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Metallogenic Considerations for Devonian Carbonates in the Fort McMurray and Fort Vermilion Areas, Alberta: A Contribution to the Carbonate-Hosted Pb-Zn (MVT) Targeted Geoscience Initiative

Alberta Energy and Utilities Board
Alberta Geological Survey

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Metallogenic Considerations for Devonian Carbonates in the Fort McMurray and Fort Vermilion Areas, Alberta: A Contribution to the Carbonate-Hosted Pb-Zn (MVT) Targeted Geoscience Initiative

D.R. Eccles and D.I. Pana

Alberta Geological Survey

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Alberta Energy and Utilities Board
Alberta Geological Survey
4th Floor, Twin Atria Building
4999 – 98th Avenue
Edmonton, Alberta
T6B 2X3

Telephone: (780) 422-3767 (Information Sales)
Fax: (780) 422-1918
E-mail: EUB.AGS-Infosales@gov.ab.ca

Web site: www.ags.gov.ab.ca

Cover photo: Hematite altered limestone of the Moberly Member, Waterways Formation, Athabasca River

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Acknowledgements

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Abstract

During the 2001 field season, the Alberta Geological Survey mapped and sampled selected sections of Upper Devonian carbonate rocks in northern Alberta near Fort McMurray, Vermilion Chutes and on Harper Creek. Twelve whole rock and 53 trace element analyses by conventional geochemistry indicate the samples collected have low economic potential. Field observations confirmed that the investigated areas are part of the Alberta Basin basinal fluids discharge system inferred to have economic potential for metallic minerals accumulation. Updip, bedding-parallel fluid migration through the carbonate sequence resulted in very limited dolomitization, locally intense iron alteration and isolated development of centimetre-size sulphide nodules. Intense recrystalization and iron-staining is associated with vertical structural discontinuities and with the Devonian-Cretaceous unconformity. Vertical tensional fractures and joints appear to be the main channelways for warm/hot mineralizing fluids. The only two carbonate-hosted lead and zinc anomalies previously reported in the investigated area are related to areas characterized by zones of vertical fracturing. The carbonate exposures examined so far along major rivers represent only a minor part of the Devonian carbonate sequence of northern Alberta. Possible metallogenic processes associated with structurally controlled fluid conduits observed in the investigated areas warrant further investigations for metallic minerals within the Western Canada Sedimentary Basin stratigraphy.

1 Introduction

During the 2001 field season, the Alberta Geological Survey (AGS) mapped and sampled selected sections of Upper Devonian rocks in the vicinity of the city of Fort McMurray and in the Vermilion Chutes area of northeastern and northeastern-central Alberta, respectively (Figure 1).

The work was completed as part of a Canada Targeted Geoscience Initiative to investigate and report on the potential for the occurrence of carbonate-hosted Mississippi Valley Type (MVT) deposits in southern Northwest Territories and northern Alberta.

This report is one of 10 GeoNote reports to be published by the AGS during the 2001-2003 duration of this project. For more detailed information on the rock stratigraphy, satellite imagery, structural geology and hydrogeology the reader is invited to read AGS GeoNotes by Adams and Eccles (2003), Buschkuehle (2003), Pana (2003) and Rice (2003). Subsequently, brief rock descriptions are presented below.

2 General Geology

The Upper Devonian rocks in the Fort McMurray area crop out along the Clearwater and Athabasca rivers and are comprised primarily of the Waterways Formation, which has been subdivided into five lithostratigraphic members (Crickmay, 1957): Mildred, Moberly, Christina, Calmut (Calumet) and Firebag. In general, these rocks are characterized by calcareous shale and argillaceous limestone alternating with clastic limestone (Green et al., 1970). The Devonian rocks are vertically 'isolated' by overlying and underlying erosional unconformities. A thin veneer (about 2 m) of arkosic sandstone (Cambrian to Devonian Granite Wash lithozone) divides Precambrian basement from overlying Devonian carbonates, and a major erosional unconformity separates the Devonian rocks from the overlying McMurray Formation deltaic quartz-rich sandstones, which are host to the Athabasca Tar Sand deposits. Farther towards the Alberta-Saskatchewan border, the Middle Devonian Methy Formation crops out along the Clearwater River. These rocks are characterized by brown to buff, massive porous dolomite, brown to grey thin-bedded dolomite and dolomitic limestone.

The Upper Devonian rocks in the Vermilion Chutes area crop out extensively along the Peace River and are composed of the Mikkwa and Grosmont formations. The Mikkwa Formation is characterized by dark grey and brownish grey to olive green, purplish-red mottled, fine-grained limestone, dolomitic limestone and shale, and the Grosmont Formation consists predominately of grey, fine-grained, granular, partly buggy dolomite (Green et al., 1970). These rocks grade northeastward into greenish grey shale, calcareous shale and siltstone of the underlying Ireton Formation.

3 Analytical Results

Bedrock sampling comprised the collection of about 2 kg grab samples within individual lithologic units. Fifty-three samples were selected for trace element analysis and 12 samples for whole-rock analysis. Sample preparation included air-drying and splitting the sample into two. One uncrushed sample split will be retained at the AGS Mineral Core Research Facility for any future analysis. The second sample split was sent to ACME Analytical Laboratories Ltd. for

- pulverizing the split to -150 mesh using a chrome-steel ring-and-puck pulverizer;
- Group 4a lithogeochemistry analytical package, which consists of total decomposition using $LiBO_2$ fusion followed by HNO_3 acid dissolution and analysis by inductively coupled plasma optical emission spectroscopy (ICP-OES); and

- Group 4b lithogeochemistry analytical package, which consists of total decomposition and analysis (same as above) for minor and trace elements, including rare-earth elements.

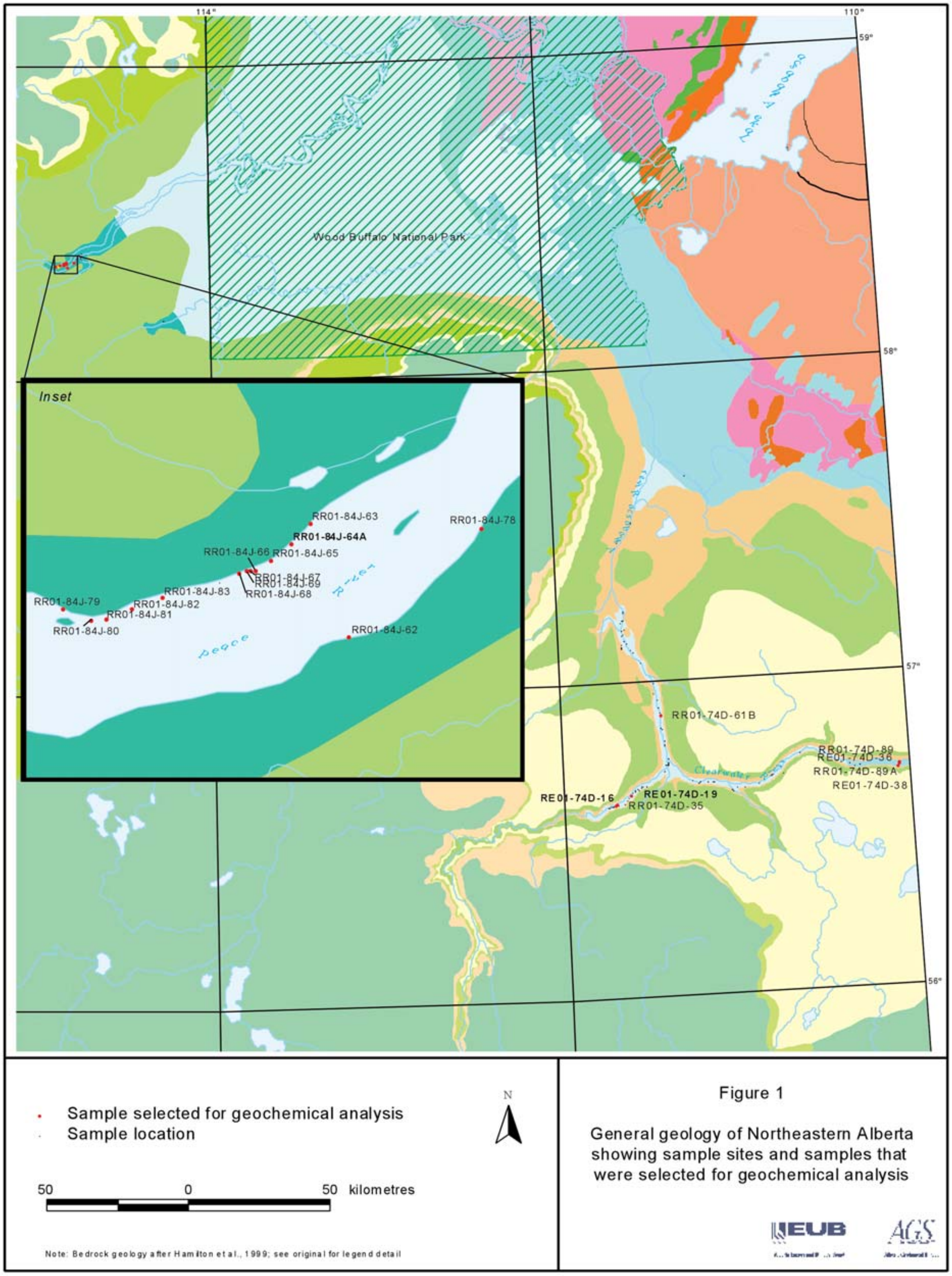


Figure 1

General geology of Northeastern Alberta showing sample sites and samples that were selected for geochemical analysis

The analytical precision quoted by ACME is ±5% and ±10% for Groups 4a and 4b, respectively. Nickel was analyzed by $LiBO_2$ in Group 4a and by aqua-regia digestion in Group 4b.

The trace- and major-element geochemical data are presented in Appendix 1. Base and precious metal values are generally low; average values include: 3.8 ppm Cu, 5.7 ppm Pb, 6.8 ppm Zn, 12.6 ppm Ni, 2.2 ppm Co, and precious metal contents of below the upper limit of detection for both Ag and Au. Maximum metal contents relative to this data set include: 24 ppm Zn from Fe-stained Moberley Member carbonate at site RE01-74D-19 (Athabasca River), and 19 ppm Cu, 233 ppm Ni and 482 ppm Cr from Upper Mikkwa limestone at site RR01-84J-64A (Vermilion Chutes).

From a mineral deposit perspective, the samples that were collected and analyzed by conventional geochemistry during 2001 fieldwork have low economic potential. The lack of significant metallic minerals along the ca. 200 km of Devonian carbonate exposure, examined in a classical discharge area of the Alberta Basin, clearly indicates the basinal fluid flow does not account for metallic mineral concentration. Field observations unequivocally confirmed the spatial relationship between carbonate alteration and fluid movement along vertical joints. These observations are presented below.

4 Potential Metal Trends in Northern Alberta

4.1 Background

The genesis of MVT deposits has been commonly related to groundwater dynamics, such as compaction-driven basinal brines (e.g., Jackson and Beales, 1967) and topographic-driven fluids movement between zones of recharge – discharge (e.g., Garven, 1985; Garven et al., 1993; Adams et al., 2000).

It has also been recognized that structures play key roles in the fluid migration and localization of MVT deposits. For example, Vearncombe et al. (1996) prefaced a chapter on the structural controls on MVT deposits by the statement that "MVT deposits are the result of the passage of large volumes of metal-bearing brines and thus provide a record of the large-scale movement of crustal hydrothermal fluids (Bethke and Marshak, 1990; Halliday et al., 1991)." They further advocated that for MVT deposits in the Lennard Shelf area, Western Australia, the principal regional control on the site of fluid focusing and mineralization is structural. In the Irish-type Pb-Zn deposits it has been demonstrated that normal faults formed conduits for ascending hydrothermal fluids (Hitzman and Beaty, 1996).

Closer to Alberta, a spatial and possibly genetical link between the Pine Point and Robb Lake deposits of Northwest Territories and British Columbia, respectively, with the Great Slave Lake Shear Zone (GSLSZ) cannot go unnoticed. Whether the Laramide or Antler orogenies are involved is still a contentious issue (e.g., Paradis et al., 1998). In the Fort McMurray area, Eccles et al. (2001) reported an association between disseminated and massive nodular sulphides and karst or fault structures at the sub-Cretaceous unconformity. They observed that competent, concretionary layers of sideritized and possibly silicified McMurray Formation contain up to 10 vol. % disseminated pyrite and marcasite, and that 'in situ' sulphide nodules form preferentially along carbon-rich layers and fractures. Eccles et al. (2001) suggested that this low temperature mineralization may be either syngenetic/diagenetic or epigenetic, and it is formed by precipitation of deep brines flowing updip at the Contact Rapids unconformity that propagate upwards via structural pathways through the Winnipegosis Formation.

This section, therefore, focuses on the potential for mineralizing fluids to migrate along joints/faults in the Devonian of northeastern Alberta. We explore the location of fault zones, sulphide mineralization associated with the faults and the timing of mineralization, which must be deemed critical in the preparation of any discussion on the mineral deposit (i.e., not just MVT) potential of Alberta.

4.2 Observations From a Section Along the Athabasca River West of Fort McMurray

Alteration in the Moberley Member is recognized by a distinctive texture, which consists of light-grey limestone with blotchy light brown to dark brown patches, thus creating a mottled appearance in the limestone. The dark-brown Fe-stained blotches generally comprise about 30 to 50 vol. % of the rock. Although the mottled limestone is characteristic of the Moberley Member and can be observed in the Moberley to the north of Fort McMurray on the Athabasca River east of Fort McMurray on the Clearwater River, pervasive alteration is confined or localized to the areas highlighted (RE01-74D-16 and RE01-74D-19) in Figure 1.

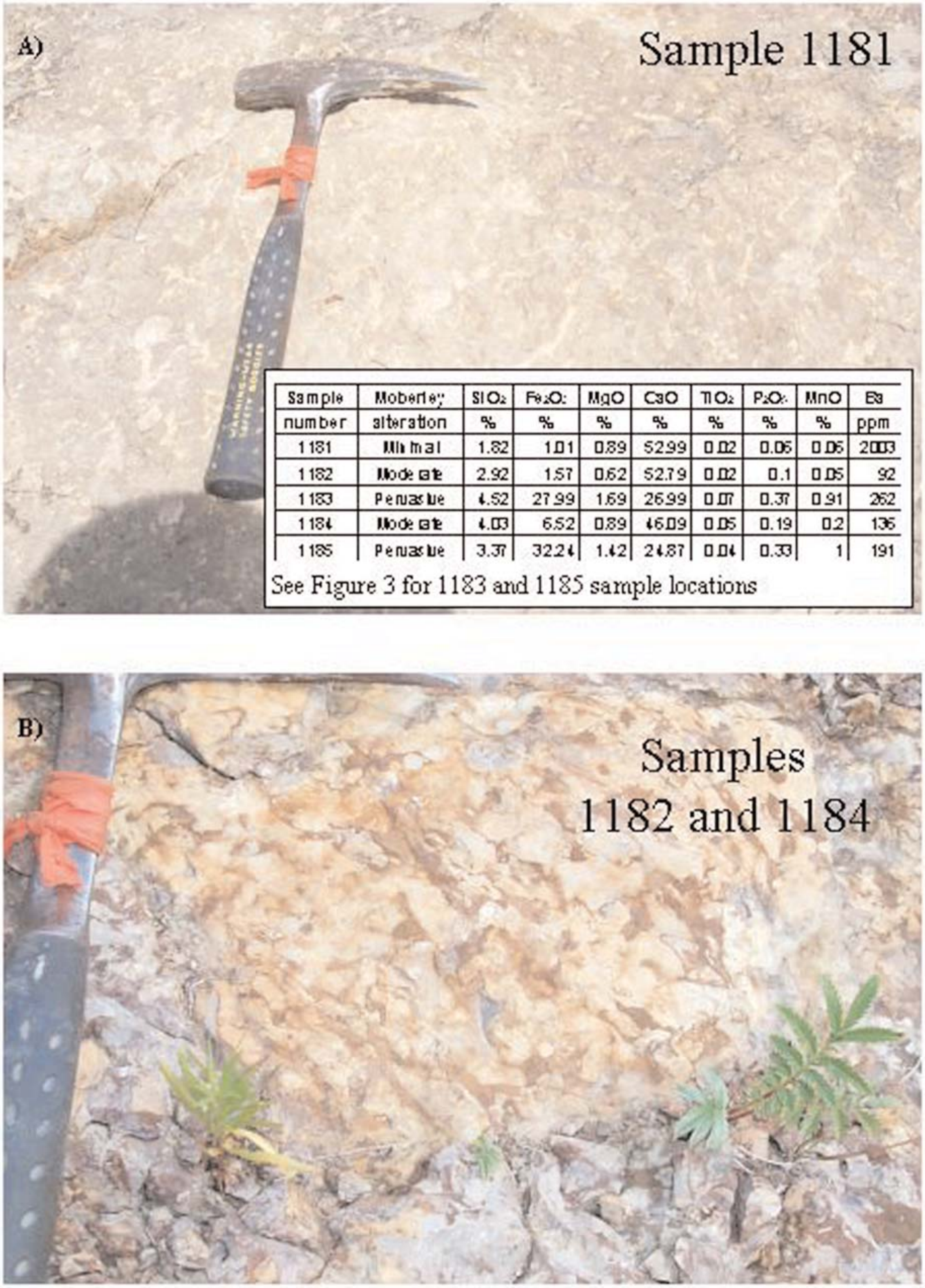
At field station RE01-74D-016, varying degrees of alteration have been noticed in the Moberley Member at the top of the Devonian, or directly below the sub-Cretaceous unconformity. We believe the alteration is related to hydrothermal events, where the more mottled and higher contrast appearance of the rock is indicative of a greater degree of alteration (Figures 2a and 2b).

At the same section, the alteration appears to climax into a near- to totally-replaced, highly Fe-stained rock (Figure 3a). Here, finely disseminated to 2-5 mm blebs (up to 10 vol. %) of greyish-black to pyrite-like sulphide is present. At this locale, the highly altered rock could not be traced, either vertically or horizontally, due to the limited exposure. The degree of alteration, or mottling, appears to increase eastward towards a north-trending creek, where the outcrop terminates.

Although difficult to single out a specific reason for why pervasive alteration occurs at this locale (RE01-74D-016), we did observe the presence of north-trending joints and possibly faults in addition to the dominant joint set trending to 240º, which parallels the local trend of the Athabasca River (Figure 3b). The north-trending joint direction is unique from many of our structural measurements near Fort McMurray (see Pana, 2003). No apparent vertical or horizontal displacement was recognized along the north-trending joints/faults. We did, however, observe the presence of moderate disseminated (up to 15%) to massive pyrite in highly altered rubble located directly within a north-trending tensional fracture that measures 0.75 m in width. In addition, finely disseminated sulphide preferentially coats the fracture's wall rock.

Complete geochemical data from samples collected at this section are presented in Appendix 1; selected data are shown on Figure 2. The pervasively altered rock samples 1183 and 1185 have a distinct whole-rock geochemical signature characterized by elevated concentrations of SiO_2, Fe_2O_3, MnO, P_2O_5 and Ba, most likely at the expense of CaO.

Farther to the east along the Athabasca River, at section RE01-74D-019, we observed more conclusive evidence that the alteration of the Moberley is related to fluid movement along vertical joints. Figure 4 shows pervasive alteration of the Moberley in and directly adjacent to vertical joints or minor fractures. The near-vertical joint has an azimuth of 127º. The material within and directly adjacent to the joints are characterized by ochre to dark brown to black alteration colour and contain minor (<5%) pyrite. We also see the first evidence of bitumen infiltration and possible silicification. Although many of the fractures at this locale have an Fe-stained 'rind', there are also fractures characterized by a 'clean rind', where rock directly adjacent to the fracture has a distinctly bleached appearance.

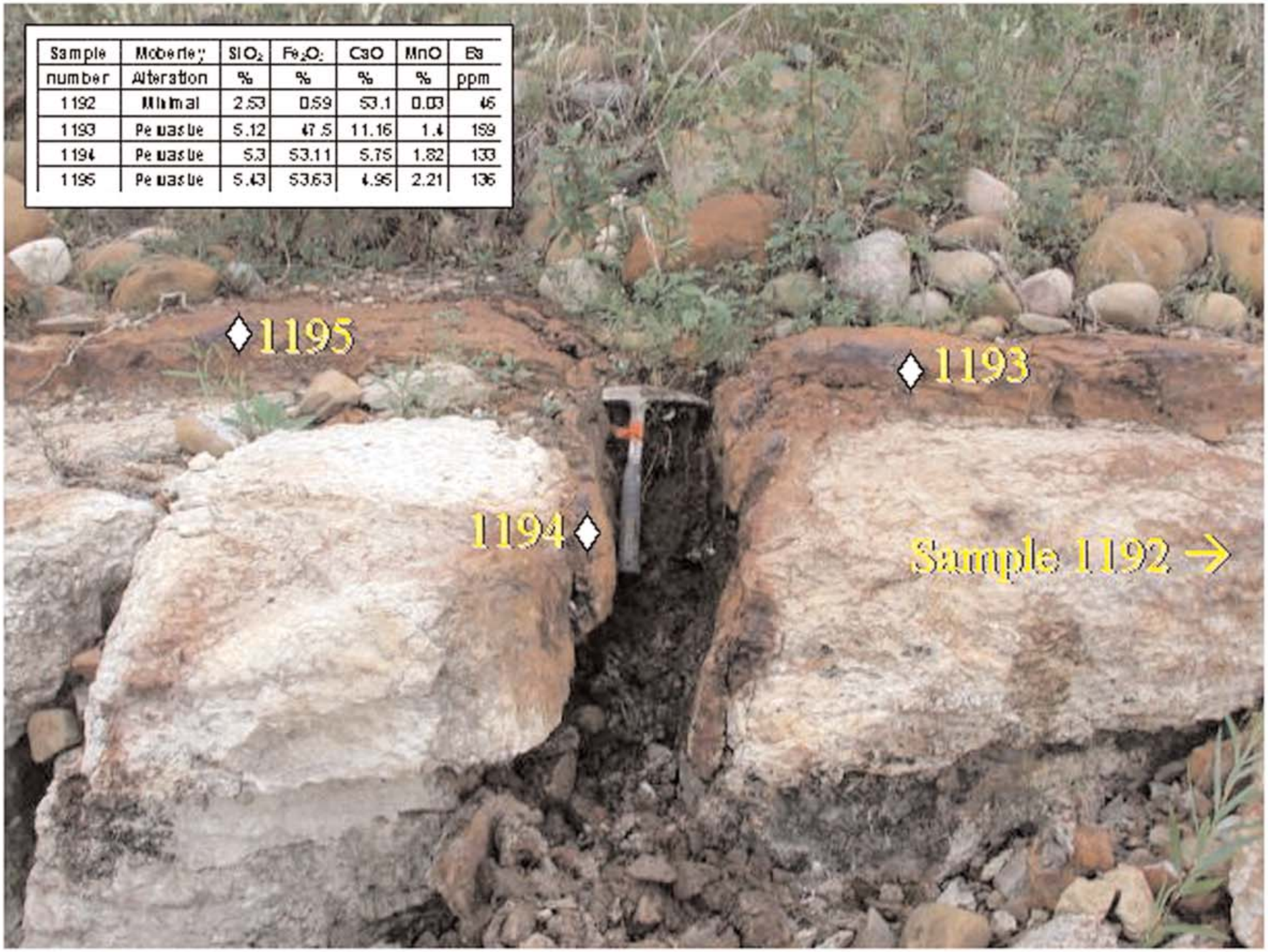


Sample number	Moberley alteration	SiO_2 %	Fe_2O_3 %	MgO %	CaO %	TiO_2 %	P_2O_5 %	MnO %	Ba ppm
1181	Minimal	1.82	1.01	0.89	52.99	0.02	0.06	0.06	2003
1182	Moderate	2.92	1.57	0.62	52.79	0.02	0.1	0.05	92
1183	Pervasive	4.52	27.99	1.69	26.99	0.07	0.37	0.91	262
1184	Moderate	4.03	6.52	0.89	46.09	0.05	0.19	0.2	136
1185	Pervasive	3.37	32.24	1.42	24.87	0.04	0.33	1	191

See Figure 3 for 1183 and 1185 sample locations

Figure 2. Various degrees of mottled alteration in Moberly Member limestone along the Athabasca River with selected geochemical data.

Figure 3. Altered and jointed Moberley Member limestone along the Athabasca River. A) samples 1183 & 1185 characterized by pervasive Fe-alteration; and B) joint sets in areas of high alteration.



Sample number	Moberley Alteration	SiO_2 %	Fe_2O_3 %	CaO %	MnO %	Ba ppm
1192	Minimal	2.53	0.59	53.1	0.03	46
1193	Pervasive	5.12	47.5	11.16	1.4	159
1194	Pervasive	5.3	53.11	5.75	1.82	133
1195	Pervasive	5.43	53.63	4.95	2.21	136

Figure 4. Pervasive iron-alteration associated with a joint in Moberley Member limestone along the Athabasca River, with sample location and selected geochemical data.

The pervasive alteration associated with the sub-vertical fracture splays out horizontally along the Devonian-Cretaceous unconformity. At the base of the section, the fracture zones contain greenish-grey smectitic clay resembling fault gouge.

The geochemical data from samples collected at this site (Figure 4) are strongly enriched in SiO_2, Fe_2O_3, MnO and Ba, and significantly depleted in CaO. We suggest this geochemical signature is related to replacement of the Moberley Member limestone by Fe-rich siliceous solutions that percolated through the Upper Devonian fracture systems.

Sulphide-rich nodules are located in the basal McMurray Formation oil sands (Figure 5) and are located at sections in the aforementioned faulted areas that have sub-Cretaceous unconformity exposure. Eccles et al. (2001) linked the genesis of the nodules to precipitation from low temperature hydrothermal fluids migrating along faults in the MacKay River and Firebag River areas north of Fort McMurray. The Fe-rich fluid precipitated pyrite at the sub-Cretaceous unconformity due to the highly reducing influence of the bitumen-saturated oil sands.

In addition to the sections along the South Athabasca River, we observed evidence of major faulting in the vicinity of the Whitemud Falls area (Clearwater River at the Alberta-Saskatchewan border) and the Fort Vermillion Chutes (Peace River). Carrigy (1959) reported the occurrence of galena at Whitemud Falls, but we did not locate this occurrence. We did observe, however, evidence of faulting together with Fe-staining, altered and vuggy dolostone or replaced limestone.

4.3 Spatial Relationships Between Sample Locations and Inferred Fractures in the Investigated Areas

An ideal MVT exploration target in the Alberta Interior Plains would be the duplication of those geological controls associated with the Pine Point deposits (Godfrey, 1985, Pana, 2003): 1) the regionally important fracture in the underlying Precambrian basement, reactivated subsequently to carbonate deposition and/or a lineament of facies change that may reflect a fault scarp between a carbonate platform and an adjacent sedimentary basin; and/or 2) a porous carbonate host (reefal and/or strained).

Fractures and fault zones are commonly associated with hydrothermal alteration. In the carbonate strata of the Western Canada Sedimentary Basin, MVT mineralization is spatially, and thus most likely genetically, related to local hallows of hydrothermal alteration. By far the most extensive alteration of the MVT carbonate host is known to be dolomitization, although silica veining and silicification are not uncommon (Godfrey, 1985). Zones of intense local silicification and/or dolomitization may record hydrothermal processes in the investigated carbonates of the Fort McMurray area. It is reasonable to assume they represent the surficial low-temperature expression of chemically active thermal waters upwelling from deeper structural levels along subvertical conduits. Basement fractures are the likely source of ore-bearing solutions released into overlying carbonate strata. However, the spatial relationships between inferred subsurface fractures and the areas of intense jointing accompanied by iron mottling, staining, silicification and carbonate replacement observed along the Athabasca and Clearwater rivers is unclear.

In the Fort McMurray area, basement fractures were inferred from aeromagnetic, magnetotelluric data (e.g., Burwash et al., 1994; Boerner et al., 2000), structural contour maps (Cotterill and Hamilton, 1995), and lineaments of thickness and facies change (Pana et al., 2001). Basement fractures inferred so far in the Fort McMurray area do not have a clear surficial expression in the investigated carbonate sequences (Figure 6).

Figure 5. Iron-rich nodules occur at the base of the McMurray Formation directly above the Devonian-Cretaceous unconformity and in an area of faulting along the Athabasca River.

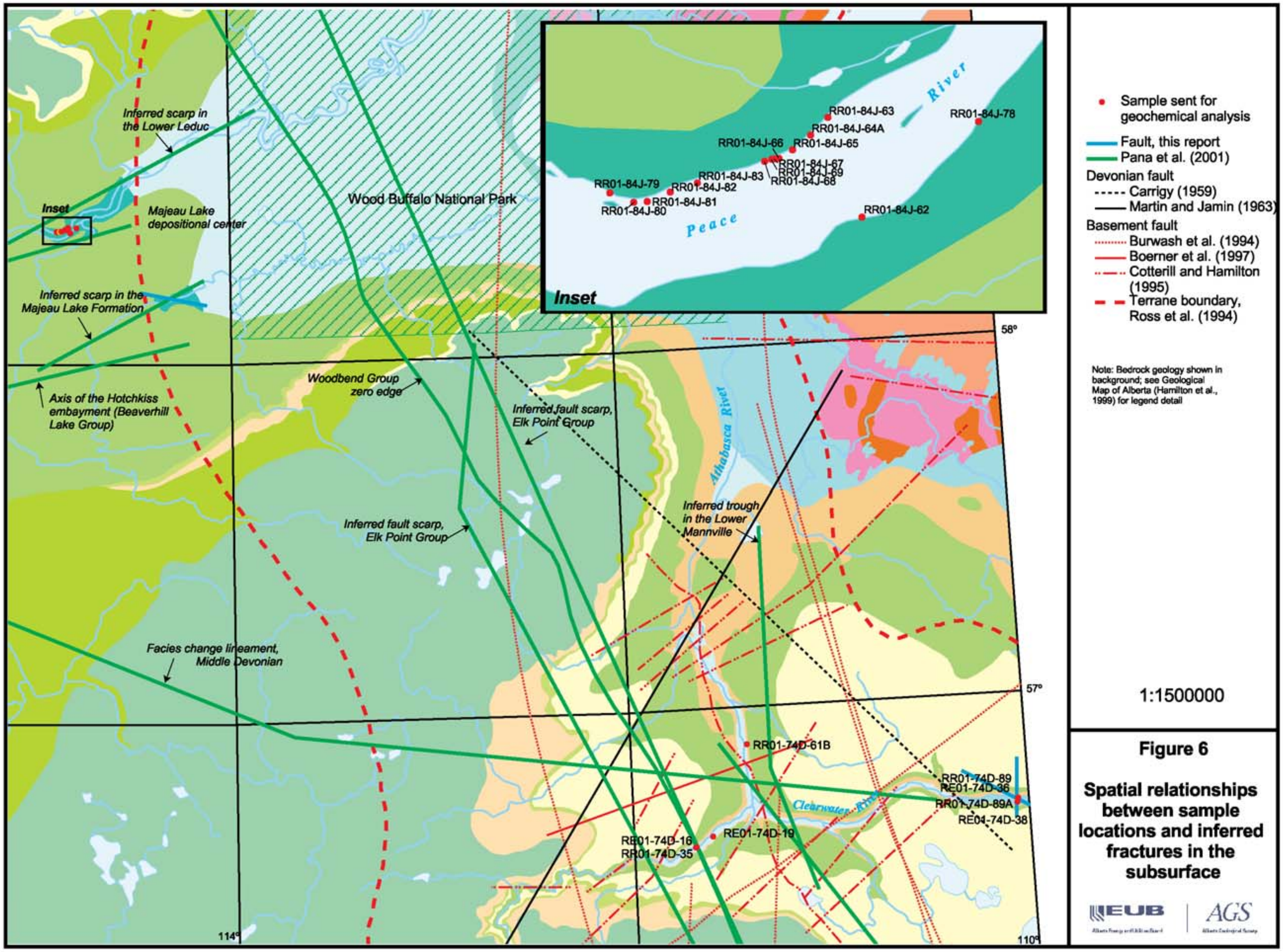


Figure 6

Spatial relationships between sample locations and inferred fractures in the subsurface

The only clear spatial relationship between a zone of intense alteration and a subsurface lineament was found in the northern bank of the Athabasca River west of Fort McMurray. Moderately to highly altered Moberley Member limestone at Stations RE01-74D-16 and RE01-74D-19 are located above a lineament of regional facies change in the Elk Point Group that coincides locally with a straight segment of the Woodbend Group zero edge and may represent an active Devonian fault scarp.

Hydrothermal dolomite found at Whitemud Falls is a clear record of hydrothermal fluids ascending through a fault zone, a location that corresponds to the previously reported galena occurrence by Carrigy (1959).

At Vermilion Chutes, the location of a 0.1% Zn anomaly reported by Gulf Minerals Ltd. (R. Rice, personal communication, 2001), gently dipping Upper Devonian carbonates are slightly sheared (Pana, 2003), suggesting again a spatial/genetic relationship between mineralization and strain. The outcrops examined and sampled at Vermilion Chutes are located near a westerly trending lineament of facies change within the Beaverhill Lake Group with shallow marine carbonates of the Slave Point to the north and basinal carbonates, shales and argillaceous carbonates to the south (Oldale et al., 1994). Along the same lineament, the lithofacies of the Lower Leduc Formation of the Woodbend Group changes from basinal shales to the north and platformal dolostone to the south (Switzer et al., 1994). This lineament of regional facies change suggests a Devonian basement hinge zone. Also, Pana (2003) recognized that the location of Vermilion Chutes is within a few kilometres from the inferred axis of the Late Devonian Hotchkiss Embayment, which represents a linear zone of enhanced subsidence along the westward projection of the Hudsonian Leland Lakes and Warren shear zones mapped by Godfrey (1986) in the Precambrian Shield. Although minor, the Zn anomaly reported by Gulf Minerals Ltd., at Vermilion Chutes warrants further investigation.

5 Conclusions

From a mineral deposit perspective, samples that were collected and analyzed by conventional geochemistry during 2001 fieldwork are considered as having low economic potential.

Field observations in the Fort McMurray area, however, provide new evidence that joints/faults acted as pathways for upwelling iron-rich fluids in the Devonian carbonate succession. In regions that may have been influenced by basement faults, vertical fracture zones are dominated by

- pervasive replacement of limestones by SiO_2, Fe_2O_3, MnO, P_2O_5 and Ba directly along vertical fractures;
- a thin, but locally extensive, resilient, iron-rich layer at the top of the Devonian; and
- numerous iron- and sulphide-rich nodules at the base of the bitumen-rich Fort McMurray Formation, which unconformably overlies the Devonian carbonates.

Thus, we conclude that the oil sands acted as a reducing cap for post Albian metal-bearing fluids and caused Fe-precipitation as sulphide and hydroxide solutions propagated upwards through the Devonian rocks.

No significant concentrations of base or precious metals were discovered during 2001 fieldwork, but the aforementioned observations hint to the fault-controlled hydrothermal activity and may help to construct mineral deposit models for northern Alberta, starting with the identification of basement faults.

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Appendix 1 - Geochemical Data from Selected Samples in the Fort McMurray and Vermilion Chutes Areas

A) Trace element geochemical data																			
Field	AGS	GSC	UTM (NAD27)			River	NTS	Lithology	Formation/Member	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As
Station	Sample number	C-number	Easting	Northing	Zone		Sheet			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm
	SI									< .1	2.7	0.2	1	< .1	0.1	0.1	4	0.02	< .1
RR01-74D-35	1046	C-406291	457187	6275123	12	South Athabasca	74D	Limestone	Waterways (Moberly)	0.5	5.9	10	11	< .1	6.2	2.5	2103	7.71	3.7
RR01-74D-35A	1047	C-406292	463563	6279697	12	South Athabasca	74D	Limestone	Waterways (Moberly)	1.1	3.9	5.8	7	< .1	6	3.4	1995	9.98	8.5
RR01-84J-78	1055	C-406358	627952	6473225	11	Peace	84J	Dolostone	Grosmont?	0.3	3.2	1.3	2	< .1	2.4	1.6	810	0.6	0.4
RR01-84J-79	1056	C-406359	621907	6471862	11	Peace	84J	Dolostone	Grosmont	< .1	2	3.6	5	< .1	2.3	0.9	213	0.22	0.5
RR01-84J-80	1057	C-406360	622304	6471720	11	Peace	84J	Dolostone	Grosmont	0.3	1.5	1.8	3	< .1	2.4	0.9	237	0.23	1.1
RR01-84J-81	1058	C-406361	622529	6471741	11	Peace	84J	Dolostone	Grosmont	1.2	1.7	1.1	3	< .1	3.8	1.3	325	0.23	2.2
RR01-84J-82	1059	C-406362	622904	6471906	11	Peace	84J	Dolomitic Limestone	Grosmont / Mikkwa	0.1	3.1	1	3	< .1	2.9	2.2	366	0.37	0.7
RR01-84J-83	1060	C-406363	623342	6472070	11	Peace	84J	Dolomitic Limestone	Grosmont / Mikkwa	0.1	4.5	1.6	3	< .1	3.4	1.8	283	0.33	1.1
RR01-74D-89	1097	C-406369	557450	6284300	12	Clearwater	74D	carbonate	Methy	0.1	1.1	4.6	9	< .1	< .1	0.8	575	1.51	1.4
RR01-74D-89A	1098	C-406370	557430	6284080	12	Clearwater	74D	carbonate	Methy	0.2	1.4	1.3	1	< .1	< .1	0.4	221	0.22	1
RR01-74D-89	1145	C-406455	557659	6284272	12	Clearwater	74D	carbonate	Methy	0.1	0.5	0.9	8	< .1	< .1	0.1	246	0.34	0.6
RE01-74D-36	1146	C-406456	557377	6284306	12	Clearwater	74D	carbonate	Methy	0.2	1	0.6	3	< .1	< .1	0.3	502	1.02	0.8
RE01-74E-37	1147	C-406457	557522	6283139	12	Clearwater	74D	carbonate	Methy	0.1	1.3	0.1	4	< .1	< .1	0.1	274	0.38	0.4
RE01-74E-37	1148	C-406458	557522	6283139	12	Clearwater	74D	carbonate	Methy	0.1	1.3	1.4	2	< .1	< .1	0.6	296	0.54	0.7
RE01-74D-38	1149	C-406459	557475	6283277	12	Clearwater	74D	carbonate	Methy	< .1	1	0.8	9	< .1	< .1	0.7	227	0.46	1.2
RE01-74D-38	Duplicate 1149	C-406459	557475	6283277	12	Clearwater	74D	carbonate	Methy	0.2	1	1.5	2	< .1	< .1	0.6	289	0.59	1.6
RE01-84J-01	1150	C-406460	660388	6453450	11	Harper Creek	84J	carbonate	Mikkwa?	0.4	0.3	1.2	< 1	< .1	< .1	0.1	688	0.58	< .1
RE01-84J-01	Duplicate: 1150	C-406460	660388	6453450	11	Harper Creek	84J	carbonate	Mikkwa?	0.5	0.3	1.3	< 1	< .1	< .1	0.1	668	0.54	< .1
RE01-74D-16	1180	C-406399	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	0.5	5.7	16.3	9	< .1	7.8	3.7	383	0.9	2.4
RE01-74D-16	Duplicate 1180	C-406399	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	< .1	4.2	7.3	9	< .1	3.3	1.8	387	0.55	1.2
RE01-74D-16	1181	C-406400	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	1.7	2.6	3.5	4	< .1	0.1	0.2	487	0.71	6.4
RE01-74D-16	1182	C-406401	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	0.1	2.3	3.3	17	< .1	< .1	0.6	513	1.24	4
RE01-74D-16	1183	C-406402	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	0.5	2.7	5	18	< .1	2.5	2.1	7767	21.14	4.2
RE01-74D-16	1184	C-406403	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	0.2	2.7	3.3	4	< .1	0.7	0.9	1712	4.63	1.1
RE01-74D-16	1185	C-406404	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	0.8	2.7	3.9	6	< .1	2	1.8	8355	21.54	6.2
RE01-74D-16	Duplicate 1185	C-406404	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	0.7	2	3.4	5	< .1	1.5	1.5	7071	18.89	5.2
RE01-74D-16	1186	C-406405	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	2.2	6.4	9.5	10	0.1	42.2	2	37	16.52	19.4
RE01-74D-16	1187	C-406406	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	0.5	2.3	7.5	4	< .1	17.6	3.3	548	11.74	3.8
RE01-74D-16	1188	C-406407	457353	6275096	12	South Athabasca	74D	Float: sulphides in sst.	McMurray	2	2.6	3.6	9	< .1	18.7	3.4	83	20.3	4.1
RE01-74D-19	1192	C-406411	462696	6278322	12	South Athabasca	74D	limestone	Waterways (Moberly)	0.1	2.2	3.3	6	< .1	< .1	0.4	313	0.39	3
RE01-74D-19	1193	C-406412	462696	6278322	12	South Athabasca	74D	Fe stained carb.	Waterways (Moberly)	0.6	2.6	4.6	5	< .1	4.1	4.5	11506	28.52	3.3
RE01-74D-19	1194	C-406413	462696	6278322	12	South Athabasca	74D	Fe stained carb.	Waterways (Moberly)	0.6	3	3.4	14	< .1	6.7	4.6	14835	31.35	2.2
RE01-74D-19	1195	C-406414	462696	6278322	12	South Athabasca	74D	Fe stained carb.	Waterways (Moberly)	0.5	7.5	3.9	24	< .1	7	6.8	18364	32.65	1.1
RE01-74D-19	1196	C-406415	462696	6278322	12	South Athabasca	74D	Float: sulphide nodules	McMurray	1.5	3.2	7	7	< .1	27.3	5.1	17	20.53	18.8
RE01-74D-19	1197	C-406416	462696	6278322	12	South Athabasca	74D	Fault Clay	Waterways (Moberly)	0.1	18.6	68.6	9	< .1	8.1	5	121	0.6	< .1
RE01-74D-19	Duplicate 1197	C-406416	462696	6278322	12	South Athabasca	74D	Fault Clay	Waterways (Moberly)	< .1	17.2	61.8	7	< .1	8.8	3.9	57	0.53	< .1
RR01-74D-61B	1231	C-406334	474733	6305779	12	North Athabasca	74D	Fe-alt cap in co3	Waterways (Moberly)	0.6	4	5	12	< .1	19.9	5.5	19830	31.91	0.3
RR01-84J-62	1233	C-406336	626078	6471584	11	Peace	84J	carbonate	Upper Mikkwa	< .1	3.1	2.8	8	< .1	3.8	2.1	296	0.63	< .1

Appendix 1 - Geochemical Data from Selected Samples in the Fort McMurray and Vermilion Chutes Areas

Field	AGS	GSC	UTM (NAD27)			River	NTS	Lithology	Formation/Member	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As
Station	Sample number	C-number	Easting	Northing	Zone		Sheet			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm
RR01-84J-63	1234	C-406337	625465	6473217	11	Peace	84J	carbonate	Upper Mikkwa	0.4	3.1	2.9	7	< .1	5.5	2.2	301	0.68	< .1
RR01-84J-64	1235	C-406338	625193	6472915	11	Peace	84J	Limestone	Upper Mikkwa	0.3	5.3	2.8	12	< .1	11.5	3.2	299	0.71	< .1
RR01-84J-64A	1236	C-406339	625193	6472915	11	Peace	84J	Limestone	Upper Mikkwa	7.4	18.6	3	9	< .1	233.2	7.2	273	0.74	< .1
RR01-84J-64B	1237	C-406340	625192	6472917	11	Peace	84J	Limestone	Upper Mikkwa	0.2	4.3	2.6	4	< .1	1.8	1.2	402	0.42	1
RR01-84J-65	1238	C-406341	624897	6472660	11	Peace	84J	Limestone	Upper Mikkwa	0.1	2.6	3.4	8	< .1	7.1	2.5	462	0.67	0.6
RR01-84J-65A	1239	C-406342	624898	6472661	11	Peace	84J	Limestone	Upper Mikkwa	0.6	3.3	4.1	9	< .1	7.4	3.4	370	1.06	2.5
RR01-84J-66	1240	C-406343	624681	6472517	11	Peace	84J	limestone	Upper Mikkwa	0.2	2.6	2	4	< .1	2	1.8	374	0.52	0.6
RR01-84J-66A	1241	C-406344	624680	6472516	11	Peace	84J	limestone	Upper Mikkwa	0.4	4	2.5	5	< .1	< .1	0.9	377	0.41	0.6
RR01-84J-67	1242	C-406345	624604	6472504	11	Peace	84J	limestone	Upper Mikkwa / Grosmont	0.3	3.9	2.9	4	< .1	5.5	1.9	234	0.33	2.4
RR01-84J-67A	1243	C-406346	624614	6472513	11	Peace	84J	dolostone	Grosmont	0.2	3.6	3.3	5	< .1	4.6	1.8	251	0.29	1.6
RR01-84J-68	1244	C-406347	624447	6472457	11	Peace	84J	dolostone	Grosmont	1.1	5.8	2.2	14	< .1	7.3	3.7	271	0.28	5.7
RR01-84J-69	1245	C-406348	624559	6472495	11	Peace	84J	dolostone	Lower Grosmont / Mikkwa	0.1	3.7	2.2	3	< .1	3.6	1.9	212	0.61	1.9
RR01-84J-69	Duplicate: 1245	C-406348	624559	6472495	11	Peace	84J	dolostone	Lower Grosmont / Mikkwa	0.2	3.9	2.4	3	< .1	4.5	2.2	236	0.64	2
RE01-84J-39	3802	C-406462	660388	6453450	11	Harper Creek	84J	carbonate	Mikkwa?	< .1	0.6	4	1	< .1	< .1	< .1	353	0.35	< .1
RE01-84J-40	3804	C-406464	624825	6472592	11	Peace	84J	carbonate	Grosmont	0.8	3.9	1.5	3	< .1	3.3	3	525	1.06	1.6
RE01-84J-40	Duplicate 3804	C-406464	624825	6472592	11	Peace	84J	carbonate	Grosmont	0.7	3.7	1.7	4	< .1	8.7	4.9	488	1.09	1.5
STANDARD DS3	STANDARD DS3									8.7	122.8	32.8	155	0.3	35	11.4	784	3	28.6
STANDARD DS3	STANDARD DS3									10.1	131	36.1	159	0.3	36.8	12.8	777	3.18	30.3
STANDARD DS3	STANDARD DS3									8.6	124.5	33.3	150	0.3	37.9	11.9	777	3.15	36
									Average Value (minus standard)	**0.66**	**3.80556**	**5.748**	**6.865**	**0.1**	**12.9375**	**2.253**	**2007.93**	**5.5737**	**2.991**

B) Whole-rock geochemical data

Field	AGS	GSC	UTM (NAD27)			River	NTS	Lithology	Formation/Member	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO
Station	Sample number	C-number	Easting	Northing	Zone		Sheet			%	%	%	%	%	%	%	%	%	%
RE01-74D-16	1180	C-406399	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	5.77	1.29	1.26	1.69	48.46	0.07	0.23	0.08	0.04	0.04
RE01-74D-16	1181	C-406400	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	1.82	0.46	1.01	0.89	52.99	0.05	0.09	0.02	0.06	0.06
RE01-74D-16	1182	C-406401	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	2.92	0.66	1.57	0.62	52.79	0.05	0.13	0.02	0.1	0.05
RE01-74D-16	1183	C-406402	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	4.52	1.44	27.99	1.69	26.99	0.05	0.23	0.07	0.37	0.91
RE01-74D-16	1184	C-406403	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	4.03	1.22	6.52	0.89	46.09	0.05	0.22	0.05	0.19	0.2
RE01-74D-16	1185	C-406404	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	3.37	1.03	32.24	1.42	24.87	0.07	0.2	0.04	0.33	1
RE01-74D-16	1187	C-406406	457353	6275096	12	South Athabasca	74D	limestone	Waterways (Moberly)	1.38	0.35	17.2	0.57	35.28	0.05	0.1	0.01	< .01	0.05
RE01-74D-19	1192	C-406411	462696	6278322	12	South Athabasca	74D	limestone	Waterways (Moberly)	2.53	0.59	0.59	0.66	53.1	0.03	0.11	0.03	0.02	0.03
RE01-74D-19	1193	C-406412	462696	6278322	12	South Athabasca	74D	Fe stained carb.	Waterways (Moberly)	5.12	1.38	47.5	0.82	11.16	0.04	0.25	0.07	0.51	1.4
RE01-74D-19	1194	C-406413	462696	6278322	12	South Athabasca	74D	Fe stained carb.	Waterways (Moberly)	5.3	1.41	53.11	0.73	5.75	0.04	0.27	0.07	0.27	1.82
RE01-74D-19	1195	C-406414	462696	6278322	12	South Athabasca	74D	Fe stained carb.	Waterways (Moberly)	5.43	1.48	53.63	0.49	4.95	0.01	0.27	0.08	0.2	2.21
RE01-74D-19	1197	C-406416	462696	6278322	12	South Athabasca	74D	Fault Clay	Waterways (Moberly)	58.44	20.62	2.22	1.29	0.63	0.13	1.9	1	0.46	0.02
RE01-74D-19	Duplicate: 1197	C-406416	462696	6278322	12	South Athabasca	74D	Fault Clay	Waterways (Moberly)	58.72	20.57	2.16	1.28	0.62	0.13	1.9	1	0.47	0.02
	STANDARD SO-17/CSB									61.65	13.86	5.85	2.35	4.68	4.12	1.41	0.62	0.95	0.53
	STANDARD SO-17/CSB									61.63	13.94	5.84	2.35	4.68	4.12	1.38	0.62	0.96	0.53

Appendix 1 - Geochemical Data from Selected Samples in the Fort McMurray and Vermilion Chutes Areas

A) Trace elemen																									
Field	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	B	Al	Na	K	W	Hg	Sc	Tl	S	Ga
Station	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppm	ppm	ppm	%	ppm
	< .1	< .5	< .1	2	0.1	< .1	< .1	1	0.06	< .001	< 1	1.4	0.01	2	0.001	< 1	0.01	0.201	< .01	< .1	< .01	< .1	< .1	< .02	< 1
RR01-74D-35	0.5	< .5	1.9	274	0.1	< .1	0.1	11	22.94	0.079	4	8	1	278	0.002	10	0.27	0.019	0.13	< .1	< .01	0.9	< .1	0.36	1
RR01-74D-35A	0.6	< .5	0.5	412	< .1	0.2	0.1	13	24.82	0.063	3	5.2	0.67	59	0.001	5	0.13	0.018	0.06	< .1	0.21	2.7	0.8	3.43	1
RR01-84J-78	0.3	< .5	0.4	64	< .1	< .1	< .1	3	20.57	0.011	2	3.1	11.66	20	0.002	16	0.11	0.015	0.06	< .1	< .01	0.6	< .1	0.06	< 1
RR01-84J-79	0.1	< .5	0.3	68	0.1	0.2	< .1	3	19.77	0.004	1	3	11.34	18	0.002	11	0.08	0.018	0.05	< .1	< .01	0.2	< .1	0.1	< 1
RR01-84J-80	0.2	< .5	0.4	73	< .1	0.1	< .1	3	20.88	0.008	2	3.6	12.28	19	0.002	19	0.11	0.022	0.06	< .1	< .01	0.2	< .1	0.07	< 1
RR01-84J-81	0.1	< .5	0.3	81	0.1	0.2	< .1	3	20.44	0.009	2	4.1	12.4	52	0.002	25	0.14	0.024	0.08	< .1	< .01	0.2	< .1	0.05	< 1
RR01-84J-82	0.7	< .5	0.9	67	< .1	0.1	< .1	7	19.6	0.013	9	7.7	12.13	43	0.002	26	0.23	0.017	0.14	< .1	0.01	0.7	< .1	0.03	1
RR01-84J-83	0.5	0.5	0.6	81	< .1	0.1	< .1	4	19.93	0.009	6	4.9	11.7	23	0.002	29	0.18	0.018	0.09	< .1	< .01	0.4	< .1	0.02	1
RR01-74D-89	1.3	< .5	0.1	91	< .1	0.1	< .1	2	21.49	0.01	1	1.4	13.31	14	0.001	18	0.04	0.009	0.01	< .1	< .01	< .1	< .1	0.04	< 1
RR01-74D-89A	0.6	< .5	< .1	93	< .1	0.1	< .1	1	21.14	0.006	1	1.3	13.46	11	< .001	33	0.01	0.012	0.01	< .1	< .01	0.1	< .1	0.05	< 1
RR01-74D-89	0.6	< .5	< .1	127	< .1	0.1	< .1	1	21.1	0.004	1	0.4	13.08	6	< .001	16	0.01	0.01	< .01	< .1	< .01	< .1	< .1	0.02	< 1
RE01-74D-36	0.7	< .5	< .1	89	< .1	0.1	< .1	2	21.4	0.003	2	2.1	12.86	15	< .001	16	0.02	0.011	< .01	< .1	< .01	0.4	< .1	< .02	< 1
RE01-74E-37	0.6	< .5	< .1	175	< .1	< .1	< .1	1	21.97	0.002	1	0.8	13.36	6	< .001	14	0.01	0.013	< .01	< .1	< .01	< .1	< .1	0.04	< 1
RE01-74E-37	0.6	0.5	0.1	188	< .1	< .1	< .1	2	20.72	0.003	1	1.1	13.07	8	< .001	16	0.01	0.012	< .01	< .1	0.01	< .1	< .1	0.05	< 1
RE01-74D-38	0.3	< .5	< .1	130	< .1	0.1	< .1	2	22.49	0.005	1	0.9	13.45	14	< .001	18	0.01	0.011	< .01	< .1	< .01	< .1	< .1	0.04	< 1
RE01-74D-38	0.4	< .5	< .1	102	0.1	0.1	< .1	1	18.8	0.005	1	1.2	10.75	19	0.001	11	0.02	0.009	0.01	< .1	0.01	0.1	< .1	0.02	< 1
RE01-84J-01	< .1	< .5	0.1	279	< .1	< .1	< .1	1	31.61	0.004	1	2.3	5.43	53	0.001	5	0.04	0.011	0.02	< .1	< .01	< .1	< .1	0.05	< 1
RE01-84J-01	< .1	< .5	0.1	276	< .1	< .1	< .1	< 1	30.99	0.004	1	1.2	5.33	53	< .001	5	0.04	0.009	0.02	< .1	< .01	< .1	< .1	0.07	< 1
RE01-74D-16	0.4	< .5	0.8	480	< .1	0.1	0.1	5	31.85	0.015	4	4.4	1.05	292	0.001	10	0.19	0.031	0.08	< .1	< .01	0.4	< .1	0.45	1
RE01-74D-16	0.3	< .5	1.2	281	0.1	< .1	< .1	4	26.81	0.024	4	4	0.7	333	0.001	6	0.19	0.017	0.08	< .1	0.01	0.8	< .1	0.29	< 1
RE01-74D-16	0.9	< .5	0.3	517	< .1	0.1	< .1	2	32.89	0.027	2	2.7	0.58	1668	0.001	3	0.08	0.021	0.03	< .1	0.01	< .1	< .1	0.39	< 1
RE01-74D-16	0.4	< .5	0.3	484	< .1	< .1	< .1	3	32	0.091	2	2.8	0.48	103	0.001	6	0.13	0.022	0.06	< .1	0.01	0.2	< .1	0.98	< 1
RE01-74D-16	0.3	< .5	0.6	267	< .1	0.1	< .1	6	18.96	0.184	6	5.1	1.02	245	0.001	1	0.22	0.028	0.08	< .1	0.01	1.4	< .1	0.4	1
RE01-74D-16	0.3	< .5	0.5	387	< .1	< .1	< .1	4	30.62	0.085	2	4	0.56	127	0.001	9	0.19	0.018	0.08	< .1	< .01	0.3	< .1	0.15	1
RE01-74D-16	0.3	< .5	0.5	247	< .1	< .1	< .1	6	16.6	0.19	4	4.5	0.93	195	0.002	6	0.17	0.029	0.06	< .1	0.01	0.4	< .1	0.44	1
RE01-74D-16	0.3	< .5	0.4	200	< .1	< .1	< .1	5	15.1	0.144	3	3.7	0.83	195	0.001	6	0.14	0.022	0.05	< .1	0.01	0.5	< .1	0.34	1
RE01-74D-16	0.1	5	0.4	5	< .1	0.9	0.2	7	0.06	0.004	1	60	0.01	11	0.001	3	0.08	0.011	0.02	1	2.94	0.1	4.3	22.94	< 1
RE01-74D-16	0.4	< .5	0.2	241	< .1	0.1	< .1	4	18.35	0.01	5	3.6	0.4	43	0.001	1	0.05	0.01	0.03	0.1	0.1	4	0.3	6.54	< 1
RE01-74D-16	0.1	5.1	0.9	7	< .1	0.2	0.2	5	0.05	0.004	3	39.5	0.01	7	0.003	< 1	0.1	0.007	0.03	0.3	0.25	0.3	0.6	29.39	< 1
RE01-74D-19	0.3	6.4	0.5	492	0.1	0.1	0.2	3	34.18	0.016	5	4.3	0.45	49	0.001	< 1	0.1	0.016	0.05	0.1	0.03	1.8	< .1	0.33	< 1
RE01-74D-19	0.3	< .5	0.9	162	< .1	0.1	< .1	8	7.63	0.26	6	6.5	0.53	144	0.002	5	0.25	0.015	0.08	< .1	0.02	1	< .1	0.29	1
RE01-74D-19	0.9	< .5	0.9	109	< .1	0.1	< .1	11	3.76	0.138	21	5.2	0.46	110	0.002	< 1	0.27	0.012	0.08	< .1	0.01	2.1	< .1	0.12	2
RE01-74D-19	0.6	< .5	0.9	208	< .1	0.6	< .1	20	3.33	0.099	44	6.7	0.32	122	0.002	3	0.31	0.01	0.09	< .1	0.01	3.2	< .1	0.05	2
RE01-74D-19	0.1	7.9	0.7	4	< .1	0.2	0.7	1	0.14	0.002	2	36.4	0.01	8	0.006	3	0.24	0.005	0.03	0.3	1.74	0.1	5.8	31.06	1
RE01-74D-19	1	< .5	14.2	1241	0.1	0.1	0.3	18	0.47	0.195	40	29.2	0.31	319	0.001	26	1.27	0.01	0.24	< .1	0.02	0.8	0.1	0.03	6
RE01-74D-19	0.6	< .5	11.4	1146	0.1	0.1	0.3	21	0.51	0.197	35	34	0.34	371	0.001	29	1.73	0.013	0.32	< .1	0.01	1.1	0.1	0.02	7
RR01-74D-61B	0.4	< .5	1.9	61	< .1	< .1	0.1	23	1.54	0.06	78	10.8	0.27	81	0.001	17	0.46	0.061	0.08	< .1	0.01	4.1	< .1	0.09	3
RR01-84J-62	0.5	< .5	1.5	486	< .1	< .1	< .1	6	30.72	0.017	6	7.7	1.12	340	0.005	11	0.29	0.018	0.18	< .1	< .01	0.8	< .1	0.04	1

Appendix 1 - Geochemical Data from Selected Samples in the Fort McMurray and Vermilion Chutes Areas

Field	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	B	Al	Na	K	W	Hg	Sc	Tl	S	Ga
Station	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppm	ppm	ppm	%	ppm
RR01-84J-63	0.4	< .5	1.7	446	< .1	< .1	< .1	6	29.22	0.014	6	9.1	0.79	103	0.005	16	0.3	0.016	0.18	< .1	< .01	0.6	< .1	0.06	2
RR01-84J-64	0.4	< .5	2.6	402	< .1	< .1	< .1	7	26.89	0.021	8	9.8	1.21	75	0.021	15	0.38	0.014	0.24	< .1	< .01	1.4	< .1	0.04	2
RR01-84J-64A	0.4	< .5	1.7	435	< .1	0.1	< .1	8	30.07	0.01	6	482.4	0.8	77	0.005	17	0.33	0.017	0.22	< .1	< .01	0.9	< .1	0.03	2
RR01-84J-64B	0.6	1.4	0.8	280	< .1	0.2	< .1	6	28.89	0.007	5	5.8	2.22	42	0.003	6	0.19	0.018	0.11	< .1	0.01	0.7	< .1	0.03	< 1
RR01-84J-65	0.4	1.1	2.3	268	< .1	< .1	< .1	10	23.42	0.028	10	11.1	2.41	42	0.004	12	0.38	0.015	0.27	< .1	0.01	1.7	< .1	0.02	1
RR01-84J-65A	0.9	0.6	1.8	209	0.1	0.2	0.1	9	24.61	0.018	6	8.5	3.1	59	0.005	14	0.3	0.017	0.19	< .1	< .01	1.2	< .1	0.03	1
RR01-84J-66	0.8	< .5	0.7	230	< .1	0.1	< .1	5	29.28	0.005	5	5.1	3.51	40	0.003	10	0.19	0.017	0.11	< .1	0.01	0.6	< .1	0.02	< 1
RR01-84J-66A	0.9	< .5	0.7	258	< .1	0.1	< .1	2	28.95	0.005	5	3.5	2.17	35	0.003	9	0.15	0.019	0.08	< .1	< .01	0.5	< .1	< .02	< 1
RR01-84J-67	0.8	< .5	0.5	67	< .1	0.1	< .1	5	18.1	0.008	4	3.4	10.18	21	0.002	20	0.13	0.015	0.07	< .1	< .01	0.5	< .1	0.02	< 1
RR01-84J-67A	0.7	< .5	0.6	82	0.1	0.1	< .1	4	19.4	0.006	4	4.1	10.7	20	0.003	27	0.14	0.017	0.08	< .1	0.01	0.5	< .1	0.03	< 1
RR01-84J-68	0.4	< .5	0.4	63	0.1	0.2	< .1	4	18.56	0.007	3	2.9	10.45	18	0.001	22	0.09	0.015	0.05	< .1	0.01	0.3	< .1	0.02	< 1
RR01-84J-69	0.4	< .5	0.6	58	< .1	0.1	< .1	4	17.32	0.014	3	3.8	9.59	67	0.001	10	0.13	0.012	0.07	< .1	0.01	0.4	< .1	0.03	< 1
RR01-84J-69	0.5	< .5	0.6	60	< .1	0.1	< .1	4	18.54	0.016	3	4	10.3	74	0.001	11	0.14	0.012	0.08	< .1	< .01	0.5	< .1	0.03	< 1
RE01-84J-39	0.1	< .5	< .1	265	< .1	< .1	< .1	2	31.04	0.005	1	0.6	0.98	50	< .001	2	0.01	0.006	0.02	< .1	< .01	< .1	< .1	0.05	< 1
RE01-84J-40	7.2	< .5	0.5	177	< .1	< .1	< .1	3	27.55	0.009	7	3	3.08	39	0.001	4	0.1	0.009	0.06	< .1	0.01	0.6	< .1	0.04	< 1
RE01-84J-40	5.5	< .5	0.5	152	0.1	< .1	< .1	4	25.14	0.009	6	11.8	3.68	37	0.001	3	0.11	0.01	0.06	< .1	0.03	0.5	< .1	< .02	< 1
STANDARD DS3	5.5	17.9	3.8	26	5	4.6	5.2	72	0.53	0.089	17	182.7	0.59	150	0.088	< 1	1.66	0.029	0.16	3.7	0.21	2.5	0.9	0.03	6
STANDARD DS3	6	20.6	4.4	29	6.2	4.5	5.5	81	0.57	0.1	19	193	0.63	151	0.093	1	1.78	0.029	0.17	3.7	0.23	2.9	1.1	0.03	7
STANDARD DS3	5.4	27	3.7	27	5.6	6.3	5.4	73	0.57	0.097	16	181.9	0.59	139	0.087	1	1.66	0.028	0.15	4.3	0.22	2.5	1.2	< .05	6
	0.712	**3.167**	**1.291**	**243.5**	**0.1**	**0.16**	**0.218**	**5.755**	**20.4298**	**0.04048**	**7.315**	**16.5981**	**5.05241**	**116.2**	**0.00243**	**12.47**	**0.204**	**0.01598**	**0.0894**	**0.36**	**0.191**	**0.907**	**1.714**	**1.94686**	**1.818**

B) Whole-rock g

Field	Cr2O3	Ba	Ni	Sr	Zr	Y	Nb	Sc	LOI	TOT/C	TOT/S	SUM
Station	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	%	%
RE01-74D-16	0.003	7802	< 20	494	18	< 10	45	1	40	11.2	0.48	99.87
RE01-74D-16	0.002	2003	< 20	430	< 10	< 10	< 10	1	42.4	12	0.27	100.12
RE01-74D-16	0.002	92	< 20	329	11	< 10	21	1	40.9	11.8	0.75	99.87
RE01-74D-16	0.002	262	< 20	237	18	10	12	2	35.4	10.7	0.33	99.72
RE01-74D-16	0.003	136	< 20	345	18	< 10	< 10	1	40.4	11.2	0.1	99.92
RE01-74D-16	0.004	191	< 20	194	17	< 10	< 10	< 1	35.2	10.7	0.39	99.83
RE01-74D-16	0.004	44	22	232	23	< 10	< 10	4	16.6	8.78	13.6	71.63
RE01-74D-19	0.001	46	< 20	355	< 10	< 10	39	2	42.3	12	0.23	100.05
RE01-74D-19	0.011	159	25	137	21	10	< 10	1	31.4	9.7	0.25	99.7
RE01-74D-19	0.013	133	< 20	100	12	24	< 10	2	31.1	10.11	0.12	99.91
RE01-74D-19	0.001	136	< 20	180	13	85	< 10	3	30.8	10.1	0.04	99.6
RE01-74D-19	0.016	531	25	1433	197	21	< 10	12	12.8	0.23	0.03	99.79
RE01-74D-19	0.016	529	30	1428	193	20	< 10	12	12.6	0.24	0.04	99.75
	0.45	401	30	282	350	27	22	23	3.4	2.44	5.35	100.01
	0.45	401	43	302	349	26	25	23	3.4	2.44	5.35	100.04