (1 large pinkish grain)

Opaques: **Chromite** (1 grain)

COMMENTS

Heavy minerals are not common. Possible ultrabasic rock remnants are: one detrital grain of **serpentine**, one grain of **chromite** and one grain of **garnet**. In linear polarized light, the garnet displays a pale pink colour. It could be a pyrope, but it needs microprobing to confirm the determination.

SOURCE AREAS OF CLASTIC MATERIAL

Clastic material in the sediments of the Hinton area give information about possible source areas. Studies that report on potential source areas of Lower Cretaceous sediments are: Leckie (1986), Stott (1982), Schultheis and Mountjoy (1978), Mellon (1967) and Rapson (1965). For Upper Cretaceous and Tertiary sediments the papers by Mack and Jerzykiewicz (1989), Rahmani and Lerbekmo (1975) and Stott (1963) can be consulted. It is generally accepted that the source areas for these sediments are somewhere in the west and resulted from the rising Cordillera. The recent publication by Gabrielse and Yorath (1992) gives good descriptions of the geology of potential source areas. Potential source areas are discussed below for the various clasts, which are divided into sedimentary, metamorphic, plutonic, volcanic and ultrabasic rocks.

SEDIMENTARY ROCKS

Sedimentary source rocks are indicated by sandstone, siltstone, mudstone and carbonate fragments. Some of the rounded quartz grains could come from sediments as well. There are unconformities in the Cretaceous succession (for example at the base of the Cadomin and the Blackstone formations), consequently the source of the sediments on top of the unconformities could be local. The source of the quartzite fragments are probably Cambrian sediments from the main Ranges (for example the Gog quartzites around Jasper).

Carbonate source rocks are indicated by carbonate fragments and chert grains. This is supported by the occasional occurrence of fossil fragments within chert grains, similar to fossil occurrences in chert nodules of Paleozoic carbonates from the Rocky Mountains. It is still difficult to explain the large proportion of chert grains in all Mesozoic and Cenozoic sediments, compared to the low percentage of chert in Paleozoic and early Mesozoic (Jurassic and Triassic) sediments. It is still possible that some of the chert comes from West of the Rocky Mountain Trench. The Slide Mountain Terrane of the Omenica Belt contains abundant chert (Gabrielse and Yorath, 1992, p.289) and can have contributed detritus to the foreland basin.

Unambiguous radiolarian cherts have not yet been found, although Leckie (1986, p.131) describes "ghosts of radiolaria in chert grains" in the Gates Formation. Radiolarian chert would come largely from the Cache Creek Terrane (part of the Intermontane Belt) west of the Omenica Crystalline Belt (Gabrielse and Yorath, 1992, p.296), which is an unlikely source for foreland basin sediments, because the Omenica Belt is generally considered the drainage divide. Consequently, there is a lack of detritus from the Intermontane Belt (west of the Omenica Belt) in the foreland Basin. However, some radiolarian chert may be present in the Slide Mountain Terrane and might have contributed to the foreland basin sediments.

METAMORPHIC ROCKS

Metamorphic lithic fragments are common in minor amounts in most sandstones, indicating that the Omenica Belt was contributing detritus to the foreland. Low grade (Greenschist Facies) metamorphic rocks are present around Jasper, while higher grade rocks are exposed a bit further west around Valemount. Almandine garnet would probably originate from this area.

PLUTONIC ROCKS

The best evidence that plutonic rocks (probably in the Omenica Belt) are being unroofed comes from the plutonic clasts in the Entrance Conglomerate (see sample ABD30-2A, which is a Monzogabbro). These pebbles are fairly large and can probably be dated. After careful comparison with potential source rocks a more precise source area could possibly be deduced. Some of the quartz and feldspar in the foreland sediments may originally come from plutonic rocks in the Omenica Belt, but might have been deposited initially in older sediments in the Main Ranges east of the Rocky Mountain Trench. Syenites form part of the Howell Creek Suite in the southern Rocky Mountains (Gabrielse and Yorath, 1992, p.508), but it is unlikely that they contributed to the detritus in the Hinton area.

VOLCANIC ROCKS

Volcanic fragments are a common component of the clastic sediments in the Hinton area. It is often assumed that plagioclase with oscillatory zoning is of volcanic origin. This explains the large percentages of volcanic detritus reported by Mack and Jerzykiewicz (1989) for post-Wapiabi sandstones. The Cadomin and Gladstone formations of the Luscar Group contains little feldspar and no plagioclase (Langenberg et al., 1987). This indicates that volcanic sources were not available until late early Albian.

Volcanic rocks are uncommon in the Rocky Mountains and Omenica Belt. Precambrian volcanic rocks of the Purcell Supergroup (Gabrielse and Yorath, 1992) and Cretaceous volcanics of the Crowsnest Formation (Peterson and Currie, 1993; Adair, 1986) and Howell Creek Suite (Skupinski and Legun) are present in the Southern Rocky Mountains. Although indications were found for the presence of trachytic grains amongst the volcanic fragments and trachytes are uncommon amongst Cordillera volcanics, except in the Howell Creek Suite (Gabrielse and Yorath, 1992), the southern Rocky Mountains is an unlikely source for the Hinton sediments. The Slide Mountain Terrane of the Omenica Belt contains felsic to intermediate volcanics and is a potential source area for the Hinton sediments.

Another possibility is that Cretaceous or older volcanic rocks covered a wide area of the Omenica and Rocky Mountain belts during the Cretaceous and have now been almost completely eroded away (Mack and Jerzykiewicz, 1989).

The Entrance Conglomerate contains some large volcanic pebbles, which could probably be dated by radiometric methods. A study of the large clasts might provide clues about precise source areas, although it is possible that the original source area is now completely eroded away.

ULTRABASIC ROCKS

Ultrabasic rocks occur in the Slide Mountain Terrane in the Cariboo Mountains near Barkerville (Gabrielse and Yorath, 1992, p.289) on the west side of the Omenica drainage divide. They are an unlikely source for foreland basin sediments, but it is possible that these rocks extended further eastward during Cretaceous times and contributed some material to the foreland. A more likely source for ultrabasic detritus (including diamond indicator minerals) are the alkaline ultrabasic rocks in the Rocky Mountains described by Pell (1987). There are several ultramafic diatremes in the Golden-Columbia Icefields area. A diamond was recovered from the Jack Pipe (Pell, 1987, p.70). Consequently, these diatremes could have contributed detritus to the Hinton sediments.

However, the large number of diamond inclusion olivines (together with diamond inclusion chromites) in specific areas is pointing to a more local source of ultrabasic rock as discussed earlier in the "Diamond Indicator Minerals" section.

PALEOCURRENT DIRECTIONS

Paleocurrent direction readings from ancient fluviatile sediments are related to depositional slope and may give indications about the location of the source area of the clasts (such as heavy minerals), which constitute the sediments. It should be realized that considerable variation of paleocurrent direction may be present in fluviatile systems, especially when the rivers are meandering. Paleocurrents in fluvial channels, if measured over a large area, reflect the regional paleoslope (Potter and Pettijohn, 1977).

Published paleocurrent data of Upper Cretaceous-Tertiary strata indicate a predominantly southwestern source (northeasterly current directions) of the detritus (Jerzykiewicz and MacLean, 1980). These directions probably represent the western edge of the predominantly southeastern current directions observed by Rahmani and Lerbekmo (1975), based on heavy mineral suites. Jerzykiewicz and Labonte (1991) have published the preliminary results of 800 measurements of directional sedimentary structures in channels of the Saunders Group. They divided the post-Wapiabi succession (Brazeau, Coalspur and Paskapoo formations) into 5 sequences: i.e. Lower Brazeau, Upper Brazeau, Lower Coalspur, Upper Coalspur and Paskapoo. Their measurements will indicate the regional paleoslope and our measurements will show the local current directions.

LOWER BRAZEAU

Outcrop ABD30-16

In this outcrop the basal Brazeau conglomerates are exposed. Groove casts (flutes) and a pebble train are present on the bottom of a bedding plane, which is probably the bottom of a channel. The average corrected direction of the 3 current indicators is towards N20^0 East (Figure 3a).

Outcrop ABD30-7

Fairly flat lying cross bedded sandstones are exposed in this outcrop. Two well defined troughs could be measured and the average corrected direction is towards N35^0 East (Figure 3b).

Discussion

Jerzykiewicz and Labonte (1991) show bimodal and polymodal direction patterns for the Lower Brazeau with NE and SE directions dominating. Our NNE directions partially confirm these directions. The presence of extensive pebble conglomerates in this part of the section may indicate tectonic activity in the West and an increase in paleoslope to the northeast.

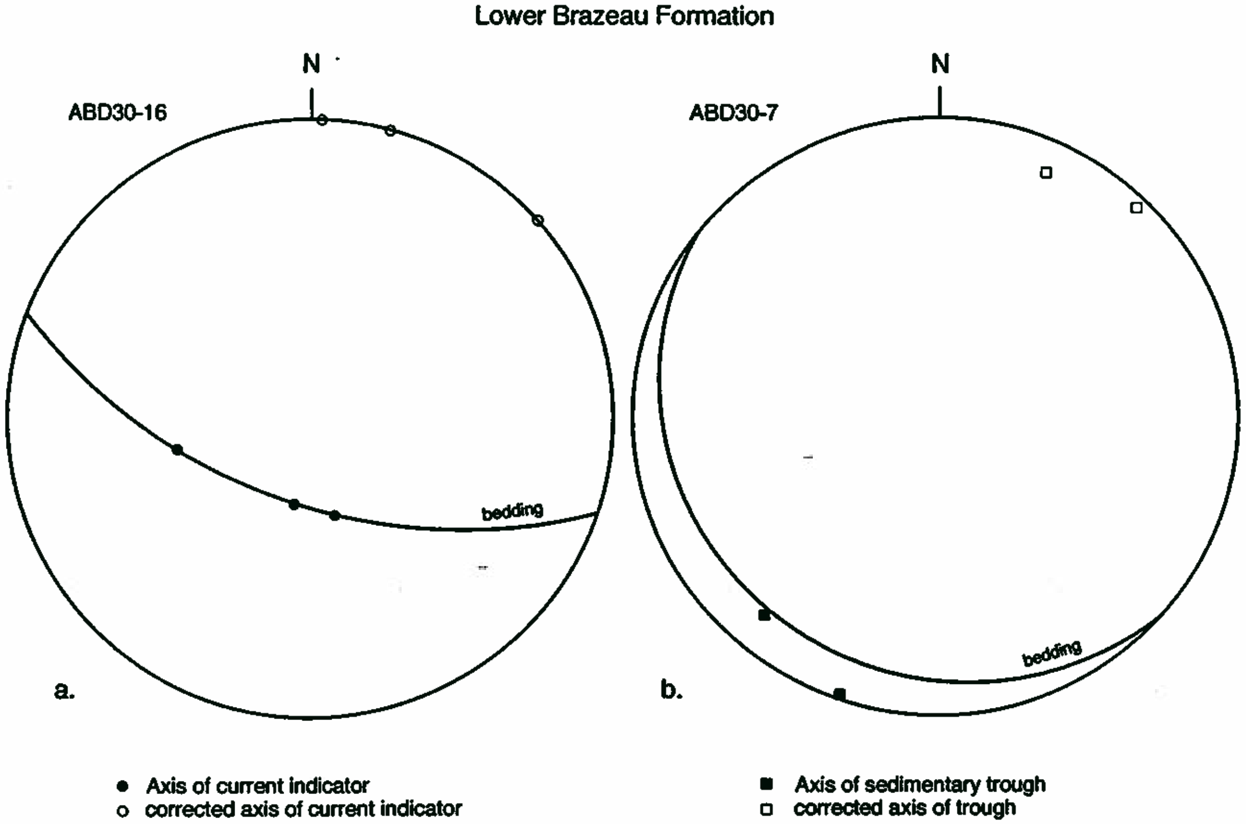


Figure 3. Paleocurrent directions for the Lower Brazeau Formation, a) outcrop ABD30-1, b) outcrop ABD30-18.

UPPER BRAZEAU

Outcrop ABD30-3

Trough cross bedded sandstones are exposed near the bridge over the Athabasca River. Three well defined troughs could be measured and the average corrected direction is towards N010° East (Figure 4a).

Outcrop ABD30-17

Steeply dipping trough cross bedded sandstones are well exposed near the bridge across the McLeod River near Mercoal. Three well defined troughs could be measured and the average corrected current direction is towards N40° East (Figure 4b).

Outcrop ABD30-21

Trough cross bedded sandstones are exposed along Highway 47 near Coalspur. Three well defined troughs could be measured; two are directed towards N350° East and the other one is directed towards N095° East (Figure 4c).

Outcrop at 466710 E - 5898050 N

This outcrop along Highway 40 was not sampled for indicator minerals, but contains some well-developed troughs. Two well defined troughs could be measured and the average corrected direction is towards N065° East (Figure 4d).

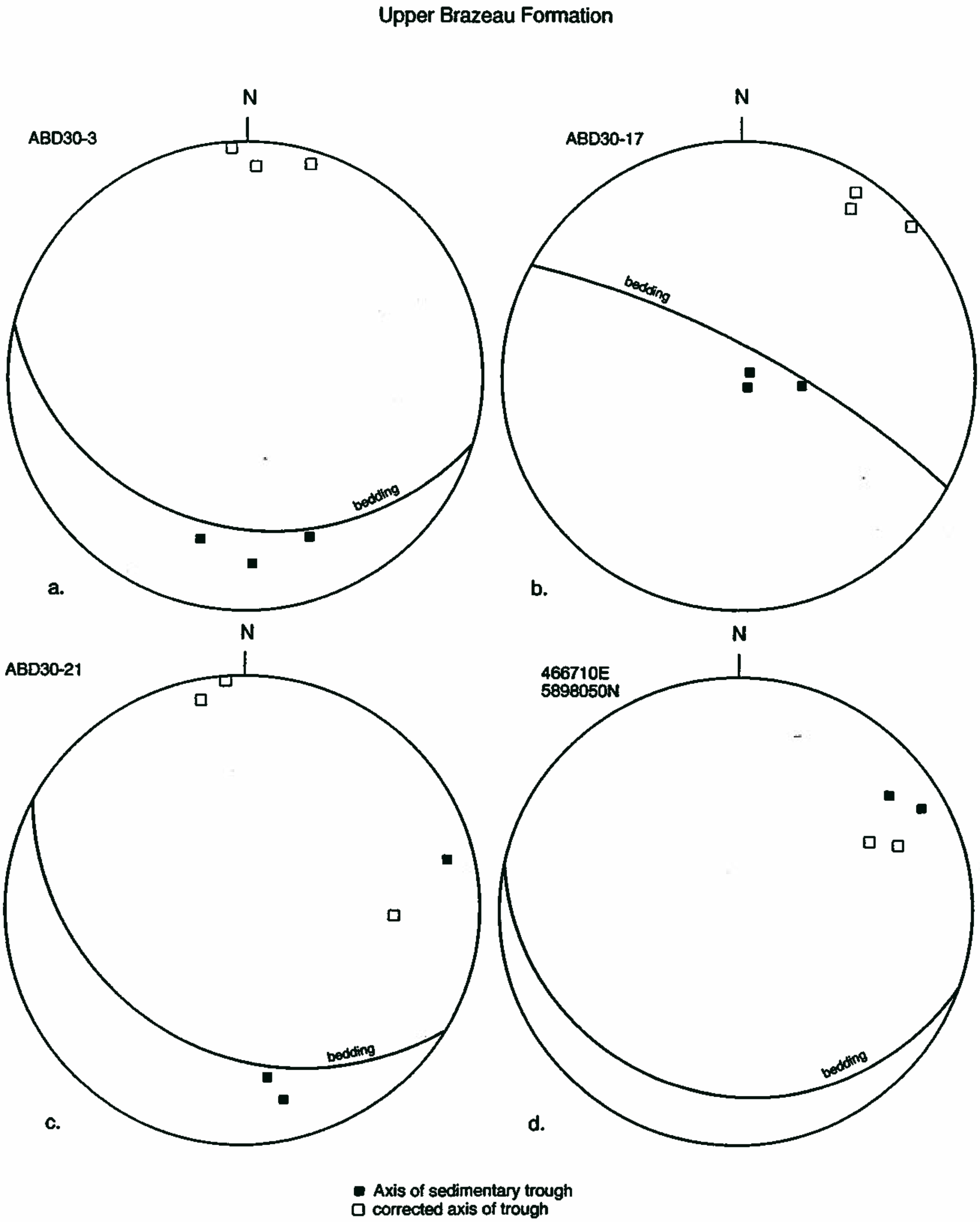
Discussion

Jerzykiewicz and Labonte (1991) show bimodal and polymodal direction patterns for the Upper Brazeau with directions between N020° East and N180° East. Our directions partially confirm these directions.

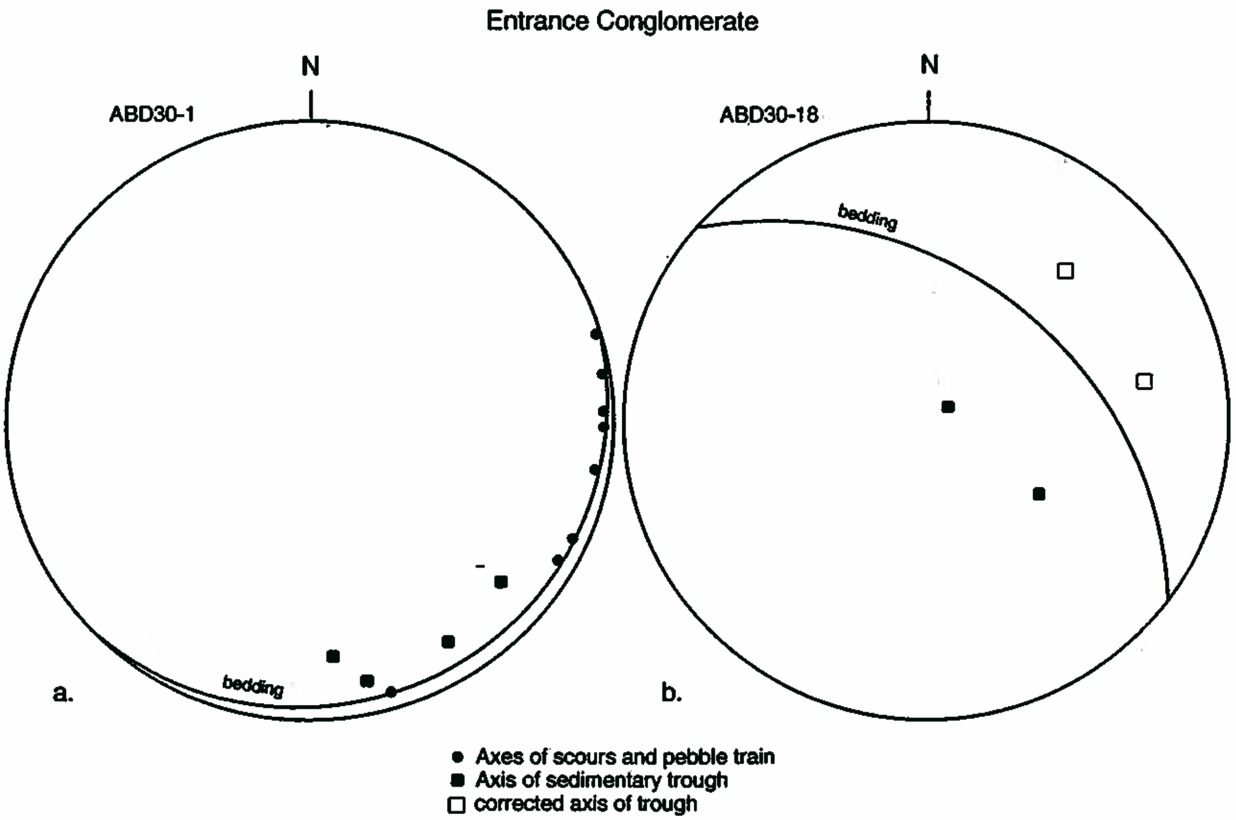
LOWER COALSPUR (INCLUDING ENTRANCE CONGLOMERATE)

Outcrop ABD30-1

The quarry in the Entrance Conglomerate near the hamlet of Entrance contains some sandstone interlayers that show well defined channels, that define troughs. Four troughs could be measured, which provided an average current direction towards N160° East (Figure 5a). The bedding is almost horizontal in this outcrop and consequently, this direction does not need to be corrected. This direction is confirmed by a pebble train in one of the channels in direction N165° East.



Figures 4. Paleocurrent directions for the Upper Brazeau Formation from 4 outcrops.



Figures 5. Paleocurrent directions from 2 outcrops of the Entrance Conglomerate.

Other current indicators are scour lineations at the base of conglomerate layers (one of these is the base of the Entrance Conglomerate). These scour lineations have directions between N070° East and N120° East. They are at a different stratigraphic level than the troughs and indicate the type of variation that can be expected in a single outcrop. It should be noted that most indicator minerals (olivines) come from the sandstone layers in-between the conglomerates.

Outcrop ABD30-18

Two well defined troughs could be measured in a small outcrop of the Entrance near Coalspur and the average corrected direction is towards N060° East (Figure 5b).

Discussion

Jerzykiewicz and Labonte (1991) show generally NE directed currents for the Entrance conglomerate, largely based on pebble imbrications. We did not find any consistent pebble imbrication directions in the Entrance Quarry. Consequently, we feel that the trough cross bedding directions give a more accurate indication of the current directions during Entrance deposition in the Entrance area.

UPPER COALSPUR

Outcrop ABD30-20

Three well defined troughs could be measured in sandstones of the Coalspur coal zone in the road exposure along Highway 47 in Coalspur and the average corrected direction is towards N100° East (Figure 6a).

Discussion

Jerzykiewicz and Labonte (1991) show bimodal direction patterns for the Upper Coalspur with directions towards N045° East and N135° East. Our directions partially confirm these observations.

PASKAPOO

West of outcrop ABD30-56 (502220 E - 5898150 N)

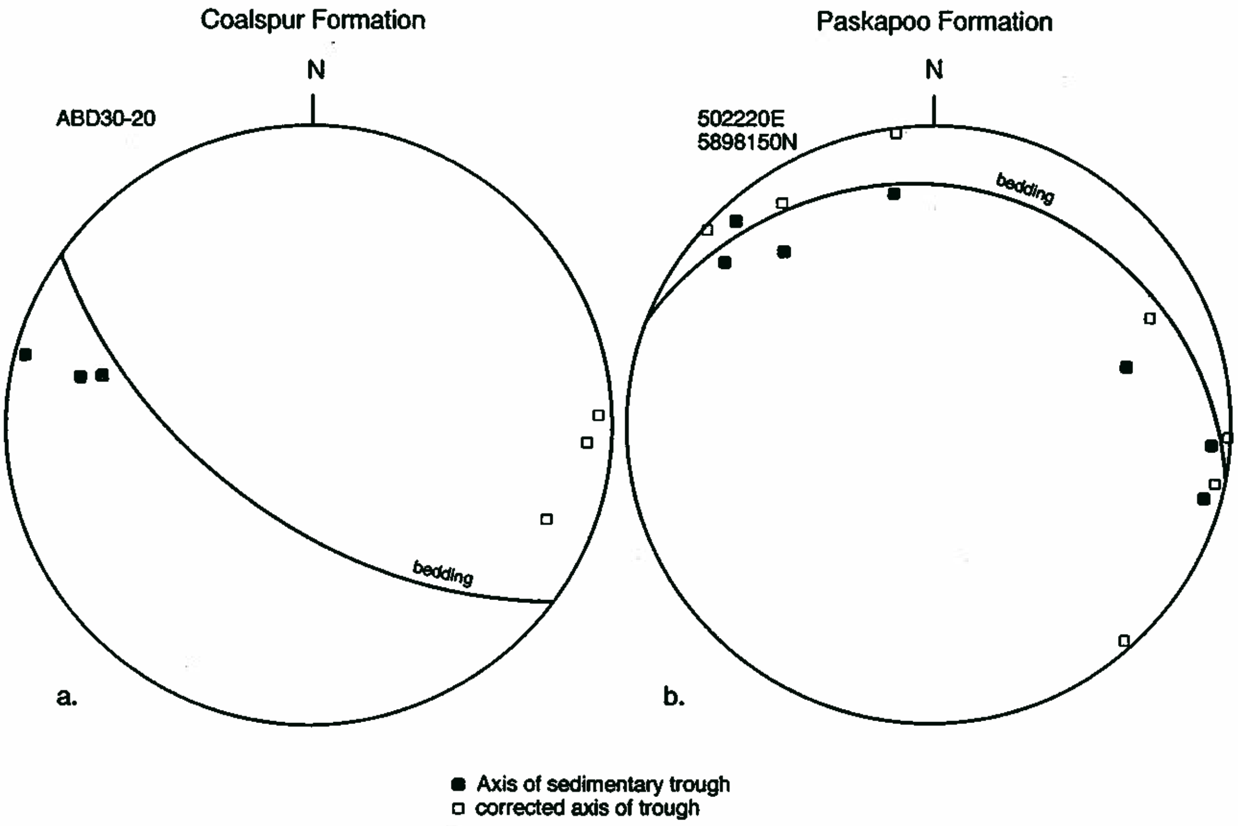
Many troughs are present in this outcrop of Paskapoo sandstones near the Robb culvert underneath the gasplant road. Seven trough could be measured and their directions show a bimodal distribution. Four channels were directed towards the east with an average of N095° East and the other three are directed towards the northwest with an average of N325° East (Figure 6b).

Discussion

Jerzykiewicz and Labonte (1991) show unimodal direction patterns for the Paskapoo with directions towards N045^{0} East. Our directions indicate that the patterns are more complicated in detail.

MAIN DIRECTIONS

The analysis shows preferred directions between N010^{0} East and N160^{0} East for Upper Cretaceous and Tertiary sediments, with a few deviating directions towards N325^{0} East (Figures 1, 3, 4 ,5 and 6).



Figures 6. Paleocurrent directions for the Coalspur and Paskapoo formations.

CONCLUSIONS

Bedrock sampling confirmed that diamond indicator minerals are present in Cretaceous and Tertiary rocks of the Hinton area, Alberta. A major find is the presence of olivines (including diamond inclusion olivines) in these sediments. Olivine has never been reported before in this part of Alberta. Recently they have also been noted in stream sediments, but never in the amounts reported from the bedrock (Cameco Corporation, 1995).

Another find is that sediments, which are older than Maastrichtian, contain diamond indicator minerals in the Cadomin area. This might indicate that there were 2 periods of ultramafic (kimberlite/lamproite?) intrusion: one in the Maastrichtian around 70 Ma ago and an older one possibly in the Aptian around 110 Ma ago.

Four anomalous areas can be delineated: i.e. the Entrance, Cadomin, Ruby Creek and Coal Valley areas. Based on bedrock samples, the Entrance and Cadomin areas rank highest in terms of diamond recovery potential. Both areas indicate the presence of ultramafic diatremes.

ENTRANCE AREA

Two samples of the Entrance Conglomerate in this area have high diamond inclusion olivine (DIO) content. A preliminary assessment indicate that the DIO's are probably from relatively local sources. Olivines break down very quickly during low-grade metamorphism and/or weathering and are altered to serpentine. Olivines seem to break down quicker than chromites. The large number of DIO's in very specific (relatively small) areas are an indication that the source of the DIO's could be nearby. Current directions in the Entrance quarry indicates that the source should be in a NNW direction.

Additional sampling could be undertaken in bedrock located NW to N from the quarry to establish an indicator train. The present location of the possible ultramafic intrusion will be further NE than the location indicated by the paleocurrent direction, because of Laramide deformation and shortening. Careful observations and measurements are needed, because the slightly older Brazeau outcrop ABD30-3 (which is nearby and contains DIO's) shows North directed paleocurrents.

CADOMIN AREA

Many diamond inclusion olivines have been found in samples as old as Aptian (sample ABD30-8 from the Nikanassin Formation) along the Cadomin railroad section. This might indicate a separate, older ultramafic (kimberlite/lamproite?) intrusion somewhere in the Cadomin area.

Additional sampling could be performed of Lower Cretaceous rocks in the Cadomin area. In addition, other areas where Lower Cretaceous rocks are exposed could be sampled. An attempt could be made to measure paleocurrent directions in these rocks. Few paleocurrents directions from the Lower Cretaceous have been reported.

RUBY CREEK AREA

The recovery of diamond indicator minerals in this area was somewhat low. Some diamond inclusion chromites (DIC's) and G11 garnets were found. It could be attempted to measure paleocurrent directions near outcrop ABD30-35, which contains DIC's. The latter outcrop is interesting, because in one sample a layer of 20 ilmenite grains was found.

COAL VALLEY AREA

The Upper Cretaceous and Tertiary bedrock in the area SW of the Coal Valley coal mine contains some diamond inclusion chromites, in addition to G3 and G4 garnets. These sediments generally show N to NE directed paleocurrents (see section on paleocurrents). This may indicate that the source of these indicator minerals is in the Cadomin area. This fits with a more SW paleo-location than the present location for the possible ultramafic intrusion, after palinpspastic restoration of this deformed part of the stratigraphy. This indicates that there might be two diatremes in the Cadomin area, one Early Cretaceous and one Late Cretaceous in age.

The area between the Coal Valley area and the Cadomin area could be further sampled to establish an indicator train pointing to a possible Cadomin Diatreme.

REFERENCES

Adair, R.N. (1986): Pyroclastic rocks of the Crowsnest Formation, Alberta; M.Sc. thesis, University of Alberta, 196 pages.

Afanasev, V.P., Varlamov, V.A. and Garanin, V.K. (1984): The abrasion of minerals in kimberlites in relation to the conditions and distance of their transportation; Geologiya i Geofizika, v.25, no.10, pp.112-117 (translated from Russian).

Bergman, S.C. (1987): Lamproites and other potassium-rich igneous rocks: a review of their occurrence, mineralogy and geochemistry; in: Fitton, J.G. and Upton, B.G.J. (editors), Alkaline Igneous rocks, Geological Society Special Publication No. 30, pp.103-109.

Cameco Corporation (1995): Alberta Diamond Project, Hinton area, Central Alberta, 1992-94 Exploration Activities, 7 volumes, Assessment Report, Alberta Department of Energy, Index No. 19950005.

Dawson, J.B. and Stephens, W.E. (1975): Statistical classification of garnets from kimberlite and associated xenoliths; Journal of Geology, v.83, pp.589-607.

DeCelles, P.G. and Langford, R.P. (1983): Two new methods of paleocurrent determination from trough cross-stratification; Journal of Sedimentary Geology, V.53, pp.629-642.

Deer, W.A., Howie, R.A. and Zussman, J. (1966): An introduction to the rock-forming minerals; Longmans, Green and Co., London, 528 pages.

Dufresne, M.B., Eccles, D.R., McKinstry, B., Schmitt, D.R., Fenton, M.M., Pawlowicz, J.G. and Edwards, W.A.D. (1996): The diamond potential of Alberta; Alberta Geological Survey, Bulletin 63, 158 pages.

Fipke, C.E., Gurney, J.J. and Moore, R.O. (1995): Diamond exploration techniques emphasising indicator mineral geochemistry and Canadian examples; Geological Survey of Canada, Bulletin 423, 86 pages.

Gabrielse, H. and Yorath, C.J. (1992): Geology of the Cordilleran Orogen in Canada, Geology of Canada, no. 4; Geological Survey of Canada, Decade of North American Geology (DNAG), Volume G-2, 844 pages, with accompanying maps.

Jerzykiewicz, T. and McLean, J.R. (1980): Lithostratigraphical and sedimentological framework of coal-bearing upper Cretaceous and lower Tertiary strata, Coal Valley area, central Alberta Foothills; Geological Survey of Canada Paper 79-12, 47 pages.

Jerzykiewicz, T. (1985a): Stratigraphy of the Saunders Group in the central Alberta Foothills - a progress report; in: Current Research, Part B, Geological Survey of Canada, Paper 85-1B, pp.247-258.

Jerzykiewicz, T. (1985b): Tectonically deformed pebbles in the Brazeau and Paskapoo formations, Central Alberta foothills, Canada, Sedimentary Geology, v.42, pp.159-180.

Jerzykiewicz, T. and Sweet, A.R. (1986): The Cretaceous-Tertiary boundary, central Alberta Foothills. I: Stratigraphy; Canadian Journal of Earth Sciences, v.23, pp.1356-1374.

Jerzykiewicz, T. and Labonte, M. (1991): Representation and statistical analysis of directional sedimentary structures in the Uppermost Cretaceous-Paleocene of the Alberta Foreland Basin; in: Current Research, Part B, Geological Survey of Canada, Paper 91-1B, pp.47-49.

Jerzykiewicz, T. (in press): Stratigraphic framework of the Uppermost Cretaceous to Paleocene of the Alberta Basin; Geological Survey of Canada, Bulletin.

Langenberg, C.W. (1993): Geological Map: Cadomin NTS Mapsheet 83F/3; Alberta Geological Survey, Geology Map 217, Map with accompanying cross sections.

Langenberg, C.W. and McMechan, M.E. (1985): Lower Cretaceous Luscar Group (revised) of the northern and north central Foothills of Alberta; Bulletin of Canadian Petroleum Geology, v. 33, pp. 1-11.

Langenberg, C.W., Macdonald, D.E., Kalkreuth, W. and Strobl, R. (1989): Coal quality variation in the Cadomin-Luscar coalfield; Alberta Research Council, Earth Sciences Report 89-1, 65 pages.

Leckie, D. (1986): Petrology and tectonic significance of Gates Formation (early Cretaceous) sediments in northeast British Columbia. Canadian Journal of Earth Sciences, v. 23, pp.129-141.

Macdonald, D.E., Langenberg, C.W. and Strobl, R.S. (1988): Cyclic marine sedimentation in the Lower Cretaceous Luscar Group and Spirit River Formation of the Alberta Foothills and Deep Basin; *In*: Sequences, Stratigraphy, Sedimentology: Surface and subsurface, D. P. James and D. A. Leckie (eds), Canadian Society of Petroleum Geologists, Memoir 15, pp. 143-154.

Macdonald, D.E., Langenberg, C.W. and Gentzis, T. (1989): A regional evaluation of coal quality in the Foothills/Mountain region of Alberta; Alberta Research Council, Earth Sciences Report 89-2, 58 pages.

Mack, G.H. and Jerzykiewicz, T. (1989): Provenance of post-Wapiabi sandstones and its implications for Campanian to Paleocene tectonic history of the southern Canadian Cordillera; Canadian Journal of Earth Sciences, v. 26, pp.665-676

Marshak, S. and Mitra, G. (1988): Basic methods of structural geology; Prentice Hall, 446 pages.

McCandless, T.E. and Gurney, J.J. (1986): Sodium in garnet and potassium in clinopyroxene: criteria for classifying mantle eclogites; Proceedings of the 4th International Kimberlite Conference, Perth, Kimberlites and related rocks, v.2, pp.827-832.

McLean, J.R. (1977): The Cadomin Formation: stratigraphy, sedimentology and tectonic implications; Bulletin of Canadian Petroleum Geology, v.25, pp.792-827.

Mellon, G.B. (1967): Stratigraphy and petrology of the Lower Cretaceous Blaimore and Mannville Groups. Alberta Research Council, Bulletin 21, 270 pages.

Mitchell, R.H. (1986): Kimberlites: Mineralogy, geochemistry and Petrology; Plenum Publishing, New York, 442 pages.

Pell, J. (1987): Alkaline Ultrabasic rocks in British Columbia, BC; Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Open File 1987-17, 109 pages.

Peterson, T.D. and Currie, K.L. (1993): Analcite-bearing igneous rocks from the Crowsnest Formation, SW Alberta; *in* Current Research, part B, Geological Survey of Canada, paper 93-1B, pp.51-56.

Pettijohn, F.J. (1975): Sedimentary Rocks, third edition; Harper & Row, 628 pages.

Potter, P.E. and Pettijohn, F.J. (1977): Paleocurrents and basin analysis; Springer Verlag, 425 pages.

Rahmani, R.A. and Lerbekmo, J.F. (1975): Heavy-mineral analysis of Upper Cretaceous and Paleocene sandstones in Alberta and adjacent areas in Saskatchewan; *In* W.G.E Caldwell

(Editor): The Cretaceous System in the western interior of North America, Geological Association of Canada, Special Paper 13, pp.607-632.

Rapson, J.E. (1965): Petrography and derivation of Jarassic-Cretaceous clastic rocks, southern Rocky Mountains, Canada; American Association of Petroleum Geologists Bulletin, v.49, pp.1426-1452.

Schultheis, N.H. and Mountjoy, E.W. (1978): Cadomin Conglomerate of western Alberta - a result of early Cretaceous uplift of the Main Ranges; Bulletin of Canadian Petroleum Geology, v.26, pp.297-342.

Skupinski, A and Legun, A. (1988): Geology of alkalic rocks at Twentynine Mile Creek, Flathead River area, SE British Columbia; Exploration in British Columbia 1988 (Part B), Ministry of Energy, Mines and Petroleum Resources, Province of British Columbia, pp.B29-B34.

Stephens, W.E. and Dawson, J.B. (1977): Statistical comparison between pyroxenes from kimberlites and their associated xenoliths; Journal of Geology, v.85, pp.433-449.

Stott, D.F. (1963): The Cretaceous Alberta Group and equivalent rocks, Rocky Mountains Foothills, Alberta; Geological Survey of Canada, Memoir 317, 306 pages.

Stott, D.F. (1982): Lower Cretaceous Ft. St.john Group and Upper Cretaceous Dunvegan Formation of the Foothills and Plains of Alberta, British Columbia, District of MacKenzie and Yukon Territory; Geological Survey of Canada, Memoir 328, 124 pages.

Tracy, R.J. and Frost, B.R. (1991): Phase equilibria and thermal barometry of calcareous ultramafic and mafic rocks and iron formations; in: D.M. Kerrick (editor): Contact metamorphism, Reviews in Minerology, v.26, Mineralogical Society of America, pp.207-289.

Winchell, A.N. (1951): Elements of Optical Mineralogy, an introduction to microscopic petrography: Part II. Description of Minerals; John Wiley & Sons, Inc., 551 pages

APPENDIX 1. MICROPROBE ANALYSES OF SELECTED GRAINS IN THIN SECTIONS

Probed by G. De Paoli on May 24, 1994.
Unable to acount for low totals in some analyses, likely H2O contamination

sample	grain	Mineral	SiO2	TiO2	Al2O	FeO	MgO	CaO	Na2O	F	Cr2O	SUM
AD3-7B	1(1)	Mg Chrom.	0.00	0.03	46.43	15.63	17.59	0.00	0.00	0.06	22.26	102.00
AD3-7B	1(2)	Mg Chrom.	0.00	0.03	45.71	15.69	17.69	0.00	0.01	0.08	22.85	102.06
AD3-7B	2C	Mg Chrom.	0.00	0.05	15.03	20.67	9.90	0.00	0.01	0.03	55.54	101.23
AD3-7B	2R	Mg Chrom.	0.00	0.08	15.20	20.82	9.91	0.01	0.00	0.00	55.18	101.20
AD3-7B	3(1)	Ilmenite	0.00	36.71	0.20	55.07	2.65	0.10	0.00	0.10	0.01	94.84
AD3-7B	3(2)	Ilmenite	0.00	33.11	0.27	57.22	3.07	0.04	0.00	0.05	0.03	93.79
AD3-7B	3(3)	Ilmenite	0.00	36.62	0.19	54.98	2.31	0.05	0.00	0.15	0.01	94.31
AD3-7B	3(4)	Ilmenite	0.00	39.02	0.25	52.20	2.23	0.11	0.00	0.00	0.06	93.87
AD3-7B	3(5)	Ilmenite	0.00	34.55	0.21	56.39	2.35	0.07	0.00	0.11	0.03	93.71
AD3-7B	4(1)	Ilmenite	0.75	70.57	0.61	20.30	0.22	0.23	0.00	0.00	0.02	92.70
AD3-7B	4(2)	Ilmenite	0.42	57.86	0.31	30.68	0.45	0.15	0.00	0.00	0.01	89.88
AD3-7B	5(1)	Mg Chrom.	0.00	0.06	11.79	25.19	7.95	0.03	0.00	0.00	53.92	98.94
AD3-7B	5(2)	Mg Chrom.	0.00	0.06	11.91	27.12	7.20	0.02	0.00	0.00	52.88	99.19
AD3-7B	5(3)	Mg Chrom.	0.00	0.05	12.05	26.32	7.71	0.02	0.01	0.00	52.96	99.12
AD3-7B	6(1)	Mg Chrom.	0.00	0.03	29.30	16.40	14.72	0.01	0.00	0.05	40.93	101.44
AD3-7B	6(2)	Mg Chrom.	0.01	0.03	28.92	16.68	14.51	0.01	0.01	0.00	41.96	102.13
AD3-7C	1(1)	Ulvospinel	0.07	1.53	7.86	71.14	7.84	0.05	0.00	0.14	4.27	92.90
AD3-7C	1(2)	Ulvospinel	0.04	1.50	7.66	71.41	7.97	0.06	0.00	0.09	4.33	93.06
AD3-7C	1(3)	Ulvospinel	0.05	1.53	7.92	71.41	7.78	0.05	0.00	0.10	4.25	93.09
AD3-7C	1(4)	Ulvospinel	0.04	1.49	7.78	71.49	7.77	0.03	0.00	0.11	4.30	93.01
AD3-7C	1(5)	Ulvospinel	0.05	1.49	7.53	71.59	7.97	0.04	0.00	0.08	4.23	92.98
AD3-7C	1(6)	Ulvospinel	0.01	1.52	7.80	71.40	7.79	0.03	0.00	0.08	4.23	92.86
AD3-7C	2(1)	Mg Chrom.	0.14	0.04	31.68	19.23	13.96	0.02	0.01	0.08	35.99	101.15
AD3-7C	2(2)	Mg Chrom.	0.00	0.06	30.95	19.35	14.06	0.01	0.00	0.04	36.83	101.30
AD3-7C	3(1)	Mg Chrom.	0.00	0.18	19.27	25.43	10.51	0.03	0.00	0.00	45.36	100.78
AD3-7C	3(2)	Mg Chrom.	0.00	0.15	19.09	24.74	10.64	0.02	0.01	0.00	46.01	100.66
AD3-7C	3(3)	Mg Chrom.	0.00	0.15	19.11	24.63	10.56	0.02	0.01	0.00	46.31	100.79
AD3-7C	3(4)	Mg Chrom.	0.00	0.16	18.98	24.92	10.55	0.02	0.00	0.04	45.53	100.20
AD3-7C	3(5)	Mg Chrom.	0.00	0.18	19.77	25.20	10.61	0.03	0.00	0.00	44.35	100.14
AD3-7C	4	Rutile	4.25	92.27	3.00	0.38	0.10	0.08	0.00	0.06	0.01	100.15
AD3-7C	5	Rutile	5.42	82.93	2.20	1.41	0.31	0.61	0.00	0.00	0.01	92.89
AD3-7C	6(1)	Mg Chrom.	0.00	0.01	32.73	19.43	14.23	0.00	0.01	0.00	34.37	100.78
AD3-7C	6(2)	Mg Chrom.	0.00	0.01	33.34	19.51	14.11	0.02	0.01	0.05	34.04	101.09
AD3-7C	7(1)	Mg Chrom.	0.00	0.04	28.99	15.93	14.89	0.00	0.02	0.03	40.62	100.52
AD3-7C	7(2)	Mg Chrom.	0.00	0.18	29.58	15.69	15.04	0.02	0.00	0.00	40.46	100.97
AD3-7C	7(3)	Mg Chrom.	0.02	0.43	29.37	15.63	14.76	0.03	0.00	0.00	40.14	100.38
AD3-7C	7(4)	Mg Chrom.	0.00	0.09	29.10	15.83	15.16	0.01	0.02	0.00	40.77	100.98
AD3-7C	7(5)	Mg Chrom.	0.00	0.06	29.13	15.93	15.13	0.00	0.00	0.00	40.93	101.18
AD3-35	1(1)	Mg Chrom.	0.02	0.01	22.19	20.18	12.22	0.08	0.01	0.00	45.89	100.60
AD3-35	1(2)	Mg Chrom.	0.01	0.03	22.34	19.95	12.10	0.09	0.00	0.00	45.31	99.83
AD3-35	1(3)	Mg Chrom.	0.00	0.03	21.73	19.99	12.16	0.24	0.02	0.02	45.77	99.96
AD3-35	1A(1)	Ilmenite	0.00	51.22	0.18	47.33	2.64	0.22	0.00	0.09	0.00	101.68
AD3-35	1A(2)	Ilmenite	0.00	51.10	0.20	47.08	2.55	0.06	0.00	0.05	0.00	101.04
AD3-35	1A(3)	Ilmenite	0.01	51.04	0.16	46.90	2.54	0.19	0.00	0.05	0.01	100.90
AD3-35	1A(4)	Ilmenite	0.00	51.10	0.15	46.97	2.57	0.15	0.00	0.00	0.00	100.94
AD3-35	1B	Ulvospinel	0.05	17.70	0.17	73.48	0.08	0.10	0.00	0.11	0.03	91.72
AD3-35	2(1)	Mg Chrom.	0.17	2.26	13.37	25.82	9.89	0.29	0.00	0.00	45.32	97.12
AD3-35	2(2)	Mg Chrom.	0.12	2.30	13.37	25.96	10.40	0.10	0.00	0.00	45.91	98.16
AD3-35	2(3)	Mg Chrom.	0.03	2.31	13.63	25.93	10.40	0.26	0.00	0.00	45.62	98.18
AD3-35	2(4)	Mg Chrom.	0.15	2.26	13.88	25.83	9.94	0.28	0.00	0.00	45.16	97.50

sample	grain	Mineral	SiO2	TiO2	Al2O	FeO	MgO	CaO	Na2O	F	Cr2O	SUM
AD3-35	2B(1)	Ilmenite	0.00	48.39	0.29	47.10	4.13	0.05	0.00	0.01	0.00	99.97
AD3-35	2B(2)	Ilmenite	0.00	48.53	0.34	47.61	4.07	0.05	0.00	0.03	0.00	100.63
AD3-35	2B(3)	Ilmenite	0.00	48.29	0.36	47.01	4.10	0.05	0.00	0.00	0.00	99.81
AD3-35	3(1)	Ilmenite	0.00	44.99	0.48	48.18	4.91	0.69	0.00	0.06	0.00	99.31
AD3-35	3(2)	Ilmenite	0.00	45.65	0.50	48.01	4.93	0.02	0.00	0.06	0.02	99.19
AD3-35	3(3)	Ilmenite	0.00	45.41	0.54	48.39	4.88	0.15	0.00	0.00	0.01	99.38
AD3-35	4	Ilmenite	0.00	32.93	0.28	60.62	2.28	0.01	0.00	0.17	0.03	96.32
AD3-35	4A	Ilm./Rutile	0.04	73.41	1.67	25.54	0.01	0.04	0.00	0.00	0.01	100.72
AD3-35	4B	Ilmenite	0.00	27.99	0.23	66.77	0.50	0.01	0.00	0.03	0.02	95.55
AD3-35	5(1)	Mg Chrom.	0.00	0.01	22.51	18.57	12.26	0.34	0.01	0.00	46.87	100.57
AD3-35	5(2)	Mg Chrom.	0.00	0.01	22.61	18.35	12.23	0.07	0.00	0.08	47.89	101.24
AD3-35	5(3)	Mg Chrom.	0.00	0.01	21.81	18.27	12.36	0.33	0.01	0.00	47.66	100.45
AD3-35	5(4)	Mg Chrom.	0.00	0.02	22.40	18.24	12.40	0.20	0.00	0.00	47.75	101.01
AD3-35	6(1)	Serpentine	41.78	0.03	2.17	6.08	36.41	0.08	0.00	0.00	0.20	86.75
AD3-35	6(2)	Serpentine	41.30	0.02	2.19	5.81	36.17	0.11	0.00	0.07	0.15	85.82
AD3-41A	1C	Mg Chrom.	0.00	0.01	24.04	17.57	13.79	0.01	0.00	0.00	46.33	101.75
AD3-41A	1R	Mg Chrom.	0.02	0.04	23.69	17.28	13.49	0.01	0.00	0.00	45.78	100.31
AD3-41A	2	Andradite	37.66	0.04	20.80	31.64	4.91	3.70	0.00	0.00	0.03	98.78
AD3-41A	2	Andradite	37.76	0.04	20.78	30.26	4.62	3.27	0.00	0.05	0.03	96.81
AD3-41A	3	Grossular	38.36	0.37	16.09	10.03	0.03	34.24	0.00	0.03	0.00	99.15
AD3-41A	4C	Mg Chrom.	0.00	0.00	30.59	17.14	14.55	0.01	0.00	0.02	39.91	102.22
AD3-41A	4R	Mg Chrom.	0.00	0.03	30.43	16.88	14.70	0.01	0.00	0.03	39.48	101.56
AD3-41A	5	Mg Chrom.	0.00	0.03	22.83	20.04	12.75	0.01	0.00	0.00	44.32	99.98
AD3-41A	6(1)	Ilmenite	0.00	48.25	0.06	44.53	1.73	0.03	0.00	0.04	0.19	94.83
AD3-41A	6(2)	Ilmenite	0.00	56.06	0.03	38.25	0.99	0.04	0.00	0.07	0.26	95.70
AD3-41A	6(3)	Ilmenite	0.00	43.21	0.09	48.59	2.06	0.02	0.00	0.06	0.22	94.25
AD3-41A	7C	Mg Chrom.	0.00	0.08	8.44	24.49	8.30	0.01	0.00	0.00	58.44	99.76
AD3-41A	7R	inclusion	78.57	0.03	2.66	5.38	1.32	0.04	0.00	0.00	14.82	102.82
AD3-41A	7R	Mg Chrom.	0.32	0.10	8.63	23.87	8.06	0.04	0.00	0.02	57.04	98.08
AD3-41B	1	Ilmenite	0.01	53.04	0.01	43.38	0.07	0.06	0.00	0.02	0.01	96.60
AD3-41B	2C	Mg Chrom.	0.02	0.02	27.82	20.31	12.25	0.01	0.03	0.00	42.06	102.52
AD3-41B	2R	Mg Chrom.	0.38	0.05	26.91	22.69	11.03	0.04	0.10	0.00	39.08	100.28
AD3-41B	3B	Mg Chrom.	0.00	0.06	7.40	20.24	7.02	0.02	0.02	0.00	63.45	98.21
AD3-41B	3S	Mg Chrom.	0.00	0.06	7.29	19.91	7.71	0.04	0.02	0.00	63.24	98.27
AD3-41B	4	Rutile	1.43	95.42	0.97	1.46	0.33	0.09	0.00	0.00	0.00	99.70
AD3-41B	5C	Mg Chrom.	0.01	0.03	15.91	29.31	5.97	0.03	0.03	0.00	47.98	99.27
AD3-41B	5R	Mg Chrom.	0.02	0.03	16.05	27.83	6.92	0.05	0.00	0.00	47.76	98.66
AD3-41B	6(1)C	Mg Chrom.	0.00	0.03	28.09	17.38	14.45	0.02	0.00	0.00	41.67	101.64
AD3-41B	6(1)R	Mg Chrom.	0.01	0.04	28.33	17.40	14.54	0.02	0.00	0.01	40.70	101.05
AD3-41B	6(2)	Magnetite	0.03	0.06	0.25	89.70	0.04	0.04	0.00	0.13	0.27	90.52
AD3-41B	7C	Mg Chrom.	0.00	0.06	36.65	15.71	15.82	0.01	0.01	0.00	33.86	102.12
AD3-41B	7R	Mg Chrom.	0.02	0.06	36.77	15.63	16.05	0.02	0.00	0.01	33.65	102.21
AD3-41B	8C	Mg Chrom.	0.35	0.46	19.61	28.63	7.96	0.09	0.02	0.00	43.13	100.25
AD3-41B	8R	Mg Chrom.	1.76	1.52	14.07	38.20	3.17	0.13	0.11	0.00	33.72	92.68
AD3-41B	8R	Mg Chrom.	0.01	0.42	20.01	29.12	7.53	0.05	0.00	0.00	41.42	98.56

APPENDIX 2

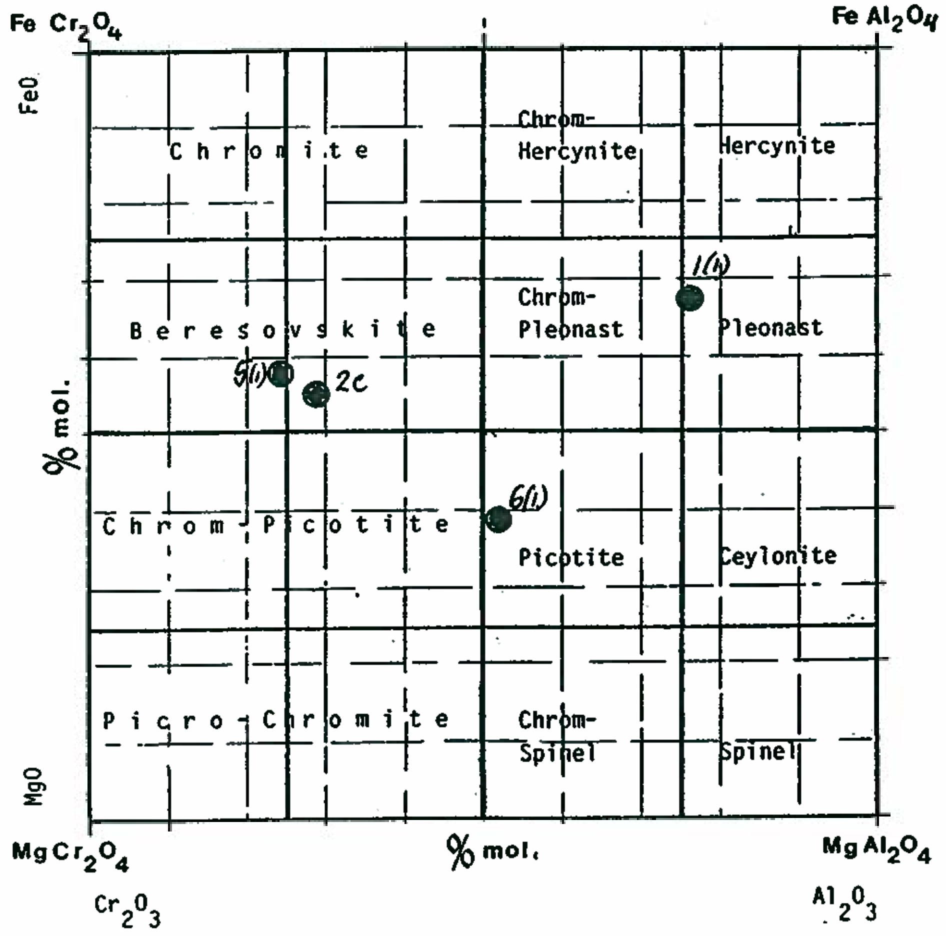
Winchell (1951) Classification of the Mg-bearing Chromites

		100%		100%		
No. Analys.		MgO	FeO	Al_2O_3	Cr_2O_3	Name of Spinel
ABD30-7B	1(1)	33.33	66.67	75.58	24.42	Pleonast
	2C	46.07	53.93	28.71	71.29	Beresovskite
	5(1)	36.02	63.98	24.63	75.37	Beresovskite
	6(1)	61.55	38.45	51.62	48.38	Picotite
ABD30-7C	2(1)	56.35	43.65	56.75	43.25	Picotite
	3(1)	42.44	57.56	38.81	61.19	Beresovskite
	6(1)	56.66	43.34	58.68	41.32	Picotite
	7(1)	62.44	37.56	51.54	48.46	Picotite
ABD30-35	1(1)	51.88	48.12	41.92	58.08	Chrom-picotite
	2(1)	40.56	59.44	34.79	65.21	Beresovskite
	5(1)	54.09	45.91	41.78	58.22	Chrome-picotite
ABD30-41A	1C	58.26	41.74	43.62	56.38	Chrom-picotite
	4C	60.27	39.73	53.28	46.72	Picotite
	5	53.11	46.89	43.41	56.59	Chrom-picotite
	7C	37.66	62.34	17.74	82.26	Beresovskite
ABD30-41B	2C	51.79	48.21	49.64	50.36	Chrom-picotite
	3B	38.16	61.84	14.90	85.10	Beresovskite
	5C	17.07	82.93	33.05	66.95	Chromite
	6(1)C	59.67	40.33	50.18	49.82	Picotite
	7C	64.16	35.84	61.68	38.32	Picotite
	8C	33.17	66.83	40.34	59.66	Beresovskite

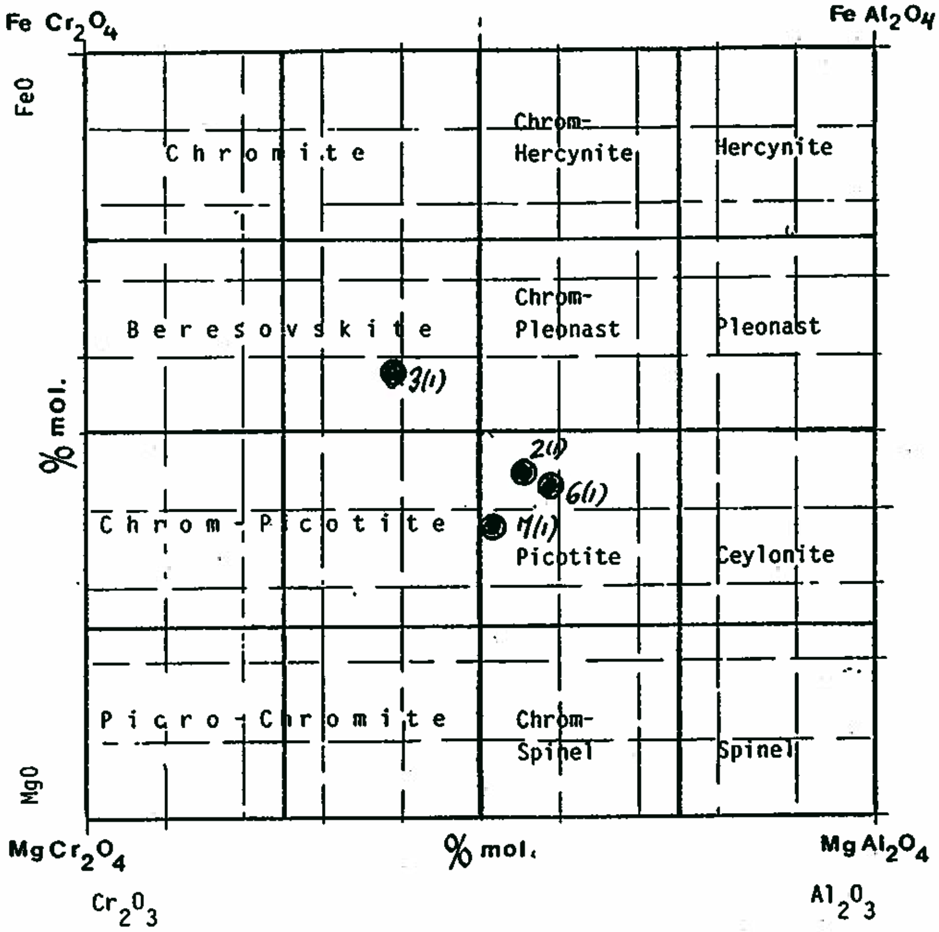
The spinel molecular contributions of MgO + FeO = 100% vs Al_2O_3 + Cr_2O_3 = 100%

(For spinels with Al_2O_3 and Cr_2O_3 only; not for spinels with Fe_2O_3 e.g. Magnetite)

Thin section: AD3-7B

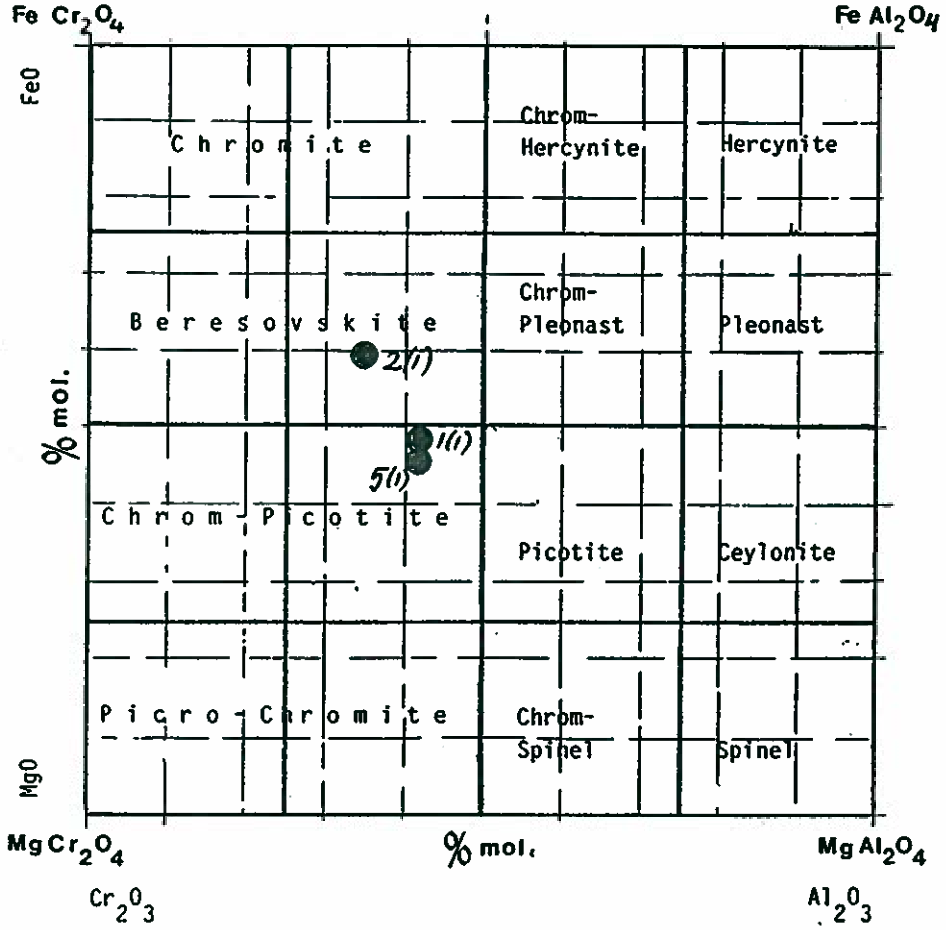


Nr. anal.	Grain description	
7B 1(1)	Pleonast	Transparent, light olive, auhedral crushed, 0.1mm in size
2c	Beresovsk.	—"— , dark red, —"— 0.2mm —"—
5(1)	Beresovsk	Semiopaque, dark red, euhedral, 0.08mm —"—
6(1)	Picotite	Transparent, dark brown, auhedral, 0.2mm —"—



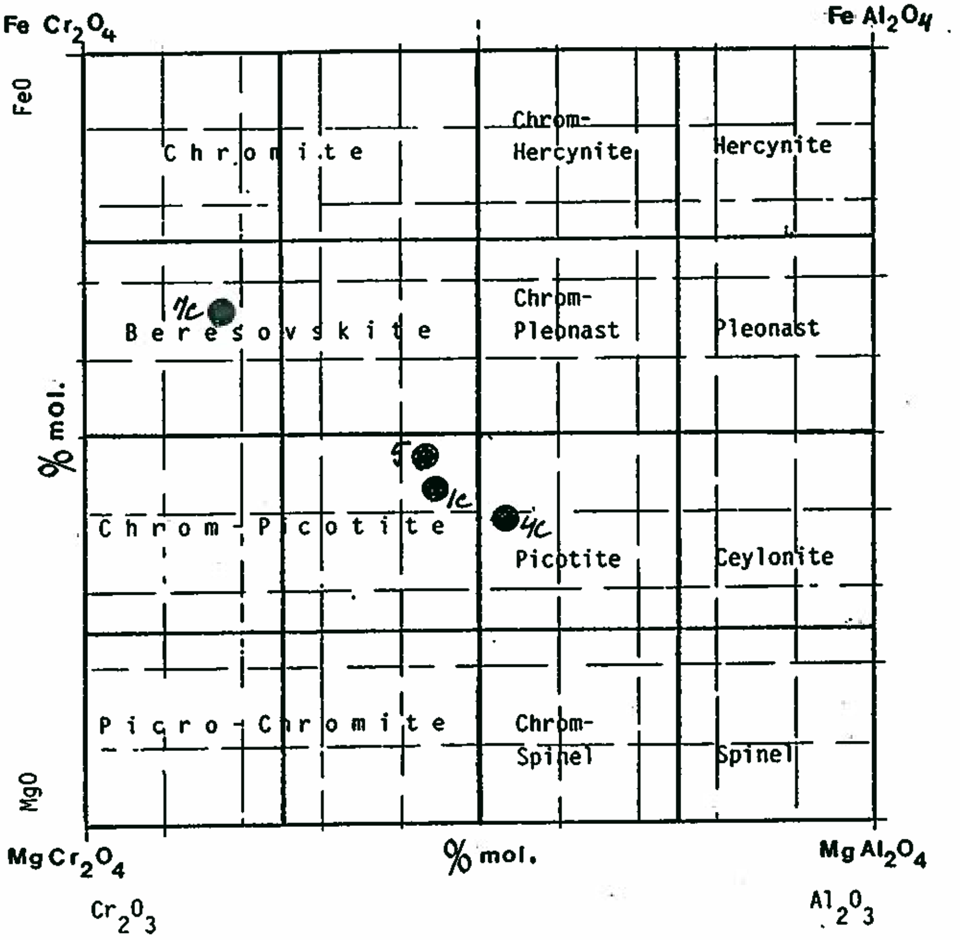
Nr. anal.	Grain description	
7C - 2(1)	Picotite	Transparent, light brown, auhedral, 0.1 mm in size
3(1)	Beresovsk.	—"— , dark redd. brown, —"— , 0.15 mm —"—
6(1)	Picotite	—"— , light brown , —"— , 0.12 mm —"—
7(1)	Picotite	—"— —"— —"— , auhedr. angul. 0.2 mm —"—

Thin section: HU7-22



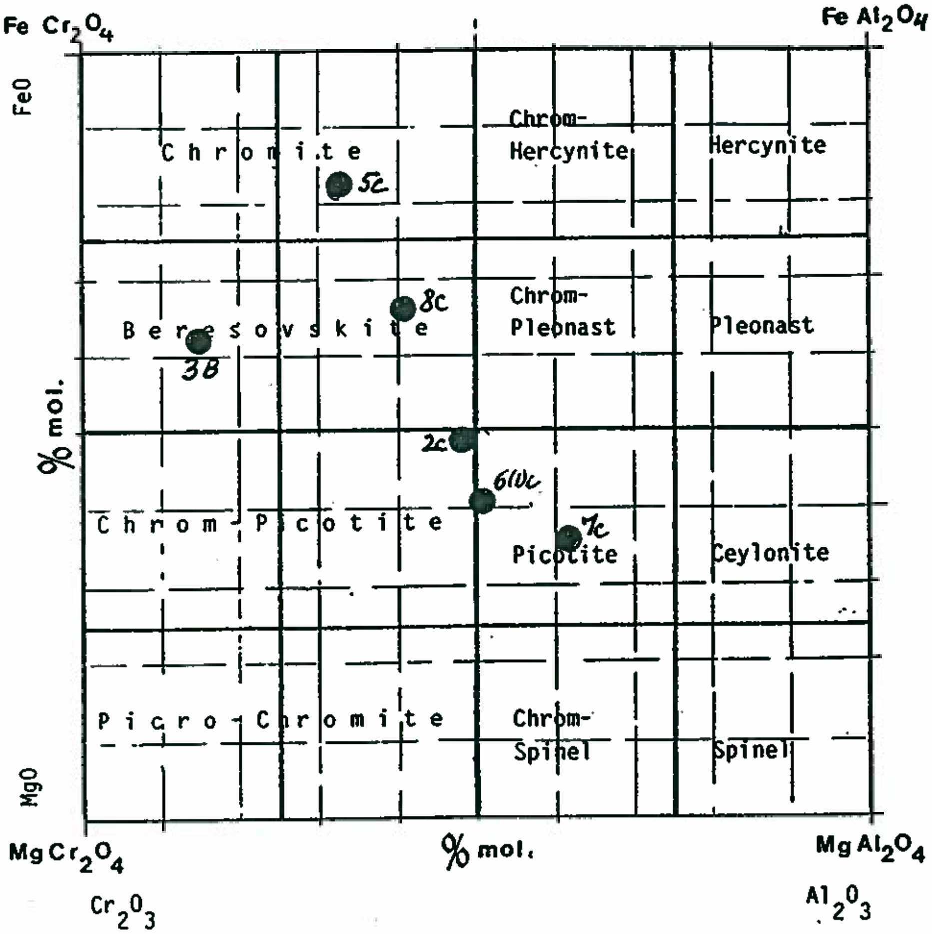
Nr. anal.	Grain description	
35 1(1)	Cr-Picotite	Transparent, dark brown, angular, 0.12mm in size
2(1)	Beresovsk.	Almost totally opaque, red on Trims, subang. 0.15mm in size
5(1)	Cr-Picotite	Transparent dark redd brown, elong. ang. 0.2mm in size

Thin section: AD3-41A



Nr. anal.	Grain description	
41A 1C	Cr-Picotite	Transparent, brown, angular, 0.1 mm in size
4C	Picotite	—"—, light brown, —"—, 0.13 mm —"—
5	Cr-Picotit	—"—, dark brown, —"—, 0.05 mm —"—
7C	Beresovskit	Transp., dark red brown, subhedral 0.08 mm —"—

Thin section: AD3-41B

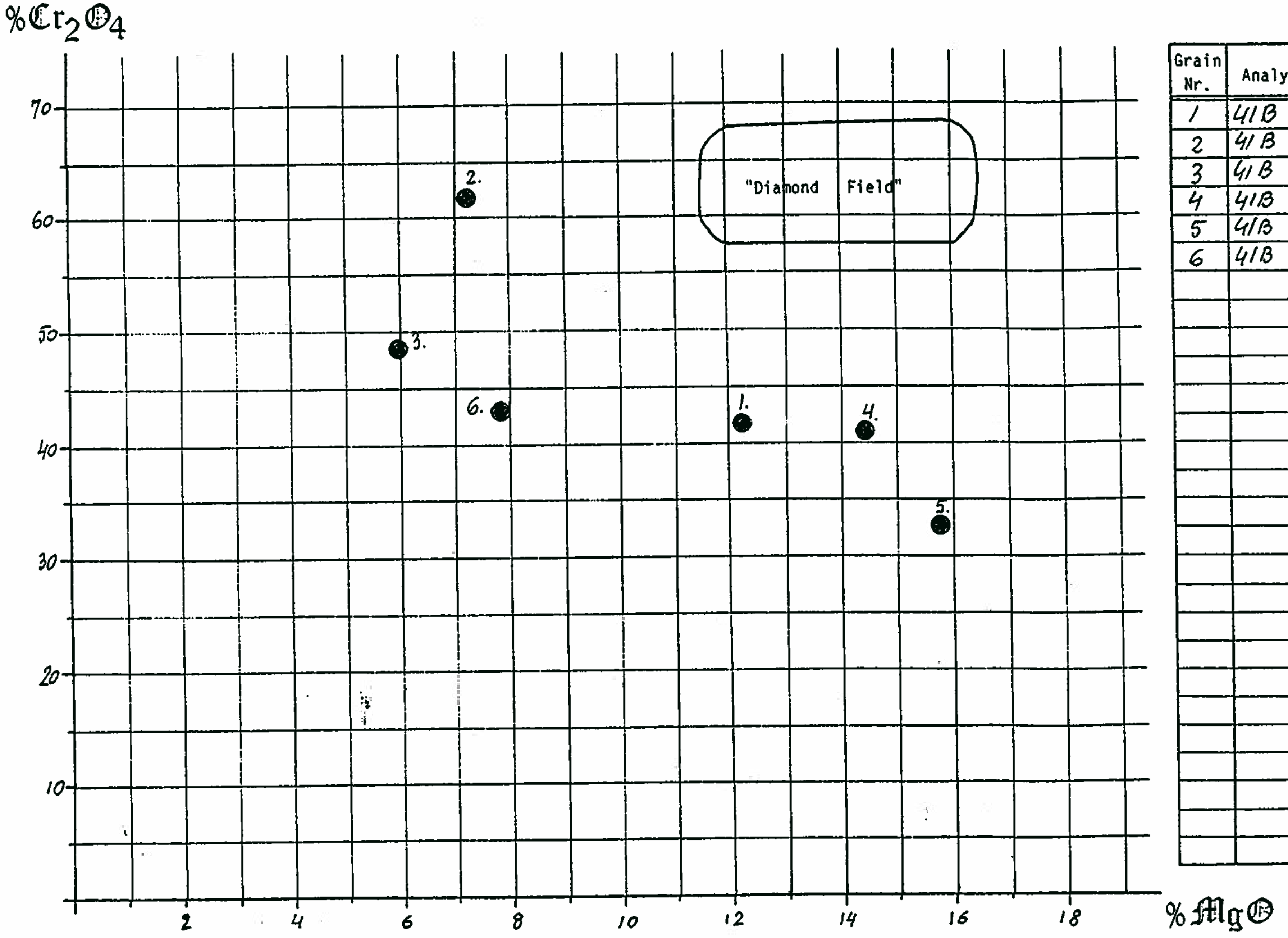


Nr. anal.	Grain description	
41B 2C	Cr-Picotite	Transparent, redd. brown, anhedral, 0.1 mm in size
41B 3B	Beresovsk.	Semiopaque, red brown, —"—, 0.08 mm —"—
41B 5C	Chromite	Transparent, dark redd. brown, —"—, 0.06 mm —"—
41B 6(1)C	Picotite	—"— light brown, euhedral, 0.07 mm —"—
41B 7C	Picotite	—"— —"— —"—, anhedral, 0.1 mm —"—
41B 8C	Beresovsk.	Semiopaque, reddish, —"—, 0.08 mm —"—

APPENDIX 3.

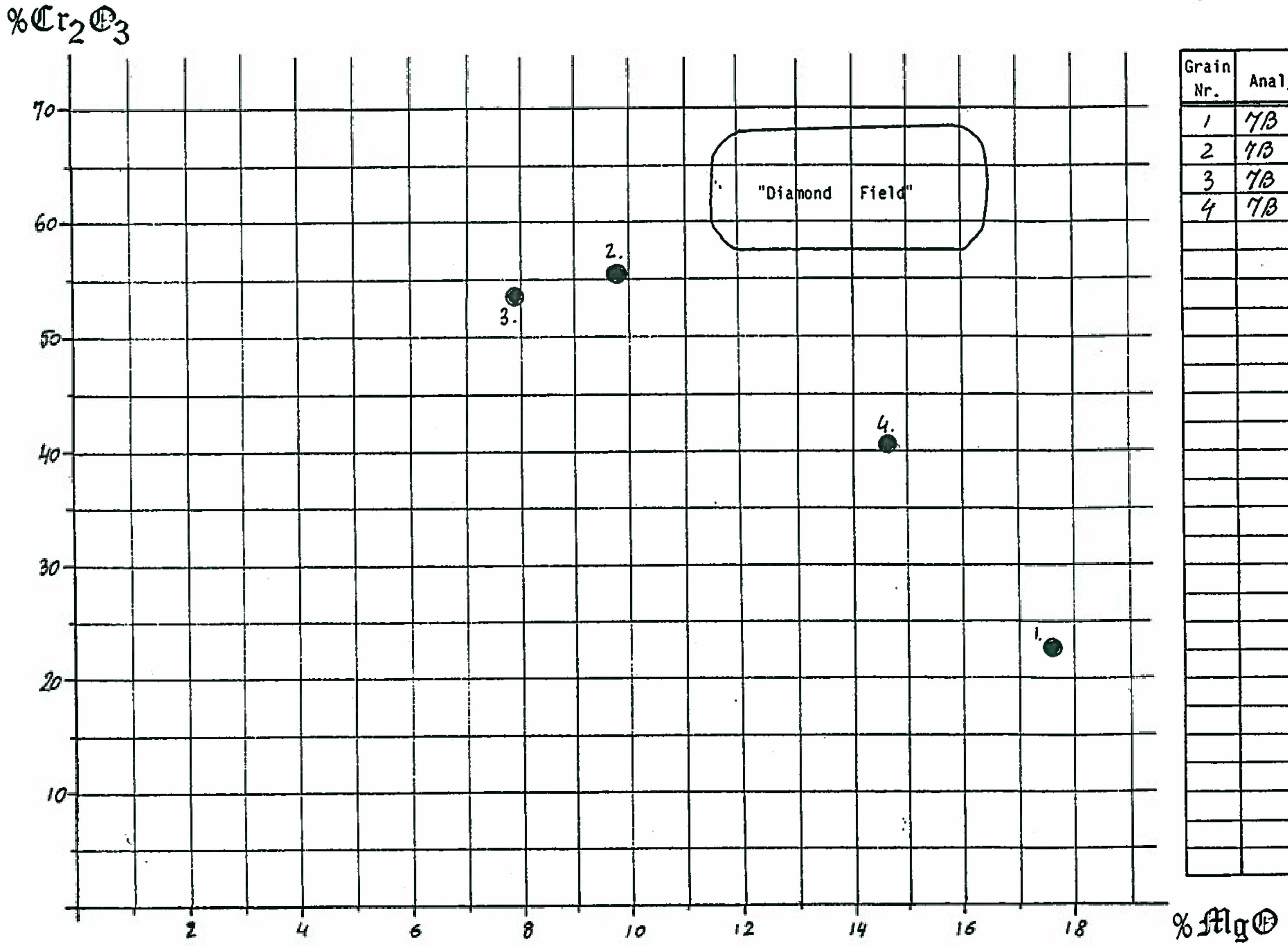
Plots of MgO versus Cr_2O_3 for Mg Chromites in thin sections

Thin section AD3-41B



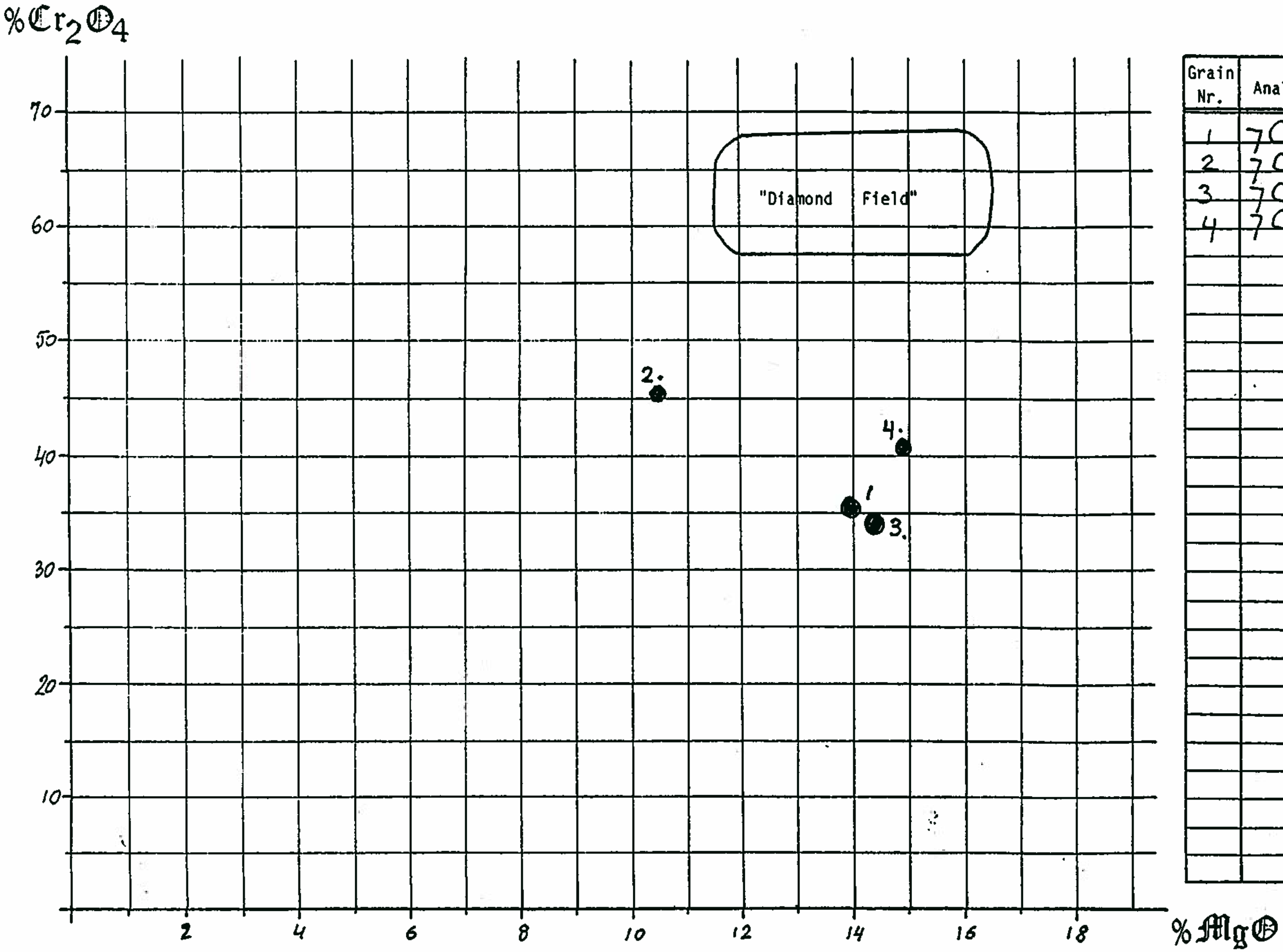
Grain Nr.	Analysis Nr.
1	41B 2C
2	41B 3B
3	41B 5C
4	41B 6(1)C
5	41B 7C
6	41B 8C

Thin section AD3-73



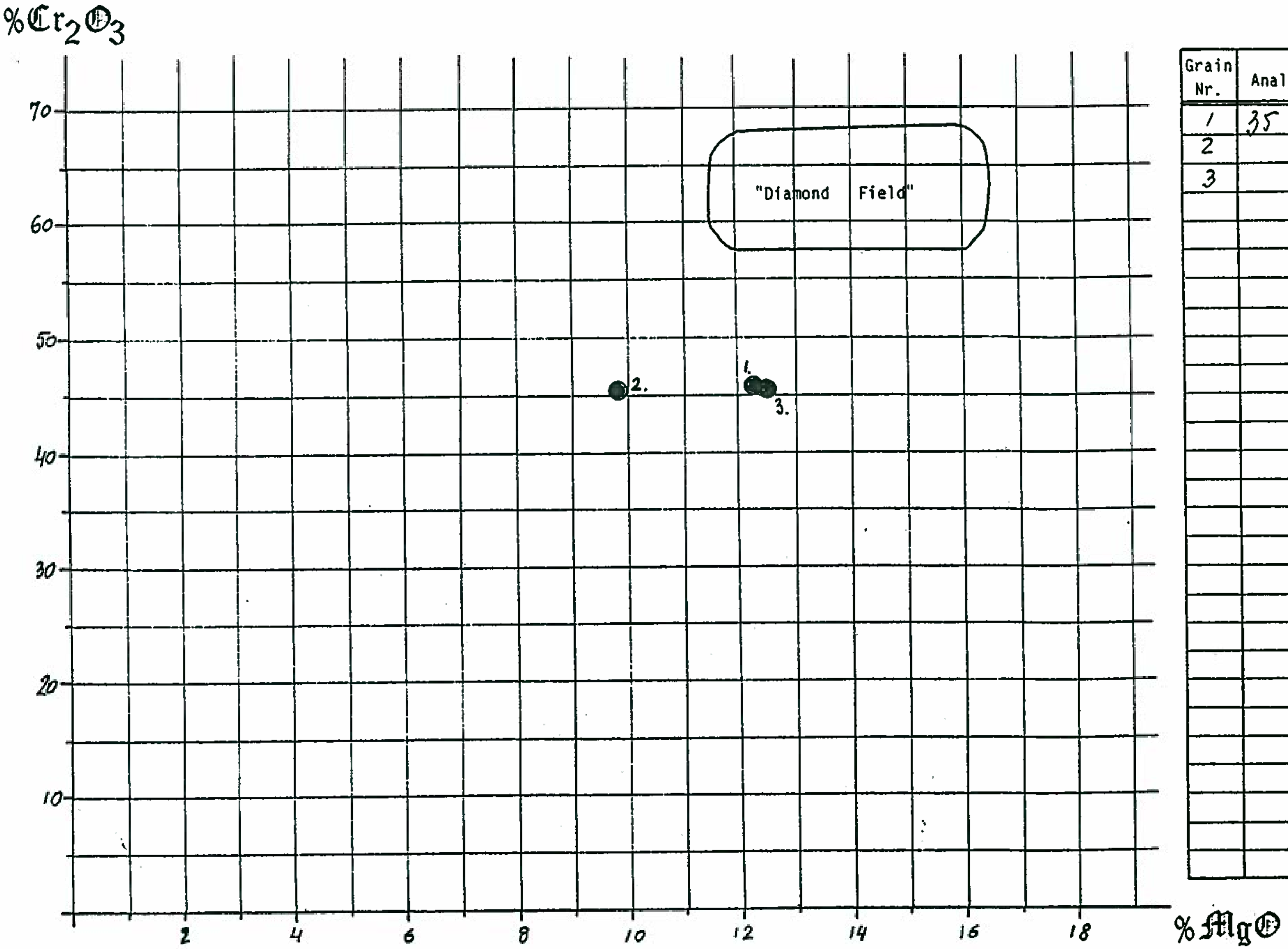
Grain Nr.	Analysis Nr.
1	7B 1(1)
2	7B 2C
3	7B 5(1)
4	7B 6(1)

Thin section AU3-7C



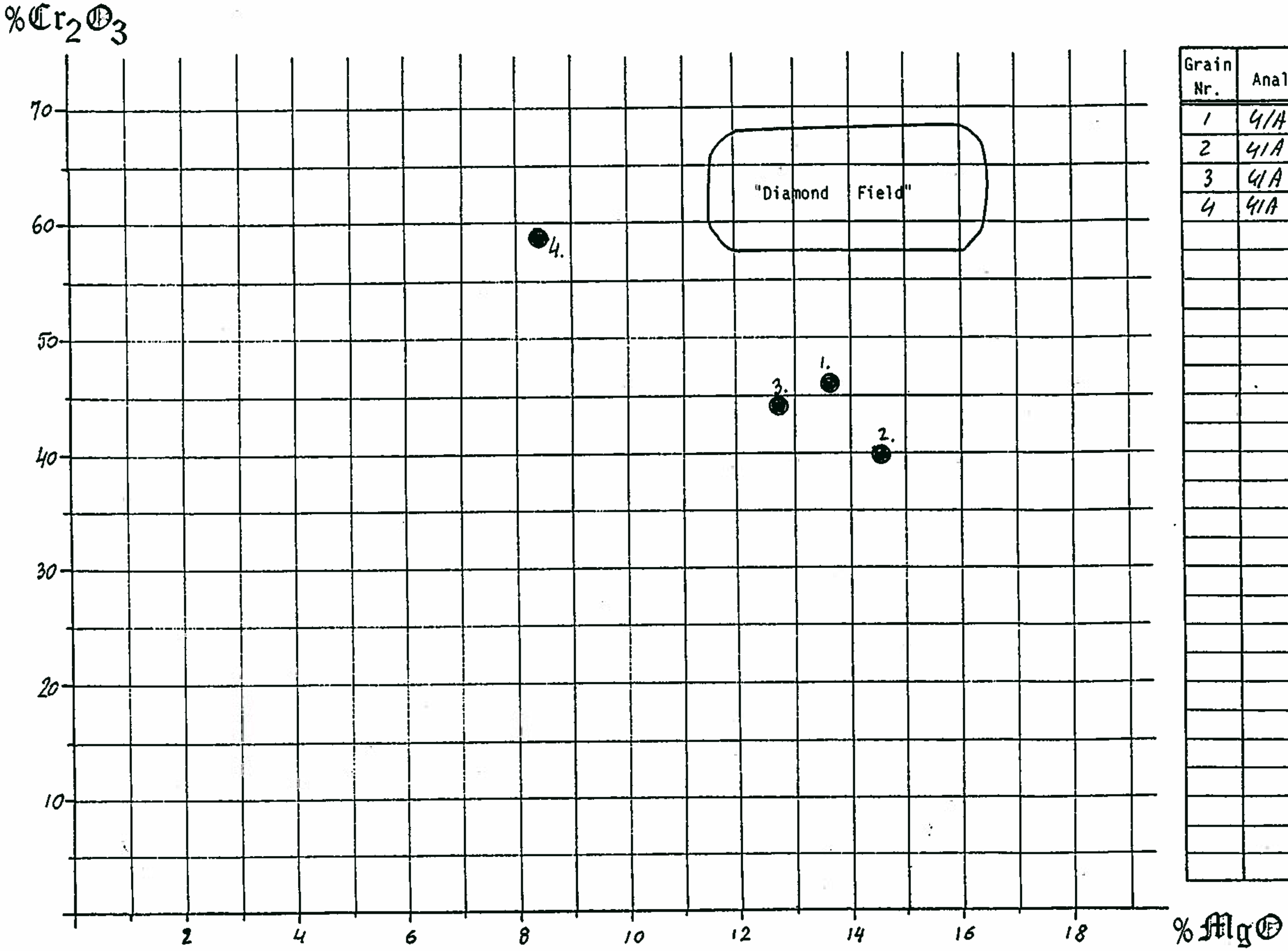
Grain Nr.	Analysis Nr.
1	7C 2(1)
2	7C 3(1)
3	7C 6(1)
4	7C 7(1)

Thin section AD3-35



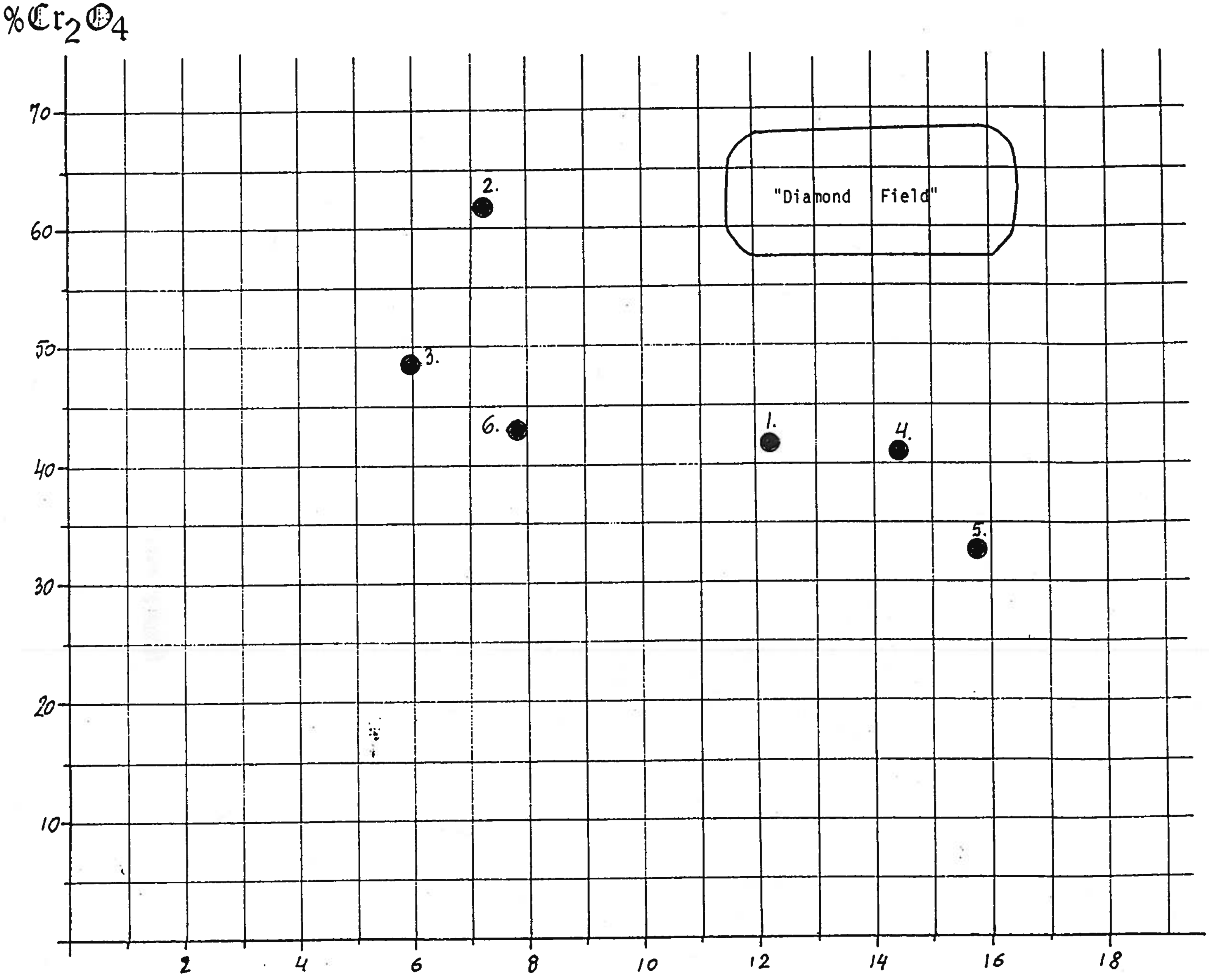
Grain Nr.	Analysis Nr.
1	35 1(1)
2	2(1)
3	5(1)

Thin section [illegible]-41 A



Grain Nr.	Analysis Nr.	
1	41A	1C
2	41A	4C
3	41A	5
4	41A	7C

Thin section HD3-41B



Grain Nr.	Analysis Nr.
1	41B 2C
2	41B 3B
3	41B 5C
4	41B 6(1)C
5	41B 7C
6	41B 8C