DIAMOND AND METALLIC MINERAL POTENTIAL OF THE KAKWA/WAPITI AREA, WEST-CENTRAL ALBERTA

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Open File Report 1998-02

Acknowledgments

The authors would like to thank Rick Richardson of the Alberta Geological Survey and Dale Fietz of Elad Enterprises Ltd. for contributing 26 bedrock samples collected during 1994 and 1995 field work from the Foothills area. Dianne Goulet of the Alberta Geological Survey is thanked for the meticulous preparation of bedrock samples for laboratory analyses. Dennis Chao of the Alberta Geological Survey is thanked for preparation of Figures 1 and 20, information system management and integration of the various data sets collected in the Kakwa/Wapiti area. Willem Langenberg and Don Scafe of the Alberta Geological Survey are thanked for editorial comments.

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Abstract

A reconnaissance field and geochemical program was completed in the Kakwa/Wapiti map area, which is located between the municipalities of Grande Prairie and Grande Cache (1:250 000 map sheet NTS 83L), to provide baseline data and as a preliminary evaluation of the metallic mineral and kimberlite or lamproite potential.

A stream sediment heavy mineral study collected and analyzed 60 stream sediment heavy mineral concentrate samples for potential diamond indicator minerals from various bedrock and surficial geology domains. A total of 133 possible diamond indicator grains were microprobed; and 35 of the 60 sites sampled reported diamond indicators including: chrome pyrope garnet (G9); eclogitic garnets (G3-calcic almandines and G5-magnesium); high chrome grossular garnets; chrome diopside; ilmenite; and chromite. At least six areas with anomalous values were delineated, particularly in the northeast quadrant, which drains the Cutbank River plateau. The abundance of diamond indicators are likely sourced from within Alberta and may originate either from a local bedrock volcanic source, or the result of a glacial "deposition" of sediments from the central regions of the province, or from both.

A bentonite geochemistry study may provide a quick and inexpensive view of the provenance under which airfall pyroclastics may have formed, and to determine if the bentonite could be used to identify local kimberlitic volcanism. A total of 9 bentonite samples were collected in the map area, from bentonitic layers ranging in thickness from between 2.0 cm and 63 cm, and analyzed for their major and trace elements. None showed a relative geochemical abundance pattern comparable to the average worldwide kimberlite or lamproite, and therefore, are likely not derived from an ultramafic source. The overall geochemical signature from rare earth element and trace element data closely duplicates the geochemical pattern for that of the average intermediate-felsic to felsic igneous rock.

A metallic minerals study collected a total of 90 bedrock samples, ranging in age from the Jurassic-Lower Cretaceous Nikanassin Formation to the Upper Cretaceous-Early Tertiary Coalspur Formation. Lithologies represented include: shale (36); siltstone (12); sandstone (17); conglomerate (6); bone bed (3); and bentonite (8). The results of the geochemical analysis yield anomalous trace metal values against the average concentration of crustal sedimentary rocks, and against background geochemical data established by this study. The study area represents a favorable environment for the emplacement of: sedimentary exhalative sulphides (Sedex); sedimentary Ni sulphides; stratabound sandstone U and Pb; sediment-hosted stratiform Cu; epithermal (Carling-type) Au; and placer concentrations. This contention is supported by the association of the following factors: a tectonically active sedimentary basin; magmatic activity; stratigraphic distribution of chemical sediments such as Ba; sandstones with permeability contrasts such as shale beds; reductants including coal zones; presence of phosphates; and evaporite deposits.

1.0 Introduction

A reconnaissance field program for diamond and metallic mineral potential was completed during the 1996 summer in the Kakwa/Wapiti study area. This study ties to other Alberta Geological Survey (AGS) projects including bedrock and Quaternary geology, land use compilation and aggregate studies. The area comprises largely the 1:250 000 map sheet NTS 83L and is located between the municipalities of Grande Prairie and Grande Cache.

The regional study utilizing automobile, boat and helicopter resulted in the collection of a total of 157 samples. The study was strategically broken into the following three separate parts for sampling, geochemical analysis and reporting purposes:

(1) Stream sediment heavy mineral study:
- 60 stream sediment samples were analyzed for heavy mineral diamond indicator grain geochemistry;

(2) Bentonite Rare Earth Element (REE) study:
- the geochemical REE signature of 7 bentonite samples were used to evaluate the use of bentonite REE data in exploration for diamondiferous diatremes; and

(3) Metallic mineral study:
- 90 bedrock samples were analyzed for major and trace element geochemistry in order to determine the metallic mineral potential.

2.0 Physiography

The map area is divisible into three broad physiographic units. These units, which largely coincide with variations in bedrock and surficial geology, include: (1) the Upper Cretaceous plains region in the northern margin of the map area; (2) a dissected tableland consisting of a series of narrow flat topped to gently rounded, northeast-sloping Upper Cretaceous to Tertiary ridges; and (3) the Foothills and Rocky Mountains, which extend across the southwest part of the map area (McPherson and Mellon, 1971).

Major rivers include the Wapiti River in the northwest, the Smoky River located in the central and eastern half of the map area, and the Simonette River in the southeast. The Wapiti River and its tributaries drain the northwestern part of the area. The Smoky River and its tributaries drain the central part of the area. The mean elevation above sea level varies from approximately 600 m in the northern part of the map sheet to approximately 1850 m in the Rocky Mountains to the southwest.

3.0 Location and Access

The 1:250 000 map sheet NTS 83L is located in the west-central part of Alberta, between the municipalities of Grande Prairie and Grande Cache. The area borders include latitudes 54°00' – 55°00' and longitudes 118°00' and 120°00'.

The area is vehicle accessible by three main south-north trending roads. Highway 40, completely paved during 1996, runs from Grande Cache to Grande Prairie and roughly parallels the west side of the Smoky River. Forestry Trunk Road 734 extends north to Highway 34, south to Highway 40 (near Owen) and runs approximately parallel to the east side of the Smoky River. The Two Lakes Road provides access to the western part of the map sheet along the Narraway River. The northern junction of the Two Lakes Road meets Highway 2 west of Grande Prairie and extends south through Two Lakes ending at Kakwa Falls. Several roads have been created throughout the central part of the map sheet by the forestry and oil/gas industries. Up to date maps may be purchased at the Alberta Environmental Protection – Wapiti River District Office in Grande Prairie.

The Smoky River and Wapiti River provide the best means for water access, but care must be taken with respect to flow rates and water depth.

4.0 Exploration History

With the possible exception of uranium and iron exploration in the late 1960's and 1970's, mineral exploration in Alberta has received little attention. The Kakwa/Wapiti map area is no exception and exploration to date has mainly focused on oil and gas, coal and industrial minerals. The exploration activity in the map area is summarized below.

Oil and Gas

The Kakwa and Wapiti gas and oil fields are located in the Deep Basin between Townships 61 and 69, Range 4 and 13, West of the 6th Meridian. The Kakwa field has hydrocarbon production from the Cardium (gas and oil), Dunvegan (oil), Cadotte (gas), Falher (gas) and the Gething (gas) formations. The Wapiti field has hydrocarbon production from the Belly River (gas), Chinook (gas), Cardium (oil), Dunvegan (oil), Paddy (gas), Cadotte (gas), Notikewin (gas), Falher (Gas), Nikanassin (gas), Gething (gas) and the Cadomin (gas) formations (F. Pittis, personal communication, 1997).

From January, 1995 to present, drilling activity in the Kakwa and Wapiti fields has been moderate. In the Kakwa field, 8 development wells and 1 exploratory well have been drilled and/or licensed. In the Wapiti field, 57 development wells and 37 exploratory wells have been drilled and/or licensed (F. Pittis, personal communication, 1997).

Coal

The northern extension of the Smoky River Coal Mine is located in the map area, and represents the only active coal production in the Kakwa/Wapiti area. Medium to low volatile bituminous coals are hosted by the Grande Cache Member (Gates Formation), which is comprised of shale and fine- to medium-grained sandstone. The member has a thickness of 155 m and contains 11 individual coal seams (Landes, 1964; Langenberg *et al.*, 1983). The No. 4 and No. 10 coal seams are the only laterally continuous seams. The No. 4 coal seam is 5 m thick and is the major economic coal seam of the area, which is mined both underground and in open pits. Bituminous-ranking coal zones hosted by the Grande Cache Member have also been discovered to the northwest of the Smoky River Coal Mine near Sherman Meadows.

Three distinct Upper Cretaceous to Tertiary coal measures in the Kakwa/Wapiti map area have been defined as a possible future resources of thermal coal in northern Alberta (Dawson *et al.*, 1994). The Red Willow, Cutbank and Kakwa coal measures contain up to 12 coal zones with variable thickness, lateral continuity and rank, ranging from lignite to high volatile A bituminous. Regional mapping and subsurface analysis have delineated several areas that contain coal seams with potentially mineable thickness at shallow depths.

Industrial Minerals

Industrial minerals include such commodities as limestone, gypsum, bentonite, clay and shale and road aggregate. Sand and gravel production is mainly for local consumption and represents important sources for highways, forestry haul roads and oil well pads in the map area. Sources of aggregate include preglacial sands and gravels, glacial fluvial deposits and fluvial (terrace) deposits.

The Fetherstonehaugh Creek gypsum deposit lies on the Alberta-British Columbia border straddling the Continental Divide near the headwaters of Fetherstonehaugh Creek. The gypsum is Triassic in age, belonging to the Starlight Evaporite Member of the lower part of the Whitehorse Formation (Gibson, 1975). Outcrop geochemistry yielded high grade gypsum with concentrations of between 95% to 98%. However, the average grade from test hole samples is low, only 75% to 80% (Comtar Chemical Ltd., 1968). Its location within the Willmore Wilderness Park, where mineral development is currently prohibited, difficult access, uncertain grade and uncertain reserves are present constraints to any future commercial development of this deposit (Hamilton, 1982).

Stratiform phosphate occurrences in Alberta have been evaluated in the shale, sandstone and siltstone of the Triassic Spray River Group, chert and black shale of the Jurassic Fernie Group and the bone bed, which is comprised of chert pebbles, bone fragments, fecal pellets and fish teeth, of the mid-Cretaceous Shaftesbury Formation. The Fernie Group, which crops out in a fairly narrow band extending from the Crowsnest Pass area northward to the Willmore Wilderness Park, has the greatest potential. Phosphatic shales at the base of the lower-middle Jurassic Fernie Group are estimated to contain 254 Mt of low grade phosphate (6% to 12% P_2O_5/m) within Alberta, of which a possible 8 Mt are in potentially exploitable land-use areas (Macdonald, 1987). Grades and thicknesses, in general, tend to be leaner towards northern Alberta.

Diamonds

To date, no exploration assessment reports pertaining to diamond exploration in the Kakwa/Wapiti map area have been submitted to the Alberta Department of Energy. Stream sediment and bedrock sampling by government and industry indicate that the Foothills of Alberta have yielded abundant chromites from northwest of Calgary to Grande Cache (Dufresne *et al.*, 1996; Ballantyne, and Harris, 1994; Langenberg and Skupinski., 1996; Sraega, 1994; Drever and Matthews, 1995).

Metallic Minerals

No known deposits of metallic minerals have been discovered in the Kakwa/Wapiti area. The map area was, at least partially, explored for uranium in the late 1960's. International Mine Services Ltd. conducted a reconnaissance uranium exploration program that involved sampling Upper Cretaceous and Paleocene continental sedimentary sequences from southern Saskatchewan to northwest Alberta (Edmond, 1970). Wapiti Formation sandstones in the Grande Prairie area were selected for follow-up work, which consisted of an airborne radiometric survey, and petrographic and geochemical studies of cuttings from oil and gas wells. Well cuttings from an oil and gas well, located west of the Latornell River (Section 8, Township 68, Range 1W6) yielded galena, chalcopyrite with Co-Ni-Fe sulphides. A second well, located west of the Kakwa River (Section 30, Township 63, Range 4W6), was reported to contain sphalerite (Edmond, 1970).

International Mine Services Ltd. also reported geochemical results, from four wells located north of Grande Prairie, which yielded concentrations of up to 100 ppm U across 6.10 m and 100 ppm U across 3.05 m. Other elements reported to be anomalous include up to 2000 ppm Zn, 200 ppm Pb, 400 ppm Ni and 400 ppm V. These analytical results, along with elements such as Mo, Cu, Se and As inspired explorationists to suggest that there are some similarities between the Upper Cretaceous and Tertiary rocks of the Grande Prairie area and the uranium-bearing sedimentary strata of the Colorado Plateau (Edmond, 1970; McPherson and Mellon, 1971). A drilling program based on the results of the 1970 program was recommended, however, there is no evidence any follow-up work was performed. Van Dyke (1981) suggested that coal zones in the Upper Cretaceous-Tertiary Scollard Formation may be favorable for uranium concentrations. To date, no important anomalous radioactivity or uranium occurrences have been discovered in the Kakwa/Wapiti map area.

In 1965, a placer gold reconnaissance survey was completed by sieving and panning approximately 1 m of Recent river alluvium from most of the major rivers in Alberta (Halferdahl, 1965). One hundred thirty-three samples yielded flour gold (gold that passed through a 35 mesh screen), including 4 samples from the Wapiti River and 8 samples from the Smoky River. Few, if any, concentrations found during the Halferdahl survey were considered high enough for economic recovery. A sample of preglacial gravel sampled from a pit near the Smoky Tower panned 1 colour in 4 pans, and geochemical analysis yielded 40 ppb Au (Richardson, 1984; Edwards, 1990). Boyle (1979) suggested that Upper Cretaceous to Paleocene sedimentary rocks may contain gold paleoplacers in the Rocky Mountain Front Ranges, although evidence for gold enrichment is sparse. Some conglomerate from the Brazeau Formation in the catchment of the North Saskatchewan River contain low, but anomalous, gold concentrations (up to 13 ppb), but no detrital gold has been visibly detected (Horachek, 1994). Leckie and Craw (1997) recently sampled the basal Cretaceous Cadomin Formation of the Alberta Foothills, and reported Au concentrations of 2 and 5 ppb, with one sample that yielded 17 ppb Au.

5.0 General Geology

The majority of the map area to the north and northeast of the deformed belt is underlain by rocks of the Upper Cretaceous Brazeau Formation, Early Tertiary Coalspur Formation and the Tertiary Paskapoo Formation (Figure 1; in pocket). The Foothills may be generalized by a series of northwest-trending folded thrust sheets that expose successively older strata towards the front ranges of the Rocky Mountains to the southwest. Triassic, Jurassic and Cretaceous marine and non-marine clastic sediments are exposed throughout the Foothills and Main Ranges, beginning just north of Waterton National Park and continuing into British Columbia just north of Grande Cache.

A brief description of the main geological units follows. For more detailed information, the reader is referred to Jerzykiewicz, 1997; McMechan and Dawson, 1995; Dawson, 1994; Langenberg *et al.*, 1987; Langenberg and McMechan, 1985; Stott, 1984; McPhersen and Mellon, 1971; Stott, 1967; Irish, 1965; and Greiner, 1955.

Triassic: Spray River Group

The oldest exposed rocks in the map area, directly west of the Stinking Springs Thrust, include the Whitehorse and Sulphur Mountain formations of the Triassic Spray River Group. (Figure 2). The Triassic system comprises a westward thickening marine sequence of easterly derived carbonate and siliclastic lithologies including interbedded silty dolostone and limestone, siltstone, sandstone and minor conglomerate and shale. The Triassic period ended with uplift, regression of the sea and probable erosion (Gordey *et al.*, 1992).

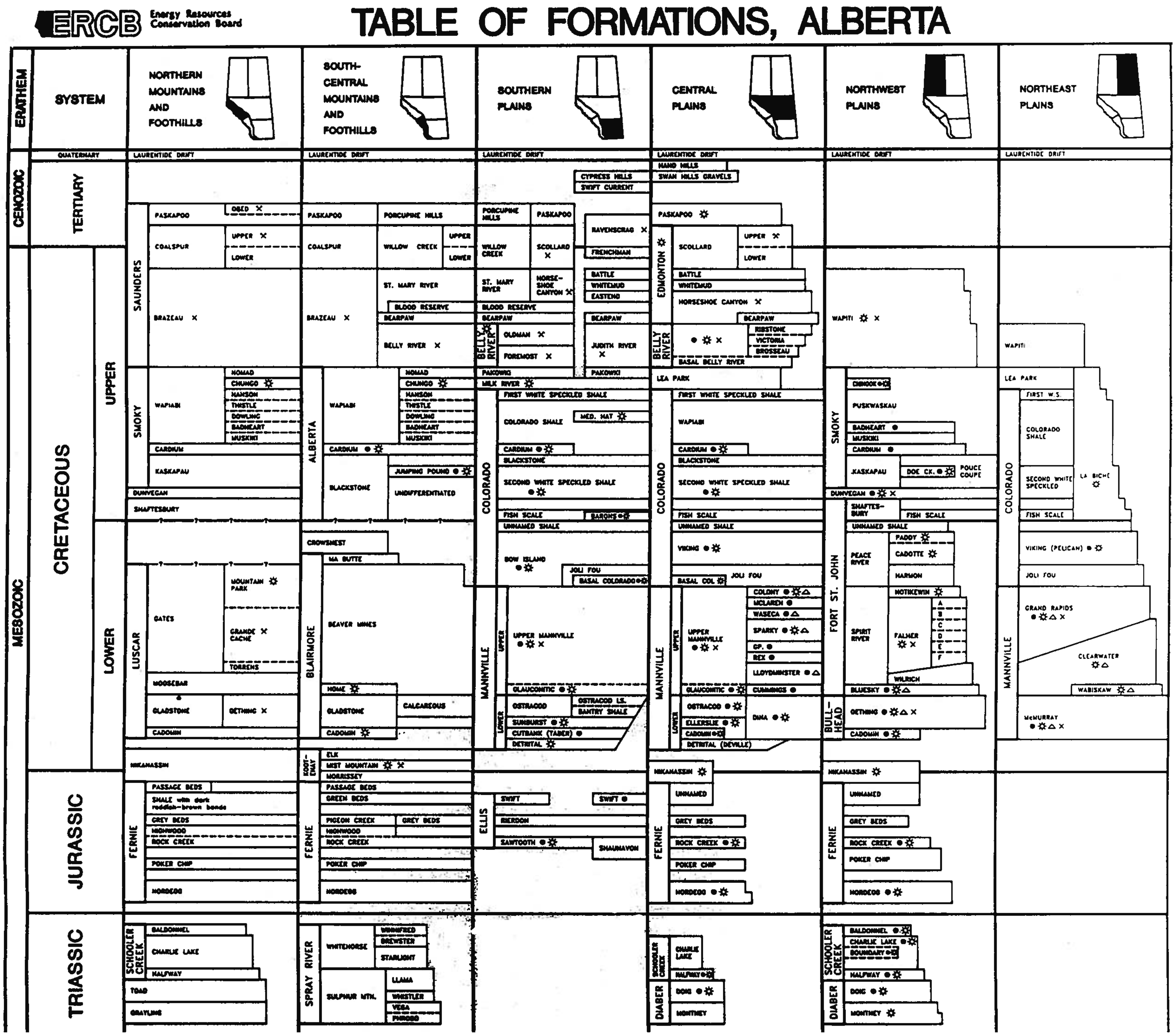
Jurassic: Fernie Formation

The Jurassic Fernie Formation consists of dark grey shale with varying amounts of rusty weathering ironstone concretions. Marine rocks are dominant in the lower part of the Fernie and transgress to an interfingering of marine and continental sedimentary rocks in the upper part of the Fernie. The thickness varies from 200 to 550 m (Irish, 1965).

Jurassic to Lower Cretaceous: Nikanassin, Monteith and Gorman Creek formations

The Jurassic to Lower Cretaceous rocks comprise the Nikanassin, Monteith and Gorman Creek formations. The Fernie Formation transitionally grades into the Upper Jurassic - Lower Cretaceous Nikanassin Formation comprised of non-marine, light grey, very fine-grained sandstones and minor dark grey shale, silty shale and argillaceous sandstone. Individual sandstone beds may be as thick as 6 m. The Monteith Formation is composed of a very fine-grained, light brown-grey sandstone that weathers light grey to pinkish in colour. The Monteith contains minor grey, carbonaceous shale and siltstone that appear to be thicker in the lower part of the formation. The Gorman Creek Formation is comprised of interlayered sandstone, siltstone, mudstone and carbonaceous shale or coal in repetitive fining-upward cycles generally 1 – 5 m thick. The sandstone is fine- to coarse-grained, carbonaceous and commonly cross laminated or cross bedded. The Gorman Creek Formation also

Figure 2. Regional Mesozoic and Cenozoic stratigraphic correlation chart for Alberta.



contains grey, carbonaceous siltstone and silty shale (Irish, 1965).

Lower Cretaceous: Luscar Group and Shaftesbury Formation

The Nikanassin Formation is overlain by the Lower Cretaceous Luscar Group, which is approximately 565 m thick and contains thick economic coal seams (Langenberg *et al.*, 1987). The Cadomin, Gladstone, Moosebar, and Gates formations together form the Luscar Group (Langenberg and McMechan, 1985). The Cadomin Formation consists of 45 m of alluvial conglomerates including black to green, red, white, light yellow and greyish white cherts and quartzites. The Cadomin forms an excellent marker unit and is remarkable for it's length and constant lithology. The Gladstone Formation is approximately 110 m thick and consists of fine- to coarse-grained, carbonaceous sandstone and local sandy pebble conglomerate with interlayered carbonaceous shale and silty shale. The Moosebar is approximately 60 m thick and consists of marine, dark grey shale with ironstone concretions and minor very fine-grained sandstone. The largely non-marine Gates Formation is about 350 m thick and is comprised of fine- to coarse-grained, well sorted, carbonaceous sandstone with interlayered grey, carbonaceous shale and siltstone, and local coal seams and sandy pebble conglomerate. These coals are mined in the Grande Cache area. The Gates Formation may be further subdivided into the Torrens, Grande Cache and Mountain Park members.

The Luscar Group is overlain by the mid-Cretaceous Shaftesbury Formation. The Shaftesbury Formation is approximately 150 m thick and consists of dark grey marine shales with increasingly laminated siltstone interbeds near the top of the section. The Shaftesbury Formation may be further subdivided into the Westgate, Fish Scales and Belle Fourche formations (Bloch *et al.*, 1993).

Upper Cretaceous: Dunvegan Formation

The Dunvegan Formation attains thicknesses of about 350 m and forms a thick wedge of carbonaceous, medium- to coarse-grained, cross bedded sandstone, siltstone and mudstone that represent a stacked series of depositional deltaic systems (Battacharya, 1991). There is considerable lateral variation in the thickness of the Dunvegan strata in the map area, but in general the formation thickens progressively from southeast to northwest (Irish, 1965). Both the upper and lower boundaries of the Dunvegan Formation with the Smoky Group and Shaftesbury Formation are best described as interfingering and highly diachronous.

The Smoky Group represents the northeastern edge of the deformed belt and may divided into the Kaskapau, Cardium and Puskwaskau formations. The Kaskapau Formation is comprised of dark grey to black shale with rusty weathering sideritic concretions. The Cardium Formation consists of fine-grained, quartz- and chert-rich sandstone with minor interbedded shale siltstone, sandstone and conglomerate. The Puskwaskau Formation is comprised of commonly silty, dark grey shale and lesser calcareous shale. The Smoky Group is overlain by the Upper Cretaceous Brazeau Formation.

Upper Cretaceous: Brazeau (Wapiti) Formation

The Upper Cretaceous Brazeau Formation represents the dominant lithology in the map area. It accounts for approximately 35% of the map area, and is dominantly located in the plains region to the north and near the margin of the folded belt (Figure 1). In the north part of the area, the Brazeau Formation has been called the Wapiti Formation (McMechan and Dawson, 1995).

The lower Brazeau Formation (lower Wapiti Formation) is approximately 1100 m thick (McMechan and Dawson, 1995) and lies stratigraphically above the Puskwaskau Formation. It is composed of light grey, fine-grained, argillaceous, carbonaceous sandstone with interbedded siltstone, silty mudstone, thin layers of coal and bentonite and locally conglomeritic. The sandstone ranges in thickness from very thin to thick (greater than 5 m), with some channel deposits up to 30 m in thickness. The sandstones grade upwards into siltstone and mudstone sequences.

The upper part of the Brazeau Formation (upper Wapiti Formation) is between 125 to 175 m (McMechan and Dawson, 1995) thick and is characterized by interbedded light grey to brownish weathering, fine-grained, carbonaceous sandstones and dark grey mudstones. The sandstone units, that range from 1 to 15 m in thickness, generally fine upwards and are commonly cross bedded.

The siltstones and silty mudstones of the Brazeau Formation are invariably smectitic in nature. Bentonitic layers ranging in thickness from 2 to 60 cm are common in the northern part of the map sheet and are almost always associated with discontinuous coal seams up to 4 m thick. Dawson (1994) reported up to 20 coal seams in the Brazeau Formation.

Upper Cretaceous to Early Tertiary: Coalspur (Scollard) Formation

The Upper Cretaceous to Early Tertiary Coalspur Formation is located in the centre of the map sheet and exposed along the axis of the Alberta Syncline (Figure 1). Strata on the northeast limb of the syncline dip gently (3° or less) to the southeast, exposing successively older beds towards the northeast. On the southwest limb of the syncline, the strata dip to the northeast with increasing steepness (5 to 15 degrees), abutting against the complexly folded and faulted Cretaceous beds that mark the northeast margin of the Foothills (McPherson and Dawson, 1995). The Coalspur is called Scollard Formation northeast of the Alberta Syncline (McPherson and Dawson, 1995). The Cretaceous/Tertiary boundary is located within the Coalspur Formation.

The lower Coalspur (lower Scollard) Formation is approximately 200 m thick (Jerzykiewicz, 1997) and lies conformably on the older Brazeau Formation. Similar in gross lithology to the underlying Brazeau Formation, the lower Coalspur is comprised of grey, fine-grained, argillaceous, carbonaceous, cross bedded sandstone and interbedded siltstone and mudstone.

The upper Coalspur (upper Scollard) Formation lies conformably above the lower Coalspur Formation and is approximately 250 m thick (Jerzykiewicz, 1997). The clastic rocks are similar to those of the underlying formation. The primary difference between the two is the extensive development of both regionally extensive and discontinuous coal. The upper Coalspur Formation contains up to 10 coal zones known as the Kakwa coal measures (Dawson, 1994).

The Cretaceous/Tertiary Coalspur Formation sandstones can be separated from the Upper Cretaceous

Brazeau Formation by their calcareous nature, and therefore, they are more resilient than the Brazeau sandstones. The lower Coalspur contains only minor amounts of coal. Silty mudstone and mudstones are slightly bentonitic in the Coalspur Formation.

Tertiary: Paskapoo Formation

The Paleocene Paskapoo Formation dominates the southeastern part of the map sheet. Resistant sandstone cliffs are light grey to buff coloured, medium- to fine-grained and cross bedded. The unit may contain interbedded siltstone and mudstone with thin sandstones and minor lenses of carbonaceous shale. The top of the formation is eroded and its minimum thickness is 850 m (Jerzykiewicz, 1997).

6.0 Stream Sediment Heavy Mineral Study

6.1 Introduction

Diamonds are formed at depths of more than 150 km in the earth's mantle, and carried to the surface by volatile-rich, ultrabasic rocks such as kimberlite or lamproite. Because the diamond content of such rocks is typically a few ppm, diamond exploration programs have placed a major emphasis on the use of mantle-derived heavy minerals; both as pathfinders to kimberlites and related rocks, and as a means of evaluating the diamond potential of exploration targets. Their resistance to weathering, distinctive colours and surface textures make visual recognition and evaluation possible. Some of the minerals have a shared paragenesis with diamonds, and have unique compositions with respect to certain major and minor elements (Gurney, 1984; McCandless and Nash, 1996; Gurney *et al.*, 1993).

A heavy mineral concentrate stream sediment study was completed in the Kakwa/Wapiti map area to provide baseline geochemical data for the area, and as a preliminary reconnaissance sampling study to evaluate the potential of the area to contain kimberlites or lamproites. The stream sediment heavy mineral study will be completed in conjunction with other Alberta Geological Survey diamond indicator studies in the Kakwa/Wapiti map area including till (Fenton *et al.*, In Prep.) and bedrock (Langenberg *et al.*, In Prep.).

6.2 Methodology

Sampling was completed during the summer and fall of 1996. Sixty stream sediment heavy mineral concentrate samples were collected and analyzed for potential diamond indicator minerals. The samples were collected from various domains of bedrock geology and surficial geology (Figure 1). Sampling was focused on the more accessible regions of the map area. A bi-directional drainage pattern exists in the map area and is defined by a series of east–west topographic ridges created by feeding rivers and creeks; and south-north trending escarpments orientated towards the major river valleys. This pattern creates suitable topography for a fluvial sampling survey. The majority of the samples were taken in proximity to automobile accessible areas, and were typically collected upstream from any man-made structures such as bridges; the Foothills samples were collected with the assistance of a helicopter.

Samples were wet-sieved, by carefully shoveling sediment into a series of three stainless steel sieves resting in a large conical pan (Figure 3). Sample sites were dug to a depth of 1 m to ensure a representative sample of the deposited material. The "lights" were panned off, and approximately 500 g of heavy mineral concentrate (< 2 mm) was collected from each site. The samples were collected from a wide variety of physiographic fluvial environments ranging from large sand and gravel bars in major rivers to minor sediment concentrations in rocky, narrow creeks. Where possible, high energy sedimentary environments were selected for heavy mineral sampling as they tend to yield the greatest concentration of heavy minerals.

Microscopic examination of the heavy mineral concentrate samples for diamond indicator minerals was completed by the Saskatchewan Research Council (SRC) within standard exploration grain sizes of 0.25 - 0.5 mm, 0.5 - 1.0 mm and 1.0 - 2.0 mm. A summary of the processing procedures are given in Swanson and Gent (1993). A simplified description of the lab procedure involves: (1) separating the sample to work with the minus 2.0 mm fraction; (2) permrolling the sample to separate the non-magnetic and quartz fractions from the paramagnetic and magnetic fractions; (3) Frantz electromagnetic separation to generate distinct fractions based on variations in magnetic susceptibility - usually magnetic, paramagnetic and non-magnetic fractions; (4) magstream to divide the non-magnetic fraction into intermediate and heavy specific gravity fractions; and (5) microscopic examination of the heavy mineral concentrate for diamond indicator minerals.

Selected silicate (garnet and diposide) and oxide (ilmenite and chromite) mineral grains were submitted to the University of Saskatchewan, Department of Geological Sciences to determine the quantitative major and trace element chemistry using an electron microprobe. The silicate grains were analyzed using an accelerator voltage of 15 kV, beam diameter of 10 μm, beam current of approximately 10 nA (nanoamperes) and all elements are measured using a maximum counting time of 40 seconds. Oxide grains are analyzed using an accelerator voltage of 20 kV, beam diameter of 5 μm, beam current of approximately 10 nA and each major cation is measured for a maximum of 40 seconds. Standards were run prior to and after the analysis to ensure the calibration remained stable during each run.

6.3 Results

A total of 133 possible diamond indicator grains were microprobed. The microprobe data were processed using mineral identification programs written in QBASIC and provided by the SRC (Quirt, 1992a,b; Gent, 1993). Thirty-five of the 60 sites sampled contained diamond indicators. Indicator minerals recovered from the map area include chrome pyrope garnet (G9), eclogitic garnets (G3-calcic almandines and G5-magnesium), high chrome grossular garnets, chrome diopside, ilmenite and chromite (Table 1).

The results of the diamond indicator microprobe analysis are used to evaluate mantle mineral macrocryst compositions, which in turn, provide an invaluable aid to any diamond exploration

Figure 3. Conical pan and screens used for heavy mineral stream sediment sampling.

Table 1. Microprobe analysis of indicator minerals from the Kakwa/Wapiti area (wt%).

PYROPE GARNET

Sample#	Mineral ID (Gent, 1993)	TiO2	Cr2O3	FeO	MgO	CaO	SiO2	Al2O3	Na2O	MnO	Total
KW96-45-001	G10 LOW Ca-Cr PYROPE	0.05	6.88	6.79	20.32	5.78	41.79	18.66	0.03	0.37	100.68
KW96-70-001	G10 LOW Ca-Cr PYROPE	0.10	7.71	7.86	17.68	7.31	41.02	17.63	0.00	0.46	99.78

HIGH Cr GROSSULAR

Sample#	Mineral ID (Gent, 1993)	TiO2	Cr2O3	FeO	MgO	CaO	SiO2	Al2O3	Na2O	MnO	Total
KW96-68-001	GROSSULAR	1.15	10.24	3.64	0.07	32.07	35.99	11.91	0.00	1.22	96.29

ECLOGITIC GARNET

Sample#	Mineral ID (Gent, 1993)	TiO2	Cr2O3	FeO	MgO	CaO	SiO2	Al2O3	Na2O	MnO	Total
KW96-12-001	G3 Ca PYROPE ALMANDINE	0.11	0.10	22.98	5.35	10.40	38.96	22.15	0.04	0.78	100.89
KW96-45-001	G3 Ca PYROPE ALMANDINE	0.10	0.01	22.21	8.01	7.47	38.99	22.07	0.05	0.33	99.25
KW96-67-001	G3 Ca PYROPE ALMANDINE	0.07	0.05	21.36	10.83	5.15	40.00	22.86	0.01	0.99	101.30
KW96-68-001	G3 Ca PYROPE ALMANDINE	0.14	0.07	22.58	4.86	10.29	38.65	22.37	0.08	1.48	100.53
KW96-12-001	G5 Mg ALMANDINE	0.04	0.07	29.12	5.73	4.11	38.49	22.20	0.00	0.36	100.12
KW96-12-001	G5 Mg ALMANDINE	0.09	0.06	28.29	7.74	2.55	38.83	21.84	0.03	0.42	99.85

CLINOPYROXENE (>0.5 wt% Cr2O3)

Sample#	Mineral ID (Gent, 1993)	TiO2	Cr2O3	FeO	MgO	CaO	SiO2	Al2O3	Na2O	MnO	Total
KW96-13-001	CPX01 SUB CALCIC DIOPSIDE	0.02	0.68	4.63	20.08	11.55	55.07	1.69	0.79	0.22	94.75
KW96-53-001	CPX02 DIOPSIDE	0.12	0.81	4.17	15.08	20.26	54.15	2.11	1.96	0.12	98.78
KW96-55-001	CPX02 DIOPSIDE	0.19	1.42	3.59	19.15	16.05	54.78	2.44	1.48	0.14	99.25
KW96-50-001	CPX5 Cr DIOPSIDE	0.18	1.01	3.12	15.76	22.08	53.77	2.19	0.71	0.14	98.95
KW96-63-001	CPX5 Cr DIOPSIDE	0.07	1.17	2.56	16.30	20.68	52.51	4.69	1.21	0.09	99.28

ILMENITE

Sample#	Mineral ID (Gent, 1993)	TiO2	Cr2O3	FeO	MgO	CaO	SiO2	Al2O3	Na2O	MnO	Total	K2O	ZrO2	Nb2O5	NiO	ZnO	Ni	Zn
KW96-34-001	SUB PICRO ILMENITE	44.29	0.01	46.96	4.86	0.00	0.00	0.41	0.00	0.45	97.08	0.00	0.04	0.02	0.01	0.04	0.00	0.00
KW96-07-001	PICRO ILMENITE	51.92	0.37	33.42	14.10	0.03	0.00	0.67	0.00	0.26	101.04	0.00	0.01	0.17	0.08	0.02	0.06	0.00
KW96-40-001	PICRO ILMENITE	51.47	0.32	34.55	12.88	0.00	0.00	0.66	0.00	0.30	100.53	0.00	0.12	0.14	0.09	0.02	0.07	0.00
KW96-45-001	PICRO ILMENITE	50.73	1.42	33.76	14.22	0.00	0.00	0.60	0.00	0.25	101.32	0.00	0.04	0.19	0.11	0.01	0.08	0.00
KW96-45-002	PICRO ILMENITE	48.87	0.69	41.48	7.28	0.00	0.00	0.02	0.00	0.39	99.09	0.00	0.11	0.24	0.03	0.00	0.00	0.00
KW96-48-001	PICRO ILMENITE	51.71	0.17	33.48	14.59	0.00	0.00	0.55	0.00	0.29	101.25	0.00	0.05	0.37	0.04	0.00	0.00	0.00
KW96-48-001	PICRO ILMENITE	53.89	2.96	27.93	16.05	0.01	0.00	0.10	0.00	0.33	101.62	0.00	0.01	0.16	0.18	0.00	0.14	0.00
KW96-61-001	PICRO ILMENITE	53.07	0.35	31.27	14.94	0.00	0.00	0.57	0.00	0.27	100.78	0.00	0.06	0.17	0.08	0.00	0.06	0.00
KW96-64-001	PICRO ILMENITE	51.24	1.31	32.33	14.66	0.01	0.00	0.70	0.00	0.25	100.86	0.00	0.06	0.19	0.10	0.01	0.08	0.00

CHROMITE

Sample#	Mineral ID (Gent, 1993)	TiO2	Cr2O3	FeO	MgO	CaO	SiO2	Al2O3	Na2O	MnO	Total	K2O	ZrO2	Nb2O5	NiO	ZnO	Ni	Zn
KW96-25-001	SUB PICRO CHROMITE	2.08	38.45	31.63	11.75	0.00	0.00	14.82	0.00	0.29	99.29	0.00	0.04	0.00	0.15	0.08	0.12	0.07
KW96-29-001	SUB PICRO CHROMITE	0.56	38.19	31.79	17.37	0.00	0.00	12.14	0.00	0.23	100.56	0.00	0.03	0.01	0.22	0.02	0.18	0.02
KW96-29-001	SUB PICRO CHROMITE	0.65	51.08	30.45	7.65	0.00	0.00	8.20	0.00	0.49	98.82	0.00	0.05	0.00	0.06	0.20	0.05	0.16
KW96-30-001	SUB PICRO CHROMITE	1.62	38.00	27.92	13.60	0.00	0.00	18.82	0.00	0.26	100.51	0.00	0.00	0.00	0.23	0.07	0.18	0.05
KW96-30-001	SUB PICRO CHROMITE	0.03	39.19	19.94	13.93	0.00	0.00	27.01	0.00	0.29	100.73	0.00	0.00	0.02	0.08	0.24	0.06	0.19
KW96-30-001	SUB PICRO CHROMITE	1.43	34.78	27.56	13.47	0.00	0.00	21.70	0.00	0.23	99.48	0.00	0.00	0.00	0.21	0.09	0.17	0.07
KW96-38-001	SUB PICRO CHROMITE	2.94	26.63	32.04	13.89	0.00	0.00	23.35	0.00	0.30	99.77	0.00	0.02	0.04	0.24	0.14	0.19	0.11
KW96-44-001	SUB PICRO CHROMITE	1.23	31.75	39.28	14.48	0.00	0.00	12.63	0.00	0.30	100.00	0.00	0.06	0.00	0.22	0.05	0.17	0.04
KW96-56-001	SUB PICRO CHROMITE	8.04	23.99	40.95	14.48	0.00	0.00	11.41	0.00	0.38	99.54	0.00	0.01	0.00	0.25	0.03	0.20	0.02
KW96-60-001	SUB PICRO CHROMITE	0.31	35.72	16.90	17.92	0.00	0.00	29.22	0.00	0.23	100.61	0.00	0.02	0.02	0.18	0.09	0.14	0.07
KW96-63-001	SUB PICRO CHROMITE	2.04	33.94	27.16	14.68	0.00	0.00	21.67	0.00	0.24	100.07	0.00	0.02	0.01	0.24	0.07	0.19	0.06
KW96-65-001	SUB PICRO CHROMITE	0.07	52.13	29.46	6.88	0.00	0.00	9.47	0.00	0.53	98.91	0.00	0.01	0.00	0.05	0.31	0.04	0.25
KW96-65-001	SUB PICRO CHROMITE	0.51	43.44	35.55	7.12	0.00	0.00	10.96	0.00	0.57	98.49	0.00	0.00	0.00	0.09	0.24	0.07	0.20
KW96-65-001	SUB PICRO CHROMITE	0.35	33.50	33.54	9.82	0.00	0.00	22.70	0.00	0.34	100.63	0.00	0.00	0.03	0.11	0.23	0.09	0.18
KW96-69-001	SUB PICRO CHROMITE	1.35	37.45	17.76	19.47	0.00	0.00	24.36	0.00	0.22	100.93	0.00	0.01	0.02	0.24	0.05	0.19	0.04
KW96-69-001	SUB PICRO CHROMITE	2.42	36.18	28.57	14.22	0.00	0.00	18.99	0.00	0.27	100.89	0.00	0.03	0.00	0.16	0.07	0.12	0.05
KW96-26-001	CHROMITE	0.52	42.88	37.42	4.51	0.00	0.00	11.60	0.00	0.69	98.23	0.00	0.00	0.00	0.12	0.48	0.09	0.38
KW96-32-001	CHROMITE	0.50	42.10	38.20	2.64	0.00	0.00	10.56	0.00	2.22	97.43	0.00	0.00	0.00	0.02	1.20	0.01	0.96
KW96-36-001	CHROMITE	0.27	49.32	37.27	0.42	0.00	0.00	6.45	0.00	2.17	97.05	0.00	0.03	0.04	0.00	1.08	0.00	0.87
KW96-04-001	PICRO CHROMITE	0.20	43.68	18.74	15.52	0.03	0.00	22.32	0.00	0.25	100.96	0.00	0.01	0.01	0.14	0.07	0.11	0.05
KW96-04-001	PICRO CHROMITE	1.83	45.39	21.91	16.76	0.00	0.00	14.20	0.00	0.26	100.63	0.00	0.00	0.01	0.22	0.05	0.17	0.04
KW96-12-001	PICRO CHROMITE	2.03	40.82	22.97	16.07	0.00	0.00	17.08	0.00	0.21	99.44	0.00	0.00	0.00	0.20	0.06	0.16	0.05
KW96-24-001	PICRO CHROMITE	0.01	48.52	20.85	12.52	0.01	0.00	16.69	0.00	0.32	99.24	0.00	0.00	0.01	0.07	0.22	0.05	0.18
KW96-24-001	PICRO CHROMITE	0.34	40.45	24.69	13.28	0.00	0.00	20.29	0.00	0.29	99.64	0.00	0.00	0.00	0.11	0.20	0.09	0.16
KW96-24-001	PICRO CHROMITE	2.19	42.68	25.89	14.40	0.00	0.00	14.24	0.00	0.24	99.92	0.00	0.01	0.00	0.22	0.06	0.17	0.05
KW96-24-001	PICRO CHROMITE	0.04	41.85	15.71	15.90	0.00	0.00	26.02	0.00	0.27	100.01	0.00	0.01	0.00	0.07	0.13	0.06	0.11
KW96-24-001	PICRO CHROMITE	0.04	60.55	19.98	10.69	0.00	0.00	8.36	0.00	0.36	100.14	0.00	0.00	0.00	0.04	0.12	0.03	0.09

Sample#	Mineral ID (Gent, 1993)	TiO2	Cr2O3	FeO	MgO	CaO	SiO2	Al2O3	Na2O	MnO	Total	K2O	ZrO2	Nb2O5	NiO	ZnO	Ni	Zn
KW96-25-001	PICRO CHROMITE	0.37	45.33	26.58	17.08	0.11	0.00	9.65	0.00	0.26	99.59	0.00	0.00	0.00	0.18	0.03	0.14	0.02
KW96-25-001	PICRO CHROMITE	0.30	52.22	23.51	14.76	0.01	0.00	9.01	0.00	0.31	100.34	0.00	0.00	0.05	0.12	0.06	0.09	0.05
KW96-25-001	PICRO CHROMITE	0.14	53.72	24.99	10.97	0.00	0.00	10.09	0.00	0.41	100.57	0.00	0.00	0.02	0.10	0.13	0.08	0.11
KW96-25-001	PICRO CHROMITE	0.27	47.75	26.43	10.81	0.00	0.00	13.60	0.00	0.40	99.59	0.00	0.01	0.02	0.08	0.22	0.06	0.17
KW96-26-001	PICRO CHROMITE	0.45	53.13	21.15	15.96	0.00	0.00	8.85	0.00	0.25	100.00	0.00	0.00	0.00	0.17	0.03	0.13	0.02
KW96-26-001	PICRO CHROMITE	1.72	42.31	28.41	11.97	0.00	0.00	14.93	0.00	0.27	99.95	0.00	0.04	0.00	0.21	0.07	0.17	0.06
KW96-26-001	PICRO CHROMITE	1.40	40.93	25.01	13.82	0.01	0.00	18.62	0.00	0.34	100.53	0.00	0.01	0.00	0.23	0.18	0.18	0.14
KW96-26-001	PICRO CHROMITE	1.57	45.91	21.51	16.35	0.00	0.00	14.77	0.00	0.24	100.62	0.00	0.00	0.00	0.23	0.05	0.18	0.04
KW96-26-001	PICRO CHROMITE	0.03	51.34	23.16	10.13	0.00	0.00	14.58	0.00	0.39	99.98	0.00	0.01	0.02	0.05	0.27	0.04	0.22
KW96-26-001	PICRO CHROMITE	0.24	47.34	21.67	14.00	0.00	0.00	16.20	0.00	0.26	99.99	0.00	0.06	0.02	0.06	0.13	0.05	0.11
KW96-27-001	PICRO CHROMITE	0.34	52.93	18.48	16.13	0.00	0.00	12.50	0.00	0.24	100.88	0.00	0.02	0.01	0.19	0.05	0.15	0.04
KW96-28-001	PICRO CHROMITE	0.91	43.79	19.91	16.63	0.00	0.00	19.34	0.00	0.21	101.08	0.00	0.00	0.00	0.21	0.07	0.17	0.05
KW96-28-001	PICRO CHROMITE	0.16	46.00	16.26	17.25	0.00	0.00	20.98	0.00	0.29	101.20	0.00	0.07	0.02	0.15	0.05	0.12	0.04
KW96-29-001	PICRO CHROMITE	1.40	44.22	18.56	18.32	0.00	0.00	17.65	0.00	0.21	100.69	0.00	0.00	0.00	0.26	0.05	0.21	0.04
KW96-29-001	PICRO CHROMITE	0.25	51.05	18.63	15.98	0.01	0.00	14.30	0.00	0.29	100.71	0.00	0.00	0.00	0.15	0.05	0.12	0.04
KW96-30-001	PICRO CHROMITE	0.07	50.17	18.81	13.37	0.00	0.00	17.36	0.00	0.31	100.35	0.00	0.00	0.01	0.05	0.19	0.04	0.15
KW96-30-001	PICRO CHROMITE	0.95	43.50	21.09	15.57	0.00	0.00	18.47	0.00	0.30	100.23	0.00	0.02	0.03	0.23	0.06	0.18	0.05
KW96-30-001	PICRO CHROMITE	1.50	42.86	20.19	16.61	0.00	0.00	18.22	0.00	0.19	99.82	0.00	0.00	0.00	0.18	0.07	0.14	0.05
KW96-32-001	PICRO CHROMITE	0.02	53.87	21.17	11.16	0.00	0.00	13.72	0.00	0.38	100.57	0.00	0.01	0.01	0.03	0.20	0.03	0.16
KW96-32-001	PICRO CHROMITE	0.09	59.30	19.29	13.03	0.01	0.00	8.09	0.00	0.32	100.20	0.00	0.01	0.00	0.05	0.04	0.04	0.03
KW96-38-001	PICRO CHROMITE	1.65	41.71	25.79	13.13	0.00	0.00	16.58	0.00	0.28	99.44	0.00	0.02	0.00	0.21	0.08	0.17	0.06
KW96-40-001	PICRO CHROMITE	0.09	58.68	18.70	12.46	0.00	0.00	10.59	0.00	0.32	100.98	0.00	0.00	0.02	0.03	0.10	0.02	0.08
KW96-41-001	PICRO CHROMITE	0.23	40.51	28.54	10.74	0.00	0.00	18.68	0.00	0.37	99.52	0.00	0.02	0.01	0.14	0.28	0.11	0.22
KW96-44-001	PICRO CHROMITE	2.14	50.34	34.19	9.27	0.00	0.00	0.45	0.00	0.44	97.15	0.00	0.00	0.05	0.15	0.11	0.12	0.08
KW96-44-001	PICRO CHROMITE	0.37	48.73	20.89	19.87	0.00	0.00	9.92	0.00	0.45	100.49	0.00	0.00	0.00	0.18	0.06	0.14	0.05
KW96-44-001	PICRO CHROMITE	0.05	50.71	22.29	11.13	0.01	0.00	14.51	0.00	0.37	99.39	0.00	0.00	0.02	0.03	0.28	0.02	0.22
KW96-44-001	PICRO CHROMITE	0.09	42.13	17.76	15.66	0.00	0.00	24.80	0.00	0.24	100.92	0.00	0.00	0.02	0.11	0.13	0.09	0.10
KW96-45-001	PICRO CHROMITE	1.23	44.09	21.92	15.71	0.00	0.00	17.39	0.00	0.21	100.78	0.00	0.00	0.01	0.17	0.04	0.13	0.03
KW96-45-002	PICRO CHROMITE	0.25	56.40	20.06	12.95	0.00	0.00	9.26	0.00	0.30	99.43	0.00	0.04	0.00	0.08	0.09	0.06	0.07
KW96-46-001	PICRO CHROMITE	0.31	46.27	30.45	9.00	0.00	0.00	12.78	0.00	0.53	99.71	0.00	0.00	0.03	0.08	0.24	0.07	0.19
KW96-46-001	PICRO CHROMITE	0.02	55.47	21.72	10.50	0.00	0.00	11.15	0.00	0.43	99.49	0.00	0.00	0.01	0.02	0.16	0.02	0.13
KW96-46-001	PICRO CHROMITE	0.06	42.98	17.53	15.28	0.01	0.00	24.15	0.00	0.27	100.80	0.00	0.01	0.00	0.08	0.12	0.06	0.10
KW96-46-001	PICRO CHROMITE	0.33	48.19	27.88	12.69	0.00	0.00	9.78	0.00	0.38	99.48	0.00	0.00	0.01	0.14	0.07	0.11	0.06
KW96-46-001	PICRO CHROMITE	0.21	55.01	16.79	17.41	0.01	0.00	10.26	0.00	0.29	100.11	0.00	0.00	0.02	0.06	0.05	0.05	0.04
KW96-50-001	PICRO CHROMITE	0.18	47.67	22.90	12.88	0.00	0.00	15.47	0.00	0.42	99.71	0.00	0.00	0.01	0.09	0.10	0.07	0.08
KW96-50-001	PICRO CHROMITE	2.72	46.28	35.16	10.19	0.00	0.00	1.73	0.00	0.42	96.89	0.00	0.08	0.01	0.24	0.07	0.19	0.06
KW96-51-001	PICRO CHROMITE	3.93	48.37	25.11	13.66	0.00	0.00	7.66	0.00	0.37	99.37	0.00	0.00	0.03	0.16	0.07	0.13	0.06
KW96-51-001	PICRO CHROMITE	2.23	51.01	18.41	17.79	0.00	0.00	10.56	0.00	0.25	100.57	0.00	0.00	0.01	0.23	0.05	0.18	0.04
KW96-51-001	PICRO CHROMITE	2.29	57.51	19.61	14.95	0.00	0.00	5.62	0.00	0.30	100.49	0.00	0.02	0.00	0.13	0.06	0.11	0.05
KW96-53-001	PICRO CHROMITE	3.03	50.10	31.59	9.48	0.00	0.00	2.20	0.00	0.35	97.02	0.00	0.00	0.02	0.12	0.13	0.10	0.10
KW96-53-001	PICRO CHROMITE	2.95	50.01	31.42	9.36	0.00	0.00	2.16	0.00	0.42	96.54	0.00	0.00	0.00	0.12	0.11	0.10	0.08
KW96-53-001	PICRO CHROMITE	0.39	54.73	19.47	15.06	0.01	0.00	9.71	0.00	0.28	99.85	0.00	0.01	0.00	0.13	0.06	0.10	0.05
KW96-53-001	PICRO CHROMITE	3.02	50.73	31.85	9.15	0.00	0.00	2.10	0.00	0.38	97.47	0.00	0.00	0.00	0.12	0.11	0.10	0.09
KW96-53-001	PICRO CHROMITE	2.98	50.00	31.44	9.19	0.02	0.00	2.15	0.00	0.39	96.42	0.00	0.00	0.00	0.12	0.13	0.09	0.11
KW96-53-001	PICRO CHROMITE	1.85	51.18	20.42	15.73	0.00	0.00	11.02	0.00	0.23	100.70	0.00	0.06	0.00	0.17	0.04	0.13	0.03
KW96-53-001	PICRO CHROMITE	1.65	57.90	19.98	14.70	0.00	0.00	5.85	0.00	0.34	100.62	0.00	0.00	0.00	0.15	0.06	0.12	0.05
KW96-60-001	PICRO CHROMITE	0.03	58.19	22.59	8.19	0.00	0.00	9.03	0.00	0.49	98.90	0.00	0.04	0.02	0.04	0.29	0.03	0.23
KW96-60-001	PICRO CHROMITE	0.02	43.92	17.44	15.46	0.00	0.00	22.94	0.00	0.31	100.30	0.00	0.00	0.00	0.12	0.10	0.10	0.08
KW96-60-001	PICRO CHROMITE	0.38	42.67	21.37	13.86	0.00	0.00	20.55	0.00	0.28	99.42	0.00	0.03	0.01	0.13	0.13	0.10	0.11
KW96-61-001	PICRO CHROMITE	0.39	52.23	19.09	15.63	0.02	0.00	13.13	0.00	0.26	100.94	0.00	0.00	0.00	0.16	0.03	0.12	0.03
KW96-61-001	PICRO CHROMITE	0.52	46.74	20.02	16.45	0.00	0.00	15.90	0.00	0.23	100.05	0.00	0.00	0.02	0.14	0.04	0.11	0.04
KW96-61-001	PICRO CHROMITE	0.60	40.11	18.74	16.49	0.00	0.00	24.27	0.00	0.22	100.71	0.00	0.05	0.00	0.16	0.07	0.12	0.06
KW96-61-001	PICRO CHROMITE	0.28	47.74	24.64	11.93	0.00	0.00	13.98	0.00	0.34	99.11	0.00	0.01	0.00	0.06	0.14	0.05	0.11
KW96-61-001	PICRO CHROMITE	0.97	46.46	8.83	24.06	0.05	0.00	19.57	0.00	0.63	100.77	0.00	0.01	0.00	0.11	0.08	0.09	0.06
KW96-63-001	PICRO CHROMITE	0.65	40.82	31.56	14.57	0.00	0.00	11.20	0.00	0.30	99.35	0.00	0.00	0.02	0.18	0.05	0.14	0.04
KW96-63-001	PICRO CHROMITE	0.39	49.22	21.35	17.12	0.00	0.00	11.52	0.00	0.26	100.04	0.00	0.00	0.04	0.11	0.02	0.08	0.02
KW96-63-001	PICRO CHROMITE	0.22	48.30	23.67	12.31	0.01	0.00	14.98	0.00	0.39	100.18	0.00	0.04	0.00	0.09	0.17	0.07	0.13
KW96-63-001	PICRO CHROMITE	0.52	54.34	19.91	15.13	0.00	0.00	9.37	0.00	0.29	99.77	0.00	0.01	0.01	0.13	0.05	0.10	0.04
KW96-63-001	PICRO CHROMITE	1.14	43.99	18.85	17.28	0.00	0.00	19.19	0.00	0.19	100.94	0.00	0.00	0.02	0.26	0.03	0.20	0.02
KW96-63-001	PICRO CHROMITE	0.33	51.16	23.39	15.41	0.02	0.00	9.41	0.00	0.32	100.32	0.00	0.07	0.03	0.14	0.05	0.11	0.04
KW96-63-001	PICRO CHROMITE	0.53	55.16	17.50	17.82	0.02	0.00	8.28	0.00	0.24	99.83	0.00	0.03	0.01	0.23	0.02	0.18	0.01
KW96-64-001	PICRO CHROMITE	0.46	46.26	27.41	16.22	0.00	0.00	9.33	0.00	0.27	100.22	0.00	0.00	0.03	0.20	0.04	0.16	0.03
KW96-65-001	PICRO CHROMITE	0.12	50.63	21.79	11.82	0.00	0.00	15.56	0.00	0.37	100.57	0.00	0.00	0.01	0.05	0.21	0.04	0.17
KW96-65-001	PICRO CHROMITE	0.05	55.17	17.11	13.88	0.00	0.00	13.66	0.00	0.37	100.45	0.00	0.00	0.01	0.06	0.13	0.05	0.10
KW96-65-001	PICRO CHROMITE	0.11	52.53	22.11	11.67	0.01	0.00	12.78	0.00	0.36	99.78	0.00	0.00	0.02	0.06	0.12	0.05	0.10
KW96-66-001	PICRO CHROMITE	0.07	54.42	26.77	9.43	0.02	0.00	6.09	0.00	0.46	97.47	0.00	0.00	0.00	0.06	0.15	0.05	0.12
KW96-66-001	PICRO CHROMITE	0.12	41.72	21.47	13.08	0.00	0.00	23.05	0.00	0.33	100.11	0.00	0.01	0.00	0.07	0.26	0.06	0.21
KW96-67-001	PICRO CHROMITE	0.26	41.80	22.66	13.50	0.00	0.00	20.49	0.00	0.35	99.36	0.00	0.00	0.00	0.12	0.19	0.09	0.15
KW96-67-001	PICRO CHROMITE	0.29	51.45	24.64	11.04	0.00	0.00	11.35	0.00	0.38	99.35	0.00	0.00	0.02	0.08	0.11	0.06	0.09
KW96-67-001	PICRO CHROMITE	0.43	42.15	25.00	12.13	0.00	0.00	20.60	0.00	0.35	100.92	0.00	0.00	0.00	0.08	0.18	0.06	0.15
KW96-68-001	PICRO CHROMITE	0.05	47.99	27.40	8.79	0.01	0.00	15.35	0.00	0.47	100.35	0.00	0.00	0.00	0.06	0.23	0.05	0.18

Sample#	Mineral ID (Gent, 1993)	TiO2	Cr2O3	FeO	MgO	CaO	SiO2	Al2O3	Na2O	MnO	Total	K2O	ZrO2	Nb2O5	NiO	ZnO	Ni	Zn
KW96-69-001	PICRO CHROMITE	0.21	47.28	25.65	11.06	0.00	0.00	15.34	0.00	0.36	100.25	0.00	0.05	0.00	0.07	0.22	0.06	0.18
KW96-69-001	PICRO CHROMITE	0.36	47.82	25.02	14.97	0.01	0.00	11.81	0.00	0.33	100.50	0.00	0.00	0.00	0.11	0.06	0.09	0.05
KW96-69-001	PICRO CHROMITE	0.32	55.21	23.51	13.88	0.01	0.00	6.65	0.00	0.33	100.05	0.00	0.00	0.00	0.11	0.04	0.08	0.03
KW96-69-001	PICRO CHROMITE	0.38	41.15	24.81	13.68	0.00	0.00	20.03	0.00	0.28	100.54	0.00	0.00	0.00	0.13	0.08	0.11	0.06
KW96-69-001	PICRO CHROMITE	1.52	43.07	23.79	14.65	0.00	0.00	16.99	0.00	0.24	100.64	0.00	0.04	0.02	0.24	0.08	0.19	0.06
KW96-69-001	PICRO CHROMITE	1.26	47.53	18.71	17.07	0.00	0.00	15.24	0.00	0.24	100.32	0.00	0.03	0.00	0.22	0.02	0.17	0.02
KW96-69-001	PICRO CHROMITE	0.02	57.58	21.97	9.47	0.00	0.00	9.23	0.00	0.44	98.97	0.00	0.02	0.00	0.04	0.20	0.03	0.16
KW96-69-001	PICRO CHROMITE	2.07	42.78	23.62	16.14	0.00	0.00	15.68	0.00	0.22	100.77	0.00	0.00	0.00	0.20	0.05	0.16	0.04
KW96-69-001	PICRO CHROMITE	0.22	40.57	31.50	10.23	0.00	0.00	17.11	0.00	0.39	100.30	0.00	0.01	0.00	0.14	0.14	0.11	0.11
KW96-69-001	PICRO CHROMITE	0.01	58.89	23.37	8.72	0.00	0.00	5.89	0.00	0.44	97.54	0.00	0.00	0.00	0.03	0.20	0.02	0.16
KW96-69-001	PICRO CHROMITE	1.43	43.84	23.81	14.25	0.00	0.00	16.80	0.00	0.28	100.70	0.00	0.02	0.00	0.19	0.07	0.15	0.06

program (Gurney and Zweistra, 1995). The major and trace element geochemistry of the indicator minerals are plotted on simple scatter plots that include the outline of diamond inclusion compositions for corresponding minerals from worldwide localities (Gurney, 1984; Gurney and Zweistra, 1995; Fipke *et al.*, 1989, 1995; Gurney and Moore, 1993; Griffin and Ryan, 1995; and Kjarsgaard, 1997). This preferred diamond inclusion field (DIF) is indicative of a high grade of diamonds, and can help to provide a qualitative or at best, semi-qualitative estimate of diamond potential. The technique has proven successful in Botswana, Venezuela, Swaziland, Brazil, Colorado/Wyoming (USA) and in the North West Territories (Canada). Indicator mineral geochemical studies indicate that the target with the best sub-calcic garnets, the highest chrome chromites, the largest population of high sodium eclogitic garnets and the most magnesian ilmenites should be accorded highest priority in an exploration program (Fipke *et al.*, 1995). However, indicator mineral geochemistry is not unfailing and results from the Kuruman area (South Africa) and the Argyle (Australia) are examples of where the method does not work. It has become apparent that the technique is more difficult to apply to lamproites and accordingly, the Argyle field of chromites is highlighted for the chromite scatter plots. Scatter plots include: (1) CaO vs Cr_2O_3 (Figure 4) for high chromium peridotitic pyrope garnets; (2) CaO vs. Cr_2O_3 (Figure 5) for peridotitic chromium diopsides (>0.5 wt% Cr_2O_3); (3) CaO vs. MgO vs total Fe (as FeO) (Figure 6), CaO vs. TiO_2 (Figure 7), Na_2O vs. TiO_2 (Figure 8) and MgO vs. FeO (Figure 9) for eclogitic G3 and G5 garnets; (4) MgO vs total Fe as FeO (Figure 10), MgO vs. Cr_2O_3 (Figure 11) and FeO vs. Cr_2O_3 (Figure 12) for picroilmenites; and (6) MgO vs. Cr_2O_3 (Figure 13), Al_2O_3 vs. Cr_2O_3 (Figure 14), TiO_2 vs. Cr_2O_3, (Figure 15), Al_2O_3 vs. TiO_2 (Figure 16), Al_2O_3 vs. MgO vs. Cr_2O_3 (Figure 17), FeO vs. MgO vs. Cr_2O_3 (Figure 18) and Ni vs. Zn (Figure 19) for chromites.

6.3.1 Pyrope Garnets

Stream sediment sampling recovered one chrome pyrope garnet (G9) in the northeast part of the map area. Sample KW96-45 was collected from Gold Creek, approximately 9.8 km west of the Bald Mountain Fire Tower. This sample site yielded the most anomalous sample collected in the map area as it also yielded a diamond inclusion quality eclogitic garnet, a chromite and a picroilmenite. A second chrome pyrope garnet was recovered from sample site KW96-70, which was collected slightly north of the map area at Brian Campground on the Smoky River located on Highway 40 just south of Grande Prairie.

The garnets classify as G10 subcalcic chrome pyropes based on Dawson and Stephens (1975) classification of garnets (Quirt, 1992a,b; Gent, 1993), comprising low concentrations of TiO_2 with moderately high Cr_2O_3 and MgO. However, Figure 4 clearly shows that the garnets do not classify as G10 garnets using the classification of Gurney (1984) because of their moderately high concentrations of CaO. The G9 chrome pyrope garnets, which are typically much more abundant than G10 garnets, are difficult to use in prospect evaluation. However, in sufficient abundances they may be indicative of a local source rock such as kimberlite, lamproite or a related intrusion.

One high chrome grossular, possibly uvarovite garnet, yielding 10.24 wt% Cr_2O_3 was recovered from Bald Mountain Creek (KW96-68). The same indicator grain also yielded a high ratio of calcium (32.07 wt% CaO) versus magnesium (0.07 wt% MgO). Given the nature of the ultramafic discoveries in north central Alberta and the presence of positive kimberlite and lamproite indicator minerals, the

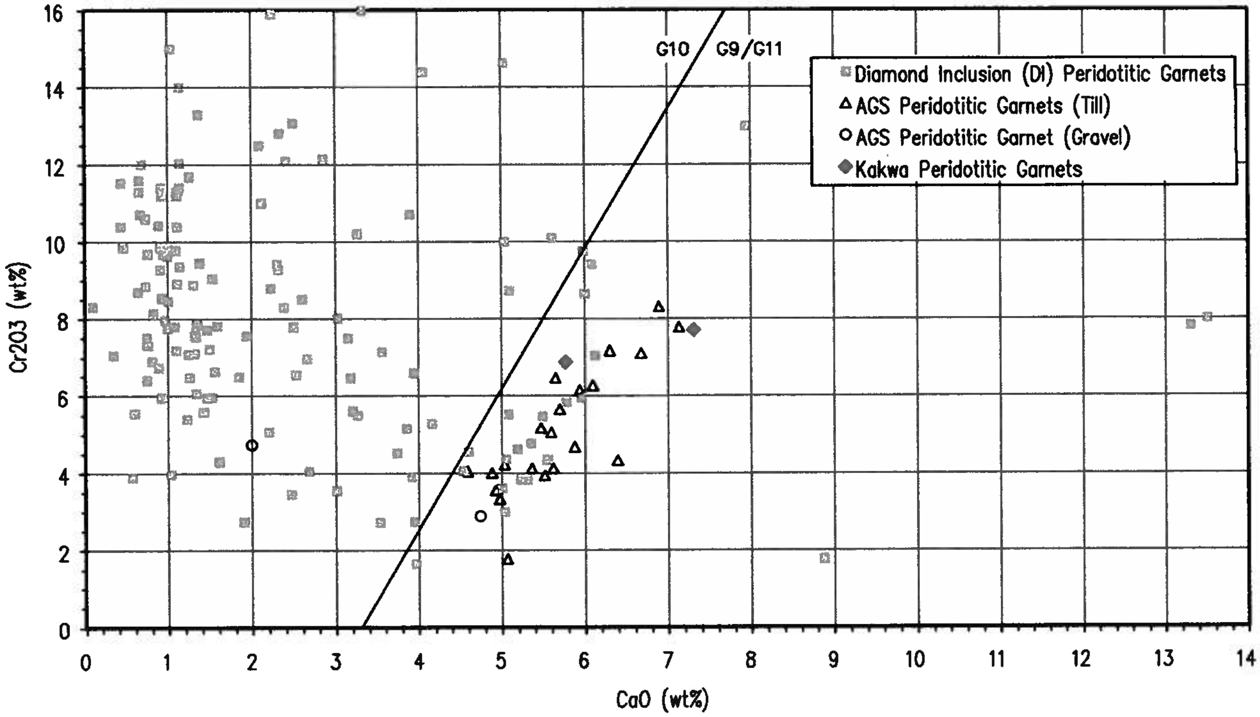


Figure 4. CaO vs Cr2O3 for peridotitic garnets from the Kakwa/Wapiti area and northern Alberta till and gravel (1995).

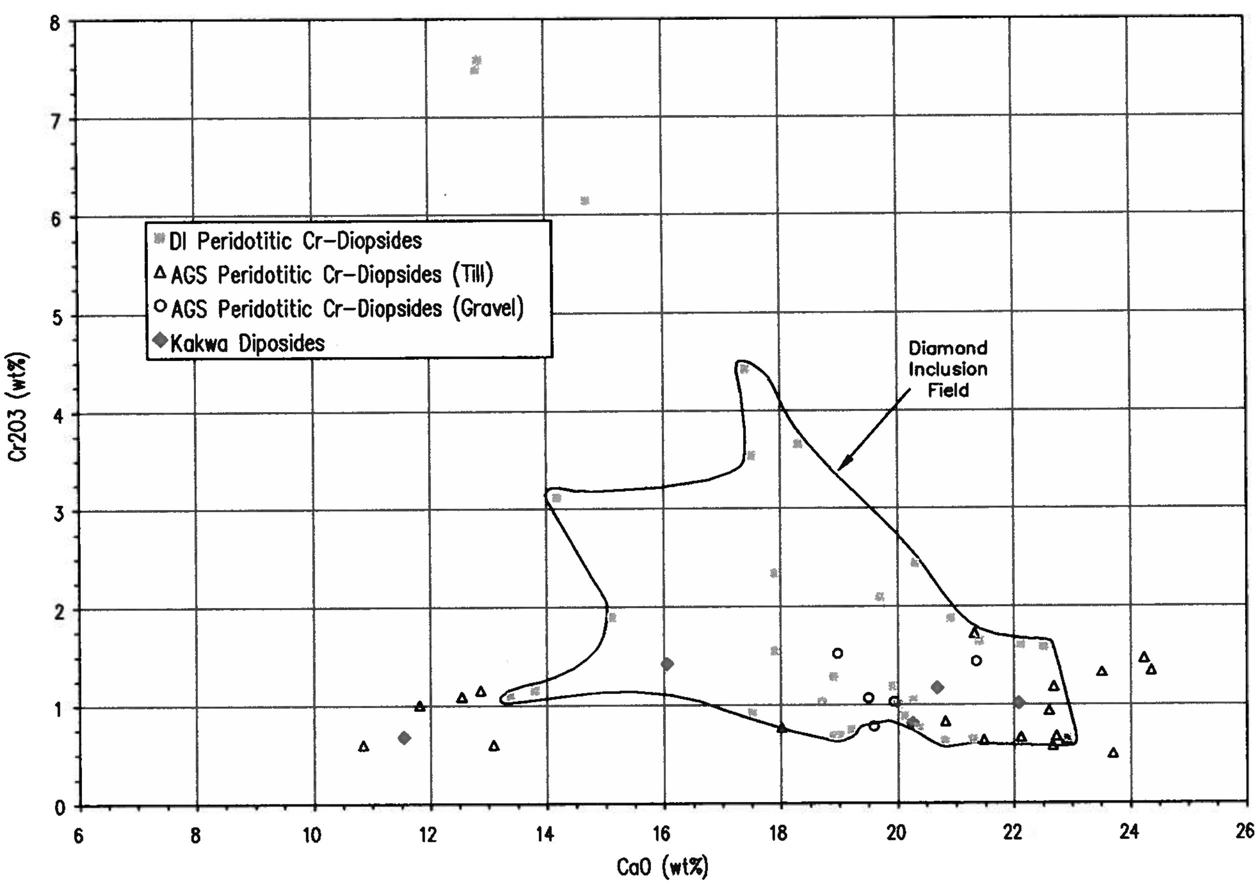


Figure 5. CaO vs Cr2O3 for peridotitic Cr- diopsides from the Kakwa/Wapiti area and northern Alberta till and gravel (1995).

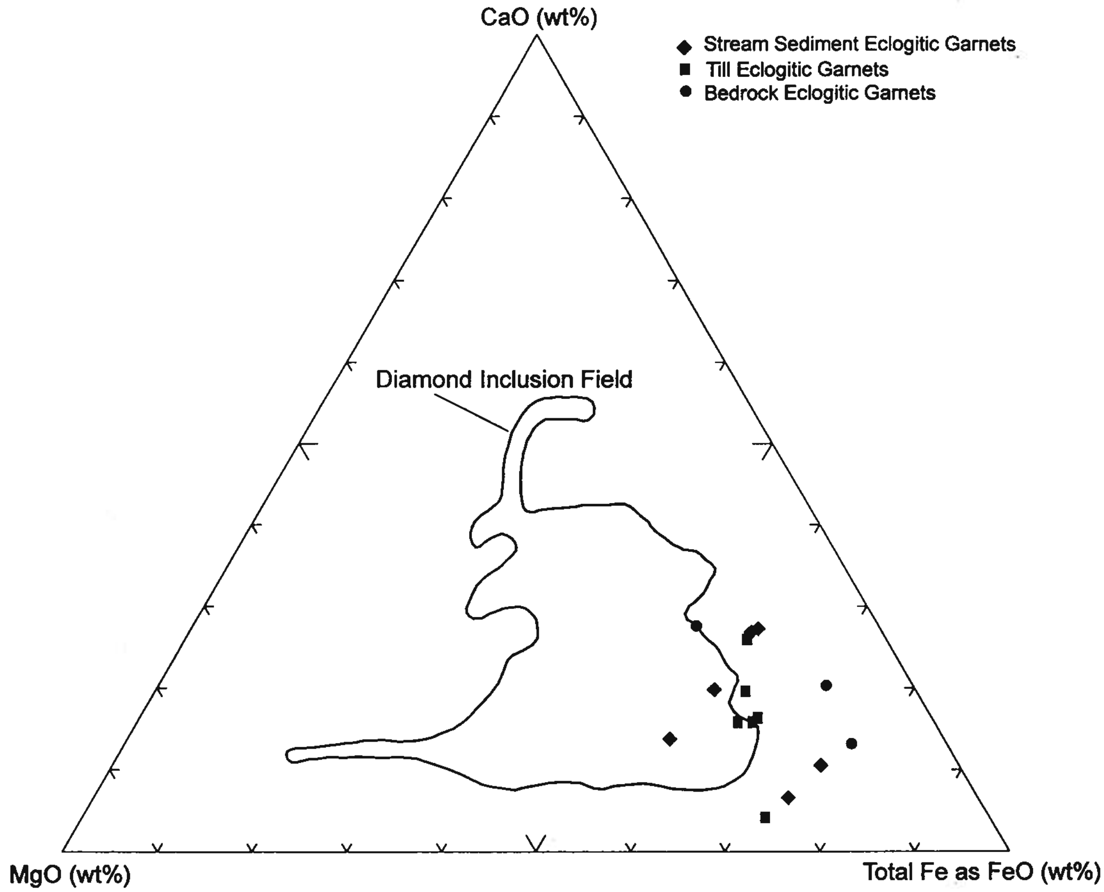


Figure 6. Ternary plot for Eclogitic Garnets from the Kakwa/Wapiti area, including till (Fenton et al., In Prep.) and bedrock (Langenberg et al., In Prep.).

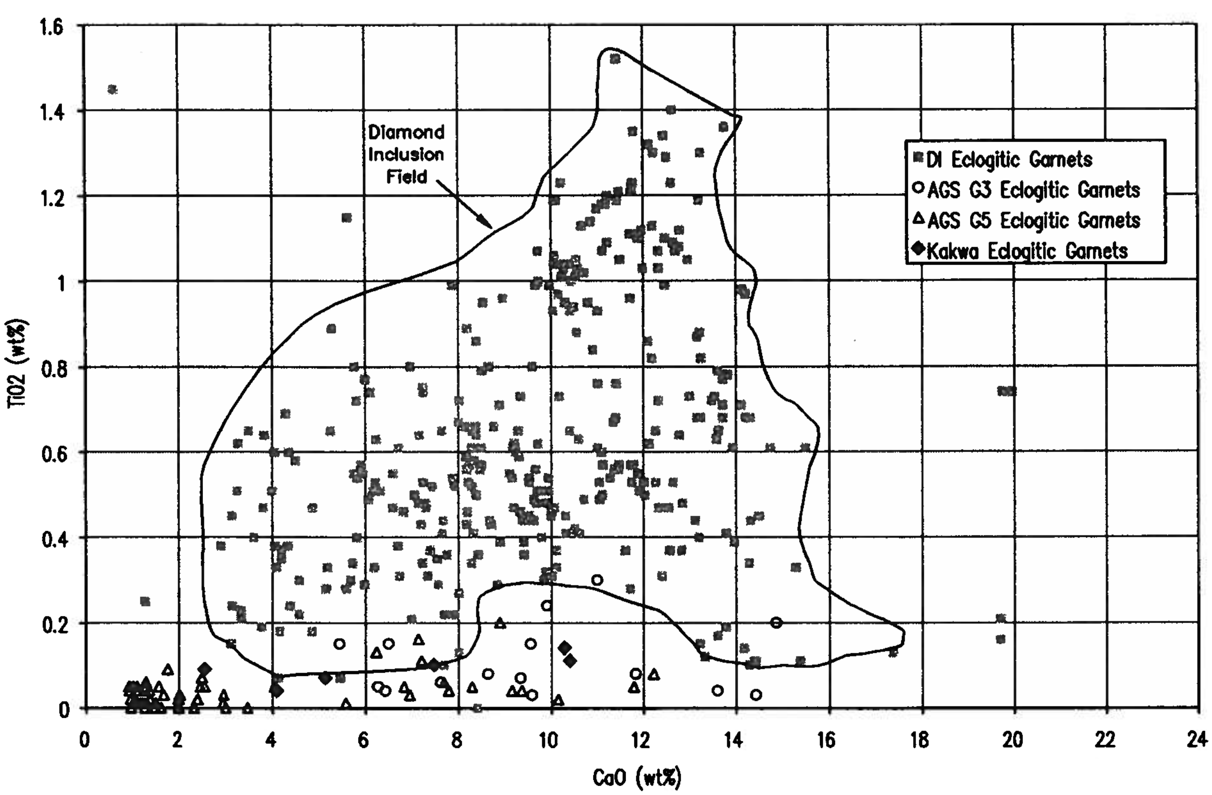


Figure 7. CaO vs TiO2 for eclogitic garnets from the Kakwa/Wapiti area and northern Alberta tills (1995).

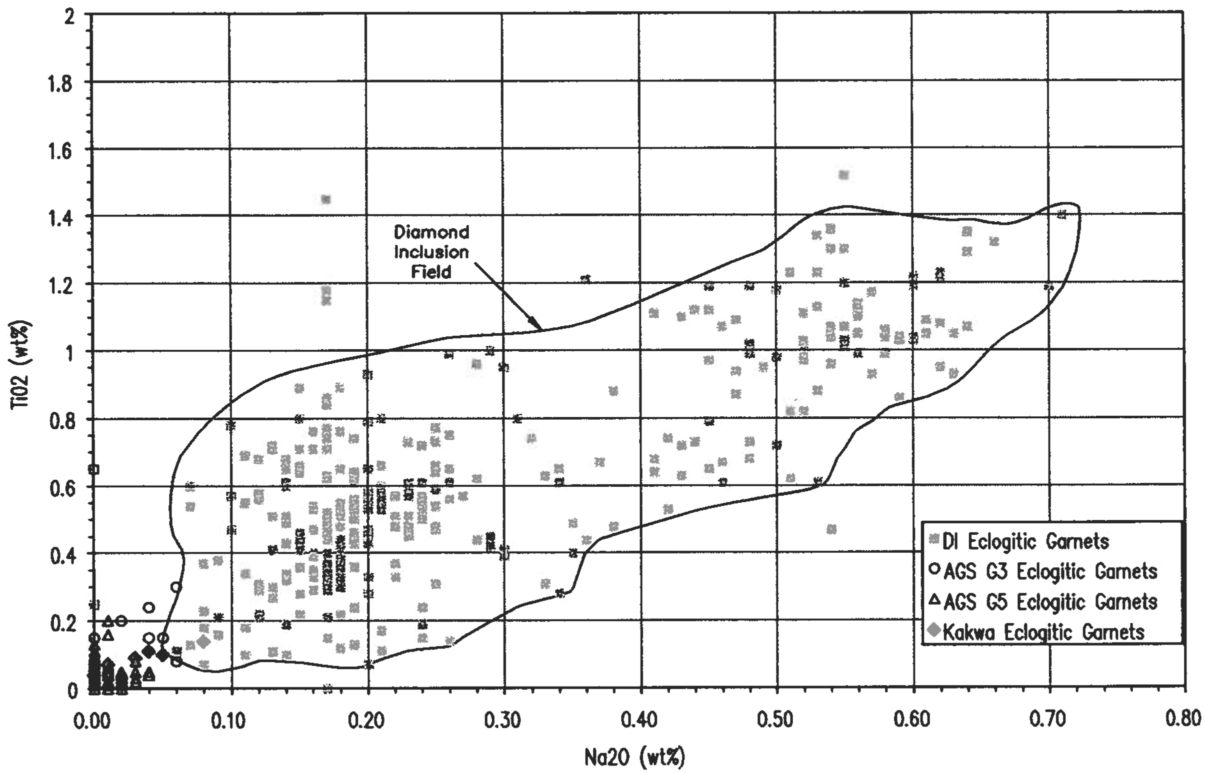


Figure 8. Na2O vs TiO2 for eclogitic garnets from the Kakwa/Wapiti area and northern Alberta tills (1995).

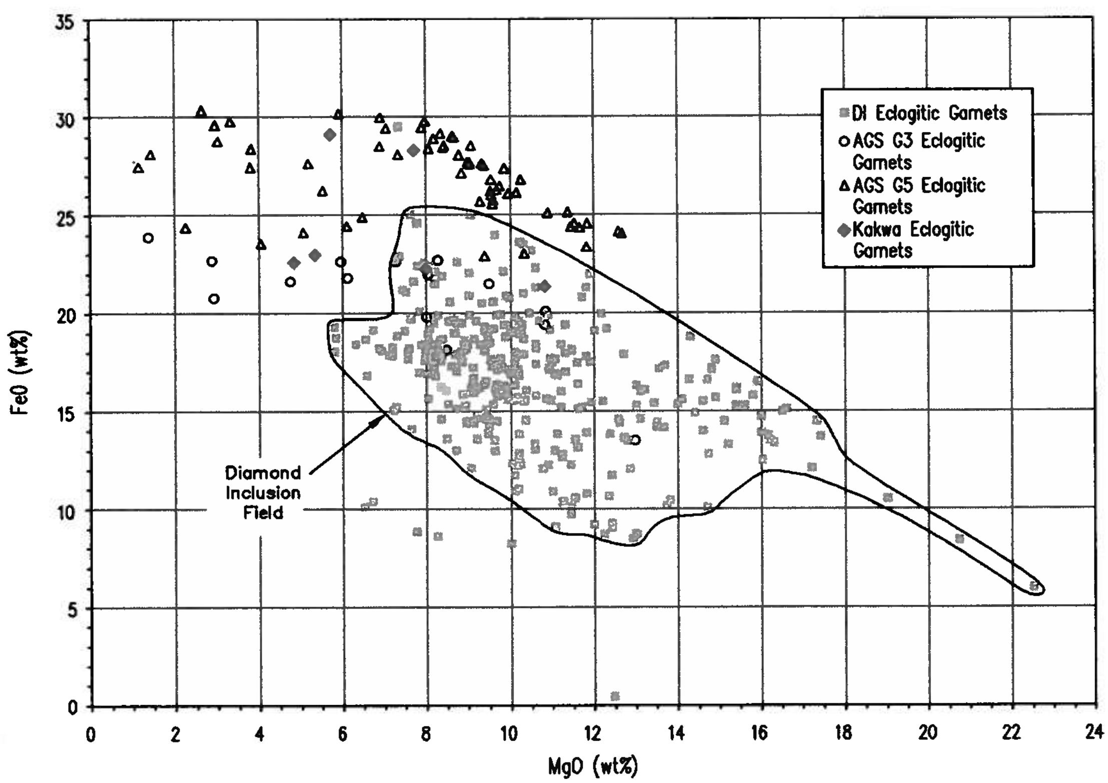


Figure 9. MgO vs FeO for eclogitic garnets from the Kakwa/Wapiti area and northern Alberta tills (1995).

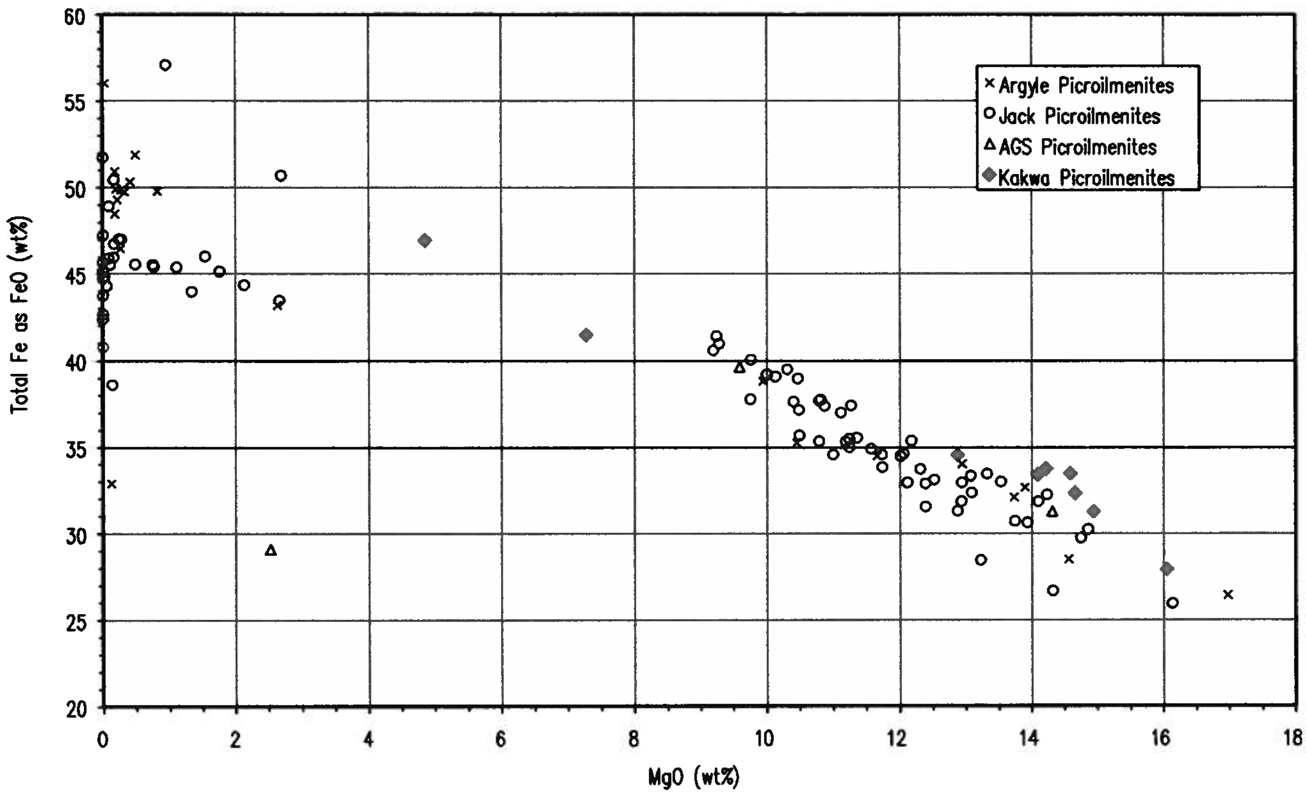


Figure 10. MgO vs Total Fe as FeO for picroilmenites from the Kakwa/Wapiti area and northern Alberta.

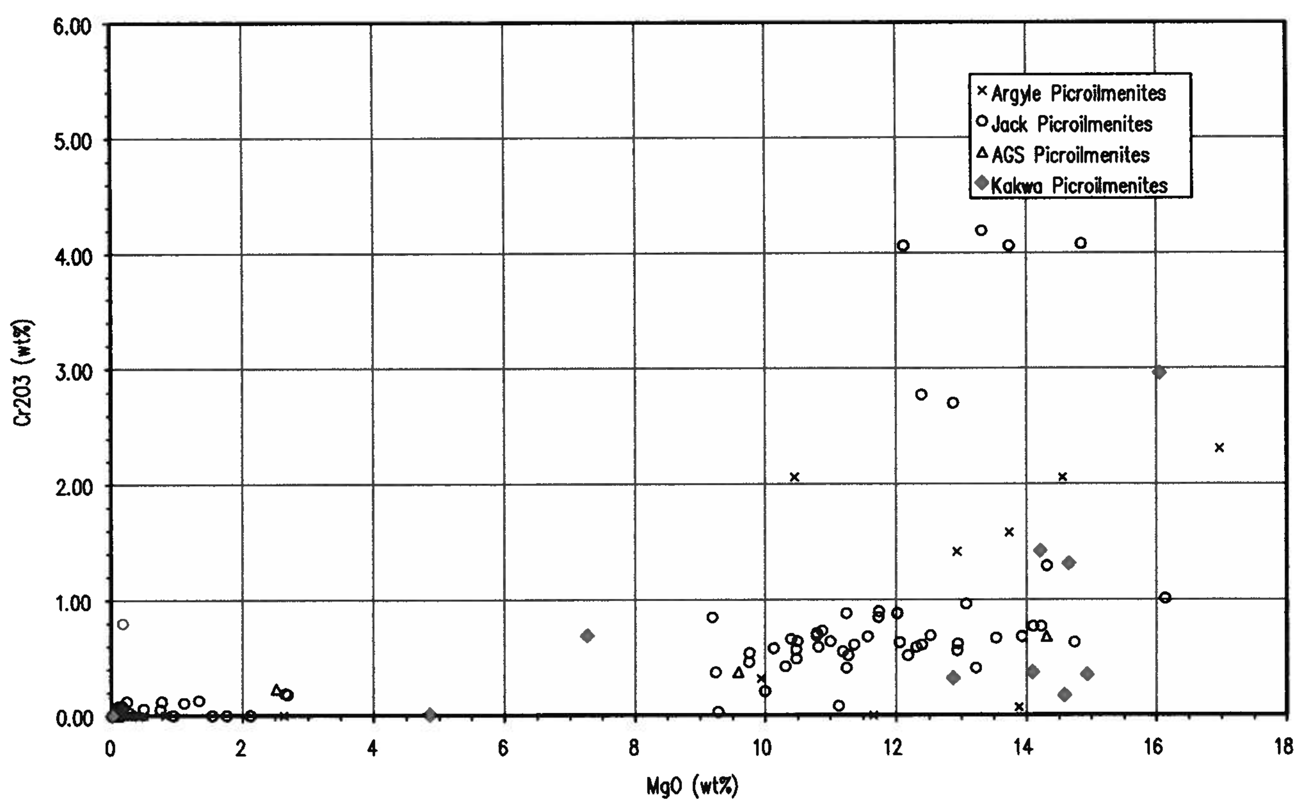


Figure 11. MgO vs Cr2O3 for picroilmenites from the Kakwa/Wapiti area and northern Alberta (1995).

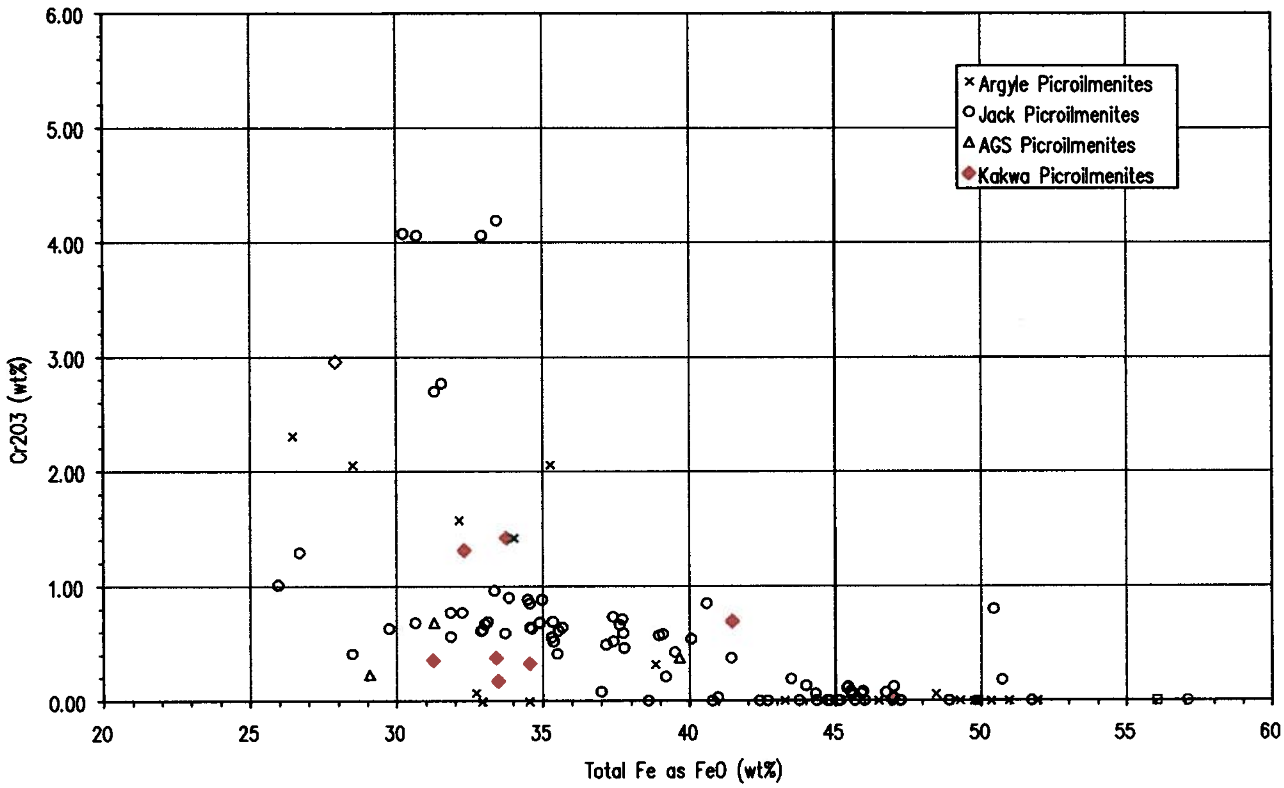


Figure 12. FeO vs Cr2O3 for picroilmenites from the Kakwa/Wapiti area and northern Alberta (1995).

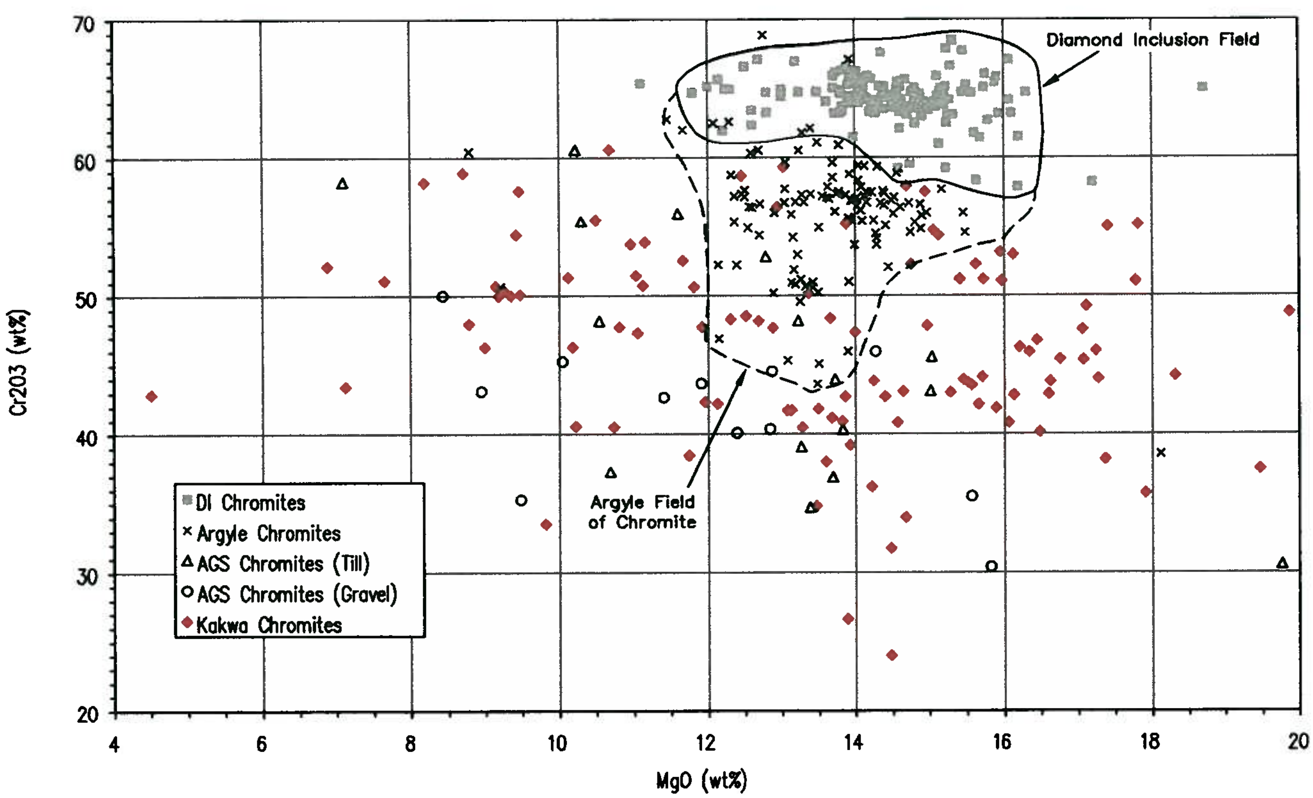


Figure 13. MgO vs Cr2O3 for chromites from the Kakwa/Wapiti area and northern Alberta till and gravel (1995).

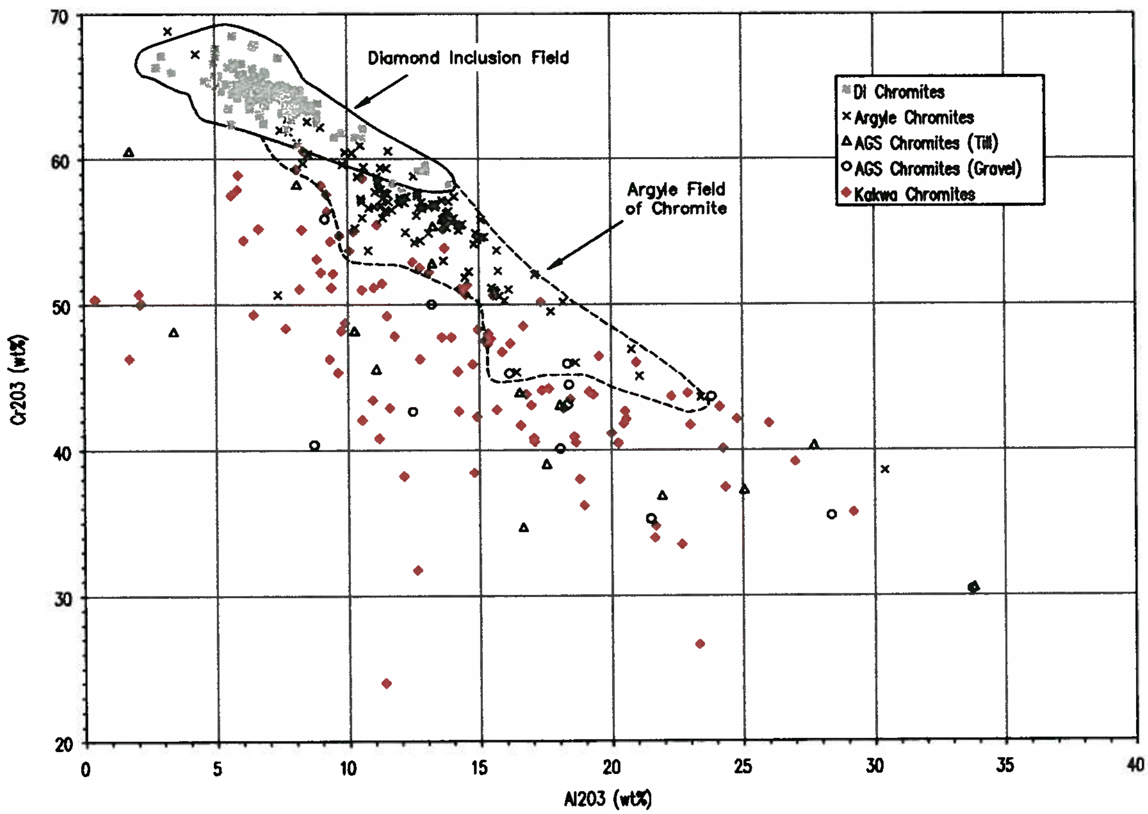


Figure 14. Al2O3 vs Cr2O3 for chromites from the Kakwa/Wapiti area and northern Alberta till and gravel (1995).

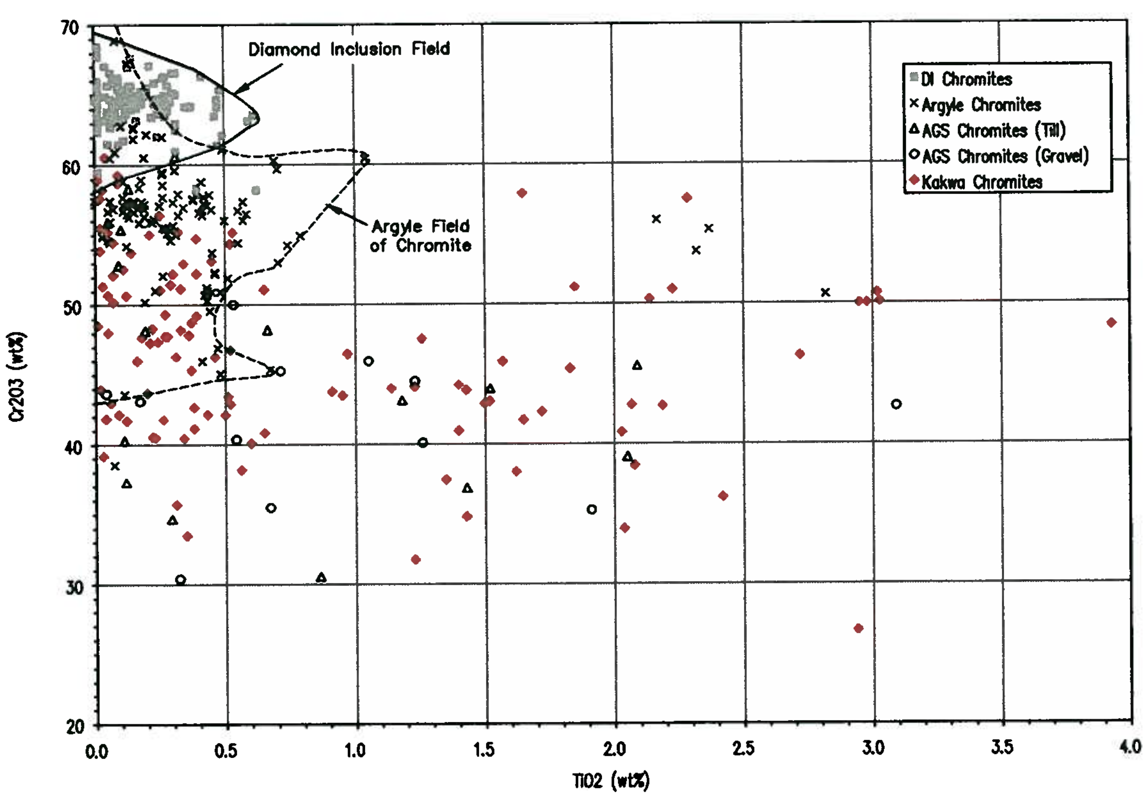


Figure 15. TiO2 vs Cr2O3 for chromites from the Kawka/Wapiti area and northern Alberta till and gravel (1995).

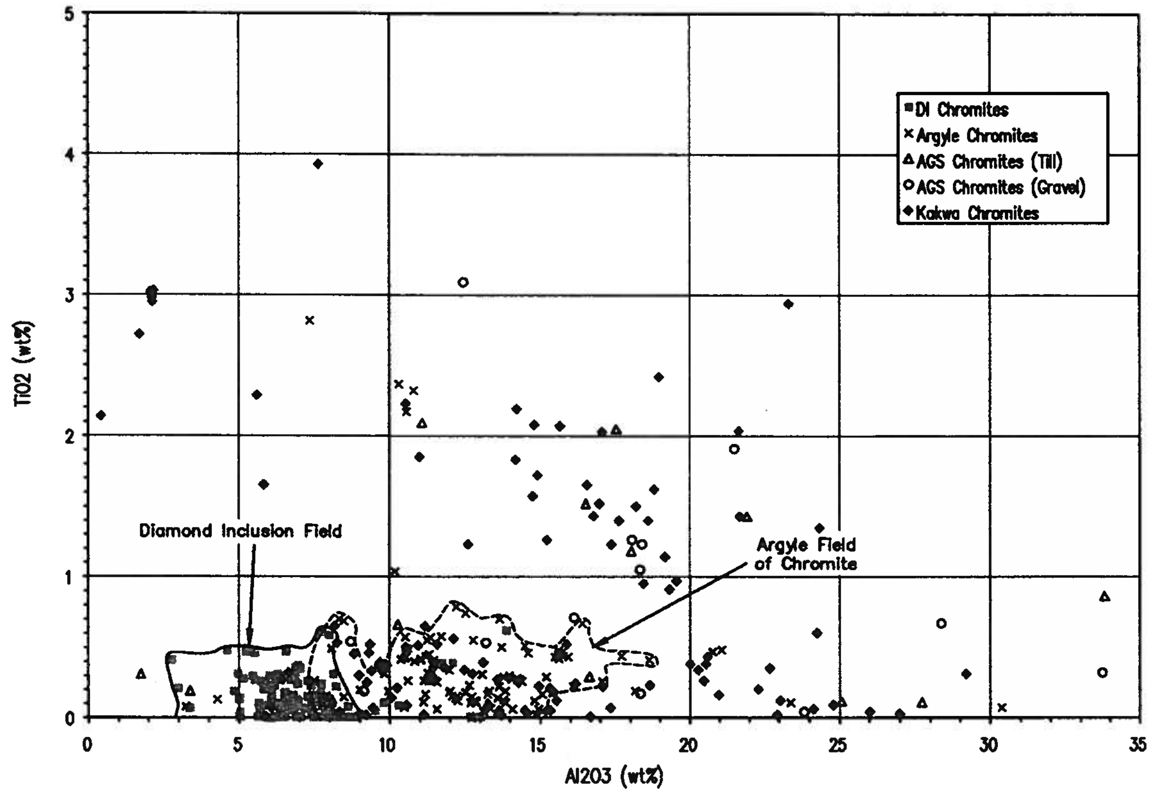


Figure 16. Al2O3 vs TiO2 for chromites from the Kakwa/Wapiti area and northern Alberta till and gravel (1995).

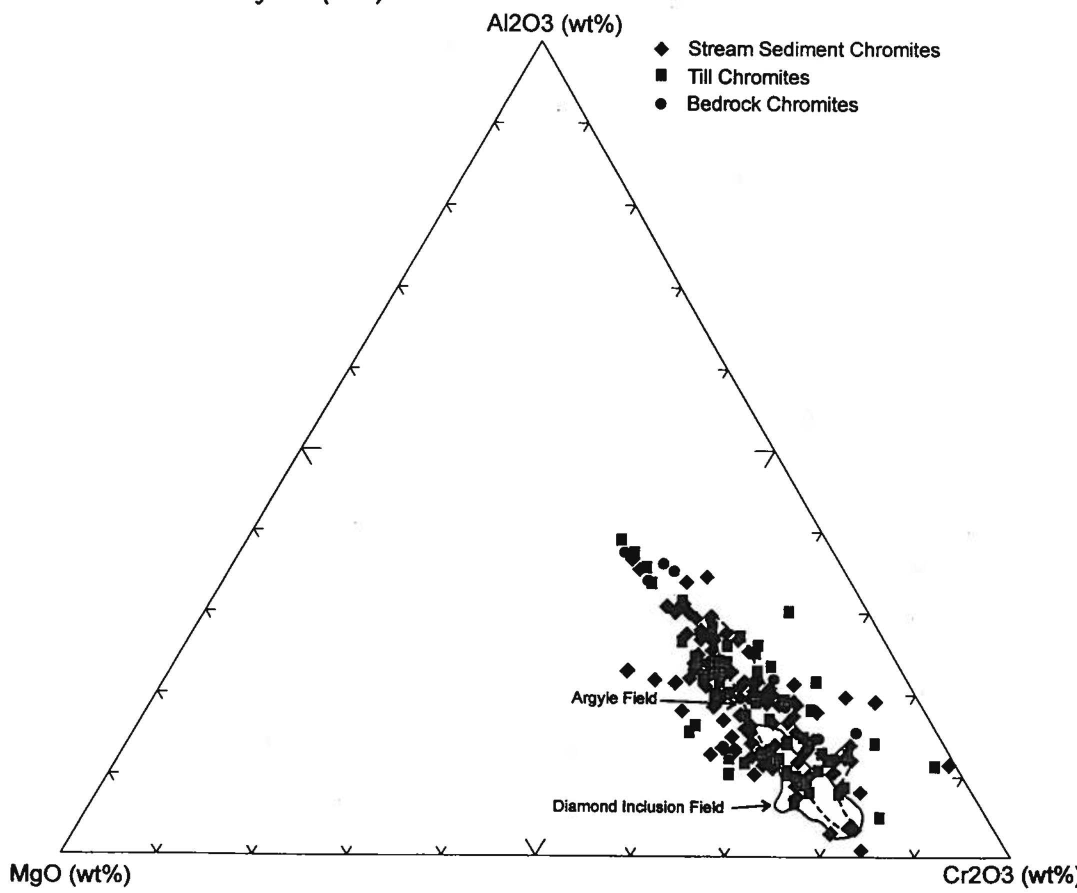


Figure 17. Ternary Al2O3, MgO and Cr2O3 plot for chromites from the Kakwa/Wapiti area, including till (Fenton et al., In Prep.) and bedrock (Langenberg et al., In Prep.).

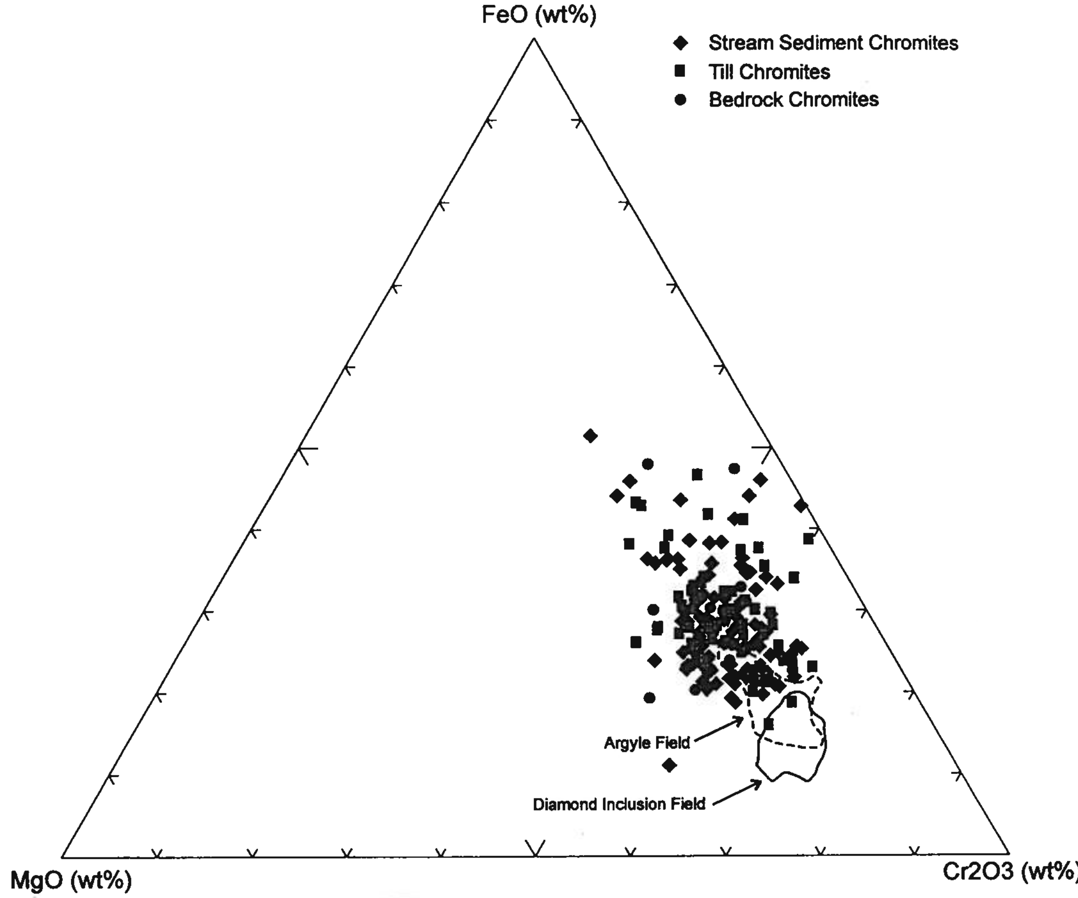


Figure 18. Ternary FeO, MgO and Cr2O3 plot for chromites from the Kakwa/Wapiti area, including till (Fenton et al., In Prep.) and bedrock (Langenberg et al., In Prep.).

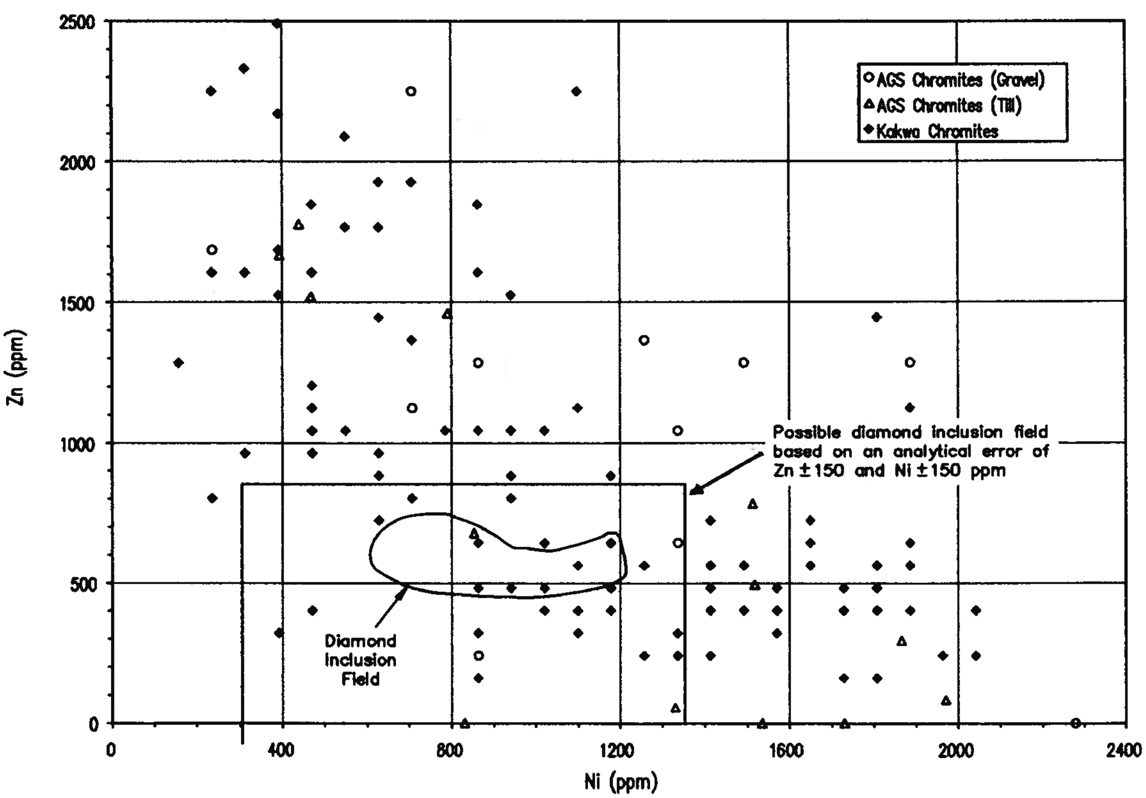


Figure 19. Ni vs Zn for chromites from the Kakwa/Wapiti area and northern Alberta till and gravel (1995).

high chrome grossular is more likely mantle xenocryst derived from CaO-rich nodules such as wehrlite than from highly under saturated volcanic rocks such as olivine basalts. In comparison, diamond indicator studies on core samples from the Mountain Lake Diatreme yielded a large number of low chrome (<0.5 wt% Cr_2O_3), ferro-magnesian grossulars (Eccles *et al.*, 1997).

6.3.2 Eclogitic Garnets

An increasing number of kimberlites are now recognized as having diamonds derived from eclogitic source rocks, on the basis of associated mineral inclusions (McCandless and Gurney, 1986; Otter and Gurney, 1988; Moore and Gurney 1985, 1989). A total of 6 potential eclogitic garnets were identified in 4 samples collected from the northern part of the map area. Three G3 eclogitic garnets (calcic pyrope almandines) were identified in three separate sample sites at the northern and northeastern edge of Bald Mountain from Gold Creek (KW96-45), from Lousy Creek (KW96-67) and from Bald Mountain Creek (KW96-68). Sample site KW96-12, which was collected from Pinto Creek, yielded one possible G3 eclogitic garnet and two possible G5 eclogitic garnets. The G3 eclogitic garnet is of marginal chemistry in comparison to diamond inclusion eclogitic garnets while the two G5 eclogitic garnets are of poor chemistry and are likely crustal garnets.

Chemical characteristics such as lower FeO contents, and moderate TiO_2 coupled with elevated Na_2O contents allow discrimination between eclogitic garnets that are potentially derived from diamondiferous samples from crustal and Cr-poor megacryst garnets, respectively (Schulze, in press). The eclogitic garnets that were recorded for samples KW96-45 and KW96-67 plot within the ternary CaO vs. MgO vs. total Fe (as FeO) diamond inclusion field (Figure 6) and contain Na_2O concentrations of 0.05 wt% and 0.01 wt%. McCandless and Gurney (1986) show that Na_2O in Group I eclogitic garnet averages 0.10±0.02 wt%. In contrast, Group II eclogitic garnet have an average Na_2O content of 0.05±0.03 wt%. The eclogitic garnet from sample KW96-68 plots near the boundary of the diamond inclusion field and should be noted with a Na_2O concentration of 0.08 wt%. However, it should be noted that the FeO concentrations from eclogitic grains collected in the Kakwa/Wapiti map area are high and yield between 21.36 wt% and 29.12 wt% FeO implying a possible crustal origin.

6.3.3 Chrome Diopsides

A total of five clinopyroxenes with >0.5 wt% Cr_2O_3 (chrome diopsides) were recovered from samples collected in the northwestern (1 grain), northeastern (1 grain), and eastern (2 grains) parts of the map area. The fifth grain was a sample collected from the Simonette River slightly east of the map area. Three of the five chrome diopsides yielded concentrations of >1 wt% Cr_2O_3. A grain from sample KW96-55, from the west arm of Lignite Creek, yielded the highest Cr_2O_3 concentration of 1.42 wt%.

Based upon a scatter plot of CaO vs. Cr_2O_3 for the chrome diopsides (Figure 5), four of the five chrome diopsides plot within the diamond inclusion field. They include chrome diopsides from samples KW96-50 from the Latornell River, KW96-53 from an unidentified creek that flows into the Smoky River, KW96-63 located on Calahoo Creek and KW96-55 from Lignite Creek. The fifth chrome diopside, which was from a sample collected east of the map area on the Simonette River

(KW96-13), is of insignificant chemistry.

6.3.4 Ilmenites

Ilmenites in lamproites and kimberlites can exhibit a wide compositional range with respect to Cr_2O_3 and MgO because they are derived from a variety of mantle and crustal rocks sampled by the ascending magma as well as the magma itself. Their major-element chemistry may be used as an index of oxidation and therefore may reflect diamond preservation potential. Mantle-derived ilmenite usually has elevated Cr_2O_3 indicative of its derivation from ultramafic source rocks; elevated MgO and low total FeO suggests low oxidation state in the magma, which appears to be crucial for diamond preservation and thus a useful additional tool in target evaluation (Gurney *et al.*, 1993; Gurney and Zweistra, 1995; Fipke *et al.*, 1995).

A total of 8 picroilmenites and 1 sub-picroilmenite were recovered from samples collected in the northern, central and Foothills parts of the map area. Sample KW96-45, which was collected from Gold Creek west of Bald Mountain, and KW96-48, which was collected from Smuland Creek in the western part of the map area, both yielded two picroilmenites.

Three picroilmenite grains from samples KW96-45, KW96-48 and KW96-64 yielded concentrations of >1.0 wt% Cr_2O_3, with the grain from sample KW96-48 containing a concentration of 2.96 wt% Cr_2O_3 (Figures 11 and 12). Seven picroilmenites from six different sample sites in the Kakwa/Wapiti map area yielded concentrations of >12 wt% MgO (KW96-07, KW96-40, KW96-45, KW96-48 - 2 grains, KW96-61 and KW96-64). One of the chromites from sample site KW96-48 yielded a concentration of 16.05 wt% MgO. This suite of seven high Mg picroilmenites all contain <35 wt% total Fe (as FeO) and exhibit a trend of decreasing FeO with increasing MgO (Figure 10), which is possibly indicative of high diamond preservation potential. The high Cr_2O_3 concentration of several of the grains may be indicative of either kimberlite or Cr-rich mantle source rocks that are brought to surface by kimberlite or related intrusions.

6.3.5 Chromites

The SRC picked the first 15 possible chromites from each heavy mineral concentrate and a total of 620 possible oxides were picked from the 60 sample sites in the Kakwa/Wapiti map area. The oxides were screened to detect possible chromite or picroilmenite grains with >3.5 wt% Cr and/or Mg. A total of 109 grains passed screening and were probed by an electron microprobe. Based on the mineral identification program developed by Quirt (1992a,b) and Gent (1993) microprobing yielded: 16 sub-picrochromites (>6 wt% MgO with <40 wt% Cr_2O_3), 3 chromites (<6 wt% MgO and >40 wt% Cr_2O_3) and 90 picrochromites (>8 wt% MgO and >40 wt% Cr_2O_3).

Chromites were recovered from 28 of the 35 sample sites that yielded indicator grains and are distributed throughout the map area. Anomalous areas, based on the number of chromites recovered in each sample, are located: (a) north and northwest of Bald Mountain from samples: KW96-46 (5 grains) from Stony Creek; and KW96-69 (13 grains) from Wilson Creek just before the confluence with Bald Mountain Creek; and (b) east of Bald Mountain including samples: KW96-25 (5 grains) from Steep Creek; KW96-26 (7 grains) from the Smoky River; and KW96-30 (6 grains) and KW96-53 (7 grains) from unidentified creeks flowing into the Smoky River. Sample sites in the rest of the map area contained between 1 and 4 chromite grains.

6.3.5a General Observations Based Upon Geochemistry

Chromites from kimberlites, lamproites or the mantle may show a wide variation in major and trace element chemistry. For exploration purposes, three compositional types of chromites are recognized as important including: (1) mantle xenocrysts of diamond inclusion field composition that contain high Cr (>60 wt% Cr_2O_3) together with moderate to high levels of Mg (10-16 wt% MgO) and low concentrations of Ti (<0.3 wt% TiO_2); (2) mantle xenocryst (P1 harzburgite and lherzolite) chromites that contain low Ti with high Cr and Mg; and (3) magmatic kimberlite and lamproite chromites with variable Cr and high Ti (P2 kimberlite) and high Mg with variable Cr (P3 lamproite) (Griffin *et al.*, 1992; Fipke, 1991; Fipke *et al.*, 1995).

Chromites from the Kakwa/Wapiti map area are characterized by 3 populations: (1) intermediate Ti and Al (1-2.5 wt% TiO_2 and 13-20 wt% Al_2O_3); (2) low Ti with variable Al (<1 wt% TiO_2 and 5-30 wt% Al_2O_3) with a large chromite population at 5-18% Al_2O_3, which overlaps the Argyle field of chromites; and (3) high Cr and Ti with low Al (>40 wt% Cr_2O_3, >2 wt% TiO_2 and <15 wt% Al_2O_3 with most <10% Al_2O_3) diagnostic of kimberlite and lamproite according to Fipke *et al.* (1996). Electron microprobe data for the 109 chromites from the Kakwa/Wapiti map area are presented in Table 1. General major and trace element observations from the data include:

- Only one sample (KW96-24), yielded a chromite with a Cr value of over 60 wt% Cr_2O_3 (60.55 wt% Cr_2O_3);

- Five chromites, from samples KW96-24-001, KW96-32-001, KW96-40-001, KW96-60-001 and KW96-69-001, yielded >58 wt% Cr_2O_3;

- A total of six chromites, from samples KW96-32, KW96-40, KW96-45, KW96-46, KW96-65 and KW96-69, yielded combined concentrations of Cr (>55 wt% Cr_2O_3), Mg (12-16 wt% MgO) and Ti (<0.35 wt% TiO_2) that are close to the diamond inclusion field;

- Titanium values are generally low, and 43 chromite grains yielded <0.3 wt% TiO_2. However, 12 chromite grains yielded >2% TiO_2 with >40% Cr_2O_3;

- Sixty-four grains comprise Cr concentrations of over 45 wt% Cr_2O_3, 67 grains comprise Mg values of between 8–15 wt% MgO, and a total of 44 chromites contain Al concentrations of between 2 and 12 wt% Al_2O_3. Twenty-three grains comprise the combined aforementioned compositions for kimberlitic chromites.

Compositional overlapping is a major problem in classifying chromites from kimberlites and lamproites versus chromites from other rock types including greenstone, ophiolite sequences, and layered ultramafic and mafic igneous complexes. These non-diamondiferous source rocks can yield chromites that overlap the kimberlite or lamproite chromite populations, or even high Cr and Mg diamond inclusion type chromites. Furthermore, several compositional populations of chromite may exist within any one kimberlite or lamproite pipe, and Griffin and Ryan (1992) have demonstrated that several sub-populations of chromite may exist within the xenocryst suite recovered from any one diatreme. Generalizations can be misleading and therefore, this study will evaluate the geochemical analysis of the chromites using the Griffin sub-populations and discriminant plot ranking techniques.

6.3.5b Griffin Sub-populations

The Griffin sub-populations were derived from proton microprobing over 1250 chromites selected from kimberlites, lamproites, South Africa and Siberia diamond inclusion chromites and garnet-chromite pairs from xenoliths and concentrates (Griffin *et al.*, 1992). The populations are comprised of the following fields: P1 includes Group I chromite harzburgite sources; P2 includes chromites from Group II kimberlites; and P3 and P4 include most chromites from lamproites. Concentrations of Cr_2O_3, TiO_2, Al_2O_3, Fe_2O_3, MgO, Zn and Ni were used to classify the Kakwa/Wapiti chromite grains into Griffin's ranking of chromite sub-populations. Gallium was not analyzed in this study. The chromite grains that satisfied classification into the following sub-populations include:

- Diamond inclusion field chromites - 2 grains
  KW96-24 and KW96-32
- Harzburgite and lherzolite xenocrysts or macrocrysts - 12 grains
  KW96-25, KW96-26, KW96-30, KW96-32, KW96-40, KW96-44, KW96-45, KW96-46, KW96-65 (3 grains) and KW96-67
- P3 magmatic lamproites - 5 grains
  KW96-25, KW96-46, KW96-61, KW96-63 and KW96-69
- P4 lamproite macrocryst - 3 grains
  KW96-24, KW96-26 and KW96-60

While the Griffin ranking classification does indicate that chromites from the Kakwa/Wapiti area contain potential indicators of kimberlite and lamproite hosts, it also reveals that a large number of chromites do not classify in any sub-population based upon Griffin's ranking system. This may mean that many of the chromites are derived from other rock types or that Griffin's database, which is based mostly on South African and Australian chromites, may not be useful for North American comparisons.

6.3.5c Discriminant Plot Ranking

During the initial stages of exploration in Alberta, and until more definite sub-populations of chromites can be defined, it may seem more logical to rank the Kakwa/Wapiti chromites based on a series of major and trace element X-Y scatter plots, including MgO vs. Cr_2O_3 (Figure 13); Al_2O_3 vs. Cr_2O_3 (Figure 14); Al_2O_3 vs. MgO vs. Cr_2O_3 or Al ternary (Figure 17); TiO_2 vs. Cr_2O_3 (Figure 15); Al_2O_3 vs. TiO_2 (Figure 16); FeO vs. MgO vs. Cr_2O_3 or Fe ternary (Figure 18); and Ni vs. Zn (Figure 19) show the relation of the Kakwa/Wapiti chromite grains in comparison to the diamond inclusion field of chromites and the Argyle Deposit, Australia field of chromites. The proximity of the chromite grains to the diamond inclusion field and the Argyle field of chromites in each of the scatter plots is recorded and used to develop an overall ranking for chromite grains from the Kakwa/Wapiti study area. This method was developed for AGS Bulletin No. 63 (Dufresne *et al.*, 1996), and has been used to document potential diamond indicator trends in Alberta. The ranking technique highlights the necessity of forecasting using a variety of grains, and that ranking is not solely classified on a single grain.

A chromite grain from sample site KW96-24 ranked as the best in this data set because it plotted in, or close to, a number of diamond inclusion fields and contains comparable chemistry to diamond inclusion chromites (Table 1). The grain plotted within the diamond inclusion fields for Cr_2O_3 vs. MgO, Cr_2O_3 vs. Al_2O_3, and Cr_2O_3 vs. TiO_2; and plotted close to the diamond inclusion field on both the Fe and Al ternaries and the Ni vs. Zn. Nickel-Zinc concentrations have been used as a discriminant to predict whether xenocryst chromites crystallized within the diamond stability field (Griffin *et al.*, 1992).

Grains from KW96-32, KW96-45, KW96-65 and KW96-69 ranked as second priority sites with excellent Ni vs. Zn concentration in combination with other elements comparable to diamond inclusion chromites. A grain from KW96-32 plotted within the diamond inclusion fields for Cr_2O_3 vs. TiO_2, Zn vs. Ni, and on the Al ternary; and close to the diamond inclusion field for Cr_2O_3 vs. Al_2O_3 and the Fe ternary. A grain from sample KW96-45 yielded values of Ni and Zn that plot within the diamond inclusion field for Ni vs. Zn and the Al ternary. Grains from samples KW96-65 and KW96-69 plot close to the diamond inclusion field for Zn vs. Ni and plot within the Argyle field of chromites on several scatter plots.

Seventeen stream sediment chromites yielded >2 wt% TiO_2, of which 12 chromites yield >40 wt% Cr_2O_3 and 10 chromites yield <15 wt% MgO. Chromites with >40 wt% Cr with high Ti - low Al are diagnostic of kimberlite and lamproite according to Fipke *et al.* (1996). It is interesting to note, that this third population of high Ti and low Al was discovered in stream sediment heavy mineral concentrates only; i.e. the chromite population was not defined in the chromites collected from till or bedrock sampling (Fenton and Pawlowicz, In Prep.; Langenberg *et al.*, In Prep.). In particular, samples KW96-51 and KW96-53, and possibly KW96-50, KW96-56 and KW96-44, may indicate that the chromites are locally derived and not derived from tills in the north and northeast.

Many of the chromites from the Kakwa/Wapiti area appear to be magmatic in nature and rank lower in terms of diamond potential. However, these chromites may be of importance since they yield concentrations of >2 wt% TiO_2 with >40 wt% Cr_2O_3, and may be derived from kimberlites and lamproites. The presence of high Ni (>600 ppm Ni) and low Zn (<700 ppm Zn), and high Cr-Ti chromites is indicative that the chromites were most likely formed within the diamond stability field (Fipke, 1995).

The Zr and Nb concentrations of the chromites were also analyzed. The presence of Zr or Nb at or exceeding 6 ppm can indicate that a chromite grain has resided in a highly alkaline magma such as kimberlite, lamproite or ultramafic lamprophyre (Griffin and Ryan, 1995). The electron microprobe detection limits for Zr and Nb are 400 ppm and 150 ppm, and are far too large to properly model using 6 ppm as a cut-off. However, the grains with elevated Zr and Nb can be recorded and, if necessary, selected for further work with the accuracy of a proton microprobe. The average proton microprobe has a minimum detection limit for Zr and Nb in chromites of 3-4 ppm. Grains from sample sites KW96-07, KW96-40, KW96-45 (2 grains), KW96-48, KW96-61, KW96-64 contained elevated amounts of Nb. Grains from sample sites KW96-26, KW96-28, KW96-40, KW96-45, KW96-50, KW96-53, KW96-61, KW96-63 yielded elevated concentrations of Zr.

6.3.5d Kakwa/Wapiti Chromites and Their Comparison to Other Alberta Chromites

Chromites from the Kakwa/Wapiti area and the Mountain Lake Diatreme yield geochemically similar characteristics, and comprise chromites that overlap the Argyle field of chromites on all scatter plots except for poor overlap for Cr_2O_3 vs. Al_2O_3. A heavy mineral geochemical study from drill core of the Mountain Lake Diatreme yielded chromites with a wide range in major and trace element chemistry, including a distinct population of high Ti - low Al chromites (Eccles *et al.*, 1997). The population of high Ti and low Al chromites with high concentrations of Cr are characteristic of kimberlites or lamproites, and are not commonly found within any other ultramafic alkalic rocks (Fipke *et al.*, 1996). The Mountain Lake Diatreme also contains a population of low Ti, low Al, high Mg chromites that approach the diamond inclusion field, but lack sufficient concentrations of Cr to overlap the diamond inclusion field. The chromites from the Kakwa/Wapiti area and the Mountain Lake Diatreme exhibit a similar trend from intermediate to high Ni and low Zn to low Ni and high Zn concentrations. The Mountain Lake Diatreme chromites yield a geochemical trend indicative of magmatic evolution similar to that of a lamproite, Type 2 kimberlite or related alkaline ultramafic rocks as defined by Mitchell (1989).

Stream sediment and bedrock sampling by government and industry indicate that the Foothills of Alberta have yielded abundant chromites from northwest of Calgary to Grande Cache (Dufresne *et al.*, 1996; Ballantyne, and Harris, 1994; Langenberg and Skupinski., 1996; Sraega, 1994; Drever and Matthews, 1995). The Hinton Trend yields similar populations to the Kakwa/Wapiti chromites as exhibited by concentrations of Ti and Al, and has a large population that overlaps the Argyle field of chromites and yields diamond inclusion field chromites. The Hinton area is currently being explored on the basis of the appearance and chemistry of chromites.

A major difference observed between Kakwa/Wapiti chromites and chromites from the Mountain Lake Diatreme and the Peace River and Wabasca Trends is that one population from the Kakwa/Wapiti chromites yields high Cr, high Mg, low Ti and low Al xenocrystic diamond inclusion chromites. Also, surveys across Alberta, including the Hinton Trend, have reported chromites that yield limited high Ti (>2 wt% TiO_2) and high Cr (>40 wt% Cr_2O_3) concentrations (Dufresne *et al.*, 1996).

6.4 Discussion and Conclusions

For the most part, the Foothills area from northwest of Calgary to Grande Cache is known as a chromite province. The Kakwa/Wapiti area is no exception, however, the presence of some very favorable silicate indicator minerals in conjunction with several excellent chromites may indicate a high potential for the presence of diamondiferous kimberlites and lamproites in the map area.

Anomalous areas in the Kakwa/Wapiti map area were depicted by the abundance of diamond indicator minerals and the quality of the chemistry for selected minerals such as peridotitic garnets, eclogitic garnets, chrome diopsides, picroilmenites and chromites, in comparison to the chemistry of kimberlite, lamproite and diamond inclusion minerals. The stream sediment survey, and subsequent ranking of diamond indicator minerals, delineated at least 6 anomalous areas in the Kakwa/Wapiti map area (Figure 20; in pocket).

(1) Northeast Map Area

A trend of 13 sample sites from Bald Mountain Creek to just west of the Latornell River, yielded abundant chromites in combination with other important indicator minerals including high quality eclogitic garnets, picroilmenites, G9 pyropic garnet and chrome diopsides. Four of these 13 sample sites yielded excellent combinations of indicator minerals including KW96-45, KW96-53, KW96-67 and KW96-68.

Sample site KW96-45 yielded multiple diamond indicator minerals of high quality chemistry. Indicator minerals include: one low calcium chrome pyrope garnet; one eclogitic garnet that plots within the diamond inclusion field and yields a Na_2O concentration of 0.05 wt%; two picroilmenites including one with >1.0 wt% Cr_2O_3; two picrochromites and a chromite grain which plots within the diamond inclusion field on the Al ternary and Zn vs. Ni scatter plots.

Sample sites KW96-53, KW96-67 and KW96-68 yielded one or more diamond indicator minerals of good to high quality chemistry and require follow-up exploration. Sample KW96-53 yielded one chrome diopside and seven chromites including four chromites that yielded concentrations of >2 wt% TiO_2 and >50 wt% Cr_2O_3, and may represent kimberlitic/lamproitic chromites. It is worth noting that sample sites KW96-51 ± KW96-44, KW96-50 and KW96-69 yielded chromites with kimberlitic/lamproitic geochemistry similar to that of KW96-53. KW96-67 yielded one eclogitic garnet, which plots in the diamond inclusion field, and three picrochromite grains. KW96-68 yielded one eclogitic garnet, which plots close to the diamond inclusion field, and one picrochromite. In addition, sample site KW96-69 located in Wilson Creek directly above the confluence with Bald Mountain Creek (and KW96-68), yielded several chromites, including one that plots within the diamond inclusion field on the Zn vs. Ni scatter plot.

Other anomalous sites in the northeast corner of the map area include KW96-26, KW96-30, KW96-32 and KW96-46, which yielded one or more moderate to good quality diamond indicator minerals. One of the three chromites collected at sample site KW96-32 yielded high quality chemistry and contains comparable chemistry to diamond inclusion chromites.

The lack of till sampling in the northeast area (to date) make it very difficult to determine the source of the indicator minerals. However, the number of anomalous sites, number of indicators at these sites and the quality of the indicator grains suggest good potential for local sources. The northeast corner of the map area ranks high in the assessment scheme for diamond potential;

(2) Smoky River Headwaters

A single site (KW96-24) yielded 5 chromites in the vicinity of the headwaters of the Smoky River in the south-central part of the map area. One of the chromites has the highest Cr content (60.5 wt% Cr_2O_3) in this data set, and is a good diamond inclusion chromite. The sample site also yielded a high Ti-Cr kimberlitic/lamproitic chromite. Tills collected by the AGS yielded high quality chromites that plot in the diamond inclusion field (Fenton and Pawlowicz, In Prep.);

(3) Narraway River Headwaters

Two sample sites (KW96-60 and KW96-61), in the Front Range near the headwaters of the Narraway River, yielded one or more moderate to good quality diamond indicator minerals. KW96-61 yielded 5 chromites, including one with similar chemistry to P3 magmatic lamproite chromites, and one picroilmenite which yielded 14.94 wt% MgO. KW96-60 yielded 4 chromites, including one grain with similar chemistry to P4 macrocryst lamproite chromites.

(4) Cutbank River Drainage Area

A broad cluster of 4 sites yielded chromites and picroilmenites from the central plateau, Cutbank River drainage area (KW96-07, KW96-25, KW96-38 and KW96-40). KW96-07 and KW96-40 yielded picroilmentites with >12 wt% MgO. Sample sites KW96-25, KW96-38 and KW96-40 yielded 5, 2 and 1 chromites respectively with moderate to good chemistry. A single chromite from KW96-40 plots close to the diamond inclusion field. Till sampling in this area yielded excellent indicator minerals including chromites that plot within the diamond inclusion field (Fenton and Pawlowicz, In Prep.);

(5) Latornell River Area

A cluster of 3 samples sites (KW96-49, KW96-50 and KW96-51) in the east-central part of the map area in the vicinity of the Latornell River, yield one or more moderate to good quality diamond indicator minerals. KW96-50 comprises a chrome diopside, which yields 1.01 Cr_2O_3, and 2 chromites including one that yields >2.0 wt% TiO_2 and >45 wt% Cr_2O_3. Three chromites from sample site KW96-51 yield concentrations of >2.0 wt% TiO_2 and >45 wt% Cr_2O_3, which may be diagnostic of kimberlite and/or lamproite. In addition sample site KW96-48, located directly northwest, yielded 2 picroilmenites including one grain with 2.96 wt% Cr_2O_3 and 16.05 wt% MgO. Till sampling in this area also yielded excellent indicator minerals (Fenton and Pawlowicz, In Prep.); and,

(6) Northwest Map Area

A cluster of 6 sample sites (KW96-12, KW96-46, KW96-63, KW96-64, KW96-65 and KW96-66) in the northwest part of the map area in the Wapiti River to Pinto Creek area, yield one or more moderate to good quality diamond indicator minerals. Sample KW96-63, yields a chrome diopside that plots within the diamond inclusion field and 8 chromites, including 2 grains with marginal chromite chemistry. KW96-64 comprises a picroilmenite that yields 2.96 wt% Cr_2O_3. Six chromites from sample site KW96-65 yielded 3 chromites with excellent Ni-Zn in combination with other elements comparable to diamond inclusion chromites.

It is interesting to note that the northeast part of the map area is covered by mostly continental derived drift and yielded abundant indicator minerals. Several of the stream sediment sites, particularly in the northeast quadrant draining the Cutbank River plateau, yielded indicator minerals of high quality including eclogitic garnets, picroilmenites, high Cr grossular and chrome diopsides along with moderate to excellent quality chromites. However, the Kakwa/Wapiti sample sites that were located in the Foothills, Rocky Mountains, and the rivers draining from them yielded few indicator minerals. Therefore, it is possible to conclude that the abundance of diamond indicators located in the northeast part of the map area have likely originated from within Alberta and have not been transported from the Rocky Mountains and may originate from: (1) a local bedrock volcanic source; (2) are the result of a glacial "dumping" of sediments from the central regions of the Province as the glaciers hit the higher topography nearing the Foothills; or (3) a combination of 1 and 2.

Based upon the wide variety of indicator minerals present and their proximity to the north slope of the Cutbank River plateau region, it is quite possible that the bulk of the anomalous indicator minerals are being sourced from erosion of bedrock in the plateau region including Brazeau Formation and older underlying sediments, or intrusions into those sediments. Unfortunately, few till samples have been collected to date in the northeast quadrant and in the area between Bald Mountain Creek to Latornell River. Therefore, it is not clear what is the source for this important trend of indicator minerals.

Anomalous chromite populations in the northeast part of the Kakwa/Wapiti map area may represent transported chromites from trends located north and northwest. The sample sites that yielded the chromites are in a down ice direction from the Peace River and Wabasca Trends (Dufresne *et al.*, 1996), and the Mountain Lake Diatreme located northeast of Grande Prairie. The anomalous sites are located about 85 km southwest of the Mountain Lake Diatreme and about 300 km southwest of the kimberlite discovery area in the Buffalo Head Hills.

7.0 Bentonite Geochemistry Study

7.1 Introduction

Bentonites, which are formed by the in situ devitrification and accompanying chemical alteration of glassy igneous material, usually tuff or volcanic ash, are composed essentially of smectite group clay minerals (dominantly montmorillonite) and varying amounts of biotite, feldspar, quartz, zircon, apatite and volcanic rock fragments. Bentonites in Alberta are characterized by their extensive areal distribution, relatively thin well defined beds and stratigraphic continuity. They have provided researchers with material for geochronological dating (e.g. Folinsbee *et al.*, 1961, 1963, 1964, 1965; Lerbekmo, 1963; Nascimbene, 1965) and have been used as a powerful stratigraphic correlation tool (e.g. Ritchie, 1960; Elder, 1988). However, several anomalously thick, discontinuous bentonites in Alberta do not fit that mold, and may be the result of modification by either secondary sedimentological processes or more localized volcanic events, some of which could be related to periodic kimberlite eruptive events (Dufresne *et al.*, 1996). Thick bentonite and tuff successions are present in the mid-Cretaceous to Tertiary succession of the Western Canada Sedimentary Basin in Alberta. This coincides with the most extensive and voluminous period of diamondiferous magmatism in the world. Kimberlites and related magmatic events from Alberta, North West Territories and Saskatchewan have been dated at mid- Cretaceous to Early Tertiary in age. From the research perspective and as a possible diamond exploration tool, the immediate question to ask is, "are some of the bentonite and tuff successions deposited in Alberta related to kimberlite and lamproite and ultramafic source magma"?

Relict parts of kimberlite pyroclastic rings may be preserved within sedimentary successions at Kasami, Kenieba Field, Mali (Hawthorne, 1975) and at Igwisi, Tanzania (Sampson, 1953), which may also contain kimberlite flows (Reid *et al.*, 1975). The Upper Albian (mid- Cretaceous), diamond-bearing, bedded kimberlites in the Fort à la Corne area of central Saskatchewan are dominated by crater facies rocks (Lehnert-Thiel *et al.*, 1992; Scott-Smith *et al.*, 1994). Multiple eruptive events, ranging from dominantly passive with less frequent explosive episodes to moderately explosive episodes, have resulted in the deposition of primary subaerial lapilli-rich kimberlite pyroclastics (air-fall lag/base surge and fine-grained to cryptocrystalline lapilli tuff and olivine crystal tuff), with related debris flows and minor deposits of resedimented volcaniclastic kimberlite at Fort à la Corne (Kjarsgaard, 1995; Leckie *et al.*, 1996). The total area over which kimberlite ash clouds dispersed at Fort à la Corne is not known. However, kimberlite pyroclastics are interstratified with Cretaceous sediments over an area of thousands of km^2 around Sturgeon Lake and Fort à la Corne, Saskatchewan (Nixon, 1995). Providing secondary influences such as prolonged weathering or diagenesis are not extreme, the resulting proximal and distal air fall deposits produced by kimberlitic volcanic events at Fort à la Corne (and by similar events in Alberta) should reflect the unique chemistry of the source magmas.

Comparative analyses of bentonites in Alberta show that a wide variation in composition and mineralogy exists for individual bentonites, and that they may be identified on the basis of their geochemical fingerprints. As would be expected, even though the bentonites are visually indistinct their geochemical fingerprinting shows that chemically different bentonites form from different composition volcanic sources. The most common parent material to bentonites located in western Alberta yields intermediate to felsic compositions (Lerbekmo, 1968; Scafe, 1975). However, a recent geochemical REE study has indicated that two bentonites collected from within mid-Cretaceous sediments in the Peace River area of Alberta yield geochemical signatures that are very similar to the geochemical signature of the Mountain Lake Diatreme and other kimberlites around the world (Dufresne *et al.*, in press).

This study has collected bentonites from the Kakwa/Wapiti map area and analyzed them for their major and trace elements. The resultant geochemical signatures of the Kakwa/Wapiti bentonites are compared to the average World-wide signatures of kimberlites and lamproites to determine if they have a similar ultrabasic volcanic signature, and whether they can be used to identify potential target areas for kimberlites and related rocks.

7.2 Methodology

A total of 9 bentonite samples were collected in the map area (Figure 1, Table 2). Grab samples weighing approximately 500 g were taken from bentonitic layers ranging in thickness from between 2.0 cm and 63 cm. The samples were collected carefully to insure minimal sampling contamination from the overlying and underlying shale, siltstone, sandstone or coal. The samples were pulverized to <100 mesh (150 microns), and sent to Becquerel Laboratories Inc. for REE geochemical analysis by neutron activation. The analysis includes La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. Care was taken to obtain the lowest minimum detection limits possible for the heavier REE elements such as Tb, Yb and Lu. The REE's are characterized by the by the addition of electrons to the inner *4f* orbitals rather than the outer shells; subsequent consequences are a predominance of the trivalent state and the contraction of ion size with increasing atomic number. Although generally incompatible, the values of their partition coefficients for any particular mineral vary systematically with atomic number, while the shapes of the partition coefficient patterns differ strikingly from one mineral to another. At least two major groups have long been distinguished as yttrium-dominant (heavy REE) and cerium-dominant (lighter REE) minerals (Wedepohl, 1978), and may be divided into groups that contain preferentially either the lighter or heavier REE, or having relatively similar compositions of both. Thus, each mineral which fractionates during the series of events culminating in the formation of an igneous rock leaves its own signature on the REE pattern of that rock. By working backwards from the REE pattern of the sample, it is often possible to identify specific minerals which have participated in the petrogenesis of that sample.

The bentonites were also analyzed by a multi element geochemical technique "Au + 47" that results from a combination of total digestion, inductively coupled plasma emission spectroscopy (ICP) and instrumental neutron activation analysis (INAA) at Activation Laboratories Ltd.

A 25 kg bentonite sample was collected from a 0.63 m thick bentonite at Pinto Creek (KW96-12-003). The ensuing heavy mineral concentrate was analyzed for diamond indicator grains. The indicator grain processing and electron microprobe analysis are identical to those described for the stream sediment heavy mineral concentrates. A 100 g sample of bentonite from KW96-12-003 was selected for X-ray diffraction analysis to determine its mineralogy.

7.3.1 Bentonite Geochemistry: Major and Trace Element Results

The geochemical data obtained through analysis of any rock type may be influenced by the rock's surrounding environment. Bentonites are no different and it is pertinent to remember that major and trace element geochemistry of bentonite will not only depend on the mineralogical and chemical composition of the primary rock, but may be affected by any number of syn- to post-depositional processes such as: (1) the proximity to the vent source will have a major influence on the presence of geochemical concentrations and distribution patterns, since soluble elements may be completely dispersed and heavier, incompatible elements such as Ti, Cr, Zr, and Ni may not travel significant

Table 2. Location and description of bentonite samples in the Kakwa/Wapiti area.

Sample ID	Location	Thickness	Host Rock and Description*
KW96-06-001	383818E/6103436N	2.5 m	Brazeau Fm. Carbonaceous smectitic shales below a 0.23 m coal seam
KW96-06-002	383798E/6103436N	1.8 m	Brazeau Fm. Carbonaceous smectitic shales below a 0.23 m coal seam
KW96-09-003	335997E/6037234N	1 to 3 cm	Coalspur Fm. Dirty bentonite between a light grey, smectitic shale and a fine-grained, argillaceous sandstone
KW96-12-002	346475E/6080080N	1 to 10 cm lens	Brazeau Fm. In the middle of a 0.45 m coal seam
KW96-12-003	346475E/6080080N	0.63 m	Brazeau Fm. Directly above a 0.45 m coal seam and below medium-grained, argillaceous sandstone
KW96-15-007	305710E/6025825N	75 cm	Boulder Creek Fm. Below a 15 cm layer of clean, quart-rich sandstone possibly equivalent to the Paddy Member (Peace River Fm.)
KW96-20-002	333970E/6005325N	2 to 3 cm	Westgate Fm. (Shaftesbury Fm.) Rusty weathered, dark grey, bioturbated shale
KW97-73-002	386147E/6079306N	7 cm	Brazeau Fm. Grey, blocky bentonite sampled from a section of interlayered smectitic shale, siltstone and sandstone
KW97-77-003	359306E/6028013N	5-10 cm	Coalspur Fm. Bentonite lenses with iron/hematite staining

*** See Appendix 1 for detailed stratigraphic sections with descriptions and sample locations.**

distances and are more easily influenced by local structures; (2) winnowing of pyroclastic cloud by wind and water; (3) postdepositional modification by bioturbation; (4) physicochemical conditions present during the alteration of glass to clay minerals, and in the weathering environment; (5) airborne ash deposition in a marine environment may alter its original signature by dissolution/precipitation reactions during argillization (Wray, 1995). When in equilibrium with seawater, authigenic clays take up REE's from seawater and may display an REE pattern similar to that of seawater (Chamley, 1989), or in contrast, if argillization takes place in a partially closed system an anomalous signature relative to shale may be preserved; (6) diagenetic modification of REE signatures may occur under highly reducing conditions where Eu is reduced from Eu^{3+} to Eu^{2+} and becomes mobile (MacRae *et al.*, 1992); and (7) the coexistence of primary, secondary and foreign materials in the kimberlite may influence the geochemical trace element pattern of any associated ash. A study on the dispersal patterns of the Kawakawa Tephra and other late Quaternary tephra layers in New Zealand observed that the best preserved deposits are in zones of high sedimentation including channel levees, submarine fans and boundary current drifts; and in contrast, preservation is poor in regions of active currents (Carter et al., 1995).

Since kimberlite, lamproite and similar tock types are comprised of highly unstable mineral phases and therefore tend to be very altered with few primary minerals present near the surface, it is logical that bentonite evaluation for diamond exploration should focus on the elements that are geochemically highly immobile in nature such as REE's and other incompatible elements.

The geochemical pattern of kimberlites and lamproites typically parallel that of highly evolved alkaline rocks. Kimberlites and lamproites are rich both in elements of ultramafic affinity (Mg, Co, Ni, Cr, Cu) and in incompatible elements (light REE, Ba, Sr, Rb, P, Nb), which gives these rocks a characteristic geochemical signature. This signature is sometimes used in regional stream and soil surveys in the search for kimberlites or lamproites and therefore, may also be applied to proximal, altered volcanic airfalls and bentonites. Figure 21a displays the average trace REE element abundances of worldwide kimberlites, lamproites, the Mountain Lake Diatreme and other rock types.

Kimberlites are characterized by a simple, steep linear REE distribution pattern that displays strongly dominant light REE enrichment and heavy REE depletion with levels that drop to near or below those of mid-ocean ridge basalts (Lu = 0.56 ppm). Lanthanum from kimberlitic rocks is enriched 100 to 1000 times chondritic abundances, while Yb is only enriched 2 to 10 times chondrite. Kimberlites yield a high total lanthanide composition of $\sum$Y,La--Yb ≈ 508 ppm (Table 3). La/Yb ratios for kimberlites range from 50 to 500 with most kimberlites ranging from 80 to 200 (Mitchell, 1989), which are significantly greater than most other mantle-derived undersaturated potassic lavas (Mitchell, 1986).

The overall geochemical characteristics of lamproites are very similar to those of kimberlite for both compatible and incompatible elements. Lamproites, however, are typically poorer in Ni, Co and Cr and richer in Rb, Ba, Sr, Zr and light REE in comparison to kimberlites (Jaques *et al.*, 1984, 1986; Bergman, 1987). Total Lanthanide concentrations for lamproites are very high with $\sum$Y,La--Yb ≈ 929 ppm. Although the overall average Eu anomaly of kimberlites or lamproites may be described as weak, the average worldwide lamproite REE pattern displays a "slightly" greater negative-trending

Figure 21. Chondrite–normalized REE plots from: (a.) various bedrock types (Wedepohl, 1978), including kimberlite (Mitchell, 1989), lamproite (Bergman, 1987), Mountain Lake Diatreme (Dufresne et al., 1997); and b.) bentonites collected in the Kakwa/Wapiti area.

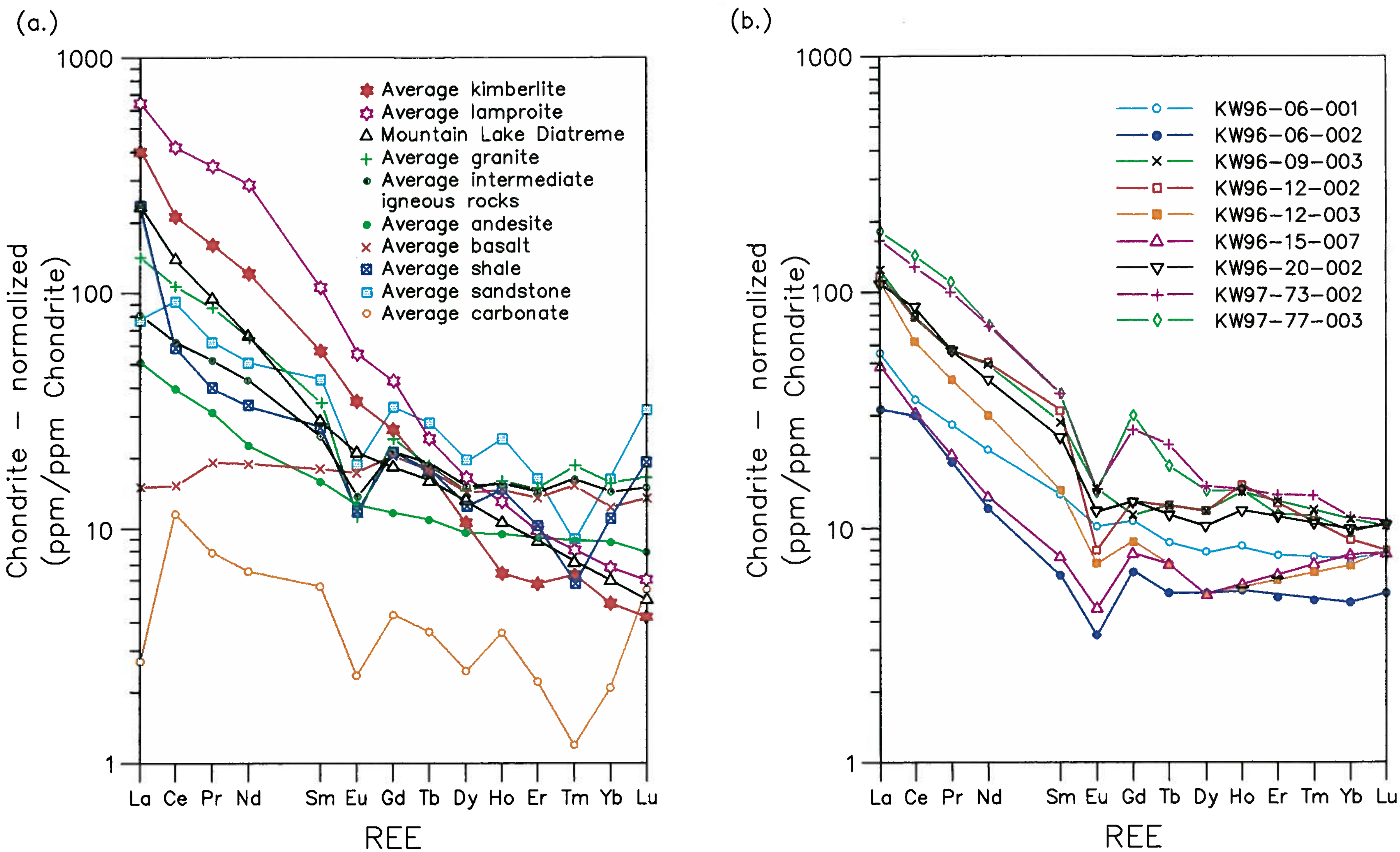
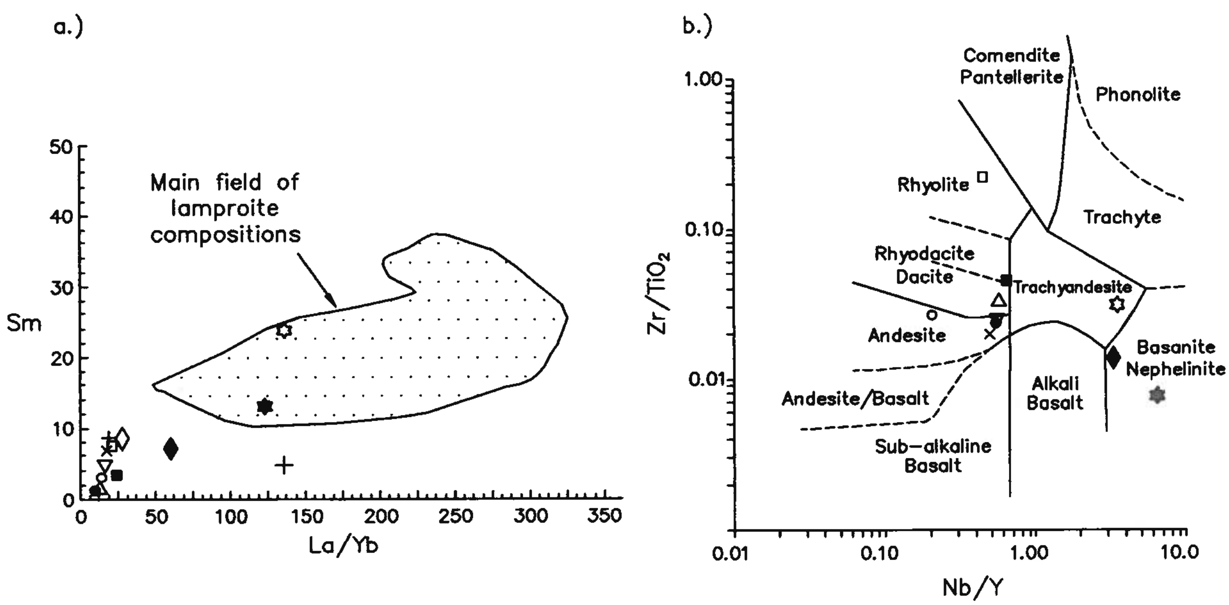


Table 3. Selected major and trace element data from bentonite samples collected in the Kakwa/Wapiti area. Includes values for the average worldwide kimberlite (Mitchell, 1989), lamproite (Bergman, 1987), the Mountain Lake Diatreme and a bentonite from the Peace River area (Dufresne et al., 1997).

Sample No., or rock type, and symbol	SiO_2 wt%	TiO_2 wt%	Zr ppm	Nb ppm	Y ppm	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Sum Y,La–Yb
○ KW96–06–001	75.52	0.74	208	4	19	21	35	<5	15	3.4	0.9	<5	0.5	3	<1	<5	<1	1.8	0.3	112
● KW96–06–002	65.76	0.68	157	6	11	12	22	<5	9	1.4	0.3	<5	0.3	2	<1	<5	<1	1.2	0.2	71
× KW96–09–003	60.81	0.76	146	14	29	47	75	8	35	6.5	1.4	<5	0.8	5	1.3	<5	<1	2.8	0.4	220
□ KW96–12–002	52.69	0.12	147	9	20	45	76	8	35	7.4	0.7	<5	0.8	5	1.4	<5	<1	2.2	0.3	209
■ KW96–12–003	55.35	0.44	197	9	14	41	60	6	22	3.5	0.6	<5	0.4	2	<1	<5	<1	1.7	0.3	161
△ KW96–15–007	76.74	0.94	291	9	16	18	30	<5	10	1.7	0.4	<5	0.4	2	<1	<5	<1	1.9	0.3	93
▽ KW96–20–002	70.66	0.77	202	11	20	43	84	8	30	5.7	1.1	<5	0.7	4	1.1	<5	11	2.4	0.4	219
+ KW97–73–002	/	/	/	/	/	62	130	13.6	52	8.8	1.4	8.4	1.3	1.7	1.3	3.5	0.5	2.9	0.4	288
◇ KW97–77–003	/	/	/	/	/	68	150	15.3	53	8.9	1.3	9.3	1.1	1.2	1.2	2.9	0.4	2.4	0.4	315
✱ Average Kimberlite	35.20	2.32	184	141	22	150	200	22	85	13	3.0	8.0	1.0	/	0.55	1.45	0.23	1.2	0.16	508
✡ Average Lamproite	52.70	3.0	922	95	27	240	400	/	207	24	4.8	13	1.4	6.3	1.1	2.4	/	1.7	0.23	929
♦ Mountain Lake	48.28	0.77	112	<50?	14	/	/	/	/	6.4	/	/	/	/	/	/	/	/	/	/
+ Peace R. bentonite	/	/	/	/	/	/	/	/	/	4.7	/	/	/	/	/	/	/	/	/	/

Figure 22. Discrimination diagrams: a.) Sm vs. La/Yb and b.) Zr/TiO_2 vs. Nb/Y for bentonite samples collected in the map area. The average kimberlite, average lamproite, Mountain Lake diatreme and a bentonite from the Peace River area are also plotted. See Table 3 for symbol descriptions.



Eu anomaly (Sm/Eu = 5.0) than the average kimberlite REE pattern (Sm/Eu = 4.3).

The analytical REE data from nine bentonite samples collected in the Kakwa/Wapiti map area are plotted on chondrite normalized multi-element diagrams (Figure 21b), where the abundance of each element is divided by the abundance of the corresponding element in a standard chondrite (Taylor and McLennan, 1985). The standard deviation of the data are dependant upon the detection limits of the laboratory analysis and vary from between 0.05 ppm to 0.1 ppm for the rare earth element research suite, which was selected for improved sensitivity. However, the data are poor for the heavy REE, particularly for Ho, Er and Tm as most samples have yielded abundances at or near the minimum detection limits of 1 ppm, 5 ppm and 1 ppm respectively (Table 3). Seven samples yielded abundances below the minimum detection limits of Er and Tm, while KW96-09-003, KW96-12-002 and KW96-20-002 are the only samples that surpassed the minimum detection limits of Ho. The REE distribution pattern plots as a straight line between Dy to Yb, or Ho to Yb, for samples with concentrations that did not exceed minimum detection limits. Samples KW97-73-002 and KW97-77-003 yielded concentrations that exceeded the minimum detection limits primarily because Bequerel Laboratories Inc. was able to provide analysis with lower detection limits than for the previously analyzed samples.

With the exception of sample KW96-06-001, the distribution patterns of the bentonite samples collected from the map area closely duplicate the REE distribution pattern for that of average felsic igneous rock, or granite (Figure 21b versus 21a). Felsic igneous rocks are characterized by a fairly linear but flat REE pattern with a pronounced negative Eu anomaly (Figure 21a). Granite La concentrations are approximately 150 times those of chondrites with a La/Yb ratio of 12.8, and a Sm/Eu ratio of 7.27. The average total lanthanide concentration for granite is $\sum$Y,La--Yb $\approx$ 290 ppm, and is nearly 3 times that of the average basaltic rocks.

Based on the REE distribution patterns (Figure 21b), and ratios such as La/Yb, Sm/Eu and the sum of Y and La to Yb, the bentonite samples collected in the Kakwa/Wapiti map area may be subdivided into three distinctive distribution patterns:

(1) Sample KW96-06-001: Elevated light REE concentration with La = 57.2 times chondrite and La/Yb = 11.67. Yields the least negative Eu anomaly of the bentonites sampled (Sm/Eu = 3.78). Note that the gradually dipping pattern between the light REE and the heavy REE is similar to the REE distribution pattern for average andesite in Figure 21a. The lanthanide total, $\sum$Y,La--Yb $\approx$ 112, is similar to the average for basalts ($\sum$Y,La--Yb $\approx$ 99).

(2) Samples KW96-06-002 and KW96-15-007: The distribution pattern is fairly similar to the majority of the samples with a fairly sharply dropping light REE, negative Eu anomaly and fairly flat heavy REE pattern. However, the samples represent the lowest light REE concentrations in the sample set and may result from a more mafic magma composition. Lanthanum concentrations yield 32.7 and 49.0 times chondrite, and La/Yb ratio's of 10.0 and 9.48 respectively. They yield a fairly negative Eu anomaly with Sm/Eu = 4.25 to 4.66. The lanthanide totals are very low $\sum$Y,La--Yb $\approx$ 71 and $\sum$Y,La--Yb $\approx$ 93 respectively;

(3) Samples KW96-09-003, KW96-12-002, KW96-12-003, KW96-20-002, KW96-73-002 and KW96-77-003: The distribution pattern is characterized by elevated light REE, dipping fairly sharply to a negative Eu value, with a fairly flat heavy REE that yields a positive Ho value. The enriched light REE concentrations yield La values that range between 117.2 and 156.7 times chondrite, with La/Yb ratio's of between 16.68 and 28.30. The samples yield negative Eu values with Sm/Eu ratio's between 4.64 and 10.57. Lanthanide content totals ($\sum$Y,La--Yb ≈) are 220, 209, 161, 219, 288 and 315 respectively, and may represent an intermediate-felsic to felsic magma origin.

None of the bentonites collected to date in the Kakwa/Wapiti map area exhibit an REE distribution pattern that is comparable to either the average worldwide kimberlite or lamproite (Figure 21a versus Figure 21b). Several of the samples collected, including KW96-09-003, KW96-12-002, KW96-12-003, KW96-20-002, KW97-73-002 and KW97-77-003 do exhibit high La values (up to 156.7 times chondrite). However, the rest of the light REE's do not exhibit the very high levels displayed by kimberlites and lamproites. It is notable that samples KW97-73-002 and KW97-77-003 yield a similar distribution pattern to that of the Mountain Lake Diatreme for the light REE's. The bentonite samples from the map area exhibit negative Eu anomalies (Sm/Eu up to 10.57). Negative Eu anomalies generally are attributed to removal of feldspar by fractionation at some stage in the magma evolution. Such a mechanism cannot be evoked for kimberlite as feldspar plays little role in kimberlite petrology and feldspar is not a stable phase at depths of generation of kimberlite magmas (Mitchell, 1975).

One may argue that because the Foothills of Alberta appears to represent a chromite-rich province, exploration should be focused on lamproites. A discrimination diagram (Figure 22a) of Sm versus La/Yb shows that the bentonite samples collected in the map area are clearly separated from the main field of lamproite compositions plotted by Mitchell and Bergman (1991). Also plotted on this diagram are values for the average kimberlite and lamproite, the Mountain Lake Diatreme, and a bentonite likely of kimberlitic origin that was sampled in the Peace River area during 1995 (Dufresne *et al.*, in press).

It is important to point out that REE should not be used alone in addressing problems related to mantle processes. Other major and trace elements can provide important information about mantle processes and therefore, REE concentration patterns should be evaluated in conjunction with other compatible and incompatible elements. A recommended suite of elements that are generally considered to be immobile and remain inert during secondary alteration processes includes Ti, Zr, Y, Nb, Ce, Ga and Sc. (Winchester and Floyd, 1977; Frey *et al.*, 1968; Cann, 1970; Pearce and Cann, 1973). One of the most successful diagrams used to infer the original magmatic composition from altered volcanic rocks uses the incompatible element ratios Zr/TiO_2 versus Nb/Y (Winchester and Floyd, 1977; Thomas *et al.*, 1990). Figure 22b shows the bentonite samples collected in the map area in comparison to the average worldwide kimberlite and lamproite. An increase in the Zr/TiO_2 ratio provides a general measure of the increase in the felsic composition, while an increase in the Nb/Y ratio provides a measure of the alkalinity. The low alkali content may be the result of preferential loss of these elements from the parent magma, but it must be recognized that the bentonite samples collected to date yield a much less alkaline composition than the highly alkaline nature of kimberlite. Bentonite samples KW96-06-001 and KW96-09-003 fall into the andesite field corroborating the possible origin indicated by the REE distribution pattern (Figure 21b). Samples KW96-06-002, KW96-12-003, KW96-15-007 and KW96-20-002 plot in the dacite and rhyodacite fields, and sample KW96-12-002 plots well into the rhyolite field. This corresponds to REE distribution patterns (Figure 21b), and previous major and trace element geochemistry work on the Late Cretaceous bentonites in western Alberta (Lerbekmo, 1968; Scafe, 1975). Lerbekmo (1968) concludes that there was a gradual change towards more siliceous volcanism from the end of the Belly River (Late Cretaceous) time onward until the end of the Cretaceous Period, or into earliest Paleocene time.

7.3.2 Bentonite Heavy Mineral Concentrate Results

In the event that a pyroclastic ash layer is deposited in proximal position to a volcanic centre (or cone), it may contain magmatic and xenocrystic indicator minerals. At Fort à la Corne, Saskatchewan olivine-rich crystal tuffs formed due to the combined effects of (1) the kimberlite magma being initially olivine rich (Mitchell, 1986, 1995); and (2) high magma fragmentation resulting in most juvenile material forming fine ash-sized particles (Leckie *et al.*, 1997). These fragmented ejecta may contain indicator minerals. As well, erosion of the volcanic ejecta may further concentrate indicator minerals in eolian and fluvial sedimentary deposits. Heavy minerals, including diamonds, have been discovered in Alberta ash deposits. For example, in 1991, nanometre-size diamonds were discovered in the Cretaceous/Tertiary bentonitic boundary clay along the Red Deer River Valley, Alberta. The diamond/iridium ratio of 1.22:1 for the boundary clay is close to that of two samples of type C2 chondritic meteorite (1.20:1 and 1.23:1), and provides further evidence for an extraterrestrial impact at the end of the Cretaceous Period (Carlisle and Braman, 1991). In an attempt to determine if a bentonite layer from the Kakwa/Wapiti area could possibly contain heavy minerals associated with kimberlitic or lamproitic eruptive events, a single 20 kg sample of bentonite (KW96-12-003) was collected from Pinto Creek and processed for heavy mineral diamond indicators.

Sample KW96-12-003 was collected from a 0.63 m thick bentonite directly above a 0.45 m seam of coal (Figure 23; Appendix 1: Cross Section KW96-12;). The layer is a light grey to greenish-grey weathering, waxy bentonite that is fairly uniform throughout and grades into a slightly silty bentonite near the top of the layer indicating sedimentary re-working. It is overlain by a 17 cm thick organic-rich clay, followed by a 22 cm wide coal seam and a massive layer of grey, medium-grained, argillaceous sandstone of the Brazeau Formation at the top of the section. See Dawson (1994) for a description of the coal resource potential. X-ray diffraction analysis using standard clay analysis techniques for the <2 μm size fraction (Thorez, 1976; Brindley and Brown, 1980), indicates that the clay matrix is composed of 100% montmorillonite.

The bentonite sample was reduced to a heavy mineral concentrate and picked for diamond indicators using the same procedures as for the stream sediment heavy mineral concentrates. Three garnets were selected as possible indicator grains from the heavy mineral concentrate. Electron microprobe analysis at the University of Saskatchewan reveals that the grains are almandines that were likely of crustal origin. Low concentrations of Cr_2O_3 and MgO indicate that further work on this sample was not warranted.

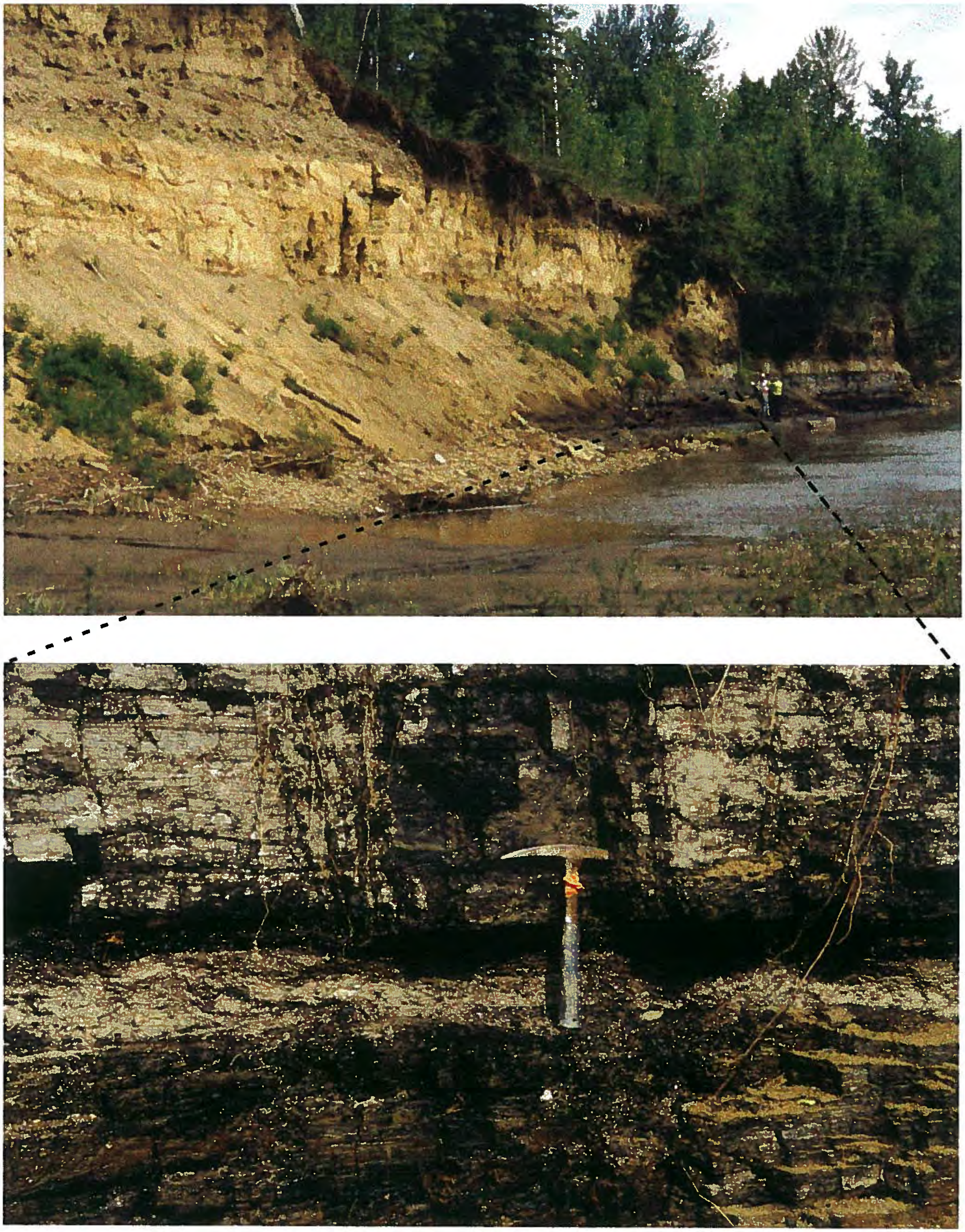


Figure 23. Brazeau Formation rocks at Pinto Creek with a detailed photo of coal and bentonite located at the base of the section.

7.4 Discussion and Conclusions

None of the bentonites collected in the Kakwa/Wapiti map area during this study exhibit an REE distribution pattern comparable to the average worldwide kimberlite or lamproite, and therefore, are likely not derived from an ultramafic source. The REE distribution patterns were divided into three separate signatures. The overall dominant REE signature closely duplicates the REE distribution pattern for that of the average intermediate-felsic to felsic igneous rock. The geochemical data from the bentonites were also evaluated using the REE values in conjunction with other incompatible elements (Zr, Ti, Nb and Y); the results indicate an andesitic to rhyolitic source for the bentonites sampled in the Kakwa/Wapiti area including: (1) samples KW96-06-001 and KW96-09-003, which plot in the andesite field corroborating the possible origin indicated by the REE distribution pattern, especially from sample KW96-06-001; (2) samples KW96-06-002, KW96-12-003, KW96-15-007 and KW96-20-002, which plot in the dacite and rhyodacite fields; and (3) sample KW96-12-002, which plots well into the rhyolite field. The results of the bentonite REE signatures and the combined REE - incompatible element patterns correspond with previous work on the Late Cretaceous bentonites in western Alberta by Lerbekmo (1968) and Scafe (1975) suggestive of a felsic source magma for the bentonites.

Rare earth elements are clearly a very useful geochemical group. As an exploration tool, REE and other incompatible elements may provide a quick and inexpensive view of the provenance under which a bentonite may have formed, and to determine if the bentonite could be used to identify local kimberlitic volcanism. Interstratified kimberlite pyroclastic deposits discovered in Saskatchewan should provoke investigation of similar air fall deposits in Alberta, especially since several of the Alberta kimberlites discovered to date, form topographic highs due to the erosion of the less-resistant sandstone and shale host rocks. This unique preservation coupled with reports that recent drill holes in the Buffalo Head Hills area may be intersecting pyroclastic aprons will provide the opportunity to study a completely intact kimberlite, including any associated airfall ash deposits.

Once a potentially kimberlitic bentonite has been identified through geochemical means, an extensive vertical and lateral sampling program should be performed in order to test whether the bentonite has been influenced by the environmental setting, and the locale should be investigated through a variety of exploration methods including other geochemical techniques such as stream, till and bedrock heavy mineral concentrate sampling leading to the implementation of a drilling program.

8.0 METALLIC MINERALS STUDY

8.1 Introduction

A variety of important minerals, including base and precious metal-bearing sulphidic horizons in northeastern, southwestern and northwestern Alberta have been found in Devonian, Jurassic and mid-Cretaceous rocks. However, metallic minerals exploration has been overshadowed by the success of oil and gas throughout the province, and the discovery of diamondiferous kimberlites in the Buffalo Head Hills area, north-central Alberta. The potential for the discovery of a metallic mineral deposit in the clastic sediments of Alberta should not be overlooked. The geological setting of Mesozoic rocks in the Western Canada Sedimentary Basin is similar to many productive metalliferous districts in the World, where consistent grades and lateral continuity along bedding make sediment-hosted deposits highly attractive exploration targets. Potential exists for the discovery of a range of mineral deposit types including: sedimentary exhalative sulphides (Sedex); sedimentary nickel sulphides; stratabound sandstone U and Pb; sediment-hosted stratiform Cu; epithermal (Carling-type) Au; and placer concentrations.

Reconnaissance scale bedrock and heavy mineral stream sediment geochemical studies were completed in the Kakwa/Wapiti study area to evaluate the metallic mineral potential and to obtain some background geochemical information. A total of 90 bedrock samples were collected from the three main physiographic regions in the map area including: the Upper Cretaceous plains region; the Upper Cretaceous to Tertiary ridges; and the uplifted Triassic to Cretaceous rocks of the Foothills and Rocky Mountains. The samples were analyzed for major and trace element geochemistry. In conjunction with the diamond indicator stream sampling study, a total of 60 heavy mineral concentrate stream sediment samples were analyzed for detrital gold.

8.2 Methodology

Sixty-eight samples were collected during the 1996 field season and an additional 22 samples were contributed to this study through field work completed in 1994 and 1995. Approximately 2 kg grab and channel samples were collected within individual lithologic units ranging in age from the Jurassic-Lower Cretaceous Nikanassin Formation to the Upper Cretaceous-Early Tertiary Coalspur Formation. Sample preparation included: air-drying; splitting the sample into two; and pulverizing one split to -150 mesh. The uncrushed sample split will be retained at the AGS Mineral Core Research Facility for further analysis. A total of 90 samples were sent to Acme Analytical Laboratories Ltd. and analyzed for major and trace element chemistry, which included: (1) 4 acid total digestion inductively coupled plasma emission spectrometry (ICP), 35-element package, using a 0.25 g split; (2) Au analysis by fire assay/ICP using a 30 g split; (3) whole rock fusion ICP with loss on ignition using a 1.25 g split; (4) total organic C using a 1 g split; and (5) total S by leco using a 1 g split. Also, 100 to 200 g of heavy mineral concentrate (<2 mm fraction) from stream sediment samples, were picked for Au grains prior to diamond indicator mineral processing at the SRC.

8.3 General Observations by Lithology Based On Bedrock Geochemical Results

For the purposes of reporting, the geochemical analyses from the Kakwa/Wapiti area are separated by lithology into shale, siltstone, sandstone, conglomerate, concretion, bone bed and bentonite. The complete geochemical data set are provided in the appendices section of this report including major and trace element geochemistry (Appendix 2), and discriminant geochemical scatter plots from the analytical data (Appendix 3). Table 4 compares the average elemental abundance in crustal sedimentary rocks with the maximum and average geochemical results from samples collected in the Kakwa/Wapiti map area. General observations, based on lithologies, are summarized below. Table 5 provides a geochemical summary of selected samples.

AVERAGE CRUSTAL ABUNDANCE *				KAKWA/WAPITI GEOCHEMICAL ANALYSIS SUMMARY													
				Shale (36 samples)		Siltstone (12 Samples)		Sandstone (17 samples)		Conglomerate (6 samples)		Concretion (4 samples)		Bone Bed (3 samples)		Bentonite (8 samples)	
Element	Shale	Sandstone	Carbonate	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave
Ag (ppm)	0.07	0.0X	0.0X	0.8	<0.5	<0.5	<0.5	0.6	<0.5	1	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5
Al (%)	8	2.5	0.42	9.61	6	14.36	5	7.63	4	5.23	2	4.89	4	0.71	0.69	10.64	7
As (ppm)	13	1	1	48	9	374	33	16	6	49	21	11	4	131	97	53	8
Au (ppb)	0.00X	0.00X	0.00X	16	3	8	3	12	2	9	3	6	2	2	2	9	2
Ba (ppm)	580	X0	10	4478	967	2238	780	1755	693	1188	645	1766	875	83	58	945	617
Be (ppm)	3	0.X	0.X	6	2	7	1	5	1	1	<1	2	1	4	4	2	<1
Bi (ppm)	X	X	X	5	<5	<5	<5	5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ca (%)	2.21	3.91	30.23	7.85	1	11.08	2	9.93	2	19.64	5	11.2	6	0.58	0.3	1.91	1
Cd (ppm)	0.3	0.0X	0.035	2.2	<0.4	5.3	1	1.7	<0.4	2.4	1	2.9	2	2.3	1	1.7	<0.4
Co (ppm)	19	0.3	0.1	33	5	10	2	25	5	33	14	33	9	<2	<2	9	3
Cr (ppm)	90	35	11	177	86	106	44	101	54	58	38	76	47	25	24	117	59
Cu (ppm)	45	X	4	66	25	76	22	39	17	26	15	35	22	15	14	36	18
Fe (%)	4.72	0.98	0.38	26.84	5	25.21	9	11.15	4	19.81	4	8.78	5	31.61	31	20.26	5
K (%)	2.66	1.07	0.27	3.03	2	2.04	1	1.76	1	1.23	1	1.65	1	0.32	0.315	2.67	1
La (ppm)	92	30	X	59	30	34	19	24	18	25	18	27	20	45	33	39	27
Mg (%)	1.5	0.7	4.7	4.35	1	4.26	1	1.95	1	2.23	1	4.21	2	0.06	0.06	1.62	1
Mn (ppm)	850	X0	1100	3606	333	4078	990	6735	710	1285	339	1158	448	<5	<5	922	151
Mo (ppm)	2.6	0.2	0.4	28	3	4	1	4	1	6	3	2	<2	48	36	33	5
Na (%)	0.96	0.33	0.04	1.83	0.21	1	0.206	1.3	0.09	0.08	0.06	0.23	0.125	2.91	2.78	1.89	1
Nb (ppm)	11	0.0X	0.3	38	9	13	7	13	5	7	2	14	8	<2	<2	14	8
Ni (ppm)	68	2	20	154	29	27	18	49	28	67	41	105	42	3	2	38	19
P (%)	0.07	0.017	0.04	0.369	0.125	0.122	0.6	0.196	0.07	0.293	0.064	0.106	0.033	0.588	0.587	0.367	0.073
Pb (ppm)	20	7	9	1181	48	48	14	24	10	62	29	14	10	<5	<5	51	21
Sb (ppm)	1.5	0.0X	0.2	7	<5	8	<5	7	>5	9	3	6	2	<5	<5	<5	<5
Sc (ppm)	13	1	1	29	12	28	10	15	8	10	6	15	8	4	3.5	14	9
Sn (ppm)	6	0.X	0.X	4	<2	5	<2	2	<2	3	<2	5	<2	4	2	6	<2
Sr (ppm)	300	20	610	662	115	352	102	272	83	777	247	270	122	1775	1628	726	218
Th (ppm)	12	1.7	1.7	23	9	28	10	9	6	6	5	14	9	46	37	22	13
Ti (%)	0.46	0.15	0.04	0.58	0.34	0.48	0.239	0.41	0.26	0.22	0.08	0.39	0.235	0.03	0.02	0.43	0.3
U (ppm)	3.7	0.45	2.2	15	<10	10	<10	10	<10	<10	<10	<10	<10	<10	<10	<10	<10
V (ppm)	130	20	20	287	175	197	94	186	101	128	69	149	90	64	61	218	111
W (ppm)	1.8	1.6	0.6	<4	<4	5	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Y (ppm)	26	40	30	32	14	42	21	22	15	23	16	40	24	3	3	21	11
Zn (ppm)	95	16	20	350	107	129	76	243	93	184	116	269	129	4	3	172	69
Zr (ppm)	160	220	19	102	51	82	39	61	40	35	20	48	38	6	5.5	110	66

* Turekian and Wedepohl (1961)

Table 4. Comparison of the average crustal sedimentary rock abundance with the Kakwa/Wapiti geochemical analysis summary.

Table 5. Geochemical summary of selected bedrock samples. Anomalous values are shaded.

Sample #	Location		Lithology	As	Al	Au**	Ba	Co	Cr	Cu	Fe	Mo	Mn	Ni	Pb	Th	U	V	Zn
	Easting	Northing		ppm	%	ppb	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
SHALE																			
KW96-12-005	346475	6080080	Lower Brazeau Fm. (organic)	< 5	7.8	< 2	4478	4	7	8	2.46	< 2	87	2	37	23	< 10	32	46
KW96-15-002	305710	6025825	Boulder Creek Fm.	9	9.61	11	1436	33	177	66	4	2	439	154	28	10	< 10	287	350
KW96-16-004	309680	6025930	Belle Fourche Fm. (smectitic)	48	3.03	4	30	< 2	53	12	20.05	28	< 5	5	< 5	13	< 10	128	10
KW96-16-007	309680	6025930	Belle Fourche Fm.	34	5.84	< 2	131	< 2	86	13	6.29	24	34	7	17	9	< 10	221	50
KW96-17-004	325816	6005921	Belle Fourche Fm. (silty)	< 5	7.28	11	1104	14	97	39	3.43	< 2	476	54	16	9	< 10	188	156
KW96-20-009	333970	6005325	Belle Fourche Fm. (silty)	9	6.12	16	776	< 2	86	31	3.02	2	32	17	20	8	< 10	182	62
KW96-61-002	314400	6015360	Gorman Creek Fm.	41	8.38	2	1484	12	122	43	4.03	4	189	41	1181	13	< 10	253	158
KW96-61-003	314400	6015360	Gorman Creek Fm.	8	3.08	2	923	5	52	25	25.1	< 2	3606	45	12	6	15	164	144
RR94-28	317409	6007659	Fernie Fm.	11	9.29	4	810	6	91	32	3.55	2	49	28	22	13	< 10	188	149
SILTSTONE																			
KW96-01-004	361896	5985030	Nikanassin Fm.	< 5	1.78	< 2	762	< 2	48	14	25.21	< 2	4078	13	7	3	< 10	110	54
KW96-17-001	325816	6005921	Belle Fourche Fm.	< 5	8.5	< 2	539	< 2	22	76	20.25	< 2	2252	14	17	28	< 10	30	129
KW96-17-002	325816	6005921	Belle Fourche Fm. (smectitic)	< 5	14.36	3	2238	< 2	27	20	8.33	4	67	8	30	19	10	72	30
KW96-28-002	401588	6073603	Lower Coalspur Fm. (smectitic)	374	6.98	8	270	10	54	20	4.36	2	65	25	48	6	< 10	105	45
SANDSTONE																			
KW96-01-007	361896	5985030	Gladstone Fm.	11	4.18	4	719	8	66	16	10.57	2	1347	49	24	8	< 10	110	243
KW96-12-007	346475	6080080	Lower Brazeau Fm.	< 5	7.63	< 2	1755	5	36	12	1.79	< 2	139	10	17	9	10	57	85
KW96-12-008	346475	6080080	Lower Brazeau Fm.	16	4.9	< 2	1230	25	38	14	16.1	4	6735	40	11	5	< 10	105	68
KW96-15-008	305710	6025825	Boulder Creek Fm. (smectitic)	16	7.44	< 2	609	< 2	101	39	2.89	2	< 5	41	5	9	< 10	186	59
KW96-20-008	333970	6005325	Belle Fourche Fm.	6	2.31	12	570	< 2	39	8	1.28	< 2	16	7	7	5	< 10	102	32
CONGLOMERATE																			
KW96-01-001	361896	5985030	Gladstone Fm..	49	5.23	9	568	23	58	26	1.73	2	251	67	62	6	< 10	97	182
KW96-01-005	361896	5985030	Cadomin Fm.	24	2.22	< 2	407	< 2	50	10	1.37	6	38	10	21	4	< 10	93	38
KW96-01-008	361896	5985030	Gladstone Fm.	< 5	1.39	< 2	681	5	20	10	19.81	< 2	1285	24	24	3	< 10	32	75
KW96-02-002	364869	5986508	Mountain Park Fm.	13	1.48	< 2	374	33	28	17	1.85	2	116	63	20	6	< 10	47	184
BONE BED																			
KW96-16-003	309680	6025930	Belle Fourche Fm. (float)	131	0.67	2	33	< 2	23	15	31.61	23	< 5	3	< 5	27	< 10	58	2
KW96-16-005	309680	6025930	Belle Fourche Fm. (smectitic)	62	0.71	2	83	< 2	25	12	29.64	48	< 5	< 2	< 5	46	< 10	64	4
KW96-20-005	333970	6005325	Fish Scales Fm. (cherty congl.)	16	3.63	5	1188	12	53	16	1.91	5	32	34	15	6	< 10	128	161
BENTONITE																			
KW96-09-003	335997	6037234	Lower Coalspur Fm.	< 5	8.74	2	732	5	117	36	2.96	2	922	32	19	10	< 10	218	172
KW96-12-002	346475	6080080	Lower Brazeau Fm.	<5	10.64	2	404	<2	5	3	3.11	<2	19	<2	51	21	<10	2	117
KW96-16-006	309680	6025930	Belle Fourche Fm.	53	2.47	< 2	32	< 2	51	10	20.26	33	12	4	15	17	< 10	124	10
KW96-20-002	333970	6005325	Westgate Fm.	< 5	6.7	9	838	< 2	113	33	2.02	2	36	23	22	11	< 10	203	67
CONCRETION																			
KW96-19-003	328337	6011030	Kaksapau Fm.	6	4.44	2	180	33	59	35	6.6	<2	572	33	14	9	<10	122	269

Shale

A total of 36 shale samples were collected and analyzed from the Fernie (3), Gorman Creek (2), Boulder Creek (2), Shaftesbury (20), Brazeau (2), Coalspur (1) and Kaskapau (6) formations. Shales are often enriched in transition metal elements such as Sc, Ti, V, Cr, Mn, Co, Ni, Cu and Zn and trace elements characteristic of sulphide deposits such as As, Sb, Se and S (Turekian and Wedepohl, 1961). The shales collected in the map area yield anomalous concentrations of Al, As, Au, Ba, Co, Cr, Fe, Mn, Mo, Nb, Ni, P, Pb, Sb, Sr, U, V and Zn against both the crustal shale average, and the average geochemical background for shale in the Kakwa/Wapiti area for (Table 4; highlighted in Table 5).

The silty shale of the Belle Fourche Formation (Shaftesbury Formation) yielded Au concentrations of 16 ppb and 11 ppb from samples KW96-20-009 and KW96-17-004, respectively. Sixteen ppb Au was the highest Au value assayed in the map area. Sample KW96-15-002, which was collected from a shale within the Boulder Creek Formation, yielded a Au concentration of 11 ppb. Sample KW96-15-002 also yields anomalous concentrations for Co (33 ppm), Ni (154 ppm), Cr (177 ppm), Cu (66 ppm), Zn (350 ppm), Ti (0.44%), Al (9.61 %), V (287 ppm), Sb (7 ppm), Y (22 ppm) and K (3.03%). The elevated concentrations of Co, Ni, Cr, Cu, Zn and Ti in sample KW96-15-002 are unique to the Kakwa/Wapiti geochemical data, and may be indicative of an ultramafic geochemical signature. However, it is interesting to note that the Cu-, Pb- and Zn-rich Kupferschiefer shales also include anomalous elements such as Mo (280 ppm), V (740 ppm), Cr (?), Ni (110 ppm) and Co (87 ppm) (Wedepohl, 1964). Sample RR94-28, from Fernie Formation shale, also displayed an interesting ultramafic signature yielding 38 ppm Nb, 0.58 % Ti, 9.29% Al and 59 ppm La. Samples KW96-16-004 and KW96-16-007, from the Belle Fourche Formation, yielded the maximum Mo concentrations from the shale samples collected of 28 ppm Mo and 24 ppm Mo respectively. An organic-rich shale from the Lower Brazeau Formation (sample KW96-12-005) yielded a Ba concentration of 4478 ppm with elevated Th (23 ppm) and Zr (102 ppm). Turekian (1968) suggests a connection of Ba with organic matter where Ba enrichment occurs when planktonic organisms known to accumulate Ba dissolve after death. However, it is worth noting the Yukon Pb-Zn shale hosted deposits have very large Ba anomalies, and a sample (KW96-61-002) from the Gorman Creek Formation shales yielded concentrations of 1181 ppm Pb and 0.8 ppm Ag. Another sample (KW96-61-003) from the same section of Gorman Creek shales yielded 3606 ppm Mn and 15 ppm U.

Siltstone

A total of 12 siltstone samples were analyzed and include the Nikanassin (2), Boulder Creek (2), Shaftesbury (4), Dunvegan (1), Coalspur (1) and Kaskapau (2) formations. The siltstones yield anomalous concentrations, relative to elemental crustal averages and background concentrations in the Kakwa/Wapiti area, for Al, As, Ba, Fe, Mn, Th, U and V (Table 4; highlighted in Table 5). Two siltstone to silty shale samples from the Belle Fourche Formation (KW96-17-001 and KW96-17-002) yielded anomalous concentrations including 14.36% Al, 2238 ppm Ba, 28 ppm Th and 10 ppm U. Sample KW96-01-004, which was collected from a rusty-weathering, 15 to 25 cm thick layer of Nikanassin Formation siltstone approximately 1 m away from the unconformity with the Cadomin Formation, yielded 4078 ppm Mn and 25.21% Fe. Sample KW96-28-002, from the Lower Coalspur Formation smectitic siltstone, yielded an anomalous Au concentration of 8 ppb. Sample KW96-28-

002 also yielded an extremely high As concentration of 374 ppm, which may indicate some fluid movement within the siltstone.

Sandstone

A total of 17 sandstone samples were analyzed from the Nikanassin (1), Gladstone (1), Mountain Park (1), Gorman Creek (2), Boulder Creek (3), Shaftesbury (1), Dunvegan (4), Brazeau (2) and Coalspur (2) formations. The sandstones yield anomalous concentrations, relative to elemental crustal averages and background concentrations in the Kakwa/Wapiti area, for Al, As, Au, Ba, Cu, Fe, Mn, Mo, Pb, Sr, U, V and Zn (Table 4; highlighted in Table 5). Sample KW96-01-007, from the Mountain Park Formation yielded 243 ppm Zn, 24 ppm Pb and 49 ppm Ni. Two samples from the Lower Brazeau sandstones yield 7.63% Al, 1755 ppm Ba, 272 ppm Sr and 10 ppm U (KW96-12-007), and 16 ppm As, 25 ppm Co, 6735 ppm Mn and 4 ppm Mo (KW96-12-008). KW96-12-007 was the only sandstone sample that yielded a detectable U value. Sample KW96-15-008, from the Boulder Creek Formation, yielded 16 ppm As, 39 ppm Cu, 186 ppm V and 58 ppm Zr. A sandstone sample (KW96-20-008) from the Belle Fourche Formation yielded a Au concentration of 12 ppb.

Conglomerate

Six conglomerate samples were analyzed including samples from the Cadomin (1), Gladstone (3), Mountain Park (1), and Boulder Creek (1) formations. Samples collected from the Gladstone Formation cherty pebble conglomerate with sulphides (up to 5% pyrite) replacing minor to abundant pelecyopods yielded anomalous concentrations of metals including: (1) 49 ppm As, 9 ppb Au, 26 ppm Cu, 58 ppm Cr, 67 ppm Ni and 62 ppm Pb from sample KW96-01-001; and (2) 19.81% Fe, 2.23% Mg, 1285 ppm Mn and 23 ppm Y from sample KW96-01-008. Sample KW96-01-005, from the Cadomin Formation conglomerate, yielded a Mo concentration of 6 ppm. Sample KW96-02-002, from the Mountain Park Formation, yielded concentrations of 33 ppm Co and 184 ppm Zn.

Fish Scales Bone Bed

Three samples were collected and analyzed from the regressive/transgressive lag deposits from the base of the Fish Scales Member of the Shaftesbury Formation. Sample KW96-20-005 yield anomalous concentrations including 5 ppb Au, 1188 ppm Ba, 7 ppm Nb, 128 ppm V, 161 ppm Zn, and 335 ppm Zr. Samples from KW96-16 contain elevated Mo concentrations of 23 ppm (KW96-16-003) and 48 ppm (KW96-16-005). The bone bed samples from KW96-16 also yield high concentrations of As (up to 131 ppm) and Sr (up to 1775 ppm).

Bentonite

Eight bentonite samples were geochemically analyzed from the Boulder Creek (1), Shaftesbury (2), Brazeau (4) and Coalspur (1) formations. Sample KW96-09-003, from a bentonite hosted by the Lower Brazeau Formation, yielded concentrations including 117 ppm Cr, 36 ppm Cu, 922 ppm Mn, 218 ppm V and 172 ppm Zn. Sample KW96-16-006, from a bentonite hosted by the Belle Fourche Formation, yielded 53 ppm As, 33 ppm Mo and 726 ppm Sr. A bentonite hosted by the Westgate

Formation (KW96-20-002) yielded 9 ppb Au.

8.4 General Correlations Based On Bedrock Geochemical Results

Discriminant geochemical scatter plots were created from the geochemical data (Appendix 3). The scatter plots are intended to depict possible correlations, or significant patterns, between the ICP trace element analysis versus a selected set of elements, including P, total S, total organic C (TOC), Al, Ca and Fe. The selected set of elements were chosen to observe the potential influences on metals such as the presence of bones, shells and teeth (P), sulphide and organic material (total S, Fe and TOC), clay alteration (Al), and carbonate cementation and diagenesis (CaO). Observations from the scatter plots are summarized below.

Shales

The mechanisms for enrichment of trace metals in shales typically involve ionic substitution in clay minerals, adsorption on clay minerals, adsorption on metallic hydroxides, precipitation of insoluble compounds (such as sulphides) and adsorption on, or reaction with, organic matter (Mercer, 1976). The geochemical data from the shales collected in the Kakwa/Wapiti area exhibit no apparent correlations for P, S, TOC and Ca versus metals to a strongly positive-trending correlation for Al versus metals. A summary of the scatter plots include:

(1) Phosphorous: With the exception of a weakly positive-trending correlation for the Gorman Creek shales, the metals vs. P did not yield any distinguishable correlations;

(2) Sulfur: Anomalous concentrations including: Ag, As, Mn, V, Sn and U from the Gorman Creek shale; Cu, Cd, Cr, Ni, V and Zn from the Boulder Creek shale; and Pb, Cr, Ba and Th from the Brazeau Formation shale yielded total S concentrations of <0.6 % and no distinguishable positive- or negative-trending correlations. Shales from the Shaftesbury and Kaskapau formations yielded total S concentrations of >2.0 %.

(3) Total Organic Carbon: The TOC does not appear to be significantly correlated with the trace metal concentrations as most samples yield <2.0 % TOC. The most anomalous samples, which include elevated concentrations of Ag, As, Au, Cd, Co, Cr, Cu, Mn, Ni, U and Zn, yield very low TOC concentrations of between 0.5 - 1.1 % and do not exhibit any distinguishable correlations. The Brazeau and Fernie Group shales yield low to moderate TOC concentrations of between 2.0 and 3.0 % with a positive-trending correlation for Pb, Zn, Ba, Cr, Ni, V, Sn, Th and Zr. Vanadium appears to be the only element that displays a moderately positive-trend with increasing TOC, particularly in the Fernie, Shaftesbury and Kaskapau formation shales;

(4) Aluminum: A noticeably strong positive-trending correlation occurs between Al and most trace elements of the Boulder Creek, Gorman Creek and Shaftesbury shales including Co, Cr, Cu, La, Nb, Ni, Pb, Sb, Sc, Th, V, Zn and Zr. A moderate-trending correlation is observed for the Kaskapau Formation shales;

(5) Calcium: Ca concentrations are generally <3 % Ca and do not exhibit any recognizable correlations. A single Fernie Group shale sample (RR94-15b) stands out in the data set with a concentration of 7.85% Ca; and

(6) Iron: A slight positive-trending correlation exists between the trace elements vs. Fe. The Fe concentrations are generally <5.0 % Fe, except in shale samples from the Gorman Creek, Shaftesbury and Kaskapau formations, which yield concentrations of >20% Fe.

A recent study, which collected bedrock samples for geochemical analysis from the Shaftesbury Formation and associated mid-Cretaceous sedimentary formations across northern Alberta, concluded that the shales with the highest TOC content (2nd White Specks Formation, Loon River Formation and parts of the Shaftesbury Formation) yield the highest metal concentrations. Furthermore, the study indicated that high TOC shales, such as the 2nd White Specks, exhibit a strong positive-trending correlation between TOC and metals and only a weak correlation of metals with Al, while the Shaftesbury and other shales with low concentrations of TOC exhibited a positive correlation of Al with metals than TOC with metals (Dufresne *et al.*, in press). Future work will focus on the correlations of metals to Fe and total S, as well as TOC. A study to assess the potential co-product potential for minerals and metals in Alberta's oil sand deposits determined that there is a positive relationship between the amount of clay-sized material (finer than 2 microns) and the Al content, and as the Al content increases so does the concentration of most trace elements (Devenny, 1993).

Shale samples collected in the Kakwa/Wapiti study area generally yield low TOC (<2 % TOC) concentrations. At this concentration of TOC, Al displays the strongest correlation with heavy metals and exhibits a strongly positive-trending relationship when plotted versus the trace metals. Aluminum likely indicates increased clay content through depositional and postdepositional processes; and may indicate that an ionic substitution of metals or adsorption of metals onto Al-rich clay minerals occurs during deposition, or later, during diagenesis, cementation and/or alteration. Aluminum content may be of importance in the Kakwa/Wapiti map area since low TOC shales such as the Gorman Creek and Boulder Creek formations exhibit a strongly positive-trending correlations between heavy metals and Al, and yield the highest metal concentrations.

Conglomerates (Including Bone Beds), Sandstones and Siltstones

The geochemical data from conglomerates (including bone beds), sandstones and siltstones exhibit weakly negative-trending correlations to moderately positive-trending correlations for selected elements including P, total S, total organic C (TOC), Al, Ca and Fe and the ICP trace element metals (Appendix 3). A summary of the observations of scatter plots includes:

(1) Phosphorous: Yields a weakly positive-trending correlation with As, Ba, Co, Cr, Cu, La, Ni, Sc, Pb, V, Y, Zn and Zr. Two samples (KW96-16-003 and KW96-16-005) from the Shaftesbury bone bed yielded the highest P concentrations of 0.588% and 0.587% P;

(2) Sulfur: No correlations were detectable for total S. Most values yielded concentrations of <1.8% S. Samples KW96-16-003 and KW96-16-005 from the Shaftesbury bone bed yielded 10.42% S and 12.44% S with anomalous values for As, Cd, La, Mo, Sn, Sr, and Th;

(3) Total Organic Carbon: Generally <1.5%, and yields weakly positive-trending correlations with Co, Cr, Cu, Nb, Sc, V, Zn and Zr. One sample (KW96-12-007) from the lower Brazeau sandstone yields 2.71% TOC;

(4) Aluminum: Yields moderate positive-trending correlations (particularly for Dunvegan Formation sandstone, and Cadomin and Gladstone formation conglomerates) with Au, Ba, Co, Cr, Cu, Nb, Ni, Sc, Th, V, Zn and Zr;

(5) Calcium: Concentrations are generally <5 % and yield weak, positive-trending correlations with the Cd, Co, Cr, Cu, Ni, Pb, Sn, Sr and Zn. Sample KW96-01-002, from the Gladstone Formation pebble conglomerate yielded 19.64 Ca; and

(6) Iron: Occurs in three main populations: <5 % Fe, 10 % - 20 % Fe, and >25 % Fe. The <5 % Fe population exhibits a moderate to strong positive correlation for Ba, Cr, Cu, La, Mn, Ni, Sc, Th, V, Y Zn and Zr. However, in the two populations >10 % Fe a slightly negative-trending correlation is observed for Au, Cr, Cu, La, Nb, Ni, Th, Zn and Zr.

With the exception of Al, which yields moderately positive-trending correlations with most metals, the geochemical data from the Kakwa/Wapiti area do not exhibit any noticeable correlations in the X-Y scatter plots for conglomerates, sandstones and siltstones.

Bentonite

A positive-trending correlation is observed between Al and the metals, particularly in the Brazeau Formation bentonites. Positive-trending correlations between Al and the metals include: a very strong correlation for Pb, V and Th; moderately strong correlations for Cu, Y, Zn and Zr; and weak correlation for Cr and Nb.

8.5 Results: Stream Sediment Sampling

Gold-bearing deposits of almost any type may serve as the source of Au in the formation of placer Au deposits. In order to evaluate the area for Au potential, including paleoplacer and placer, 60 stream sediment heavy mineral concentrate samples were sent to the SRC for gold separation and concentration superpanning, which optimizes the retention of fine-grained Au. Twenty of the 60 samples yielded gold grains that are dominantly smaller than 200 microns wide by 200 microns long, and largely exhibit abraded physical characteristics providing evidence for transportation from a distal Au source (Table 6).

Table 6. Visible gold grain count and description.

						Largest Grain	Average Size	Grain
	Location			Sample	Number of	Width x Length	Width x Length	Description
Samples	Easting	Northing	River/Creek	Weight (g)	Au Grains	(microns)	(microns)	(# of grains - D, I, A)*
KW96-13-001	424745	6110928	Simmonette R.	472.47	40	320x440	114x149	3 - I; 3 - A/I; 34 - A
KW96-23-001	368477	5992515	Sheep Cr.	35.48	3	200x260	93x133	1 - I; 1 - A/I; 1 - A
KW96-26-001	402893	6070498	Smoky R.	394.10	2	200x200	160x180	2 - A
KW96-27-001	403241	6070688	Smoky R.	203.59	1	40x60	40x60	A/I
KW96-28-001	401588	6073603	Unamed Creek	275.39	1	140x200	140x200	A
KW96-30-001	404402	6079743	Unamed Creek	206.93	3	240x280	173x260	3 - A
KW96-32-001	388187	6082463	Bald Mountain Cr.	203.70	6	220x220	150x173	6 - A
KW96-33-001	397573	6063575	Unamed Creek	102.39	2	100x100	80x90	1 - I; 1 - A
KW96-36-001	373409	6039664	Unamed Creek	86.23	3	60x80	40x53	3 - A
KW96-43-001	384200	6083000	Campbell Cr.	188.22	3	40x80	40x60	3 - A
KW96-44-001	384339	6078337	Big Mountain Cr.	107.37	1	60x100	60x100	A
KW96-45-001	386758	6075258	Gold Cr.	107.37	2	220x220	150x165	2 - A
KW96-46-001	361316	6074210	Stony Cr.	134.86	6	100x100	70x87	2 - I; 2 - A/I; 1 - I/D; 1 - D
KW96-47-001	357560	6093080	Iroquois Cr.	145.65	1	120x200	120x200	A
KW96-48-001	420439	6054747	Smuland Cr.	149.62	1	60x100	60x100	I
KW96-53-001	412230	6060975	Unamed Cr.	104.29	2	140x180	120x140	1 - A; 1 - A/I
KW96-64-001	322152	6081429	Wapiti R.	196.23	11	160x240	98x173	6 - I; 3 - A/I; 1 - I/D; 1 - D
KW96-65-001	342043	6094414	Wapiti R.	184.97	3	60x220	73x140	3 - I/D
KW96-66-001	335900	6071800	Nose Cr.	157.88	2	80x120	60x100	2 - A/I
KW96-70-001	384350	6103750	Wapiti R.	179.29	6	140x140	120x160	3 - A/I; 1 - I/D; 2 - A

* D = Delicate (proximal characteristics)

I = Irregular

A = Abraded (placer-type Au)

The largest rivers in the map area, including the Simonette River (east of the study area) and the Wapiti and Smoky Rivers, yielded the largest concentrations of Au grains. Sample KW96-13-001, from the Simonette River, yielded 40 Au grains including one grain that measured 320 x 440 microns and 5 grains measuring over 200 x 200 microns. Three samples (KW96-64-001, KW96-65-001 and KW96-70-001) collected from the Wapiti River yielded a total of 20 Au grains. Of the smaller drainage creeks, sample KW96-32-001 from Bald Mountain Creek, yielded an unusually high abundance of heavy minerals and 6 Au grains. Sample KW96-46-001, from Stony Creek, yielded 6 Au grains which exhibited irregular to delicate characteristics.

8.6 Potential Deposit Types

The geological setting of the Kakwa/Wapiti map area is similar to that of many productive metalliferous districts in the World, where consistent grades and lateral continuity along bedding make sediment-hosted deposits highly attractive exploration targets. The potential exists for the discovery of a range of mineral deposit types including: sedimentary exhalative sulphides (Sedex); sedimentary Ni sulphides; stratabound sandstone U and Pb; sediment-hosted stratiform Cu; epithermal (Carling-type) Au; residually enriched deposits; and placer deposits of a variety of metals. The association of stratiform phosphate and evaporite deposits within a sedimentary basin provides a favorable environment for many of the forementioned deposit types.

This section summarizes the potential deposit types that may exist in the Kakwa/Wapiti area, provides "neighboring province" deposit examples, and reports on potentially deposit-associated geochemical anomalies from selected samples.

Sedimentary Exhalative Sulphides (Sedex) Deposits

Sedimentary exhalative sulphides (Sedex) deposits occur in sedimentary basin terrains, where the deposits are hosted by the cover sequence to an intracontinental rift system that has been filled by continental clastics, volcanics (tuff, lava) and/or marine clastics. Zinc, lead and silver are the primary metals recovered; copper is generally a minor product. Typical hydrothermal products of Sedex deposits include sulphides, carbonates, quartz and barite. Barite may be abundant (deposits of mainly Phanerozoic age), or minor (deposits of mainly Proterozoic age); iron sulphide (pyrite and pyrrhotite) content is also highly variable (Lydon, 1996).

The bulk of the Canadian Paleozoic Sedex deposits are located in the Selwyn Basin located in the Yukon and northern British Columbia. The Selwyn Basin, which is interpreted to cover the site of an Upper Proterozoic rift zone (Abbott *et al.*, 1986), is filled by the Cambrian to Silurian Road River Group shales and carbonaceous cherts and is unconformably overlain by coarsening upwards clastic wedges comprised of shales and conglomerates of the Devonian - Mississippian Earn Group (Gordey *et al.*, 1982). The Faro Deposit, which is located in the Anvil Range of the Selwyn Basin, has yielded 57.6 Mt of 5.7% Zn, 3.4% Pb, 36 g/t Ag and is a prime example of a location where barite deposits are directly related to Sedex deposits (Jennings and Jilson, 1986).

Volcanic rocks may be a minor component of strata associated with Sedex deposits, and penecontemporaneous intrusions may be present regionally. Considerable debate exists whether the Sedex deposits are dominantly seafloor metalliferous sediments which are deposited around hydrothermal vent fields or are dominantly the products of subsurface replacement of sediments around the hydrothermal upflow conduits. The Kakwa/Wapiti map area, particularly the northern part of the map area, are characterized by thick sequences of shale and numerous layers of volcanic ash, which range in thickness from 2 to 60 cm. The bentonites comprise a significant portion of the Upper Cretaceous and Lower Tertiary siltstone and silty mudstone strata, and are invariably smectitic in nature. Sample KW96-09-003, which was collected from a bentonite layer within the Lower Coalspur Formation, yielded 172 ppm Zn with 36 ppb Cu and 732 ppb Ba. A bentonite sample from the Lower Brazeau Formation, sample KW96-12-002, yielded 51 ppm Pb and 117 ppm Zn.

Occurrences of sphalerite and galena have been reported in oil and gas well cuttings from Upper Cretaceous Brazeau (Wapiti) Formation sandstones and siltstones (Edmond, 1970), and at the contact between Triassic Spray River and Upper Cretaceous Belly River sediments in the Grande Prairie area (Hitchon, 1977, 1993: Dubord, 1987, 1988). These sulphide occurrences, coupled with the presence of favorable lithologies, indicate that the Cretaceous clastic rocks of northern Alberta have the potential to contain stratiform sediment-hosted Pb-Zn deposits.

Shale, sandstone and conglomerate samples collected from the Kakwa/Wapiti map area yield anomalous concentrations of Zn, Pb and Ag including: (1) sample KW96-61-002, from the Gorman Creek Formation shale, yields concentrations of 1181 ppm Pb and 0.8 ppm Ag, and sample KW96-15-002 yielded 350 ppm Zn and 28 ppm Pb; (2) sample KW96-01-007, from Nikanassin Formation sandstone, yields 243 ppm Zn and 24 ppm Pb; and (3) sample KW96-01-001, from the Cadomin Formation conglomerate, yields 62 ppm Pb, and sample KW96-02-002, from the Mountain Park Formation pebble conglomerate yielded 184 ppm Zn. Barium concentrations are also elevated throughout the geochemical data set, particularly in shales, where 12 of the 36 samples collected yielded concentrations of >1000 ppm Ba and up to 4478 ppm Ba from an organic-rich shale (sample KW96-12-005).

From the regional perspective, the Kakwa/Wapiti represents a favorable environment for Sedex deposits as indicated by the presence of: (1) a sedimentary basin that may have developed in a tectonically active environment through association with the Peace River Arch and the Western Alberta Arch; (2) magmatic activity (bentonite layers) that are contemporaneous with sedimentation and may, or may not, be locally derived; (3) elevated concentrations of Ba, which may represent synsedimentary hydrothermal sulphide mineralization; and (4) anomalous Pb and Zn concentrations of up to 1181 ppm Pb assayed from a Gorman Creek Formation shale, and 350 ppm Zn assayed from a Boulder Creek Formation shale.

Sedimentary Nickel Sulphide Deposits

Sedimentary nickel sulphides occur in basinal sedimentary terrains similar to those that host Sedex deposits, and have much in common in terms of physical characteristics and genesis. Significant Ni occurrences recognized to date are typically thin, sheet-like, Ni-enriched pyritic sulphide layers of great lateral extent in phosphoritic marine shale basins (Hulbert, 1996). Primary metals include Ni, Zn, Mo and platinum group elements (PGEs). The Nick Deposit, which is located within the Mackenzie Platform tectonic province, Yukon, comprises stratiform Ni-Zn-PGE mineralization hosted within a Middle to Upper Devonian shale sub-basin. The sulphide layer, which ranges in thickness from 0.4 to 10 cm, yields average grades of 5.3% Ni, 0.73% Zn, 770 ppb PGE's+Au, and up to 61 ppm Re (Hulbert *et al.*, 1992). Anomalous levels of U, Mo, Ba, Se, As, V and P are also present. The Nick mineralization is located near the stratigraphic contact between the siliceous shale, mudstone, phosphatic chert and spheroidal limestone of the lower Earn Group, and the older calcareous black shale of the Road River Group. Stratigraphically controlled Ni-Zn mineralization was recently discovered in the Taiga basin, Yukon, where drill hole REN97-08 (at -60 degrees) intersected 0.51% Ni with 0.41% Zn over 25.5 m, including a 5.3 m intersection grading 1.42% Ni and 0.70% Zn (Canada NewsWire, 1997). Detailed geochemical profiles through the lower Earn Group, hosting the Nick mineralization, reveal that these black shales are chemically similar to other North American black shales (Hulbert, 1996) including shales deposited in the Western Canada Sedimentary Basin.

In the Kakwa/Wapiti area, potential for shale-hosted Ni-Zn deposits may exist in a black shale member that is near the top of the Triassic Sulphur Mountain Formation, and the black shales of the Fernie Group. Pyrite was actually mined from the Fernie Group at the Thorne Mine located on the east side of Moose Mountain near the head of Bragg Creek in southwestern Alberta. The pyrite is reported to be quite thickly distributed in the shales and assayed up to 631 ppm Zn, 227 ppm As, 89 ppm Mo and 10 ppm Cd (Williamson *et al.*, 1993). Furthermore, Williamson et al. (1993) reported that the Sulphur Mountain Formation and Fernie Group may be favorable host rocks for stratiform Ni-Zn deposits, particularly where they are within or near the bounds of the deep-seated structural breaks such as the Bighorn Tear Fault.

Sample KW96-15-002, from the Boulder Creek Formation shale, yielded elevated concentrations including 154 ppm Ni, 350 ppm Zn, 66 ppm Cu, 33 ppm Co and 1436 ppm Ba. Sample KW96-19-003, from a concretionary layer in the Kaskapau Formation yielded 105 ppm Ni with 269 ppm Zn, 35 ppm Cu, 14 ppm Pb and 33 ppm Co. Results from INAA analysis for silver, gold and iridium (used as an indicator for PGE) yield relatively low concentrations, which include up to 16 ppb Au (KW96-20-009) and 0.80 ppm Ag (KW96-61-003) in shales from the Shaftesbury and Gorman Creek formations. Sample site KW96-16 yielded elevated Mo concentrations from Shaftesbury Formation shale, bentonite and bone bed samples including: two shale samples, which yielded 28 ppm and 24 ppm Mo; two bone bed samples, which assayed 23 and 48 ppm Mo; and a bentonite sample, which yielded 33 ppm Mo. Sample site KW96-16 also yielded anomalous P concentration (0.369% P). Twelve of the 36 shale samples collected yielded concentrations of >1000 ppm Ba and up to 4478 ppm Ba from an organic-rich shale (sample KW96-12-005).

<u>Stratabound Clastic-hosted U, Pb and Cu Deposits</u>

Stratabound clastic-hosted U, Pb and Cu deposits are characterized by disseminations of the ore minerals, which occur in marine, paralic, lacustrine and continental host rocks at or near a redox boundary. Sandstone U and sandstone Pb are often associated with reductive layers, which may be located within otherwise porous oxidizing sandstones. The Bowren River Basin, which is situated in British Columbia approximately 160 km west of the Kakwa/Wapiti map area, comprises U occurrences that are hosted in Upper Cretaceous lignites and organic-rich siltstones. Uraniferous occurrences are also present in the ash tuffs, which contain organic fragments and some sandstone in the Upper Cretaceous of the Spatsizi Plateau and Mount Helveker areas in British Columbia. The occurrences discovered to date are uneconomic, however, the hosting sedimentary strata are favorable targets for further U exploration and Cu, Ag and Pb deposits. Uranium deposits in northwestern Saskatchewan are dominantly unconformity-type deposits where linear or ovoid U deposits occur discontinuously along the northern and eastern edges of the Athabasca Basin and at the Carswell Structure and are associated with the sub-Athabasca unconformity. Sample KW96-12-007 from the Lower Brazeau Formation was the only sandstone sample from the Kakwa/Wapiti map area that surpassed the minimum detection limit and yielded 10 ppm U. Notable siltstone samples include: sample KW96-17-002 from silty shales of the Belle Fourche Formation, which yielded 10 ppm U; and sample KW96-61-003 from the Gorman Creek Formation silty shales, which yielded 15 ppm U.

The commodities produced from sandstone Pb are mainly Pb with lesser Zn; Ag is rarely recovered. The George Lake East Pb-Zn occurrence, which is located in the Aphebian Wollaston Fold Belt of northeastern Saskatchewan, is characterized by variable sphalerite, galena, pyrite, pyrrhotite and arsenopyrite occurring in argillaceous shales that are interlayered with thin beds of white grey quartzites. Analyses of samples from outcrop and float at the George Lake Pb-Zn occurrence yielded maximum concentrations of up to 8.02% Zn, 9.25% Pb and 268 g/t Ag (Coombe, 1994).

Many of the clastic wedges in the foreland basin of Alberta contain geological features that are considered favorable for sandstone-hosted Pb-Zn mineralized zones, including transgressive basal sandstones or conglomerates, vertical to subvertical faults which may be related to intracratonic rifting, interlayered impermeable cap rocks such as shales or mudstones, and the presence of evaporites in the stratigraphic section (Olson *et al.*, 1994). Targets deemed to be structurally favorable for sandstone-hosted stratiform Pb-Zn deposits include those stratigraphic units that were deposited within or adjacent to the Peace River Arch, Western Alberta Arch, and those locales with prominent vertical to subvertical, northeasterly-trending transverse, tear or normal faults.

The average Pb concentration for the Kakwa/Wapiti map area is 10 ppm Pb. Notable samples include: sample KW96-01-007 from the Gladstone Formation silty sandstone, which yielded 243 ppm Zn, 24 ppm Pb and 49 ppm Ni; and sample KW96-01-006 from the Nikanassin Formation shale, which yielded 21 ppm Pb and 179 ppm Zn. Notable non-sandstone samples with elevated Pb-Zn include: Gorman Creek Formation shale sample KW96-61-002, which yielded 1181 ppm Pb and 158 ppm Zn; and a sample of Kaskapau Formation concretionary sample KW96-19-003, which yielded 14 ppm Pb and 269 ppm Zn.

Sediment-hosted Cu (Kupferschiefer-type and Redbed-type) deposits typically occur as zonally distributed, disseminated sulphides at oxidation-reduction boundaries in anoxic rocks at the base of a marine or large-scale saline lacustrine transgressive cycle, which overlies, or is interbedded with, continental redbeds. With the exception of the Redstone area, Mackenzie Mountains, N.W.T., most Kupferschiefer-type occurrences in Canada are thin, low grade, and of minor importance. The carbonaceous shale-hosted Redstone deposit is estimated at 37 Mt averaging 3.9% Cu and 11.3 g/t Ag, but is deemed not attractive because of its remote, undeveloped region, and because it only averages 1 m thick (Ruelle, 1982). The JAN or Janice Lake showing, Saskatchewan, comprises disseminated chalcocite, native copper, malachite and magnetite plus rare chalcopyrite and bornite mineralization that is hosted by the Aphebian age Wollaston Group Sandfly Lake-Daly Lake Group meta-conglomerates and meta-arkoses (dark red sandstone pebbles in a grey arkose matrix) at the pelite-conglomerate contact. One drill hole from the Janice Lake showing averaged 0.21% Cu over 4.6 m.

Edmond (1970) reported the discovery of chalcopyrite in well cuttings of Brazeau (Wapiti) Formation sandstone, siltstone and shale. Maximum Cu concentrations from samples collected in the Kakwa/Wapiti map area yielded concentrations that were 2.5 times background and include 76 ppm Cu from the Belle Fourche Formation siltstone (KW96-17-001) and 66 ppm Cu from the Boulder Creek Formation shale (KW96-15-002).

Although the metal concentrations from the small number of sandstone samples collected during this study are not particularly anomalous, the potential for sedimentary clastic-hosted U, Pb and Cu deposits in the Kakwa/Wapiti area must still be considered. The sedimentary strata comprise favorable characteristics including: (1) sandstones with permeability contrasts such as shale beds; (2) the presence of reductants including coal zones; and the presence of channels of sandstone at the periphery of the sedimentary basin.

Epithermal Carlin-Type Gold Deposits

Epithermal Carlin-type gold deposits are hosted in calcareous to clastic sedimentary rocks, which may be intruded at depth by magma. Mineralization is variably younger (> 1 Ma) than the host rocks and the deposits have a large areal extend, large reserves and low ore grades (e.g., 2.5 g/t Au). Anomalous geochemical concentrations include Au, Ag, and base metals, plus the volatile elements Hg, Sb, As and Tl. Gold deposits on the Carlin Trend are hosted in Lower Paleozoic sedimentary rocks that are subdivided into three major packages including: (1) an autochthonous shelf to outer shelf carbonate and clastic sequence (eastern assemblage) comprised of micrite, silty limestone to dolomitic limestone, siliceous mudstone and siltstones; (2) an allochthonous, predominantly eugeoclinal siliciclastic sequence (western assemblage) comprised of sedimentary chert, mudstone, siliceous mudstone and minor greenstone; and (3) a Late Mississippian overlap sequence comprised of a coarsening upward clastic sequence from mudstone into sandstone and conglomerate (Teal and Jackson, 1997).

The formation of Carlin-type deposits has usually been attributed to epithermal hydrothermal processes associated with the emplacement of high-level felsic intrusions and rhyolitic volcanism (Bagby and Berger, 1985; Romberger, 1986: Berger and Henley, 1989). However, Wilson and Parry (1990) recently dated the alteration associated with gold mineralization at the Mercur deposits, north-central Utah to be between 122 Ma and 193 Ma; and therefore, postulated that the Au is related to Rocky Mountain-style thrust faulting along the Manning Canyon detachment during the Mesozoic and not associated with spatially-associated Tertiary felsic stocks and rhyolites.

Carlin trend deposits may also provide environments unique to the emplacement of other deposit types. Emsbo *et al.* (1997) report evidence for a previously unrecognized type of Au mineralization on the Barrick Goldstrike property (northern Carlin Trend, Nevada) that is geochemically, mineralogically, and temporally distinct from the classic Carlin-type mineralization and indicates a Sedex deposit assemblage. Mineralization is characterized by a mineral assemblage that includes barite, sphalerite, minor boulangerite, pyrite, galena, minor tetrahedrite, tennantite, chalcopyrite and native gold. Hot spring environments have been inferred for Au mineralization in Canada. These deposits (and steam heated zones in general) are thought to have characteristically high precious metal/base metal ratios resulting from the deposition of Au in an upper, gas-rich, or boiling portion of the geothermal system (Buchanan, 1981). The Cinola deposit, which occurs in the Sulphurets district of British Columbia, is the principal sediment-hosted adularia-sericite epithermal Au deposit in Canada. It comprises hot spring type lode gold, where Au occurs dominantly as disseminations in siliceous and/or finely veined, Cretaceous-Tertiary conglomerates, sandstones and shales.

Exploration for Carlin type epithermal gold deposits is difficult because Au and Ag grades are generally low and very fine-grained. Therefore, even where Au-Ag deposits are eroded they typically are not geographically associated with important placer gold accumulations. Only four bedrock samples collected from the Kakwa/Wapiti map area yielded >10 ppb Au and three of the four samples were from the Belle Fourche Formation including KW96-17-004 (11 ppb Au), KW96-20-008 (12 ppb Au) and KW96-20-009 (16 ppb Au).

Residually Enriched Deposits

Residually enriched deposits are sedimentary concentrations of commodities achieved by in situ weathering of a suitable precursor rock. Mineral enrichment may be achieved by two separate processes: (1) concentration of resistates, where minerals that are resistant to chemical weathering become concentrated through dissolution and removal of the surrounding matrix; and (2) supergene enrichment, where the minerals that are relatively soluble in oxygenated surface waters, but insoluble in reduced solutions, are reprecipitated, generally as new ore minerals, in the lowest part of the oxidizing zone and/or in the underlying reduced environment.

Stratiform Phosphate Deposit Byproducts

A number of metals such as U, V and REE are found in anomalously high quantities in phosphates. Gulbrandson (1977) estimated the average concentration of U in phosphates of southeastern Idaho to be 33 times background (90 ppm U). A study by Macdonald (1987) concluded that phosphorites from the Spray River and Fernie groups compare geochemically with other worldwide phosphorites and are enriched with elements including Ag, As, Cd, Mo, Ni, Se, U, Zn and Zr. Geochemical data from Macdonald's study indicate that U and V concentrations in Alberta phosphates yield up to 295 ppm U and 446 ppm V, and that phosphates from the Fernie and Exshaw formations yield the highest average U concentrations of 40-60 ppm U.

The presence of phosphates is often indicative of the potential for other deposit types. The association of pyritic black shale+phosphorate+glauconite+chert is typical of upwelling zones and related to high biological activity (Parrish *et al.*, 1986; Skinner, 1993), and may define important environments for sedimentary Ni sulphide and, over time, Lake Superior-type iron formation (Chandler and Christie, 1996). Highly anomalous Zn concentrations from the 2nd White Specks shale are associated with high P (Dufresne et al., in press).

The average concentration of P and P_2O_5 from 36 shale samples collected in the Kakwa/Wapiti area is 0.125% P and 0.24% P_2O_5. Three shale samples were collected from the Fernie Group, which is comprised of low to moderate P and represents the dominant phosphate-bearing strata in Alberta. Fernie Group shale samples yielded low concentrations of P including: sample RR94-15a (0.156% P; 0.41% P_2O_5), RR94-15b (0.062% P; 0.32% P_2O_5) and RR94-28 (0.133% P; 0.28% P_2O_5). Sample KW96-61-003 from Gorman Creek Formation shale, yielded 0.333% P and 0.72% P_2O_5. Samples KW96-16-003 and KW96-16-005 from the Shaftesbury Formation bone bed, yielded 0.588% P (1.53% P_2O_5) and 0.587% P (1.63% P_2O_5) respectively. It is interesting to note that sample KW96-16-003 also yielded 131 ppm As, and sample KW96-16-005 yielded 48 ppm Mo.

Evaporite Deposits Association

Evaporite deposits including marine evaporite deposits; nonmarine evaporite deposits and duricrust deposits are important sources for salt, potash and gypsum. Evaporite deposits in large basins are, in general, laterally associated with sandstone-hosted Cu, U and V, and Pb-Zn±Ag Sedex deposits. Therefore, it is worth noting the proximity of the Triassic Fetherstonehaugh Creek Gypsum deposit, which lies on the Alberta-British Columbia border straddling the Continental Divide near the headwaters of Fetherstonehaugh Creek.

Placer and Paleoplacer Concentrations

Placer and paleoplacer concentrations of detrital heavy minerals containing elements such as Au, PGE's, Sn, W, REE's, Ti, Zr, Th, U and Fe are common in clastic sedimentary rocks. Placer deposits form wherever vigorous water, air currents or weathering have sorted heavy and light, large and small, mineral and rock clasts, and thus produced lenses or layers containing heavy minerals in greater abundance than elsewhere in clastic sedimentary strata. Paleoplacers are consolidated or even metamorphosed placer deposits that have been buried with the rocks in which they were deposited and by younger sediments or volcanic rocks.

The Lower Cretaceous to Tertiary sediments of Alberta were deposited in continental and coastal environments, and therefore, should be favorable for the accumulation of placers in fluvial channel deposits. Giusti (1983) indicated that the gold flakes recovered from the North Saskatchewan, Redwater and Vermilion Rivers originated from multiple sources, or from different lithological horizons, and were probably derived from original Au sources located in the mountains. He postulated that Au was redeposited in Cretaceous times by rivers flowing from the west and influenced by many cycles of erosion and deposition with further complications from glaciation. Horachek (1994) completed an investigation of potential paleoplacers directly west of Rocky Mountain House, and concluded that the presence of Au in the Brazeau, Cadomin, Hoadley and Mountain Park formations indicates that Cretaceous strata are the source of the placer Au in the North Saskatchewan River. The basal Cretaceous Cadomin Formation of the Alberta Foothills yielded Au concentrations of up to 17 ppb, and provide evidence for "windows" of gold deposition influenced by the position of the drainage divide associated with an accretionary prism to the west (Leckie and Craw, 1997).

Gold grains recovered in the Kakwa/Wapiti map area are dominantly smaller than 200 x 200 microns, and largely exhibit abraded physical characteristics providing evidence for transportation from a distal Au source. The larger rivers such as the Simonette River (east of the study area) and the Wapiti and Smoky Rivers yielded the largest concentrations of Au grains. Of the smaller drainage creeks, both Bald Mountain Creek and Stony Creek yielded 6 Au grains and included grains that exhibited irregular to delicate characteristics.

8.7 Discussion and Conclusions

Sedimentary- and basin-related mineral deposits are present throughout Canada, and particularly in neighboring provinces to Alberta. Yet, there has been very little minerals exploration in Alberta; a province that, for the most part, provides a readily available infrastructure. A total of 90 bedrock samples, ranging in age from the Jurassic-Lower Cretaceous Nikanassin Formation to the Upper Cretaceous-Early Tertiary Coalspur Formation, were collected in the Kakwa/Wapiti map area. The study sampled representative lithologies from the map area and collected 36 shale, 12 siltstone, 17 sandstone, 6 conglomerate, 3 bone bed, and 8 bentonite samples. The results of the geochemical analysis yield anomalous trace metal values against the average concentration of crustal sedimentary rocks, and against background geochemical data established by this study. Geochemical highlights from selected formations in the Kakwa/Wapiti map area include:

- A Nikanassin Formation siltstone yielded 4078 ppm Mn and 25.21% Fe. The Gorman Creek Formation shales yielded concentrations of up to 1181 ppm Pb, 0.8 ppm Ag, 3606 ppm Mn and 15 ppm U.

- A Cadomin Formation conglomerate yielded a Mo concentration of 6 ppm. Gladstone Formation conglomerates yielded concentrations of up to 49 ppm As, 9 ppb Au, 26 ppm Cu, 58 ppm Cr, 67 ppm Ni, 62 ppm Pb, 19.81% Fe, 2.23% Mg, 1285 ppm Mn and 23 ppm Y. A Mountain Park Formation silty sandstone yielded 243 ppm Zn, 24 ppm Pb and 49 ppm Ni; and a conglomerate that yielded 184 ppm Zn and 33 ppm Co. A Boulder Creek Formation shale yielded anomalous concentrations for 11 ppb Au, 33 ppm Co, 154 ppm Ni, 177 ppm Cr, 66 ppm Cu, 350 ppm Zn, 0.44% Ti, 9.61 % Al, 287 ppm V, 7 ppm Sb, 22 ppm Y and 3.03% K. A Boulder Creek Formation sandstone yielded 16 ppm As, 39 ppm Cu, 186 ppm V and 58 ppm Zr.

- Silty shales of the Belle Fourche Formation yielded Au concentrations of 16 ppb, 12 ppb and 11 ppb; and anomalous concentrations including 14.36% Al, 2238 ppm Ba, 28 ppm Th, 28 ppm Mo and 10 ppm U. A bentonite layer from within the Belle Fourche Formation yielded 53 ppm As, 33 ppm Mo and 726 ppm Sr. The Fish Scales Formation bone bed yielded anomalous concentrations of up to 5 ppb Au, 1188 ppm Ba, 7 ppm Nb, 128 ppm V, 161 ppm Zn, 35 ppm Zr, 23 and 48 ppm Mo, 131 ppm As and 1775 ppm Sr. A bentonite layer hosted by the Westgate Formation shales yielded 9 ppb Au.

- An organic-rich shale from the Lower Brazeau Formation yielded a Ba concentration of 4478 ppm with 23 ppm Th and 102 ppm Zr. Lower Brazeau sandstones yielded concentrations of up to 7.63% Al, 1755 ppm Ba, 272 ppm Sr, 10 ppm U, 16 ppm As, 25 ppm Co, 6735 ppm Mn and 4 ppm Mo. A bentonite, hosted by the Lower Brazeau Formation, yielded 117 ppm Cr, 36 ppm Cu, 922 ppm Mn, 218 ppm V and 172 ppm Zn.

- A Lower Coalspur Formation smectitic siltstone, yielded an anomalous Au concentration of 8 ppb and an extremely high As concentration of 374 ppm.

- Barium concentrations are elevated throughout the geochemical data set, particularly in shales, where 12 of the 36 samples collected yielded concentrations of >1000 ppm Ba and up to 4478 ppm Ba.

While goal of the geochemical study is to provide some background data for industry, it is worth noting that the 90 samples collected in the Kakwa/Wapiti map area are not enough to justify placing a value on the potential for the map area to host metallic mineral deposits. However, the geological and geochemical data do supply enough information to discuss the geochemical correlations observed and potential deposit models. Geochemical correlations from the shales and clastic sediments, including conglomerates, bone beds, sandstones and siltstones, collected in the Kakwa/Wapiti map area indicate that Al displays a strong correlation with heavy metals and exhibits a strongly positive-trending relationship when plotted versus the trace metals. Aluminum, which possibly indicates increased clay content through depositional and postdepositional processes, may indicate metals were adsorbed onto Al-rich clay minerals during deposition, or later, during diagenesis, cementation and/or alteration. No apparent correlations to very weak, positive-trending relationships are observed when P, total S, total organic carbon, Ca and Fe were plotted versus the trace metals.

This study has shown that despite the lack of minerals-related exploration, the Kakwa/Wapiti map area represents a favorable environment for the emplacement of several deposit types including: sedimentary exhalative sulphides (Sedex); sedimentary Ni sulphides; stratabound sandstone U and Pb; sediment-hosted stratiform Cu; epithermal (Carling-type) Au; residually enriched deposits; and placer concentrations. The factors that promote these mineral deposit models include the associations of: (1) a sedimentary basin that may have developed in a tectonically active environment; (2) magmatic activity (bentonite layers) that are contemporaneous with sedimentation and may, or may not, be deposited locally; (3) stratigraphic distribution of chemical sediments such as Ba, which may represent synsedimentary hydrothermal sulphide mineralization; (4) sandstones with permeability contrasts such as shale beds; (5) a presence of reductants including coal zones; and the presence of channels of sandstone at the periphery of the sedimentary basin; (6) a presence of phosphates, which is often indicative of the potential for other deposit types such as U, V, REE and sedimentary Ni sulphide; and (7) evaporite deposits in large basins, which are, in general, laterally associated with sandstone-hosted Cu, U and V, and Pb-Zn±Ag Sedex deposits.

9.0 Overall Discussion and Conclusions

A reconnaissance field and geochemical program was completed in the Kakwa/Wapiti map area, which is located between the municipalities of Grande Prairie and Grande Cache (1:250 000 map sheet NTS 83L), to provide baseline geological and geochemical data, and as a preliminary evaluation of the metallic mineral and kimberlite or lamproite potential. The study was strategically broken into the following three separate parts for sampling, geochemical analysis and reporting purposes.

Stream Sediment Heavy Mineral Study

Sixty stream sediment heavy mineral concentrate samples were collected and analyzed for potential diamond indicator minerals from various bedrock and surficial geology domains. A total of 133 possible diamond indicator grains were microprobed and 35 of the 60 sites sampled reported diamond indicators. Indicator minerals recovered from the map area include chrome pyrope garnet (G9), eclogitic garnets (G3-calcic almandines and G5-magnesium), high chrome grossular garnets, chrome diopside, ilmenite and chromite. The stream sediment survey, and subsequent ranking of diamond indicator minerals, delineated at least 6 anomalous areas in the Kakwa/Wapiti map area. Particularly in the northeast quadrant draining the Cutbank River plateau, which yielded indicator minerals of high quality including eclogitic garnets, picroilmenites, high Cr grossular and chrome diopsides along with moderate to excellent quality chromites.

The abundance of diamond indicators located in the northeast part of the map area versus few indicators from sample sites in the Rocky Mountains, Foothills and rivers draining from them, indicate the grains are likely sourced from within Alberta and may originate from: 1.) a local bedrock volcanic source and erosion of bedrock in the plateau region including Brazeau Formation and older underlying sediments; 2.) the result of a glacial deposition of sediments from the central regions of the province as southwestward flowing Laurentide ice collided with the margin of the Cutbank Plateau; or 3.) a combination of 1 and 2. The sample sites that yielded the diamond indicators are in a down ice direction from the Peace River and Wabasca Trends (Dufresne *et al.*, 1996), and the Mountain Lake Diatreme located northeast of Grande Prairie. The anomalous sites are located about 85 km southwest of the Mountain Lake Diatreme and about 300 km southwest of the kimberlite discovery area in the Buffalo Head Hills.

Bentonite Geochemistry Study

Bentonites in Alberta are characterized by their extensive areal distribution, relatively thin well defined beds and stratigraphic continuity. They have provided researchers with material for geochronological dating (e.g. Folinsbee *et al.*, 1961, 1963, 1964, 1965; Lerbekmo, 1963; Nascimbene, 1965) and have been used as a powerful stratigraphic correlation tool (e.g. Ritchie, 1960; Elder, 1988). However, several anomalously thick, discontinuous bentonites in Alberta do not fit that mold, and may be the result of modification by either secondary sedimentological processes or more localized volcanic events, some of which could be related to periodic kimberlite eruptive events. From the research perspective and as a possible diamond exploration tool, the immediate question to ask is, "are some of the bentonite and tuff successions deposited in Alberta related to kimberlite and lamproite and ultramafic source magma"?

A total of 9 bentonite samples were collected in the map area, from bentonitic layers ranging in thickness from between 2.0 cm and 63 cm, and analyzed for their major and trace elements. The resultant geochemical signatures of the Kakwa/Wapiti bentonites are compared to the average World-wide signatures of kimberlites and lamproites to determine if they have a similar ultrabasic volcanic signature, and whether they can be used to identify potential target areas for kimberlites and related rocks.

None of the bentonites collected in the Kakwa/Wapiti map area during this study show a relative geochemical abundance pattern comparable to the average worldwide kimberlite or lamproite, and therefore, are likely not derived from an ultramafic source. The REE distribution patterns were divided into three separate signatures, with the overall dominant REE signature closely duplicating the REE distribution pattern for that of the average intermediate-felsic to felsic igneous rock. The geochemical data from the bentonites were also evaluated using the REE values in conjunction with other incompatible elements (Zr, Ti, Nb and Y); the results indicate an andesitic to rhyolitic source for the bentonites sampled in the Kakwa/Wapiti area. The results of the bentonite REE signatures and the combined REE - incompatible element patterns correspond with previous work on the Late Cretaceous bentonites in western Alberta by Lerbekmo (1968) and Scafe (1975) suggestive of a felsic source magma for the bentonites.

Rare earth elements are clearly a very useful geochemical group. As an exploration tool, REE and other incompatible elements may provide a quick and inexpensive view of the provenance under which a bentonite may have formed, and to determine if the bentonite could be used to identify local kimberlitic volcanism. Interstratified kimberlite pyroclastic deposits discovered in Saskatchewan should provoke investigation of similar air fall deposits in Alberta, especially since several of the Alberta kimberlites discovered to date, form topographic highs due to the erosion of the less-resistant sandstone and shale host rocks. This unique preservation coupled with reports that recent drill holes in the Buffalo Head Hills area may be intersecting pyroclastic aprons will provide the opportunity to study a completely intact kimberlite, including any associated airfall ash deposits.

Metallic Minerals Study

A total of 90 bedrock samples, ranging in age from the Jurassic-Lower Cretaceous Nikanassin Formation to the Upper Cretaceous-Early Tertiary Coalspur Formation, were collected in the Kakwa/Wapiti map area. Lithologies represented include: shale (36); siltstone (12); sandstone (17); conglomerate (6); bone bed (3); and bentonite (8).

The results of the geochemical analysis yield anomalous trace metal values against the average concentration of crustal sedimentary rocks, and against background geochemical data established by this study. Gold concentrations yielded values of 16 ppb, 12 ppb and 11 ppb from the Belle Fourche Formation silty shale, and 11 ppb Au from Boulder Creek Formation shale. Base metal concentrations yielded up to 1181 ppm Pb from the Gorman Creek Formation shale, 154 ppm Ni, 350 ppm Zn, 66 ppm Cu, 177 ppm Cr and 33 ppm Co from Boulder Creek shales, 243 ppm Zn from the Mountain Park sandstone, 4078 ppm Mn from Nikanassin Formation siltstone, 33 ppm Mo and 48 ppm Mo from Belle Fourche bentonite and Fish Scales Formation bone bed.

Despite the lack of minerals-related exploration, the Kakwa/Wapiti map area represents a favorable environment for the emplacement of several deposit types including: sedimentary exhalative sulphides (Sedex); sedimentary Ni sulphides; stratabound sandstone U and Pb; sediment-hosted stratiform Cu; epithermal (Carling-type) Au; residually enriched deposits; and placer concentrations. The factors that promote these mineral deposit models include the associations of: (1) a sedimentary basin that may have developed in a tectonically active environment; (2) magmatic activity (bentonite layers) that are contemporaneous with sedimentation and may, or may not, be deposited locally; (3) stratigraphic distribution of chemical sediments such as Ba, which may represent synsedimentary hydrothermal sulphide mineralization; (4) sandstones with permeability contrasts such as shale beds; (5) a presence of reductants including coal zones; and the presence of channels of sandstone at the periphery of the sedimentary basin; (6) a presence of phosphates, which is often indicative of the potential for other deposit types such as U, V, REE and sedimentary Ni sulphide; and (7) evaporite deposits in large basins, which are, in general, laterally associated with sandstone-hosted Cu, U and V, and Pb-Zn±Ag Sedex deposits. Many of these factors have been associated with mineralization in the literature.

10.0 References

Abbott, J. G., Gordey, S. P. and Tempelman-Kluit, D. J. 1986. Setting of sediment-hosted stratiform lead-zinc deposits in Yukon and northeastern British Columbia, *In:* Mineral Deposits of Northern Cordillera (ed.) J.A. Morin. The Canadian Institute of Mining and Metallurgy, Special Volume 37. pp. 1-18.

Bagby, W. C. and Berger, B. R. 1985. Geological characteristics of sediment-hosted, disseminated precious-metal deposits in the western United States. *In:* B.R. Berger and P.M. Bethke (eds.) Geology and Geochemistry of Epithermal Systems, Reviews in Economic Geology, Vol. 2. pp. 169-202.

Ballantyne, S. B. and Harris, D. C. 1994. The exploration significance of central Alberta Modern and Tertiary alluvial platinum group minerals, chromites, ilmenites and placer gold. Unpublished abstract and table of microprobe data provided at the Calgary Mining Forum, February 10 & 11, 1994.

Battacharya, J. and Walker, R. G. 1991. River- and wave-dominated depositional systems of the Upper Cretaceous Dunvegan Formation, northwestern Alberta. *In:* Bulletin of Canadian Petroleum Geology, Vol. 39, No. 2 (June, 1991). pp. 165-191.

Bergman, S. C. 1987. Lamproites and other potassium-rich igneous rocks: A review of their occurrence, mineralogy and geochemistry. In J. G. Fitton and B. G. J. Upton (eds.) Alkaline Igneous Rocks, Geological Society of London, Special Publication No. 30. pp. 103-190.

Berger, B. R. and Henley, R. W. 1989. Advances in the understanding of epithermal gold-silver deposits, with special reference to the western United States. *In:* R.R. Keays, W.R.H. Ramsay and D.I. Groves (eds.), The Geology of Gold Deposits: The Perspective in 1988, Economic Geology Monograph 6. pp. 405-423.

Bloch, J., Schroder-Adams, C., Leckie, D. A., McIntyre, D. J., Craig J. and Staniland, M. 1993. Revised stratigraphy of the lower Colorado Group (Albian to Turonian), western Canada. *In:* Bulletin of Canadian Petroleum Geology, Vol. 41, No. 3 (Sept., 1993). pp. 325-348.

Boyle, R. W. 1979. The geochemistry of gold and its deposits. Geological Survey of Canada, Bulletin 280. 584 p.

Buchanan, L. J. 1981. Precious metal deposits associated with volcanic environments in the southwest. *In:* Relations of Tectonics to Ore Deposits in the South Cordillera (ed.) W.R. Dickinson and W.D. Payne. Arizona Geological Society Digest, V. XIV. pp. 237-261.

Canada NewsWire. 1997. Blackstone Resources Inc. - Yukon Drilling Intersects Significant Nickel Horizon 800 Mineral Claims Staked. October 23, 1997

Cann, J. R. 1970. Rb, Sr, Y, Zr and Nb in some ocean floor basaltic rocks. Earth and Planetary Science Letter 10. pp. 7-11.

Carlisle, D. B. and Braman, D. R. 1991. Nanometre-size diamonds in the Cretaceous/Tertiary boundary clay of Alberta. Nature, V. 352, August, 1991. pp. 708-709.

Carter, L., Nelson, C. S., Neil, H. L. and Froggatt, P. C. Correlation, dispersal and preservation of the Kawakawa Tephra and other late Quaternary tephra layers in the southwest Pacific Ocean. New Zealand Journal of Geology and Geophysics, 1995, Vol. 38. pp. 29-46.

Chamley, H. 1989. Clay sedimentology. Springer, Berlin, 623 p.

Chandler, F. W. and Christie, R. L. 1996. Stratiform phosphate. *In:* Geology of Canadian Mineral Deposit Types, (ed.) O.R. Eckstrand, W.D. Sinclair and R.I. Thorpe. Geological Survey of Canada, Geology of Canada, No. 8, p. 33-40 (also Geological Society of America, The geology of North America, V. P-1)

Coombe, W. 1994. Sediment-hosted base metal deposits in the Wolaston Basin, northern Saskatchewan. Saskatchewan Energy and Mines Report No. 213.

Dawson, F. M., Kalkreuth, W. D. and Sweet, A. R. 1994. Stratigraphy and coal resource potential of the Upper Cretaceous to Tertiary strata of northwestern Alberta; Geological Survey of Canada, Bulletin 466. 59 p.

Dawson, J. B. and Stephens, W. E. 1975. Statistical classification of garnets from kimberlite and associated xenoliths. *In:* Journal of Geology, 1976, Vol. 84, pp. 495-496.

Devenny, D. W. 1993. Phase I of a study to access the potential of co-product minerals and metals in Alberta's oil sand deposits. Alberta Geological Survey, Open File Report 1993-24. p. 215.

DOMTAR Chemicals Ltd. 1968. Report on work done on the Fetherstonehaugh Creek gypsum deposit. Alberta Research Council unpublished report, Economic Minerals File GYP-AF-02. 20 p.

Drever, G. and Matthews, R. 1995. Alberta diamond project: Hinton area, central Alberta. Cameco Corporation. Metallic and Industrial Mineral Permits 9393030015 to 9393030016, 9393030018, 9393030020, 9393030022 to 9393030034, 9393030036 to 9393030041, 9393030046 to 9393030048, 9393030052, 9393030060 and 9393030061. Mineral Assessment File 19950005, Alberta Geological Survey.

Dubord, M. P. 1987. Carbonate hosted Pb-Zn potential of northeastern Alberta and the applicability of petroleum data for mineral exploration. Alberta Research Council, Open File Report 1987-07. 42 p.

Dubord, M. P. 1988. Lead-zinc potential of northeastern Alberta Phanerozoic rocks. Geoscience

Canada, Vol. 15. p. 111-112.

Dufresne, M. B., Eccles, D. R., McKinstry, D. R., Schmitt, D. R., Fenton, M. M., Pawlowicz, J. G. and Edwards, W. A. D. 1996. The diamond potential of Alberta. Alberta Energy and Utilities Board, Alberta Geological Survey, Bulletin No. 63. 158 p.

Dufresne, M. B., Leckie, D. A. and Eccles, D. R. 1998. Study of the geochemical and stratigraphic setting of the Shaftesbury and associated mid-Cretaceous formations in northern Alberta and its potential to host ore deposits. Geological Survey of Canada, Open File Report [in press].

Eccles, D. R., Dufresne, M. B. and Kjarsgaard, B. A. 1997. Heavy mineral geochemical analysis of the Mountain Lake Diatreme. *In:* D. A. Leckie and B. A. Kjarsgaard (eds.) Geology of a Late Cretaceous possible kimberlite at Mountain Lake, Alberta. Geological Survey of Canada, Open File Report 3441, pp. 159-174.

Edmond, B. A. 1970. Report on the Grande Prairie exploration permits, Alberta - an exploration venture for sandstone-type uranium mineralization in the Western Alberta Basin. International Mine Services Ltd., Toronto, Ontario. Alberta Research Council, Economic Minerals File Reports U-Af-101(1), U-Af-102(1), U-Af-103(1), U-Af-104(1), U-Af-105(1), U-Af-106(1).

Edwards, W. A. D. 1990. Placer gold occurrences in Alberta. Alberta Research Council, Open File Report 1990-09. pp. 72.

Elder, W. P. 1988. Geometry of Upper Cretaceous bentonite beds: Implications about volcanic source areas and paleowind patterns, Western Interior, United States. Geology 16. pp. 835-838.

Fenton, M. F. and Pawlowicz, J. In Preparation Final report on the surficial geology and Quaternary stratigraphy in the Kakwa/Wapiti area. Alberta Energy and Utilities Board, Alberta Geological Survey.

Fipke, C. E., Gurney, J. J. and Moore, R. O. 1995. Diamond exploration techniques emphasizing indicator mineral geochemistry and Canadian examples. Geological Survey of Canada, Bulletin 423. 86 p.

Fipke, C. E., Moore, R. O. and Gurney, J. J. 1989. The development of advanced technology to distinguish between diamondiferous and barren diatremes. Geological Survey of Canada, Open File Report 2124. 1175 p.

Folinsbee, R. E., Baadsgaard, H. and Lipson, J. 1961. Potassium-Argon dates of Upper Cretaceous ash falls, Alberta. Annals of the New York Academy of Sciences 91. pp. 352-363.

Folinsbee, R. E., Baadsgaard, H., Cumming, G. L. 1963. Dating of volcanic ash beds (bentonites) by the K-Ar method. Nuclear Geophysics, Nuclear Science Series, Report 38. pp. 70-82.

Folinsbee, R. E., Baadsgaard, H., Cumming, G. L. and Nascimbene, J. 1964. Radiometric dating of the Bearpaw Sea. Bulletin of the American Association of Petroleum Geologists 48. 525 p.

Folinsbee, R. E., Baadsgaard, H., Cumming, G. L. and Nascimbene, J. 1965. Late Cretaceous radiometric dates from the Cypress Hills of Western Canada. *In:* Guidebook for the Alberta Society of Petroleum Geologists. 15th Annual Field Conference, Part I. pp. 162-174.

Frey, F. A., Haskin, M. A., Poetz, J. A. and Haskin, L. A. 1968. Rare earth abundances in some basic rocks. Journal of Geophysical Research 73. pp. 6085-6098.

Gent, M. R. 1992. Diamonds and precious gems of the Phanerozoic Basin, Saskatchewan; preliminary investigations: Saskatchewan Geological Survey Open File Report 92-2. 67 p.

Gent, M. R. 1993. Mineralogical and group classification program. Saskatchewan Energy and Mines, Data File 18.

Gibson, D.W. 1975. Triassic rocks of the Rocky Mountain Foothills and Front Ranges of northeastern British Columbia and west-central Alberta. Geological Survey of Canada, Bulletin 247. 61 p.

Giusti, L. 1983. The distribution, grade and mineralogical composition of gold-bearing placers in Alberta. University of Alberta, M.Sc. Thesis. 397 p.

Gordey, S. P., Abbott, J. G. and Orchard, M. J. 1982. Devono-Mississippian (Earn Group) and younger strata in east-central Yukon. *In:* Current Research, Part B. Geological Survey of Canada, Paper 82-1B. pp. 93-100.

Gordey, S. P., Geldsetzer, H. H. J., Morrow, D. W., Bamber, E. W., Henderson, C. M. *et al.*, 1992. Upper Devonian to Middle Jurassic Assemblages. Part A. Ancestral North America. *In:* H. Galbrielse and C. J. Yorath (eds.) Geology of the Cordilleran Orogeny in Canada, Geology of Canada, No. 4. Decade of North American Geology (DNAG) Vol. G-2; Geological Survey of Canada. pp. 219–328.

Greiner, H.R. 1955. Two Lakes, Alberta; Geological Survey of Canada, Paper 55-14. 9 p.

Griffin, W. L., Ryan, C. G., Gurney, J. J., Sobolev, N. V. and Win, T. T. 1992. Chromite macrocrysts in kimberlites and lamproites: Geochemistry and origin. *In:* Proceedings of the 5th International Kimberlite Conference, 1991. Comphania de Pequisa de Recursos Minerais, Special Publication 2/91. pp. 142-144.

Griffin, W. L. and Ryan, C. G. 1995. Trace elements in indicator minerals: area selection and target evaluation in diamond exploration. *In:* Journal of Geochemical Exploration 53 (1995), pp. 311-337.

Gulbrandsen, R.A. 1977. By-product resources in phosphate ore of southeastern Idaho. Geological Society of America Abstracts with Program, Vol. 9, No. 6. pp. 728.

Gurney, J. J. 1984. A correlation between garnets and diamonds in kimberlites. *In:* J. E. Glover and P. G. Harris (eds.) Kimberlite occurrence and origin: a basis for conceptual models in exploration. Geology Department and University Extension, The University of Western Australia, 8, pp. 143-166.

Gurney, J. J., and Zweistra, P. 1995 The interpretation of the major element compositions of mantle minerals in diamond exploration. Journal of Geochemical Exploration V. 53., Nos. 1-3, Special Issue. pp. 293-309.

Gurney, J. J., Melmstaedt, H. H. and Moore, R. O. 1993. A review of the use and application of mantle mineral geochemistry in diamond exploration. Pure and Applied Geochemistry, 65, pp. 2423-2442.

Halferdahl, L. B. 1965. The occurrence of gold in Alberta rivers. Alberta Research Council, Open File Report 1965-11. 22 p.

Hamilton, W.N. 1982. Salt and gypsum in Alberta. CIM Bulletin, October, 1982. pp. 73-89.

Hawthorne, J. B. 1975. Model of a kimberlite pipe. Phys. Chem. Earth, 9. pp. 1-15.

Hitchon, B. 1977. Geochemical links between oil fields and ore deposits in sedimentary rocks. *In:* P. Garrad (ed.) Proceedings of the Forum on Oil and Ore in Sediments, Imperial College, London, England. p. 1-34.

Hitchon, B. 1993. Geochemistry of formation waters, northern Alberta, Canada: Their relation to the Pine Point ore deposit. Alberta Research Council, Open File Report 1993-14. pp. XX

Horachek, Y. 1994. Investigation of potential paleoplacers in the Cretaceous strata of the North Saskatchewan River watershed. Alberta Research Council, Open File Report 1994-19. 28 p.

Hulbert, L. J., Gregoire, D. C. and Paktunc, D. 1992. Sedimentary Nickel, Zinc and Platinum-group-element mineralization in Devonian black shales at the Nick Property, Yukon, Canada: A new deposit type. Exploration Mining Geology, Vol. 1, No. 1. pp. 39-62.

Hulbert, L. J. 1996. Sedimentary Nickel Sulphides. *In:* Geology of Canadian Mineral Deposit Types, (*ed.*) O.R. Eckstrand, W.D. Sinclair and R.I. Thorpe. Geological Survey of Canada, Geology of Canada, No. 8, p. 152-158. (also Geological Society of America, The geology of North America, V. P-1)

Irish, E. J. W. 1965. Geology of the Rocky Mountain Foothills, Alberta; Geological Survey of Canada, Memoir 334. 241 p.

Kjarsgaard, B. A. 1996. Prairie Kimberlites. *In:* A. N. LeCheminant, D. G. Richardson, R. N. W. DiLabio and K. A. Richardson (eds.), Searching for Diamonds in Canada, Geological Survey of Canada, Open File Report 3228. pp. 69-72.

Kjarsgaard, B. A. 1997. Diamonds in Alberta: Studies of potential host hocks of deep-seated origin and applications of indicator mineral exploration techniques. *In:* R.W. Macqueen (ed.) Exploring for minerals in Alberta: Geological Survey of Canada Geoscience Contributions, Canada-Alberta Agreement on Mineral Development (1192-1995). Geological Survey of Canada, Bulletin 500. pp. 185-207.

Janse, A. J. A., Downie, I. F., Reed, L. E. and Sinclair, I. G. L. 1986. Alkaline intrusions in the Hudson Bay Lowlands, Canada: exploration methods, petrology and geochemistry. *In:* J. Ross (ed.) Kimberlites and Related Rocks, Proceedings of the Fourth International Kimberlite Conference, Perth 1986. GSA Special Publication. pp. 469-471.

Jaques, A.L., Lewis, J. D., Smith, C. B., Gregory, G. P., Gerguson, J., Chappell, B. W. and McCulloch, M. T. 1984. The diamond-bearing ultrapotassic (lamproitic) rocks of the West Kimberley region, Western Australia. *In:* J. Kornprobst (ed.), Kimberlites I: Kimberlites and Related Rocks, Elsevier Press, New York. pp. 225-254.

Jaques, A. L., Lewis, J. D. and Smith, C. B. 1986. The kimberlites and lamproites of Western Australia. Geological Survey of Western Australia, Bulletin 132.

Jennings, D. S. and Jilson, G. A. 1986. Geology and sulphide deposits of the Anvil Range, Yukon. *In:* Mineral Deposits of Northern Cordillera (ed.) J.A. Morin. The Canadian Institute of Mining and Metallurgy, Special Volume 37, pp. 339-361.

Jerzykiewicz, T. 1997. Stratigraphic framework of the uppermost Cretaceous to Paleocene strata of the Alberta basin; Geological Survey of Canada, Bulletin 510. 121 p.

Kjarsgaard, B. A. 1995. Research on kimberlites and applications of diamond exploration techniques in Saskatchewan, *In:* D. Richardson (ed.) Investigations completed by the Saskatchewan Geological Survey and the Geological Survey of Canada under the Geoscience Program of the Canada-Saskatchewan Partnership Agreement on Mineral Development (1990-1995): Geological Survey of Canada Open File 3119, pp. 213-226.

Landes, K. K. 1963. Exploration report - Smoky River area: McIntyre Mines internal report.

Langenberg, C. W. and Skupinski, A. 1996. The provenance of diamond indicator minerals in bedrock of the Hinton area, Alberta Foothills. Alberta Energy and Utilities Board, Open File Report 1996-09. pp. 66.

Langenberg, C. W. 1983. Structural and sedimentological framework of Lower Cretaceous coal-bearing rocks in the Grande Cache area, Alberta. Edmonton Geological Society Field Trip, 1983. pp. 26.

Langenberg, C. W., Kalreuth, W. and Wrightson, C. B. 1987. Deformed Lower Cretaceous coal-bearing strata; Alberta Research Council, Alberta Geological Survey, Bulletin No. 56. 54 p.

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. 23, pp. 7-77.

Langenberg, C. W. *et al.* In Preparation Bedrock diamond indicators from the Kakwa/Wapiti area. Alberta Energy and Utilities Board, Alberta Geological Survey.

Leach, D.L. and Sangster, D.F. 1993. Mississippi Valley-type lead-zinc deposits. *In:* Mineral Deposit Modelling (ed.) R.V. Kirkham, J.M. Duke, W.D. Sinclair, and R.I. Thorpe. Geological Association of Canada, Special Paper 40. pp. 289-314.

Lehnert-Theil, K., Loewer, R., Orr, R.G. and Robertshaw, P. 1992. Diamond-bearing kimberlites in Saskatchewan, Canada: the Fort à la Corne case history. Exploration and Mining Geology, V. 1. pp. 391-403.

Leckie, D. A. and Craw, D. 1997. Anomalous gold occurrences in Cretaceous and Tertiary conglomerates and gravels of Alberta. *In:* R.W. Macqueen (ed.) Exploring for minerals in Alberta: Geological Survey of Canada Geoscience Contributions, Canada-Alberta Agreement on Mineral Development (1192-1995). Geological Survey of Canada, Bulletin 500. pp. 331-344.

Leckie, D. A., Kjarsgaard, B. A., Bloch, J., McIntyre, D., McNeil, D., Stasiuk, L. and Heaman. 1997. Emplacement and reworking of Cretaceous, diamond-bearing crater facies kimberlite of central Saskatchewan, Canada. GSA Bulletin, August, 1997, v. 109, no. 8. pp. 1000-1020.

Lerbekmo, J. F. 1963. Petrology of the Belly River Formation, southern Alberta Foothills. Sedimentology 2. pp. 54-86.

Lerbekmo, J. F. 1968. Chemical and modal analyses of some Upper Cretaceous and Paleocene bentonites from western Alberta. Canadian Journal of Earth Sciences 8. pp. 1505-1511.

Lydon, J. W. 1996. Sedimentary exhalative sulphides (Sedex). *In:* Geology of Canadian Mineral Deposit Types, (*ed.*) O.R. Eckstrand, W.D. Sinclair and R.I. Thorpe. Geological Survey of Canada, Geology of Canada, No. 8, p. 130-152 (also Geological Society of America, The geology of North America, V. P-1)

MacRae, N. D., Nesbitt, H. W. and Kronberg, B. I. 1992. Development of a positive Eu anomaly during diagenesis. Earth Planet. Sci. Lett., 109. pp. 585-591.

McMechan, M. E. and Dawson, F. M. 1995. Geology and structure cross-section, Wapiti, Alberta; Geological Survey of Canada, Map 1875A, scale 1:250 000.

McPherson. R. A. and Mellon, G. B. 1971. Geologic features and mineral resources of the Wapiti-Grande Cache Region, northwestern Alberta: As related to highway engineering; Alberta Research Council, Alberta Geological Survey, Open File Report 1971-2. 28 p.

McCandless, T. E. and Nash, W. P. 1996. Detrital Mantle indicator minerals in southwestern Wyoming, U.S.A. Evaluation of mantle environment, igneous host and diamond exploration significance. *In*. Exploration Mining Geology., Vol. 5, No. 1. pp. 33-44.

McCandless, T. E. and Gurney, J. J. 1986. Sodium in garnet and potassium in clinopyroxene: criteria for classifying mantle eclogites. *In:* J. Ross (ed.) Kimberlites and Related Rocks, Vol. 2, Proceedings of the Fourth International Kimberlite Conference, Perth 1986. GSA Special Publication No. 14.

Mcdonald, D. E. 1987. Geology and resource potential of phosphates in Alberta. Alberta Research Council, Alberta Geological Survey, Earth Sciences Report 87-2. 65 p.

Mellon, G. B. 1972. Mineral resources of northwest-central Alberta. Alberta Research Council, Alberta Geological Survey, Open File Report 1972-4. 9 p.

Mercer, W. 1976. Minor elements in metal deposits in sedimentary rocks - a review of recent literature. *In:* K. H. Wolf (ed.) Handbook of Stratabound and Stratiform Ore Deposits. Vol. 2. New York. Elsevier.

Mitchell, R. H. 1989. Aspects of the petrology of kimberlites and lamproites: Some definitions and distinctions. *In:* J. Ross (ed.) Kimberlites and Related Rocks, Proceedings of the Fourth International Kimberlite Conference, Perth 1986. GSA Special Publication No. 14. pp. 17-45.

Mitchell, R. H. 1986. Kimberlites: Mineralogy, Geochemistry and Petrology of kimberlite. Plenum Publishing Corp., New York. 442 p.

Mitchell, R. H. and Brunfelt, A. O. 1975. Rare earth element geochemistry of kimberlite. Physical Chemistry of the Earth 9. pp. 671-686.

Moore, R. O. and Gurney, J. J. 1985. Pyroxene solid solution in garnets included in diamonds. *In:* Nature, 318, pp. 553-555.

Moore, R. O. and Gurney, J. J. 1988. Mineral inclusions in diamonds from the Monastery kimberlite, South Africa. *In:* J. Ross (ed.) Kimberlites and Related Rocks, Vol. 2, Proceedings of the Fourth International Kimberlite Conference, Perth 1986. GSA Special Publication No. 14.

Nascimbene, G. G. 1965. Bentonites and the geochronolgy of the Bearpaw Sea. Bulletin of Canadian Petroleum Geology 13.

Nixon P. H. 1995. The morphology and nature of primary diamondiferous occurrences. Journal of Geochemical Exploration 53. pp. 41-71.

Olson, R. A., Dufresne, M. B., Eccles, D. R., Freeman, M. E. and Richardson, R. J. H. 1994. Regional metallogenic evaluation of Alberta. Alberta Research Council, Alberta Geological Survey, Open File Report 1994-8. pp. 239.

Otter, M. L. and Gurney, J. J. 1988. Mineral inclusions in diamonds from the Sloan Diatremes, Colorado-Wyoming State Line kimberlite district, North America. *In:* J. Ross (ed.) Kimberlites and Related Rocks, Vol. 2, Proceedings of the Fourth International Kimberlite Conference, Perth 1986. GSA Special Publication No. 14.

Parrish, J. T., Ziegler, A. M., Scotese, C. R., Humphreville, R. G. and Kirschvink, J. L. 1986. Proterozoic and Cambrian phosphorites - specialist studies: Early Cambrian paleogeography, palaeoceanography and phosphorites. *In:* Phosphate Deposits of the World, Volume 1, Proterozoic and Cambrian Phosphorites, (ed.) P.J. Cook and J.H. Shergold. International Geological Correlation Programme, Project 156. Phosphorites, Cambridge University Press. pp. 280-294.

Pearce, J. A. and Cann, J. R. 1973. Tectonic setting of basic volcanic rocks determined using trace element analyses. Earth and Planetary Science Letters 19. pp. 290-300

Pearce, J. A., Harris, N. B. W. and Tindle, A. G. 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology 25. pp. 956-983.

Pittis, F. 1997. Alberta Energy and Utilities Board, Resources Division, Resource Appraisal Group. Personal Communication.

Quirt, D. 1992a. Garclass – a program to classify garnets using the algorithm of Dawson and Stephens (1975). Saskatchewan Research Council Publication R-1230-10-E-92.

Quirt, D. 1992b. Minclass – a program to classify garnets and pyroxenes using the discriminant functions of Dawson and Stephens (1975) and Stephens and Dawson (1977). Saskatchewan Research Council Publication R-1230-12-E-92.

Reid, A. M., Donaldson, C. H., Dawson, J. B., Brown, R. W. and Ridley, W. L. 1975. The Igwisi Hills extrusive “kimberlites”. Phys. Chem. Earth, 9. pp. 199-219.

Richardson, R. J. H. 1984. Aggregate resources of the Wapiti map area, NTS 83L. Alberta Research Council, Open File Map 1983-17.

Ritchie, W. D. 1960. The Kneehills Tuff. Journal of the Alberta Society of Petroleum Geologists 8. pp. 339-341.

Romberger, S. B. 1986. Disseminated gold deposits. *In:* (eds.) R.G. Roberts and P.A. Sheahan. Ore Deposit Models, Geoscience Canada, Reprint Series. pp. 21-30.

Ruelle, J. C. 1982. Depositional environments and genesis of stratiform copper deposits of the Redstone Copper Belt, Mackenzie Mountains, N.W.T. *In:* Precambrian sulphide deposits, H.S. Robinson Memorial Volume, (ed.) R.W. Hutchinson, C.D. Spence and J.M. Franklin. Geological Association of Canada, Special Paper 25. pp. 701-737.

Ruotsala, A. P. 1974. Smectite with well-developed crystal habit - an alteration product of kimberlites. Clay Minerals Society 11th Meeting, 23rd Annual Clay Minerals Conference, Cleveland, Ohio. 1 p.

Sampson, D. N. 1953. The volcanic hills at Igwisi. Petrological notes by K. C. Dunham. Rec. Geol. Surv. Kenya, No. 58.

Scafe, D. W. 1975. Alberta bentonites. Alberta Research Council, Alberta Geological Survey, Economic Geology Report 2. 19 p.

Scott Smith, B. H., Skinner, E. M. W. and Clement, C. R. 1983. Further data on the occurrence of pectolite in kimberlite. Mineralogical Magazine, 47. pp. 75-78.

Scott Smith, B. H., Orr, R. G., Robertshaw, P. and Avery, R. W. 1994. Geology of the Fort à la Corne kimberlites, Saskatchewan. CIMM Meeting, October, 1994. pp. 19-24.

Scott Smith, B. H. 1995. Petrology and diamonds. Exploration Mining Geology. Vol. 4, No. 2. pp. 127-140.

Skinner, H. C. 1993. A review of apatites, iron and manganese minerals, and their roles as indicators of biological activity in black shales. Precambrian Research. V. 61. pp. 209-229.

Smith, C. B., Gurney, J. J., Skinner, E. M. W., Clement, C. R. and Ebrahim, N. 1985. Geochemical character of southern African kimberlites: a new approach based upon isotopic constraints. Trans. Geol. Soc. S. Afr. 88, pp. 267-280.

Sraega, D. I. 1994. Ram River Government Assessment Report. Takla Star Resources Ltd. and Fairstar Exploration. Metallic and Industrial Mineral Permits 9393030136 to 9393030169 to 9393030181, and 9393030421 to 9393030436. Assessment File Report 19940005, Alberta Geological Survey. 199 p.

Stott, D. F. 1970. Mesozoic stratigraphy of the Interior Platform and Eastern Cordilleran Orogeny. *In:* Geology and Economic Minerals of Canada, R. J. W. Douglas (ed.); Geological Survey of Canada, Economic Geology Report 1. pp. 438–445.

Stott, D. F. 1984. Cretaceous sequences of the Foothills of the Canadian Rocky Mountains. *In:* The Mesozoic of Middle North America. D. F. Stott and D. J. Glass (eds.); Calgary, Canadian Society of Petroleum Geologists, Memoir 9. pp. 43–67.

Swanson, F. J. and Gent, M. R. 1993. Results of reconnaissance diamond indicator mineral sampling, Saskatchewan. *In:* Dunne, K. P. E. and Grant, B. (eds.), Mid-Continent Diamonds. GAC-MAC Joint Annual Meeting, Edmonton, Alberta, May 17-18, 1993. pp. 113-119.

Sweet, A. R. 1996. Applied research report on seven samples from the Wapiti Formation, Mountain

Lake, north-central Alberta. *In:* D. A. Leckie and B. A. Kjarsgaard (eds.) Geology of a Late Cretaceous possible kimberlite at Mountain Lake, Alberta. Geological Survey of Canada, Open File Report 3441, pp. 132-141.

Taylor, S. R. and McLennan, S. M. 1985. The continental crust: Its composition and evolution. Blackwell, Oxford. 312 p.

Teal, L and Jackson, M. 1997. Geological overview of the Carlin Trend gold deposits and descriptions of recent deep discoveries. *In:* Carlin-Type Gold Deposits Field Conference (ed.) T.B. Thompson. Society of Economic Geologists. Guidebook Series, V. 28 pp. 3-38.

Thomas, R. G., Eberth, D. A., Deino, A. L. and Robinson, D. 1990. Composition, radioisotopic ages, and potential significance of an altered volcanic ash (bentonite) from the Upper Cretaceous Judith River Formation, Dinosaur Provincial Park, southern Alberta, Canada. Cretaceous Research 11. pp. 125-162.

Underschultz, J. R. 1991. Tectonic loading in the Canadian Cordillera as recorded by mass accumulation in the Foreland Basin. Tectonics, v. 10, no. 2. pp. 367-380.

Van Dyke, C. W. 1981. A uranium resource evaluation of post-Proterozoic sedimentary formation in Alberta. Unpublished M.Sc. Thesis, Department of Geology, University of Alberta, Edmonton.

Weaver, C. E. 1963. Interpretative value of heavy minerals from bentonites. Journal of Sedimentary Petrology, Vol. 33, No. 2. pp. 343-349.

Wedepohl, K. H. 1964. Untersuchungen am Kupferschiefer in Nordwestdeutschland: Ein Beitrag zur Deutung der Genese bituminoser Sedimente. Geochim. Cosmochim. Acta, 28. pp. 305-364.

Wedepohl, K. H. 1978. Senior Editor. Handbook of Geochemistry, Vol. II/5 Elements La (57) to U (92). Springer Verlag.

Williamson, J., Dufresne, M. B. And Olson, R. A. 1993. The Southern Alberta Rift in southwest Alberta, program to identify targets for metallic mineral exploration. Alberta Research Council, Alberta Geological Survey, Open File Report 1993-13A and 13B.

Wilson, P. N. and Parrt, W. T. 1990. Mesozoic hydrothermal alteration associated with gold mineralization in Mercur district, Utah. Geology Vol. 18. pp. 866-869.

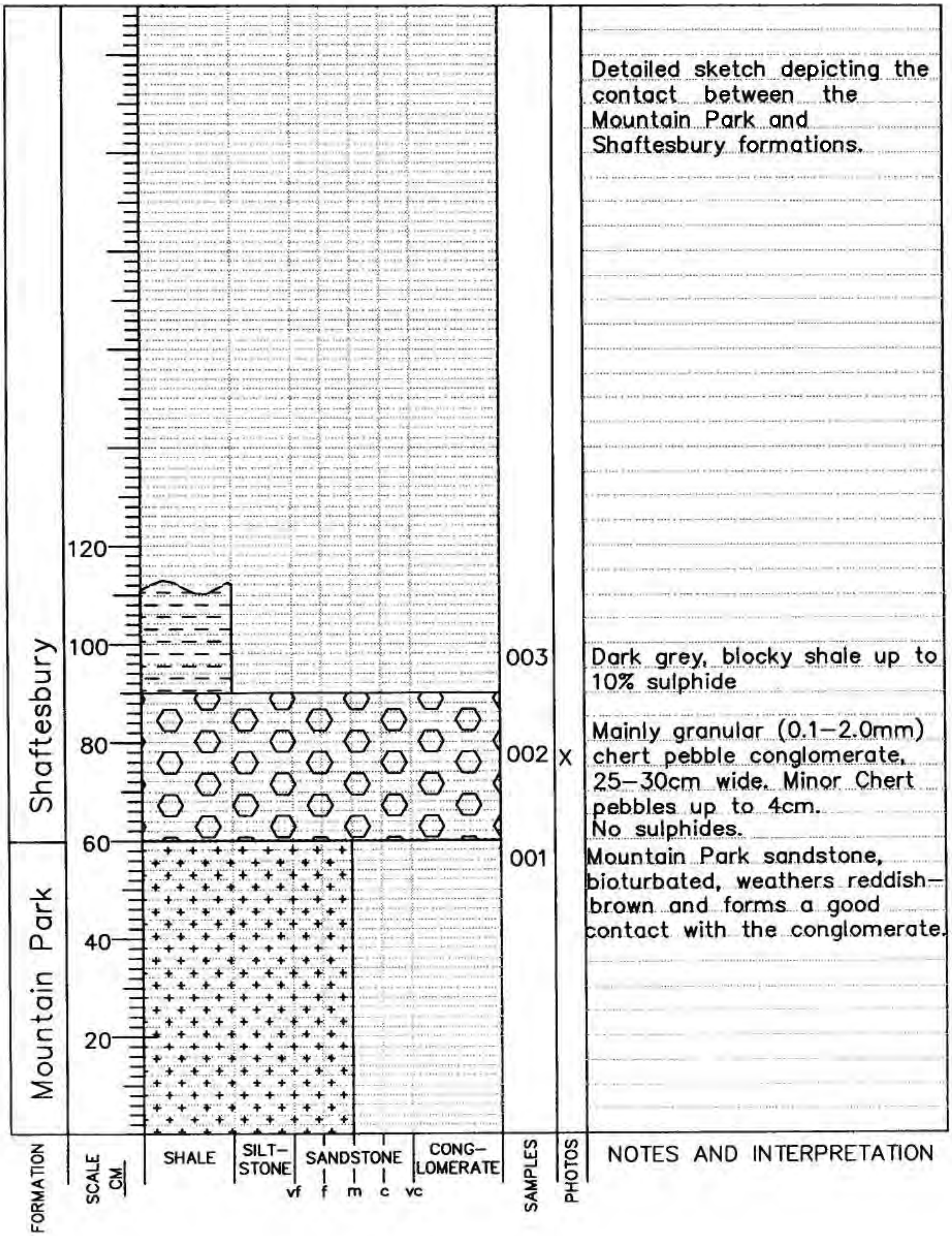
Wray, D. S. 1995. Origin of clay-rich beds in Turonian chalks from Lower Saxony, Germany - a rare earth element study. Chemical Geology 119. pp. 161-173.

APPENDIX 1

Selected stratigraphic cross sections from the Kakwa/Wapiti area (NTS 83L).

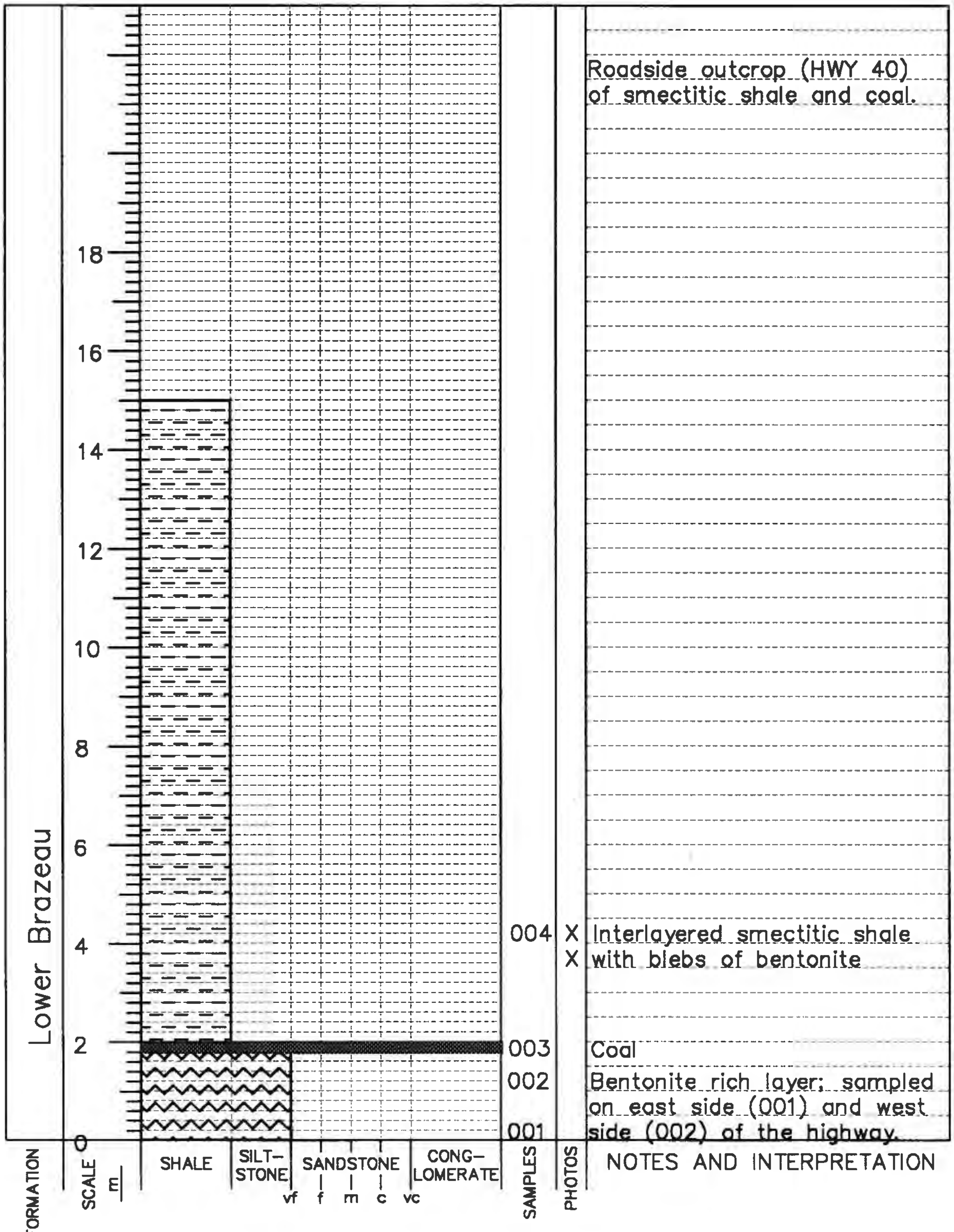
Station Identifier: KW96–02

Location (UTM): 364869E, 5986508N



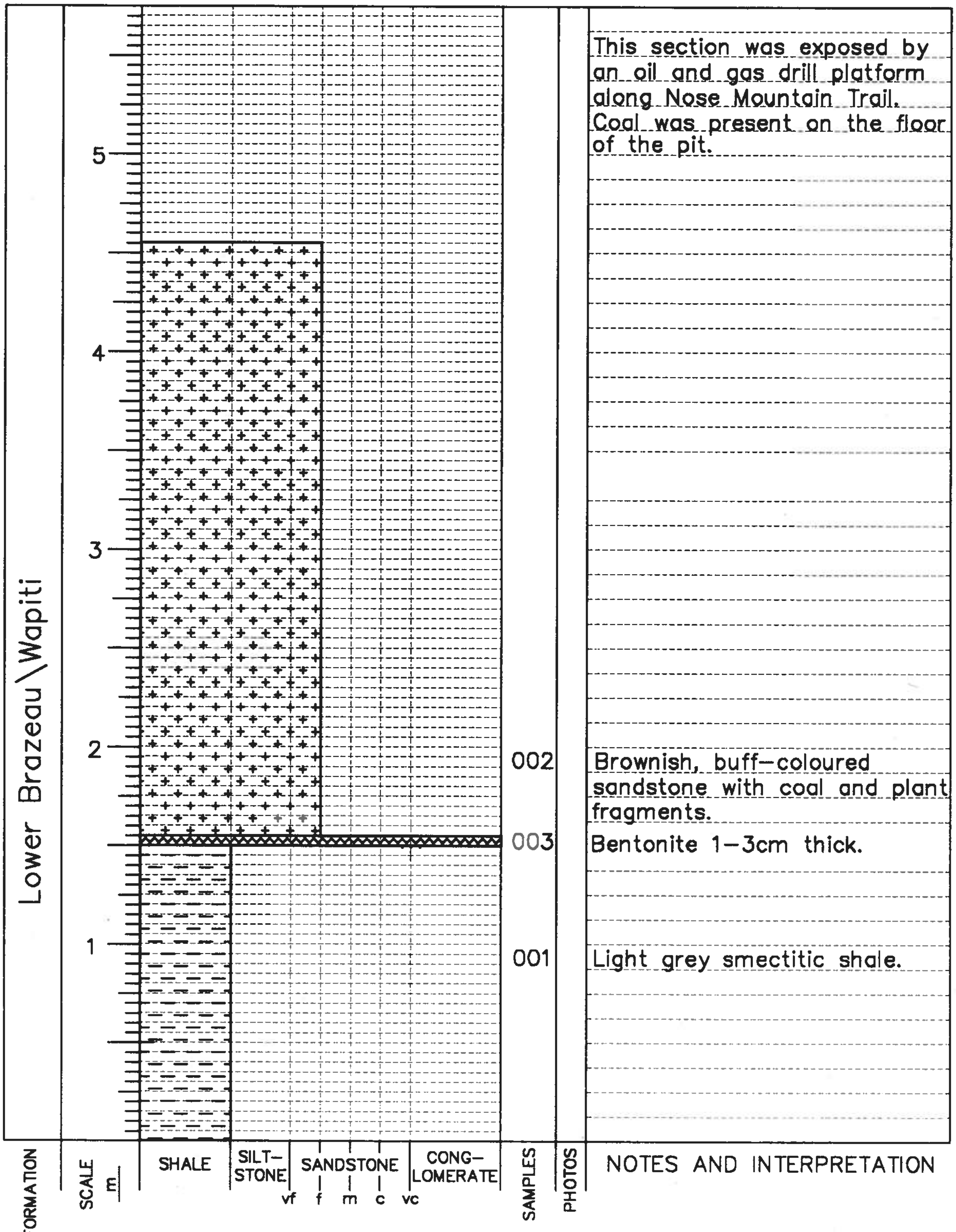
Station Identifier: KW96-06

Location (UTM): 383798E, 6103436N



Station Identifier: KW96-09

Location (UTM): 335997E, 6037234N



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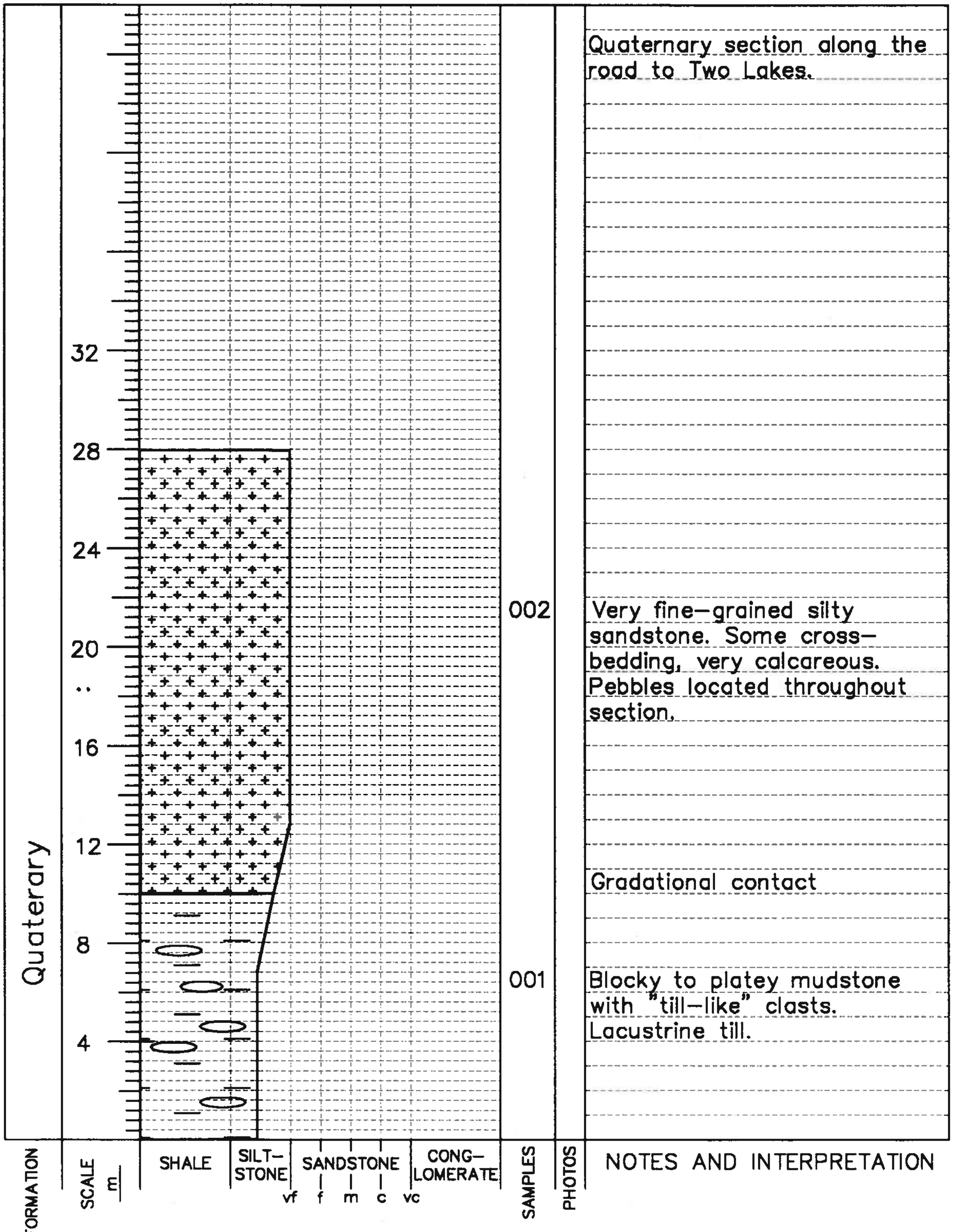

Station Identifier: KW96-12

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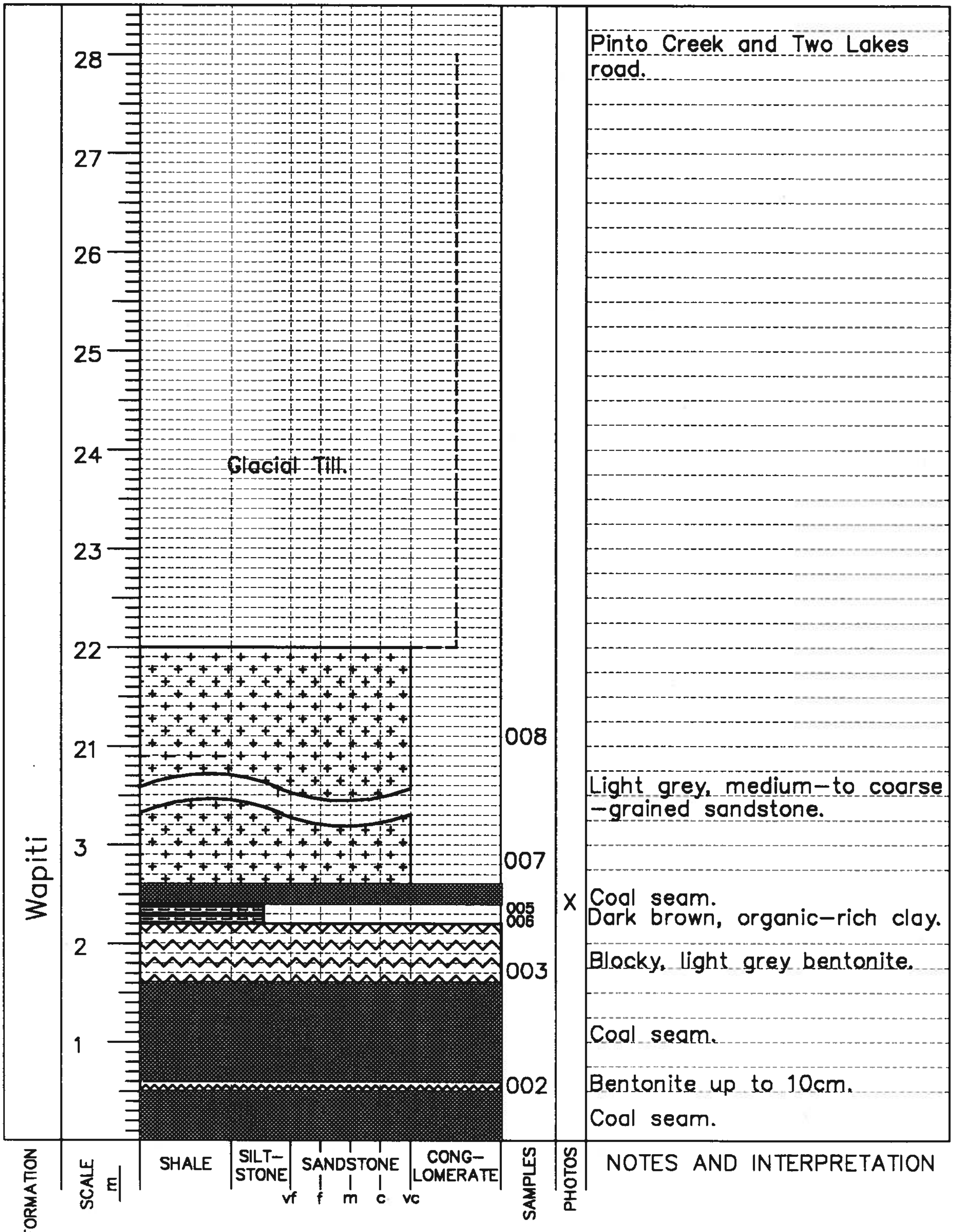
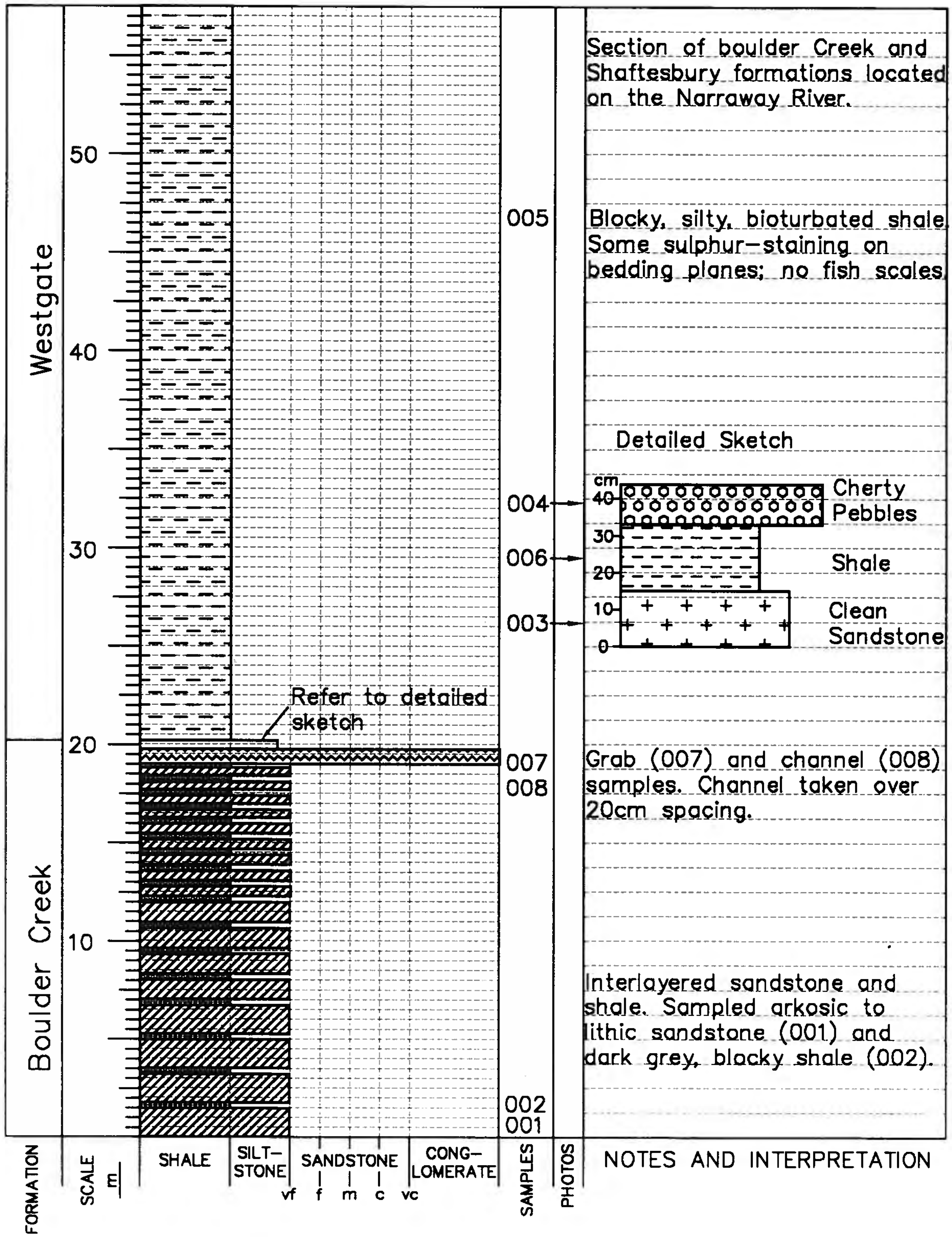


Station Identifier: KW96-15

Location (UTM): 305710E, 6025825N



Station Identifier: KW96-17

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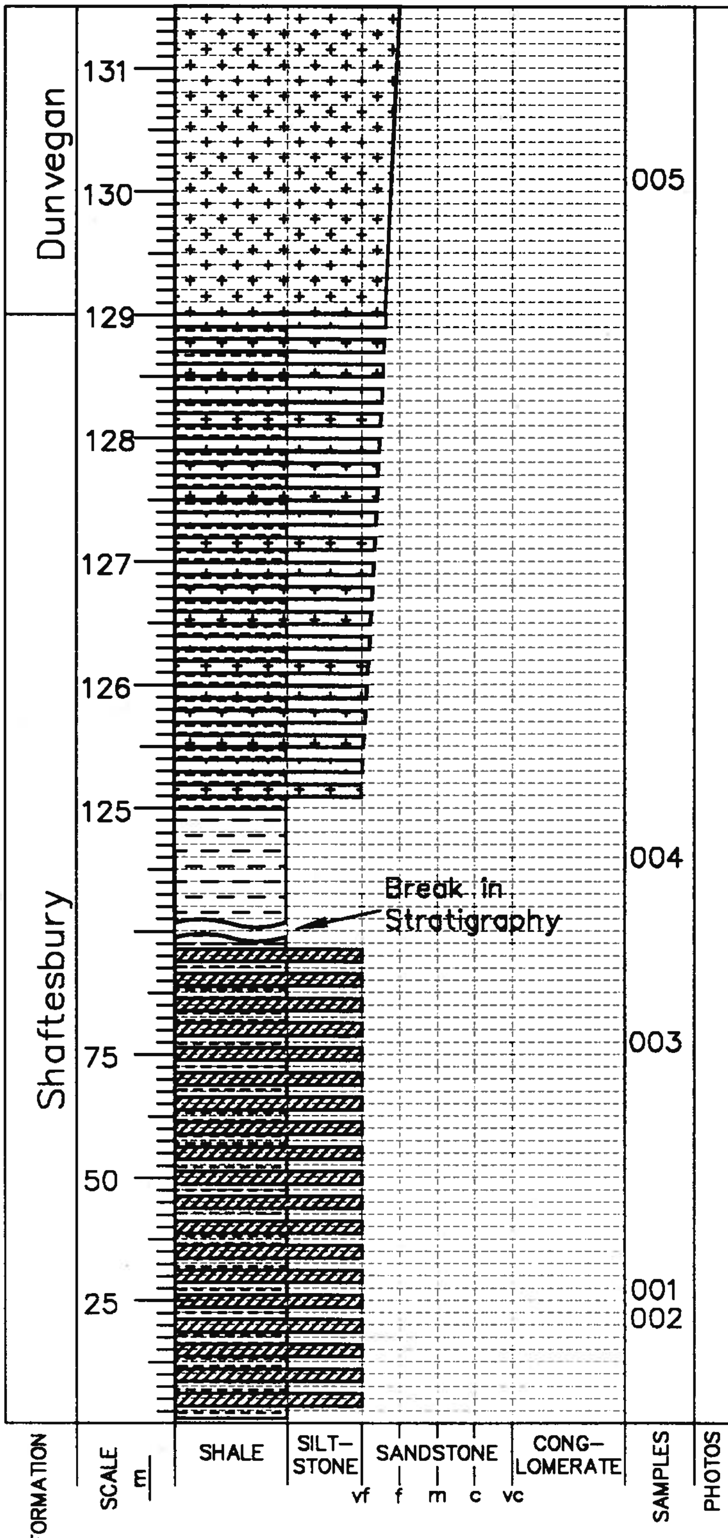


Folded section of Shaftesbury and Dunvegan formations on Lynx Creek.

Rusty, weathered sandstone with some woody fragments.

Gradational contact of interlayered marine to deltaic sandstone and silty shale.

Shale

003–Rusty, weathered, siliceous–looking, 10cm concretionary layer of fine–grained sandstone.

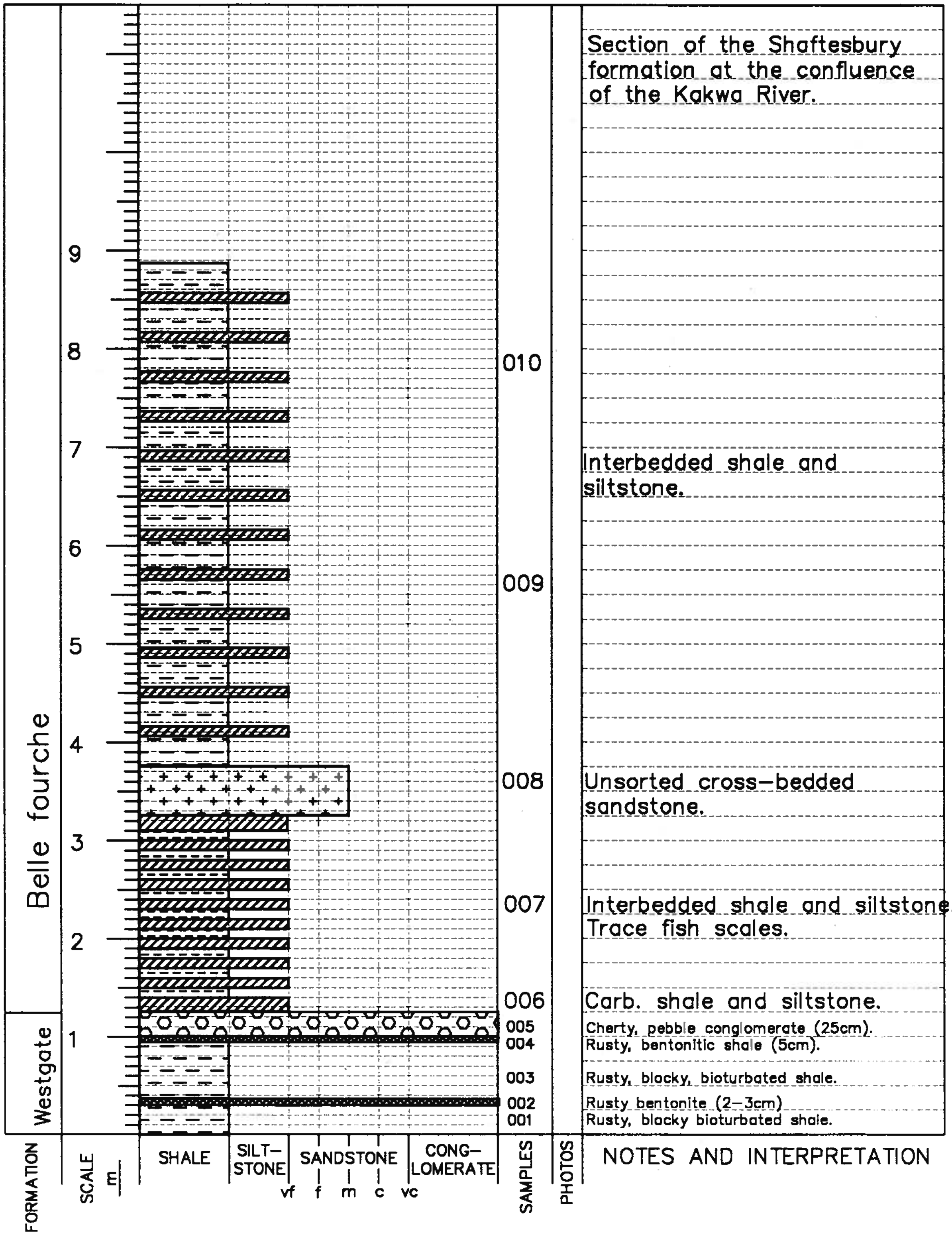
Interbedded shale and siltstone.

001–rusty, weathered, concretionary sandstone, intercalated with bentonite.

002– 1cm layer of bentonite

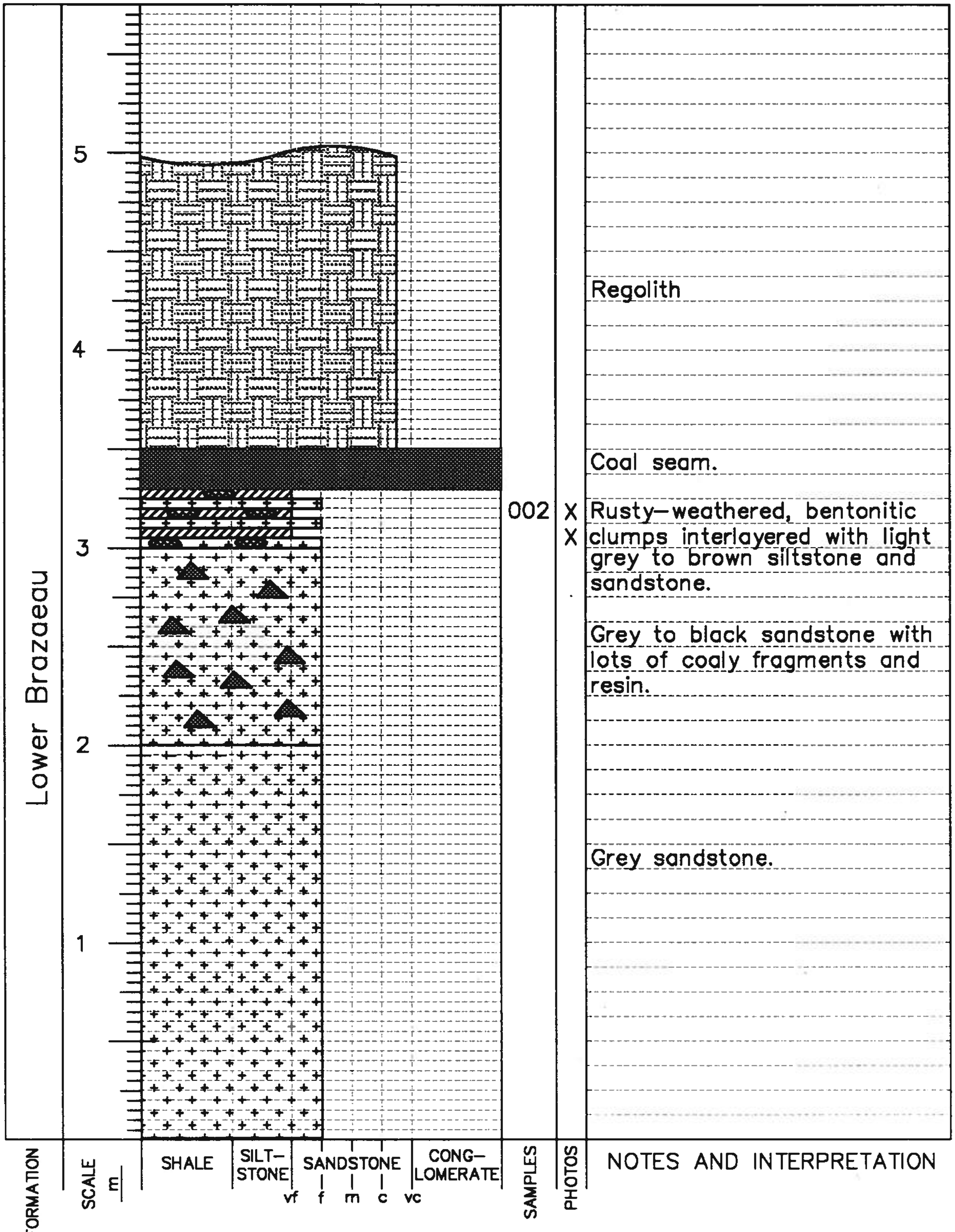
Station Identifier: KW96-20

Location (UTM): 333970E, 6005325N

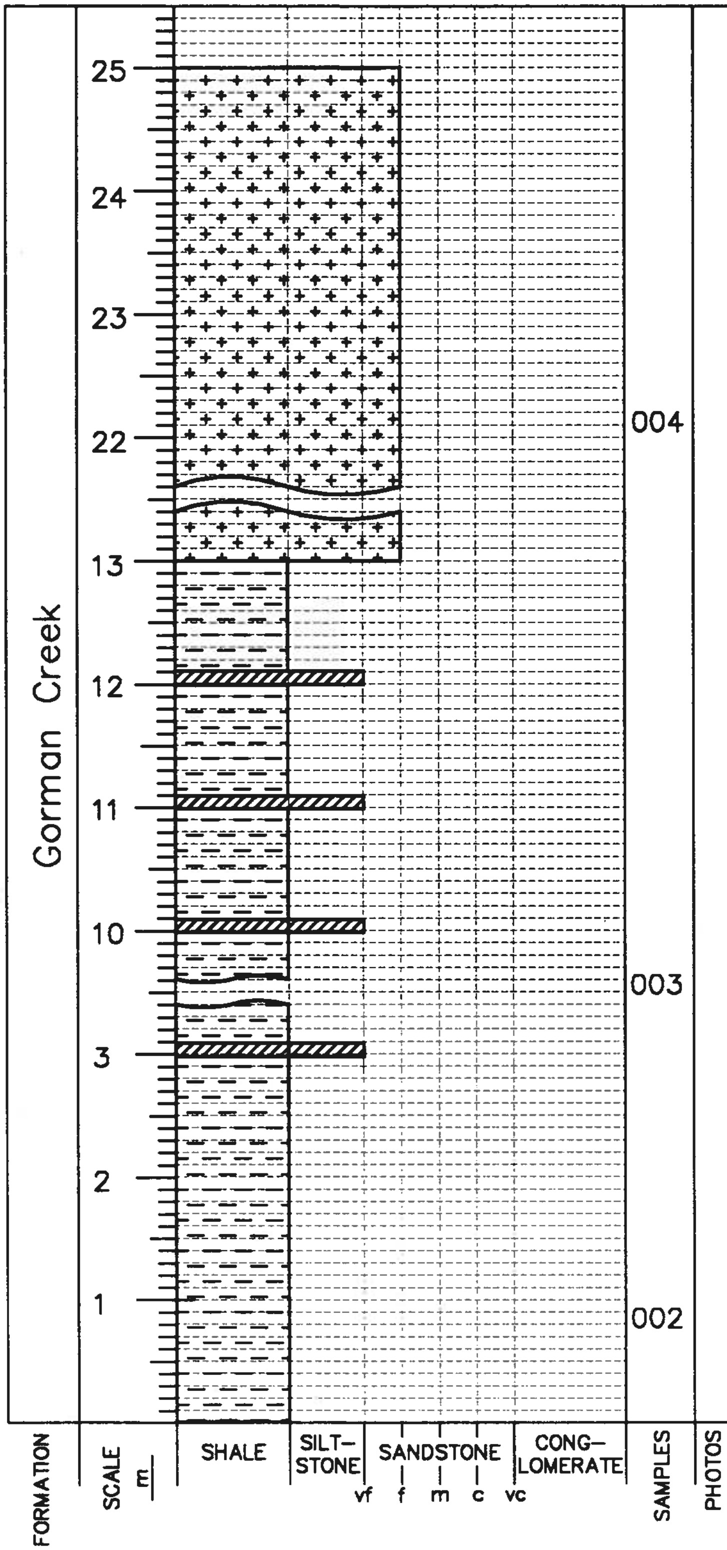


Station Identifier: KW96-28

Location (UTM): 401588E, 6073603N



Station Identifier: KW96-61
Location (UTM): 314400E, 6015360N



NOTES AND INTERPRETATION

Section of the Gorman Creek Formation at Lick Creek and the Two Lakes road.

Massive, light buff in colour, medium-grained sandstone and siltstone.

Interlayered grey, blocky shale and siltstone. (90%shale)

Sample of the rusty siltstone approximately 3cm in width.

Grey, blocky, bioturbated shale with rusty locals and minor sulphur-staining.

APPENDIX 2

Major and trace element geochemistry from metallic mineral samples in the Kakwa/Wapiti area (NTS 83L).

Appendix 2. Major and trace element geochemistry from metallic mineral samples in the Kakwa/Wapiti area (NTS 83L)

Sample #	Lithology	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	Al	Na	K	W	Zr	Sn	Y	Nb	Be	Sc	Au**	TOT/S	ORG/C
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb	%	%
KW96-61-004	Dunvegan Fm Ss	< 2	17	17	131	< .5	47	12	424	3.12	< 5	< 10	< 4	8	90	< .4	< 5	< 5	131	1.13	0.123	23	72	1.04	872	0.28	6.06	0.61	1.4	< 4	44	2	19	7	2	11	< 2	0.02	0.43
RR94-13b	Shaftesbury Fm Sst - Ss (Con)	< 2	13	7	25	< .5	21	< 2	22	0.53	< 5	< 10	< 4	5	31	0.6	< 5	< 5	63	0.03	0.005	13	37	0.1	1766	0.39	2.69	0.03	0.16	< 4	48	< 2	9	14	< 1	4	< 2	0.27	0.03
RR94-14a	Shaftesbury Fm Sst - Ss	< 2	16	7	113	< .5	17	3	87	0.93	8	< 10	< 4	5	47	0.4	< 5	< 5	106	0.7	0.053	17	43	0.27	584	0.18	3.05	0.12	0.93	< 4	31	< 2	20	7	< 1	7	4	0.19	0.51
RR94-14b	Shaftesbury Fm silty Sh	< 2	13	6	30	< .5	8	< 2	3002	26.84	< 5	< 10	< 4	5	67	< .4	< 5	< 5	61	1.55	0.214	13	34	2.57	909	0.09	1.86	0.12	0.63	< 4	15	2	18	2	6	5	3	0.31	0.39
RR94-15a	Fernie Fm Sh	3	28	12	219	0.5	42	6	398	2.51	< 5	< 10	< 4	8	124	1	< 5	< 5	218	2.88	0.156	31	103	1.52	1250	0.31	6.58	0.09	2.45	< 4	35	< 2	24	7	2	11	2	0.09	2.5
RR94-15b	Fernie Fm Sh	< 2	14	7	131	0.5	25	5	662	3.3	< 5	< 10	< 4	6	177	1.1	7	< 5	120	7.85	0.062	18	57	3.26	1035	0.17	3.37	0.07	1.46	< 4	22	< 2	23	4	1	7	3	0.22	1.21
RR94-18b	Kaskapau Fm Sh	< 2	23	12	136	< .5	37	6	92	2.8	8	< 10	< 4	9	104	< .4	< 5	< 5	193	0.78	0.077	35	105	1.1	787	0.38	7.79	0.3	2.23	< 4	51	2	18	11	2	13	6	1.26	1.26
RR94-18c	Kaskapau Fm silty Sh	< 2	16	11	45	< .5	18	< 2	1297	20.3	< 5	< 10	< 4	7	92	0.9	< 5	< 5	125	2.44	0.024	20	59	4.35	573	0.19	3.51	0.11	1.16	< 4	31	< 2	25	4	< 1	23	< 2	0.73	1.01
RR94-23a	Kaskapau Fm Sst	< 2	14	< 5	52	< .5	17	< 2	1024	19.47	< 5	< 10	< 4	7	96	< .4	8	< 5	149	1.87	0.031	19	57	4.26	487	0.16	3.31	0.13	1.08	< 4	22	< 2	18	3	< 1	28	< 2	0.3	0.49
RR94-23b	Kaskapau Fm silty Sh	< 2	20	21	122	< .5	28	6	76	2.37	8	< 10	< 4	8	91	< .4	< 5	< 5	114	0.87	0.072	23	61	0.68	471	0.23	4.83	0.28	1.28	< 4	35	< 2	15	8	1	10	5	1.35	0.68
RR94-24a	Dunvegan Fm Sst - Ss	< 2	7	< 5	62	< .5	15	4	64	1.49	6	< 10	< 4	3	31	< .4	< 5	< 5	40	0.31	0.056	10	20	0.37	188	0.07	1.82	0.23	0.47	< 4	10	< 2	13	2	< 1	3	< 2	0.16	0.24
RR94-24b	Dunvegan Fm Sst - Ss	< 2	11	14	49	< .5	20	2	63	2.12	9	< 10	< 4	6	74	< .4	< 5	< 5	97	0.14	0.051	24	56	0.33	446	0.26	4.5	0.65	0.94	< 4	27	< 2	11	8	1	7	4	0.97	0.44
RR94-24c	Dunvegan Fm silty Sh	< 2	20	12	86	< .5	21	< 2	51	2.77	6	< 10	< 4	9	93	< .4	< 5	< 5	197	0.05	0.06	34	106	0.59	1790	0.4	7.8	0.4	2.04	< 4	46	< 2	14	10	2	13	4	0.4	0.95
RR94-25b	Boulder Creek Fm Sst	< 2	16	< 5	113	< .5	19	2	38	1.33	6	< 10	< 4	5	49	< .4	< 5	< 5	120	0.1	0.064	22	52	0.31	655	0.23	3.61	0.14	1.22	< 4	37	< 2	15	10	1	7	3	0.65	0.54
RR94-25c	Boulder Creek Fm Sst - Ss	< 2	16	< 5	103	< .5	13	< 2	40	1.08	6	< 10	< 4	6	48	< .4	< 5	< 5	108	0.13	0.07	23	50	0.38	628	0.26	3.8	0.19	1.32	< 4	39	< 2	15	10	1	7	2	0.3	0.42
RR94-25d	Shaftesbury Fm Sh	2	35	11	312	< .5	85	15	214	2.77	< 5	< 10	< 4	10	88	1.1	< 5	< 5	185	0.94	0.078	34	92	1.14	826	0.34	7.27	0.22	2.23	< 4	45	< 2	30	10	2	12	6	1.4	1.02
RR94-25e	Shaftesbury Fm Sst (Con)	2	27	11	91	< .5	18	2	38	2.32	11	< 10	< 4	7	63	0.6	< 5	< 5	149	0.1	0.106	27	76	0.49	702	0.28	4.89	0.23	1.65	< 4	41	< 2	13	10	1	9	6	0.95	0.86
RR94-26	Gorman Creek Fm Sst - Ss	< 2	23	< 5	90	< .5	16	< 2	18	0.31	8	< 10	< 4	5	66	0.4	< 5	< 5	104	0.59	0.196	21	55	0.15	469	0.18	3.26	0.03	1.41	< 4	35	< 2	22	4	< 1	4	4	0.05	0.98
RR94-27b	Shaftesbury Fm Sst	3	12	22	90	< .5	19	< 2	1357	10.41	6	< 10	< 4	20	227	0.8	< 5	< 5	20	11.08	< .002	23	13	3.38	779	0.06	4.55	0.07	0.43	< 4	22	4	42	5	< 1	3	3	0.68	0.14
RR94-28	Fernie Fm Sh	2	32	22	149	< .5	28	6	49	3.55	11	< 10	< 4	13	136	< .4	< 5	< 5	188	0.36	0.133	59	91	0.51	810	0.58	9.29	0.47	2.25	< 4	58	< 2	21	38	2	13	4	0.1	2.48
RR95-08	Shaftesbury Fm Sh	17	33	19	127	0.6	22	5	71	4.26	13	< 10	< 4	11	110	< .4	< 5	< 5	220	0.21	0.131	34	108	0.48	1171	0.36	6.79	0.3	2.03	< 4	49	< 2	13	10	2	11	4	0.16	1.46
RR95-09a	Kaskapau Fm Sh	4	21	8	51	< .5	13	< 2	30	3.32	12	< 10	< 4	10	89	0.4	< 5	< 5	244	0.01	0.087	37	117	0.45	993	0.45	8.13	0.26	2.42	< 4	49	< 2	10	11	2	13	< 2	0.38	1.62
RR95-09b	Kaskapau Fm Sst	3	21	10	89	< .5	15	3	26	2.76	< 5	< 10	< 4	7	44	< .4	< 5	< 5	83	0.32	0.071	16	38	0.22	317	0.16	2.46	0.22	0.74	< 4	25	< 2	15	5	1	7	2	2.26	0.4
	C = C; Ss = Ss;																																				
	Sst = Sst; Sh = Sh;																																				
	Con = Con																																				

35 Element ICP/Au** by Fire Assay ICP/Total S by Leco/Total Organic C

Appendix 2. Major and trace element geochemistry from metallic mineral samples in the Kakwa/Wapiti area (NTS 83L)

Sample #	Lithology	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	Al	Na	K	W	Zr	Sn	Y	Nb	Be	Sc	Au**	TOT/S	ORG/C
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb	%	%
KW96-01-001	Gladstone Fm. pebble C	2	26	62	182	1	67	23	251	1.73	49	< 10	< 4	6	195	1.6	9	< 5	97	4.74	0.059	17	58	1	568	0.17	5.23	0.08	1.23	< 4	29	< 2	17	3	< 1	8	9	0.28	1.11
KW96-01-002	Gladstone Fm. pebble C	< 2	16	37	55	< .5	46	9	529	3.08	7	< 10	< 4	5	777	0.5	< 5	< 5	24	19.64	< .002	20	17	0.82	731	0.04	1.37	0.08	0.42	< 4	12	< 2	12	< 2	< 1	3	8	0.68	0.38
KW96-01-003	Nikanassin Fm Sst	< 2	17	< 5	65	< .5	27	8	2804	15.43	< 5	< 10	< 4	6	92	< .4	< 5	< 5	63	1.67	0.086	29	38	1.21	695	0.18	2.84	0.06	1.04	< 4	29	< 2	30	3	1	14	4	1.01	0.66
KW96-01-004	Nikanassin Fm Sst	< 2	14	7	54	< .5	13	< 2	4078	25.21	< 5	< 10	< 4	3	79	0.8	< 5	< 5	110	2.52	0.122	10	48	1.88	762	0.07	1.78	0.04	0.61	< 4	13	< 2	29	< 2	7	13	< 2	0.12	0.54
KW96-01-005	Cadomin Fm C	6	10	21	38	< .5	10	< 2	38	1.37	24	< 10	< 4	4	53	< .4	< 5	< 5	93	0.06	0.041	18	50	0.09	407	0.1	2.22	0.04	0.54	< 4	23	< 2	5	< 2	< 1	4	< 2	0.22	0.85
KW96-01-006	Nikanassin Fm Ss	2	35	21	179	< .5	35	3	469	3.6	< 5	< 10	< 4	8	79	0.7	< 5	< 5	125	3.09	0.059	22	81	1.95	756	0.24	4.76	0.07	1.76	< 4	39	< 2	17	5	1	11	3	0.03	0.43
KW96-01-007	Gladstone Fm silty Ss	2	16	24	243	< .5	49	8	1347	10.57	< 5	< 10	< 4	8	78	1.7	< 5	< 5	110	2.7	0.08	19	66	1.54	719	0.19	4.18	0.09	1.48	< 4	31	< 2	19	3	1	11	4	0.52	1.42
KW96-01-008	Gladstone Fm pebble C	< 2	10	24	75	< .5	24	5	1285	19.81	< 5	< 10	< 4	3	497	2.4	< 5	< 5	32	10.86	< .002	10	20	2.23	681	0.04	1.39	0.03	0.31	< 4	8	3	23	< 2	< 1	10	< 2	0.62	0.54
KW96-02-001	Mountain Park Fm Ss	< 2	21	9	130	< .5	23	4	181	1.17	< 5	< 10	< 4	7	68	1.1	< 5	< 5	85	1.13	0.153	23	81	0.55	298	0.2	3.19	0.05	0.76	< 4	42	< 2	22	4	1	6	< 2	0.39	0.29
KW96-02-002	Mountain Park Fm C	2	17	20	184	< .5	63	33	116	1.85	13	< 10	< 4	6	94	< .4	< 5	< 5	47	1.3	0.293	18	28	0.24	374	0.05	1.48	0.06	0.32	< 4	14	< 2	23	< 2	< 1	5	< 2	1.04	0.22
KW96-02-003	Westgate Fm Sh	< 2	15	22	55	0.5	12	< 2	24	1.74	8	< 10	< 4	8	106	< .4	< 5	< 5	205	0.29	0.068	32	101	0.43	729	0.39	6.64	0.18	2.04	< 4	57	< 2	8	11	2	10	3	0.67	1.21
KW96-06-001	Lower Brazeau B	< 2	15	14	34	< .5	21	2	82	2.13	< 5	< 10	< 4	5	165	< .4	< 5	< 5	64	0.25	0.006	20	42	0.28	775	0.36	5.8	1.39	1.93	< 4	51	< 2	10	4	< 1	8	< 2	0.04	0.02
KW96-06-002	Lower Brazeau B	< 2	26	11	67	< .5	24	4	77	3.05	< 5	< 10	< 4	8	215	< .4	< 5	< 5	118	0.39	0.005	11	67	0.5	945	0.39	8.04	1.41	1.77	< 4	65	< 2	7	6	1	14	< 2	0.07	0.09
KW96-06-004	Lower Brazeau smectitic Sh	2	21	33	70	< .5	10	< 2	62	2.13	< 5	< 10	< 4	12	197	< .4	< 5	< 5	68	0.44	0.007	31	42	0.47	812	0.35	8.56	1.16	0.95	< 4	94	3	14	11	2	9	2	0.06	2.42
KW96-09-001	Lower Coalspur Fm smectitic Sh	< 2	22	16	99	< .5	29	6	92	1.47	< 5	< 10	< 4	10	72	< .4	< 5	< 5	136	0.99	0.067	32	73	0.8	569	0.31	6.38	0.07	2.29	< 4	61	< 2	11	8	1	8	2	0.02	0.19
KW96-09-002	Lower Coalspur Fm Ss	< 2	8	13	46	< .5	16	4	506	2.63	8	< 10	< 4	5	98	< .4	< 5	< 5	73	7.8	0.015	13	31	1.66	247	0.08	1.66	0.03	0.64	< 4	34	2	16	< 2	< 1	5	< 2	0.06	1.2
KW96-09-003	Lower Coalspur B	2	36	19	172	< .5	32	5	922	2.96	< 5	< 10	< 4	10	104	1.7	< 5	< 5	218	1.58	0.102	39	117	1.22	732	0.39	8.74	0.08	2.67	< 4	62	< 2	21	10	2	14	2	0.03	0.58
KW96-11-001	Quaternary lacustrine till	2	30	15	109	< .5	35	8	408	2.94	< 5	< 10	< 4	9	165	0.6	< 5	< 5	130	5.33	0.029	25	76	1.63	730	0.34	6.94	0.52	1.98	< 4	48	< 2	15	7	1	11	2	0.2	1.33
KW96-11-002	Quaternary lacustrine till	2	33	20	114	< .5	45	10	457	3.48	< 5	< 10	< 4	11	160	0.9	< 5	< 5	157	6.87	0.017	29	94	1.94	730	0.32	7.89	0.39	2.48	< 4	47	< 2	15	6	2	13	3	0.04	0.76
KW96-12-002	Lower Brazeau Fm B	< 2	3	51	117	< .5	< 2	< 2	19	3.11	< 5	< 10	< 4	21	199	< .4	< 5	< 5	2	1.54	< .002	36	5	1.62	404	0.06	10.64	0.22	0.32	< 4	94	6	15	9	< 1	4	2	0.08	0.34
KW96-12-003	Lower Brazeau Fm B	< 2	8	34	61	< .5	8	9	51	2.43	< 5	< 10	< 4	22	230	0.4	< 5	< 5	19	1.91	0.052	35	3	1.6	420	0.27	9.2	0.38	0.11	< 4	110	< 2	11	11	< 1	4	< 2	0.05	0.01
KW96-12-004	Lower Brazeau Fm float	5	9	< 5	60	< .5	47	29	7229	20.72	6	< 10	< 4	4	102	< .4	< 5	< 5	111	1.21	0.112	20	39	0.32	1440	0.15	4.56	0.64	0.6	< 4	38	< 2	23	2	2	17	4	0.04	0.62
KW96-12-005	Lower Brazeau Fm organic clay	< 2	8	37	46	< .5	2	4	87	2.46	< 5	< 10	< 4	23	205	< .4	< 5	< 5	32	1.57	0.016	33	7	1.15	4478	0.2	7.8	0.32	0.25	< 4	102	4	11	7	< 1	7	< 2	0.3	2.69
KW96-12-007	Lower Brazeau Fm Ss	< 2	12	17	85	< .5	10	5	139	1.79	< 5	10	< 4	9	272	< .4	7	< 5	57	1.32	0.022	22	36	0.61	1755	0.28	7.63	1.3	1.31	< 4	57	2	10	8	1	9	< 2	0.07	2.71
KW96-12-008	Lower Brazeau Fm Ss	4	14	11	68	< .5	40	25	6735	16.1	16	< 10	< 4	5	117	< .4	< 5	5	105	1.69	0.119	17	38	0.36	1230	0.16	4.9	0.72	0.63	< 4	37	< 2	20	2	< 1	15	< 2	0.01	0.64
KW96-15-001	Boulder Creek Fm Sst	< 2	12	11	46	< .5	25	< 2	27	0.55	< 5	< 10	< 4	7	22	< .4	< 5	< 5	69	0.06	0.004	11	25	0.1	242	0.48	2.53	0.02	0.13	< 4	82	< 2	9	13	< 1	4	4	0.05	0.04
KW96-15-002	Boulder Creek Fm Sh	2	66	28	350	0.5	154	33	439	4	9	< 10	< 4	10	80	2.2	7	< 5	287	0.38	0.091	37	177	1.3	1436	0.44	9.61	0.08	3.03	< 4	60	3	22	11	3	15	11	0.09	0.96
KW96-15-003	Boulder Creek Fm silty Ss	3	15	11	31	< .5	34	2	6	1.43	16	< 10	< 4	5	22	< .4	< 5	< 5	105	0.01	0.008	12	55	0.19	364	0.41	3.67	0.03	0.46	< 4	61	< 2	7	13	< 1	5	< 2	0.03	0.07
KW96-15-004	Boulder Creek Fm pebble C	3	13	22	114	< .5	41	19	122	1.41	35	< 10	< 4	5	46	< .4	9	< 5	65	0.45	0.228	19	39	0.14	567	0.09	2.05	0.03	0.5	< 4	22	< 2	20	3	< 1	6	2	0.2	0.24
KW96-15-005	Westgate Fm silty Sh	2	17	8	38	< .5	9	< 2	13	1.91	15	< 10	< 4	8	64	< .4	< 5	< 5	183	0.02	0.072	26	89	0.38	911	0.33	5.68	0.12	1.93	< 4	55	< 2	7	11	1	10	5	0.19	1.1
KW96-15-006	Boulder Creek Fm Sh	3	23	28	95	< .5	47	4	16	0.99	9	< 10	< 4	9	48	< .4	5	< 5	166	0.01	0.025	27	121	0.43	861	0.36	6.65	0.06	1.91	< 4	57	2	8	10	1	11	4	0.07	1.44
KW96-15-007	Boulder Creek Fm B	2	12	5	25	< .5	38	< 2	5	0.95	11	< 10	< 4	7	31	< .4	< 5	< 5	141	0.02	0.007	13	74	0.22	791	0.43	6.3	0.04	0.43	< 4	65	< 2	7	14	< 1	6	3	0.08	0.04
KW96-15-008	Boulder Creek Fm B-Ss	2	39	5	59	< .5	41	< 2	< 5	2.89	16	< 10	< 4	9	31	< .4	< 5	< 5	186	0.02	0.011	13	101	0.32	609	0.36	7.44	0.05	0.94	< 4	58	< 2	6	11	< 1	7	< 2	0.11	0.02
KW96-16-001	Shaftesbury Fm Sh	2	32	24	166	< .5	53	17	449	3.31	5	< 10	< 4	9	102	< .4	< 5	< 5	196	0.24	0.078	27	105	0.78	1315	0.37	8.2	0.48	2.01	< 4	49	4	15	9	2	14	3	0.35	0.9
KW96-16-002	Belle Fourche Fm silty Sh	3	19	15	44	< .5	10	< 2	29	3.33	9	< 10	< 4	10	91	< .4	< 5	< 5	163	0.04	0.09	26	90	0.43	1375	0.33	6.25	0.35	1.74	< 4	53	< 2	9	10	2	11	2	0.59	1.09
KW96-16-003	Belle Fourche Fm float-bone bed	23	15	< 5	2	< .5	3	< 2	< 5	31.61	131	< 10	< 4	27	1481	< .4	< 5	< 5	58	0.02	0.588	20	23	0.06	33	0.02	0.67	2.91	0.32	< 4	5	4	3	< 2	4	4	2	10.42	0.17
KW96-16-004	Belle Fourche Fm B-Sh	28	12	< 5	10	< .5	5	< 2	< 5	20.05	48	< 10	< 4	13	662	< .4	< 5	< 5	128	0.53	0.369	24	53	0.19	30	0.14	3.03	1.83	0.98	< 4	29	< 2	6	5	< 1	6	4	6.71	0.93
KW96-16-005	Belle Fourche Fm B-bone bed	48	12	< 5	4	< .5	< 2	< 2	< 5	29.64	62	< 10	< 4	46	1775	2.3	< 5	< 5	64	0.58	0.587	45	25	0.06	83	0.03	0.71	2.66	0.31	< 4	6	< 2	3	< 2	4	3	2	12.44	0.28
KW96-16-006	Belle Fourche Fm B	33	10	15	10	< .5	4	< 2	12	20.26	53	< 10	< 4	17	726	0.7	< 5	< 5	124	1.33	0.367	26	51	0.19	32	0.13	2.47	1.89	0.8	< 4	19	2	5	2	< 1	5	< 2	8.11	0.78
KW96-16-007	Belle Fourche Fm Sh	24	13	17	50	< .5	7	< 2	34	6.29	34	< 10	< 4	9	145	0.7	< 5	< 5	221	1.8	0.175	27	86	0.43	131	0.31	5.84	0.27	1.68	< 4	48	< 2	9	7	1	10	< 2	2.75	1.6
KW96-17-001	Belle Fourche Fm Sst-Sh-Ss	< 2	76	17	129	< .5	14	< 2	2252	20.25	< 5	< 10	< 4	28	48	5.3	< 5	< 5	30	0.86	0.054	22	22	1.4	539	0.12	8.5	0.14	0.58	5	44	5	43	5	< 1	9	< 2	0.74	0.11
KW96-17-002	Belle Fourche Fm B-Sst-Sh	4	20	30	30	< .5	8	< 2	67	8.33	< 5	10	< 4	19	69	0.7	< 5	< 5	72	0.02	0.119	13	27	0.54	2238	0.48	14.36	0.13	1	< 4	66	2	12	12	< 1	8	3	0.75	0.13
KW96-17-003	Belle Fourche Fm Con	< 2	13	9	131	< .5	24	2	1158	8.78	< 5	< 10	< 4	14	270	2.9	< 5	< 5	25	11.2	< .002	20	16	3.75	851	0.06	3.74	0.06	0.51	< 4	29	5	40	3	1	4	< 2	0.22	0.2
KW96-17-004	Belle Fourche Fm silty Sh	< 2	39	16	156	< .5	54	14	476	3.43	< 5	< 10	< 4	9	97	0.4	< 5	< 5	188	0.39	0.104	30	97	0.89	1104	0.4	7.28	0.53	1.86	< 4	53	< 2	17	6	2	14	11	0.07	1.3
KW96-17-005	Dunvegan Fm Ss	< 2	16	8	109	< .5	53	10	398	3.2	6	< 10	< 4	7	95	< .4	< 5	< 5	122	0.47	0.102	22	66	0.71	1327	0.28	5.61	0.61	1.25	< 4	38	< 2	13	5	1	10	5	0.09	0.36
KW96-19-002	Kaskapau Fm Sh	8	23	15	91	< .5	28	5	59	4.47	25	< 10	< 4	8	106	< .4	< 5	< 5	201	1.43	0.071	30	92	0.54	144	0.36	7.03	0.29	1.88	< 4	51	< 2	11	5	2	13	3	2.56	2.05
KW96-19-003	Kaskapau Fm Con	< 2	35	14	269	< .5	105	33	572	6.6	6	< 10	< 4	9	122	2	6	< 5	122	10.86	< .002	18	59	4.21	180	0.21	4.44	0.18	1.19	< 4	33	< 2	32	3	2	15	2	2.7	1.16
KW96-19-004	Kaskapau Fm Sh	3	26	8	118	< .5	37	9	79	4.87	13	< 10	< 4	8	93	< .4	< 5	< 5	178	1.85	0.081	28	89	0.54	125	0.34	6.72	0.29	1.82	< 4	44	< 2	12	6	2	11	2	2.81	1.75
KW96-20-001	Westgate Fm Sh	< 2	28	17	108	< .5	21	2	67	3.02	< 5	< 10	< 4	7	63	< .4	< 5	< 5	166	0.02	0.031	34	70	0.27	560	0.3	4.94	0.07	1.12	< 4	50	< 2	12	5	1	10	< 2	0.08	0.05
KW96-20-002	Westgate Fm B	2	33	22	67	1	23	< 2	36	2.02	< 5	< 10	< 4	11	75	< .4	< 5	< 5	203	0.01	0.045	34	113	0.44	838	0.4	6.7	0.11	1.62	< 4	58	< 2	12	10	1	13	9	0.1	0.59
KW96-20-003	Westgate Fm Sh	2	43	11	151	< .5	32	4	63	4.42	< 5	< 10	< 4	11	64	< .4	< 5	< 5	175	0.01	0.022	34	100	0.29	741	0.39	5.84	0.08	1.17	< 4	58	< 2	17	9	1	13	3	0.15	0.29
KW96-20-004	Westgate Fm B-Sh	2	38	< 5	89	< .5	33	< 2	23	1.68	6	< 10	< 4	13	98	< .4	< 5	< 5	225	0.01	0.031	35	115	0.42	2238	0.44	7.85	0.1	1.41	< 4	64	< 2	12	11	1	13	4	0.11	0.26
KW96-20-005	Fish Scales Fm pebble congl.	5	16	15	161	0.5	34	12	32	1.91	16	< 10	< 4	6	68	0.6	< 5	< 5	128	0.16	0.131	25	53	0.25	1188	0.22	3.63	0.05	0.96	< 4	35	< 2	12	7	1	8	5	0.41	0.65
KW96-20-006	Fish Scales Fm silty Sh	2	18	17	58	< .5	16	< 2	53	2.15	5	< 10	< 4	7	67	< .4	< 5	< 5	188	0.03	0.086	29	81	0.42	792	0.37	5.68	0.08	1.59	< 4	56	< 2	9	11	1	10	< 2	0.25	0.89
KW96-20-007	Fish Scales Fm silty Sh	< 2	14	9	41	< .5	13	< 2	23	1.8	6	< 10	< 4	8	59	< .4	< 5	< 5	183	0.02	0.087	26	76	0.36	815	0.34	5.06	0.08	1.46	< 4	48	< 2	7	10	1	9	7	0.2	1.03
KW96-20-008	Belle Fourche Fm Ss	< 2	8	7	32	< .5	7	< 2	16	1.28	6	< 10	< 4	5	35	< .4	< 5	< 5	102	0.03	0.064	15	39	0.19	570	0.16	2.31	0.06	0.77	< 4	33	< 2	6	5	< 1	6	12	0.18	0.64
KW96-20-009	Belle Fourche Fm silty Sh	2	31	20	62	< .5	17	< 2	32	3.02	9	< 10	< 4	8	64	< .4	< 5	< 5	182	0.02	0.095	29	86	0.6	776	0.36	6.12	0.09	1.83	< 4	49	< 2	9	10	2	11	16	0.13	1.09
KW96-20-010	Belle Fourche Fm silty Sh	3	17	12	24	< .5	5	< 2	18	2.05	5	< 10	< 4	7	58	< .4	< 5	< 5	166	0.01	0.084	25	75	0.32	655	0.32	4.76	0.1	1.44	< 4	51	< 2	7	9	1	9	< 2	0.19	1.05
KW96-21-002	Shaftesbury Fm silty Sh	2	37	15	173	< .5	45	9	103	2.82	7	< 10	< 4	8	111	0.6	< 5	< 5	227	0.69	0.089	33	102	1.12	1105	0.39	7.79	0.21	2.38	< 4	55	< 2	15	11	2	13	5	0.85	1.32
KW96-22-001	Shaftesbury Fm silty Sh	2	32	14	49	< .5	13	< 2	27	3.95	16	< 10	< 4	8	71	< .4	< 5	5	183	0.03	0.11	27	91	0.57	1015	0.33	6.3	0.31	1.88	< 4	49	< 2	7	9	2	11	< 2	0.28	1.1
KW96-22-002	Shaftesbury Fm silty Sh	< 2	18	9	71	< .5	15	< 2	25	2.92	11	< 10	< 4	7	69	< .4	< 5	< 5	167	0.05	0.113	27	78	0.49	871	0.31	5.36	0.27	1.61	< 4	50	< 2	9	8	2	10	< 2	0.57	1.09
KW96-28-002	Lower Coalspur Fm B and Sst	2	20	48	45	< .5	25	10	65	4.36	374	< 10	< 4	6	352	< .4	< 5	< 5	105	1.15	< .002	16	54	0.65	270	0.35	6.98	1	1.69	< 4	46	< 2	7	6	1	11	8	1.83	0.39
KW96-39-001	Upper Coalspur Fm Float	< 2	20	10	55	< .5	23	4	2323	16.29	< 5	< 10	< 4	5	74	< .4	< 5	< 5	74	7.24	0.116	15	32	1.35	483	0.1	2.79	0.07	0.89	< 4	34	< 2	20	< 2	< 1	8	< 2	< .01	0.61
KW96-39-002	Upper Coalspur Fm Sst-Ss	< 2	14	6	71	0.5	38	11	1202	11.15	5	< 10	< 4	7	80	< .4	6	< 5	84	6.21	0.171	17	34	1.59	893	0.11	2.83	0.13	1.02	< 4	55	< 2	20	2	5	8	< 2	0.02	0.63
KW96-58-001	Gorman Creek Fm Ss	< 2	23	< 5	92	0.6	17	3	458	2.58	< 5	< 10	< 4	4	121	0.8	< 5	< 5	84	9.93	0.139	14	45	1.18	418	0.14	2.57	0.03	0.86	< 4	32	< 2	18	2	< 1	5	3	0.03	0.35
KW96-61-002	Gorman Creek Fm Sh	4	43	1181	158	0.5	41	12	189	4.03	41	< 10	< 4	13	120	< .4	6	< 5	253	0.15	0.133	36	122	0.76	1484	0.38	8.38	0.35	2.28	< 4	67	4	21	12	2	19	2	0.19	0.96
KW96-61-003	Gorman Creek Fm Sst-Sh	< 2	25	12	144	0.8	45	5	3606	25.1	8	15	< 4	6	145	< .4	< 5	< 5	164	2.83	0.333	14	52	1.99	923	0.11	3.08	0.13	0.87	< 4	28	< 2	32	< 2	< 1	29	2	0.37	0.48

35 Element ICP/Au** by Fire Assay ICP/Total S by Leco/Total Organic C

Appendix 2. Major and trace element geochemistry from metallic mineral samples in the Kakwa/Wapiti area (NTS 83L)

Sample #	Lithology	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	Ba	Ni	Sr	Zr	Y	Nb	Sc	LOI	SUM
		%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%
KW96-01-001	Gladstone Fm. pebble C	67.18	9.5	2.44	1.62	6.8	0.06	1.54	0.34	0.25	0.03	0.007	629	58	188	106	22	10	< 10	10.1	100.02
KW96-01-002	Gladstone Fm. pebble C	35.83	3	4.53	1.33	29.17	0.08	0.5	0.12	0.16	0.07	0.003	851	29	837	185	25	< 10	< 10	25	100.07
KW96-01-003	Nikanassin Fm Sst	47.34	5.39	21.75	1.97	5.69	0.06	1.33	0.55	0.26	0.36	0.004	740	22	920	293	46	< 10	< 10	15.2	100.19
KW96-01-004	Nikanassin Fm Sst	21.69	3.84	39.45	3.36	3.97	0.01	0.81	0.23	0.34	0.57	0.006	846	< 20	83	80	29	< 10	< 10	25	99.45
KW96-01-005	Cadomin Fm C	88.33	4.62	1.83	0.15	0.1	0.02	0.74	0.22	0.14	< .01	0.008	422	< 20	50	188	11	< 10	< 10	3.8	100.07
KW96-01-006	Nikanassin Fm Ss	65.27	8.99	5.07	3.17	4.38	0.07	2.21	0.53	0.21	0.06	0.01	819	26	76	162	20	10	< 10	10	100.15
KW96-01-007	Gladstone Fm silty Ss	54.37	7.96	15.24	2.56	3.87	0.09	1.88	0.4	0.22	0.18	0.008	770	45	78	117	21	< 10	< 10	12.2	99.14
KW96-01-008	Gladstone Fm pebble C	15.01	3.2	30.88	4.05	16.18	0.03	0.43	0.12	0.07	0.18	0.001	792	< 20	532	45	23	< 10	< 10	29.2	99.56
KW96-02-001	Mountain Park Fm Ss	82.31	6.75	1.72	1.01	1.92	0.04	0.96	0.47	0.45	0.03	0.012	333	37	67	367	31	< 10	< 10	4.3	100.1
KW96-02-002	Mountain Park Fm C	86.03	3.2	2.62	0.43	2.12	0.06	0.43	0.12	0.81	0.01	0.003	437	57	91	95	23	< 10	< 10	3.1	99.04
KW96-02-003	Westgate Fm Sh	70.96	13.22	2.58	0.78	0.52	0.24	2.54	0.81	0.15	< .01	0.022	825	< 20	112	197	19	10	< 10	7.1	99.11
KW96-06-001	Lower Brazeau B	75.52	11.52	3.2	0.53	0.58	2.15	2.44	0.74	0.01	0.01	0.008	890	23	173	208	19	< 10	< 10	3.1	100.01
KW96-06-002	Lower Brazeau B	65.76	14.56	4.13	0.84	0.63	1.97	2.27	0.68	0.03	0.01	0.011	993	34	210	157	11	< 10	10	8.2	99.31
KW96-06-004	Lower Brazeau smectitic Sh	62.78	15.96	2.94	0.79	1.08	1.6	1.3	0.64	0.02	0.01	0.007	859	< 20	224	209	22	11	< 10	11.9	99.23
KW96-09-001	Lower Coalspur Fm smectitic Sh	73.08	12.18	2.21	1.43	1.62	0.09	2.71	0.68	0.17	0.01	0.01	625	31	72	186	19	< 10	< 10	5.4	99.74
KW96-09-002	Lower Coalspur Fm Ss	62.26	3.21	3.73	2.7	11.22	0.05	0.83	0.2	0.18	0.07	0.005	263	< 20	92	202	16	< 10	< 10	14.7	99.24
KW96-09-003	Lower Coalspur B	60.81	16.32	4.17	2.12	2.48	0.13	3.18	0.76	0.28	0.12	0.016	812	46	106	146	29	14	11	9.1	99.68
KW96-11-001	Quaternary lacustrine till	56.34	12.12	4.14	2.64	7.53	0.71	2.37	0.67	0.2	0.05	0.008	812	40	160	121	19	12	< 10	13	99.96
KW96-11-002	Quaternary lacustrine till	49.2	13.9	4.86	3.14	9.46	0.55	2.89	0.64	0.18	0.06	0.01	821	36	158	99	19	12	10	14.9	99.97
KW96-12-002	Lower Brazeau Fm B	52.69	18.2	4.18	2.62	2.33	0.31	0.44	0.12	0.01	< .01	< .001	422	< 20	191	147	20	< 10	< 10	19	100.02
KW96-12-003	Lower Brazeau Fm B	55.35	16.71	3.31	2.61	2.84	0.5	0.17	0.44	0.12	0.01	< .001	423	< 20	217	197	14	< 10	< 10	17.7	99.89
KW96-12-004	Lower Brazeau Fm float	40.98	8.83	30.95	0.58	1.84	0.87	0.82	0.28	0.28	0.93	0.005	1534	26	97	85	21	< 10	11	12.5	99.16
KW96-12-005	Lower Brazeau Fm organic clay	60.46	14.25	3.27	1.8	2.03	0.42	0.29	0.36	< .01	< .01	< .001	4462	< 20	198	155	< 10	< 10	< 10	16.3	99.99
KW96-12-007	Lower Brazeau Fm Ss	65.41	14.94	2.5	0.98	1.7	1.71	1.6	0.47	< .01	0.01	0.004	1873	< 20	269	212	< 10	< 10	12	10.1	99.81
KW96-12-008	Lower Brazeau Fm Ss	47.66	10.5	24.42	0.68	2.34	1.04	0.75	0.3	0.17	0.8	0.002	1396	36	118	135	14	< 10	25	11.8	100.74
KW96-15-001	Boulder Creek Fm Sst	90.07	5.39	0.78	0.19	0.13	0.03	0.18	1	0.04	< .01	0.006	268	52	23	284	16	< 10	< 10	1.9	99.82
KW96-15-002	Boulder Creek Fm Sh	61.26	17.57	5.42	2.17	0.65	0.12	3.38	0.8	0.19	0.05	0.018	1549	160	85	139	33	14	13	7.6	99.55
KW96-15-003	Boulder Creek Fm silty Ss	84.93	7.83	1.97	0.35	0.03	0.03	0.63	0.85	0.07	< .01	0.01	388	45	24	281	15	10	< 10	3	99.82
KW96-15-004	Boulder Creek Fm pebble C	88.75	4.21	1.88	0.26	0.74	0.03	0.7	0.2	0.59	0.02	0.005	568	52	42	103	23	< 10	< 10	2.4	99.91
KW96-15-005	Westgate Fm silty Sh	76.12	11.08	2.71	0.71	0.03	0.17	2.41	0.74	0.24	< .01	0.013	1015	< 20	70	269	18	12	< 10	5.4	99.85
KW96-15-006	Boulder Creek Fm Sh	74.19	13.75	1.46	0.84	0.03	0.07	2.42	0.79	0.07	< .01	0.015	1010	53	57	197	18	10	< 10	5.8	99.65
KW96-15-007	Boulder Creek Fm B	76.74	13.45	1.47	0.45	0.04	0.03	0.6	0.94	0.05	< .01	0.013	941	60	37	291	16	< 10	< 10	5	99
KW96-15-008	Boulder Creek Fm B-Ss	72.26	14.54	4.01	0.58	0.04	0.06	1.32	0.76	0.03	< .01	0.017	661	41	35	275	14	13	< 10	6.3	100.08
KW96-16-001	Shaftesbury Fm Sh	66.74	15.09	4.7	1.34	0.4	0.67	2.52	0.72	0.18	0.06	0.012	1436	71	109	186	24	12	11	6.4	99.13
KW96-16-002	Belle Fourche Fm silty Sh	70.86	12.24	4.88	0.82	0.08	0.49	2.29	0.76	0.23	< .01	0.013	1625	< 20	94	141	19	10	< 10	6.9	99.88
KW96-16-003	Belle Fourche Fm float-bone bed	8.07	1.48	46.25	0.09	0.04	4.39	0.47	0.09	1.53	< .01	0.003	3188	21	1589	26	< 10	< 10	< 10	36.9	100.05
KW96-16-004	Belle Fourche Fm B-Sh	29.59	6.11	28.76	0.35	0.87	2.63	1.38	0.35	0.96	< .01	0.008	2013	< 20	682	91	< 10	< 10	< 10	28.9	100.35
KW96-16-005	Belle Fourche Fm B-bone bed	8.19	1.89	43.98	0.1	1.03	4.37	0.52	0.1	1.63	< .01	< .001	299	21	2416	47	< 10	< 10	< 10	37.1	99.26
KW96-16-006	Belle Fourche Fm B	27.88	5.55	28.39	0.33	2.04	2.75	1.22	0.3	0.94	< .01	0.005	1500	28	906	85	< 10	< 10	< 10	29.7	99.49
KW96-16-007	Belle Fourche Fm Sh	60.23	11.53	8.83	0.74	2.69	0.29	2.32	0.63	0.46	< .01	0.015	1637	25	171	175	16	10	< 10	12.1	100.17
KW96-17-001	Belle Fourche Fm Sst-Sh-Ss	28.24	17.46	29.03	2.49	1.4	0.1	0.91	0.23	0.18	0.3	0.001	643	36	60	116	48	< 10	< 10	19.8	100.29

Whole Rock Fusion ICP

Appendix 2. Major and trace element geochemistry from metallic mineral samples in the Kakwa/Wapiti area (NTS 83L)

Sample #	**Lithology**	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	Cr2O3	Ba	Ni	Sr	Zr	Y	Nb	Sc	LOI	SUM
		%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%
KW96-17-002	Belle Fourche Fm B-Sst-Sh	44.08	26.33	10.98	0.9	0.04	0.1	1.45	0.74	0.31	0.01	0.002	2711	24	91	484	19	15	< 10	14.4	99.89
KW96-17-003	Belle Fourche Fm Con	31.38	8.14	12.81	6.27	15.95	0.01	0.72	0.13	0.07	0.16	0.001	1079	42	333	74	38	< 10	< 10	24.3	100.18
KW96-17-004	Belle Fourche Fm silty Sh	67.33	14.44	4.71	1.47	0.58	0.68	2.56	0.74	0.27	0.06	0.014	1289	77	113	205	24	11	10	6.9	100.03
KW96-17-005	Dunvegan Fm Ss	74.67	11.21	4.45	1.18	0.72	0.8	1.8	0.56	0.25	0.05	0.008	1534	67	107	178	19	< 10	< 10	4.2	100.21
KW96-19-002	Kaskapau Fm Sh	59.52	14.38	6.33	0.95	2.12	0.32	2.6	0.73	0.18	0.01	0.012	1146	38	126	162	20	14	10	12.7	100.09
KW96-19-003	Kaskapau Fm Con	32.98	9.91	9.94	7.22	15.6	0.15	1.6	0.47	0.25	0.08	0.01	1035	137	155	105	35	< 10	11	21.8	100.24
KW96-19-004	Kaskapau Fm Sh	59.26	13.3	6.71	0.89	2.71	0.32	2.44	0.68	0.24	0.01	0.014	1151	67	109	165	21	10	< 10	13.4	100.22
KW96-20-001	Westgate Fm Sh	76.84	10.72	4.3	0.47	0.03	0.01	1.59	0.62	0.08	0.01	0.012	646	39	77	309	21	< 10	< 10	4.7	99.55
KW96-20-002	Westgate Fm B	70.66	14.25	2.76	0.76	0.03	0.07	2.29	0.77	0.14	< .01	0.015	962	65	94	202	20	11	10	7.1	99.06
KW96-20-003	Westgate Fm Sh	72.83	11.95	6.13	0.51	0.03	0.02	1.64	0.82	0.12	0.01	0.014	832	52	74	267	25	10	< 10	5.9	100.17
KW96-20-004	Westgate Fm B-Sh	69.37	16.34	2.28	0.72	0.03	0.06	2.04	0.82	0.1	< .01	0.016	2419	40	112	242	19	14	10	7.3	99.55
KW96-20-005	Fish Scales Fm pebble congl.	80.9	8.69	2.7	0.48	0.27	< .01	1.35	0.47	0.37	< .01	0.006	1399	65	81	152	19	< 10	< 10	4.4	99.92
KW96-20-006	Fish Scales Fm silty Sh	75.84	11.8	2.91	0.72	0.07	0.03	2.15	0.77	0.2	0.01	0.012	862	37	81	313	21	< 10	< 10	5.5	100.22
KW96-20-007	Fish Scales Fm silty Sh	77.95	10.63	2.51	0.64	0.05	0.02	2.02	0.67	0.22	< .01	0.012	894	31	72	227	16	< 10	< 10	5.3	100.22
KW96-20-008	Belle Fourche Fm Ss	86.7	5.42	1.72	0.35	0.06	< .01	1.09	0.34	0.18	< .01	0.005	627	37	41	213	10	< 10	< 10	3.1	99.11
KW96-20-009	Belle Fourche Fm silty Sh	72.17	12.83	4.23	1.04	0.05	0.06	2.55	0.73	0.23	< .01	0.011	867	27	79	218	18	10	< 10	5.9	100
KW96-20-010	Belle Fourche Fm silty Sh	77.58	10.04	2.85	0.56	0.08	0.07	2.02	0.66	0.24	< .01	0.011	726	30	72	241	15	< 10	< 10	5.5	99.78
KW96-21-002	Shaftesbury Fm silty Sh	65.51	15.19	3.77	1.81	1.09	0.2	2.96	0.73	0.23	0.01	0.013	1307	63	125	174	24	11	10	8.1	99.89
KW96-22-001	Shaftesbury Fm silty Sh	68.88	12.86	5.38	0.97	0.05	0.35	2.6	0.67	0.27	< .01	0.01	1102	32	85	221	14	10	< 10	6.9	99.18
KW96-22-002	Shaftesbury Fm silty Sh	73.69	10.88	3.93	0.81	0.09	0.29	2.27	0.61	0.24	< .01	0.009	911	33	77	248	16	< 10	< 10	6.2	99.23
KW96-28-002	Lower Coalspur Fm B and Sst	61.43	13.98	6.02	1.08	1.75	1.28	2.24	0.64	0.05	0.01	0.007	1296	49	392	127	10	< 10	< 10	11.4	100.18
KW96-39-001	Upper Coalspur Fm Float	30.91	6.15	25.25	2.59	11.09	0.16	1.12	0.27	0.27	0.29	0.009	569	30	75	126	14	< 10	12	22.6	100.84
KW96-39-002	Upper Coalspur Fm Sst-Ss	47.47	5.92	16.76	2.86	9.13	0.21	1.22	0.29	0.34	0.14	0.007	537	38	73	217	16	< 10	10	16.1	100.59
KW96-58-001	Gorman Creek Fm Ss	54.62	5.3	4.09	2.16	14.99	0.08	1.06	0.34	0.29	0.05	0.01	474	24	122	415	14	< 10	< 10	16.8	99.95
KW96-61-002	Gorman Creek Fm Sh	65.92	16.17	5.49	1.21	0.34	0.45	2.84	0.7	0.26	0.01	0.015	1559	42	108	171	17	11	28	7.3	101.02
KW96-61-003	Gorman Creek Fm Sst-Sh	24.8	6.26	36.12	3.45	4.02	0.17	0.92	0.24	0.72	0.39	0.004	970	32	139	93	24	< 10	49	22.2	99.5
KW96-61-004	Dunvegan Fm Ss	71.68	11.17	4.54	1.63	1.49	0.8	1.61	0.55	0.2	0.04	0.009	874	47	75	159	13	< 10	15	6	99.91
RR94-13b	Shaftesbury Fm Sst - Ss (Con)	89.48	5.77	0.77	0.18	0.04	< .01	0.2	0.85	< .01	< .01	0.014	2067	< 20	32	228	14	< 10	< 10	2.9	100.6
RR94-14a	Shaftesbury Fm Sst - Ss	85.73	6.45	1.45	0.5	1	0.07	1.1	0.47	0.18	0.01	0.013	653	34	50	239	22	< 10	< 10	3.3	100.43
RR94-14b	Shaftesbury Fm silty Sh	23.16	4.21	38.9	4.14	2.13	0.07	0.76	0.24	0.56	0.37	0.005	971	< 20	73	104	15	< 10	< 10	24.7	99.44
RR94-15a	Fernie Fm Sh	61.87	11.42	3.65	2.43	3.9	0.03	2.87	0.65	0.41	0.05	0.016	1361	65	126	175	23	10	< 10	11.8	99.38
RR94-15b	Fernie Fm Sh	51.21	6.84	4.97	5.22	10.94	0.01	1.78	0.43	0.32	0.09	0.011	1136	35	185	228	21	< 10	< 10	18.4	100.48
RR94-18b	Kaskapau Fm Sh	66.87	14.13	4.4	1.83	1.08	0.32	2.69	0.84	0.17	0.01	0.018	915	61	106	199	23	12	10	8.1	100.67
RR94-18c	Kaskapau Fm silty Sh	25.79	7.15	30.21	6.81	3.14	0.05	1.37	0.43	0.05	0.16	0.009	599	23	92	109	22	< 10	16	25	100.31
RR94-23a	Kaskapau Fm Sst	29.4	6.88	28.51	6.96	2.6	0.09	1.27	0.37	0.15	0.13	0.009	516	< 20	99	99	16	< 10	20	23.6	100.09
RR94-23b	Kaskapau Fm silty Sh	75.9	9.55	3.7	1.18	1.23	0.27	1.6	0.58	0.19	0.01	0.011	522	25	92	249	20	< 10	< 10	6.1	100.46
RR94-24a	Dunvegan Fm Sst - Ss	88.89	4.01	2.12	0.69	0.44	0.22	0.56	0.18	0.18	0.01	0.007	204	< 20	31	59	13	< 10	< 10	2.1	99.46
RR94-24b	Dunvegan Fm Sst - Ss	78.91	9.28	3.11	0.6	0.21	0.83	1.13	0.54	0.13	0.01	0.011	474	21	78	253	16	< 10	< 10	4.7	99.59
RR94-24c	Dunvegan Fm silty Sh	68.85	14.26	4.33	1.02	0.08	0.5	2.68	0.88	0.14	0.01	0.016	2019	32	99	239	22	14	10	7.5	100.66
RR94-25b	Boulder Creek Fm Sst	83.19	7.7	2.01	0.56	0.16	0.1	1.47	0.51	0.22	< .01	0.01	711	32	51	241	19	< 10	< 10	3.8	99.9
RR94-25c	Boulder Creek Fm Sst - Ss	83.41	7.91	1.65	0.69	0.22	0.17	1.56	0.54	0.18	< .01	0.01	676	28	49	246	20	< 10	< 10	3.4	99.91

Whole Rock Fusion ICP

Appendix 2. Major and trace element geochemistry from metallic mineral samples in the Kakwa/Wapiti area (NTS 83L)

Sample #	**Lithology**	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	Cr2O3	Ba	Ni	Sr	Zr	Y	Nb	Sc	LOI	SUM
		%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%
RR94-25d	Shaftesbury Fm Sh	68.11	13.35	4.16	1.94	1.41	0.24	2.75	0.63	0.21	0.03	0.015	977	112	92	227	33	14	< 10	7.3	100.37
RR94-25e	Shaftesbury Fm Sst (Con)	75.78	10.37	3.49	0.89	0.16	0.26	2.07	0.53	0.27	< .01	0.01	761	22	68	264	17	13	< 10	5.4	99.41
RR94-26	Gorman Creek Fm Sst - Ss	84.28	7.05	0.48	0.28	0.91	< .01	1.7	0.39	0.47	< .01	0.006	499	32	67	404	22	< 10	< 10	3.7	99.42
RR94-27b	Shaftesbury Fm Sst	27.1	9.7	15.4	5.5	16.65	0.02	0.48	0.12	0.07	0.18	0.004	841	26	240	84	36	< 10	< 10	24.5	99.92
RR94-28	Fernie Fm Sh	59.36	17.76	5.41	0.91	0.57	0.67	2.81	0.98	0.28	0.01	0.013	890	41	153	276	30	43	12	11.1	100.1
RR95-08	Shaftesbury Fm Sh	67.37	12.55	6.19	0.82	0.34	0.36	2.46	0.63	0.29	0.01	0.012	1212	24	114	210	16	14	< 10	8.5	99.79
RR95-09a	Kaskapau Fm Sh	64.58	14.96	5.1	0.8	0.03	0.3	2.9	0.84	0.21	< .01	0.01	1049	21	97	202	17	18	11	9.3	99.26
RR95-09b	Kaskapau Fm Sst	83.64	5.19	3.87	0.38	0.47	0.19	0.87	0.34	0.2	< .01	0.006	602	< 20	43	215	17	< 10	< 10	4.3	99.6
	C = C; Ss = Ss;																				
	Sst = Sst; Sh = Sh;																				
	Con = Con																				

Whole Rock Fusion ICP

APPENDIX 3

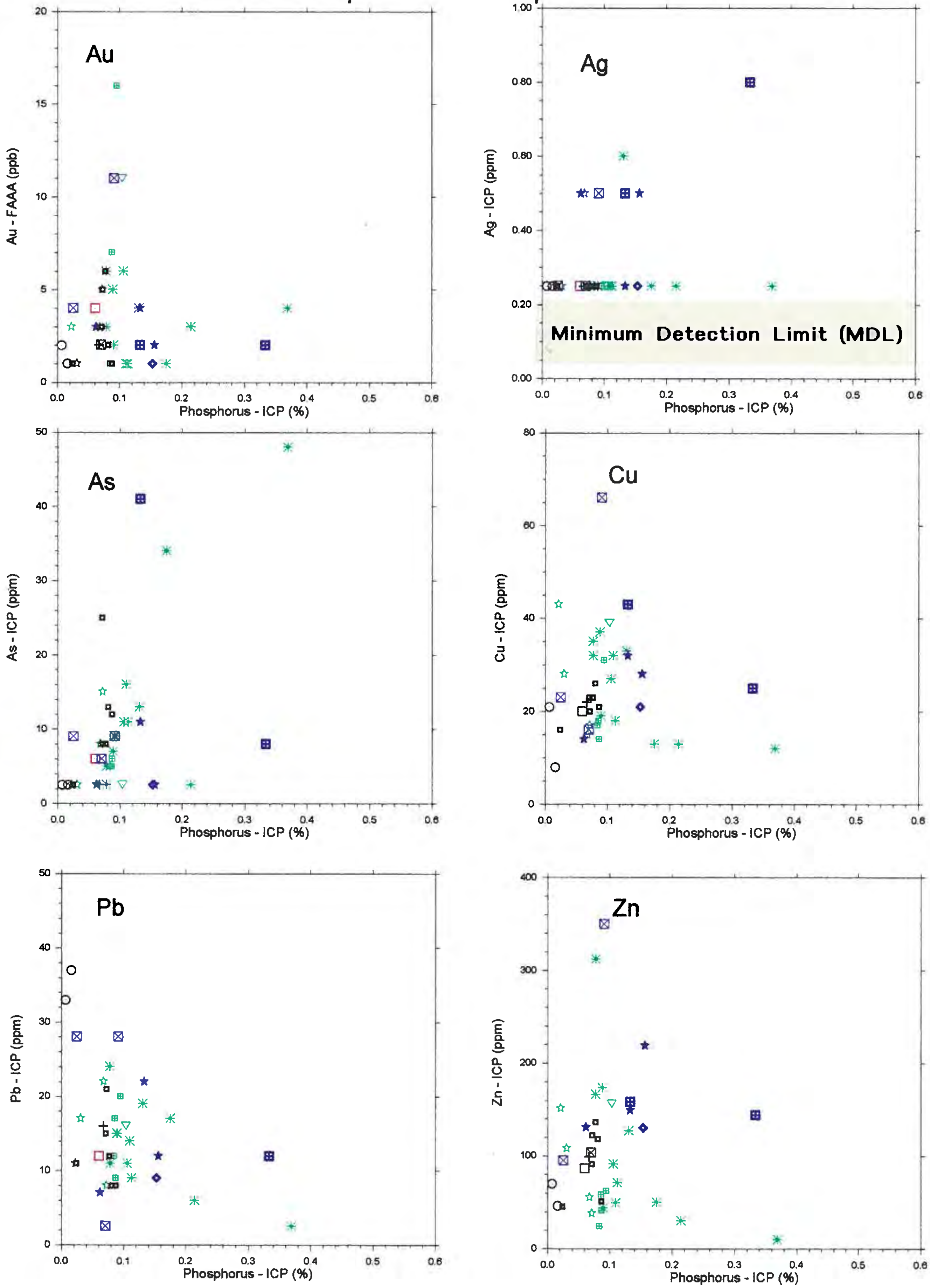
Geochemical plots from metallic mineral samples in the Kakwa/Wapiti area (NTS 83L).

Shale Legend

Shales occur in the following formations:

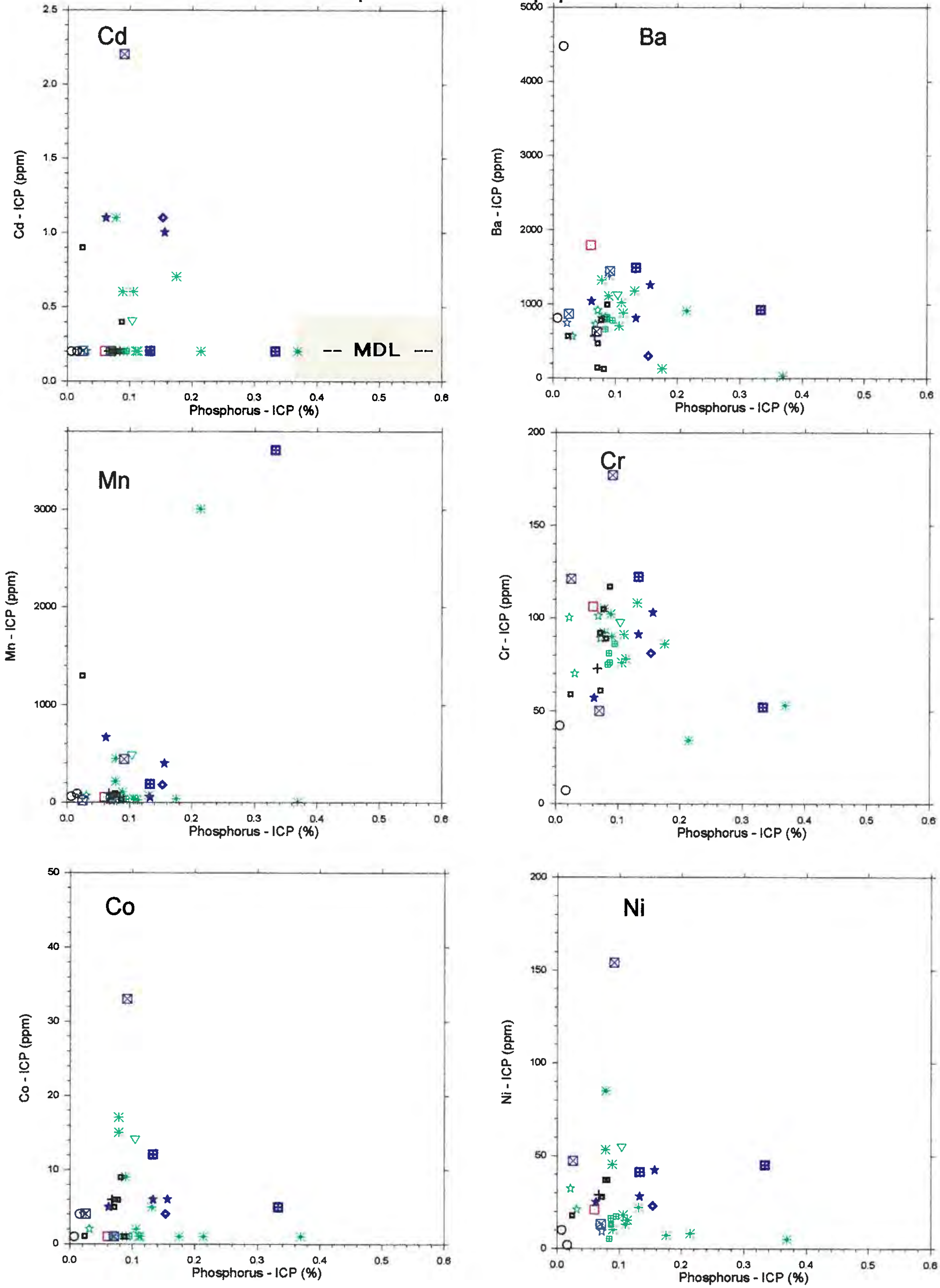
- ⊠ Boulder Creek
- ✳ Shaftesbury
- ✡ Westgate
- ⊞ Fish Scales
- ▽ Belle Fourche
- ⊡ Dunvegan
- ▪ Kaskapau
- ⊙ Brazeau/Wapiti
- \+ Coalspur
- ✶ Fernie
- ⊞ Gorman Creek
- ◇ Mountain Park

Wapiti: Shales - Phosphorus



Sh_p-1.srf

Wapiti: Shales - Phopsphorus



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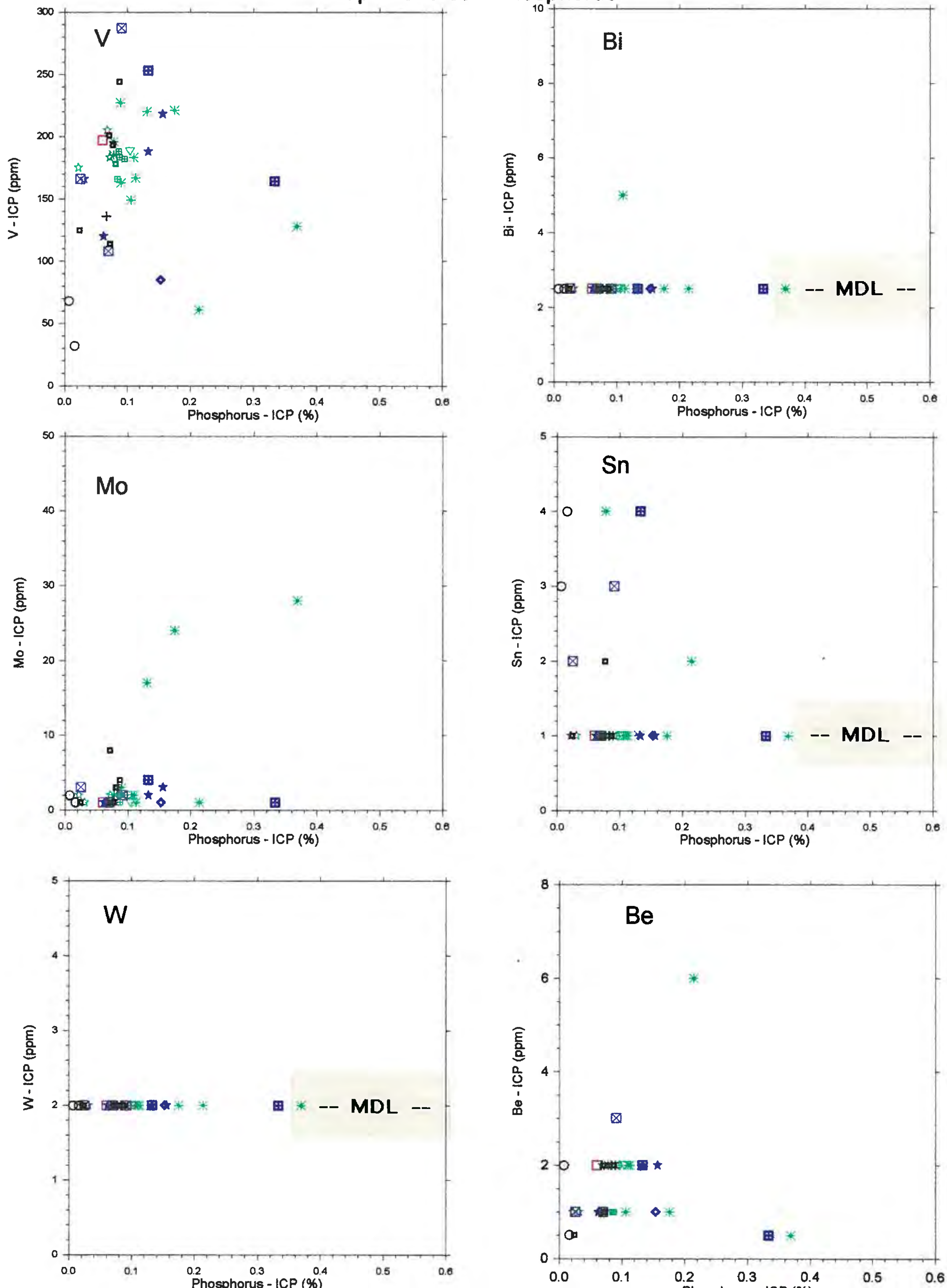
Wapiti: Shales - Phosphorus



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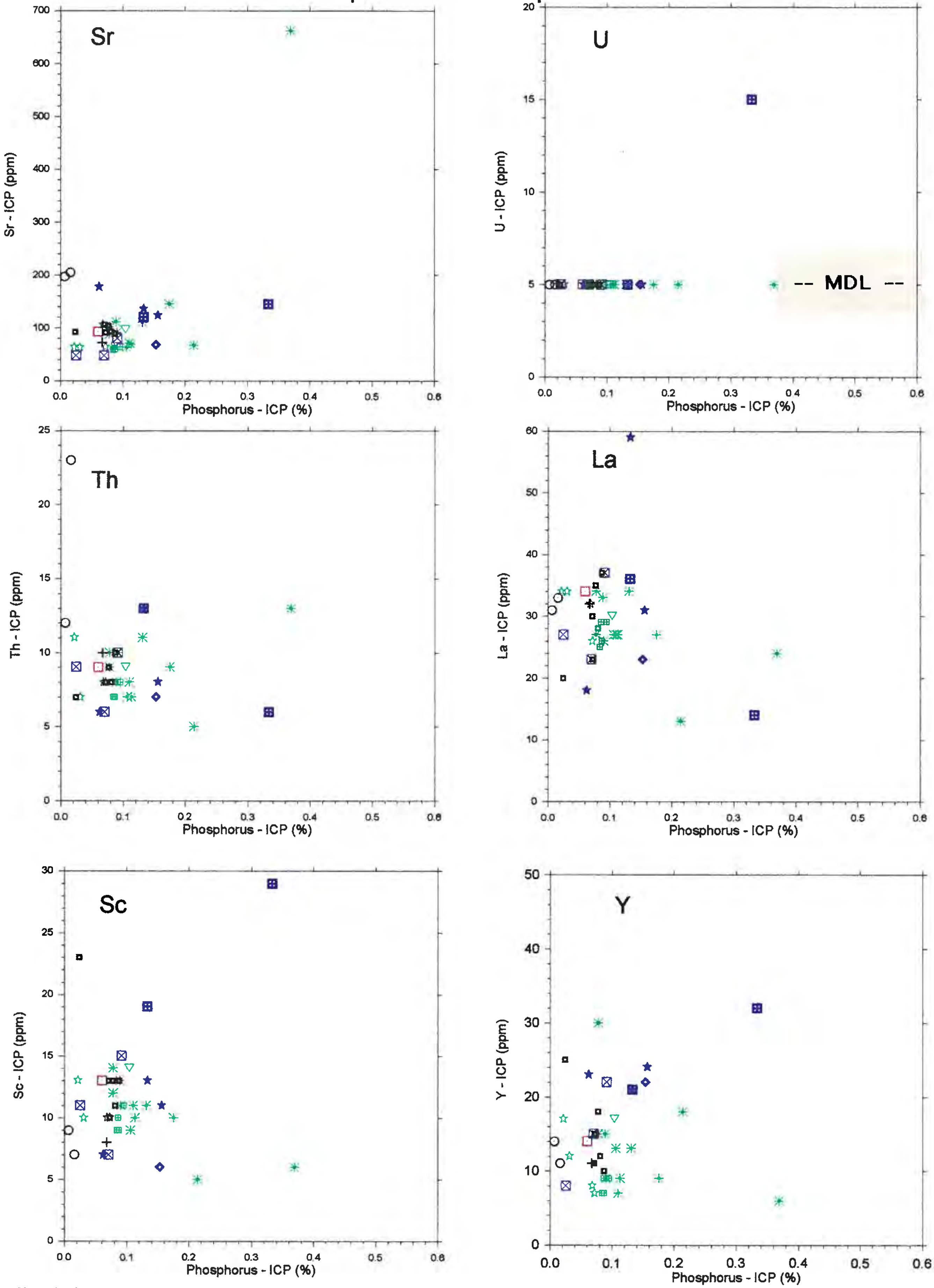
Wapiti: Shales - Phosphorus



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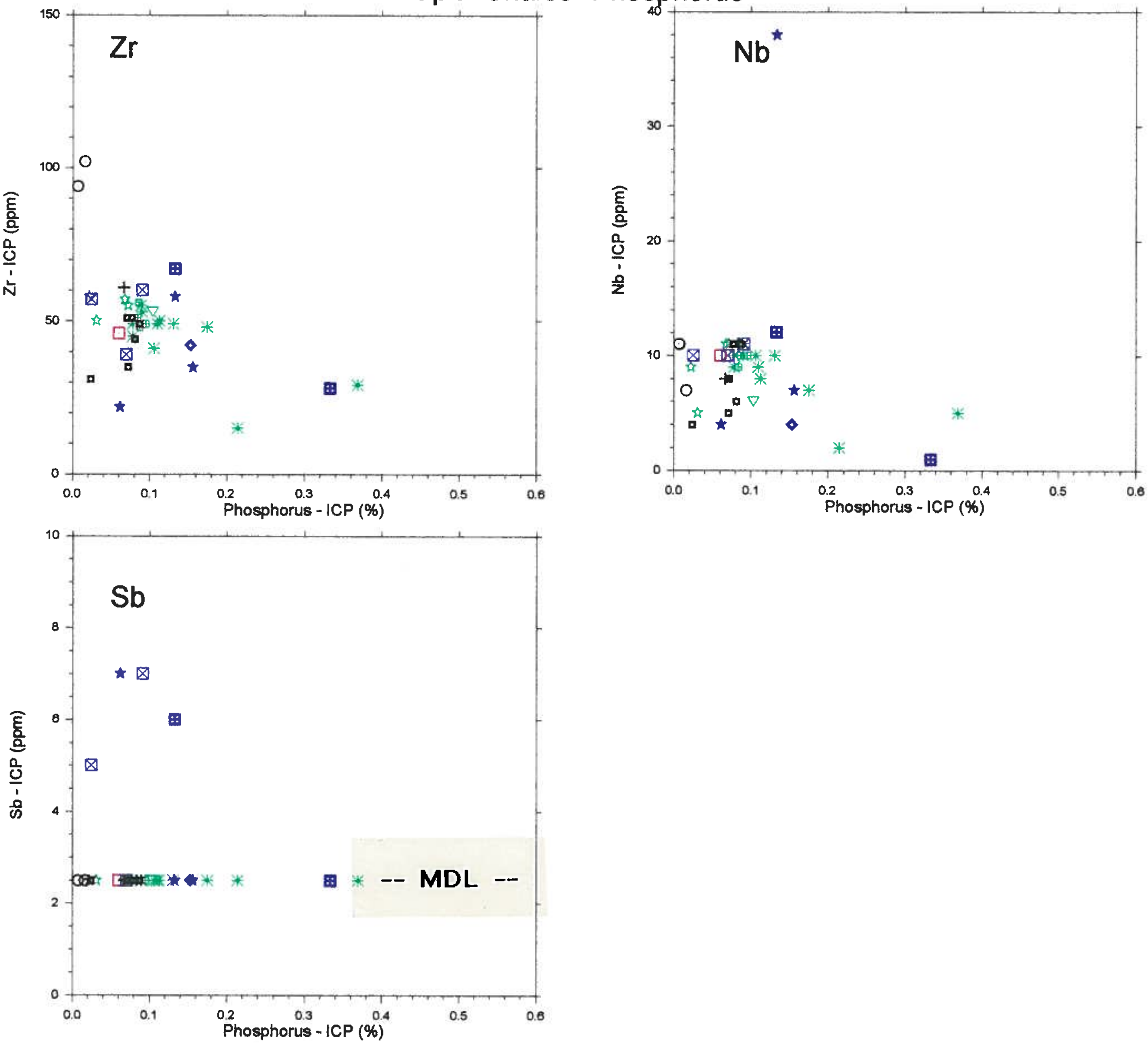
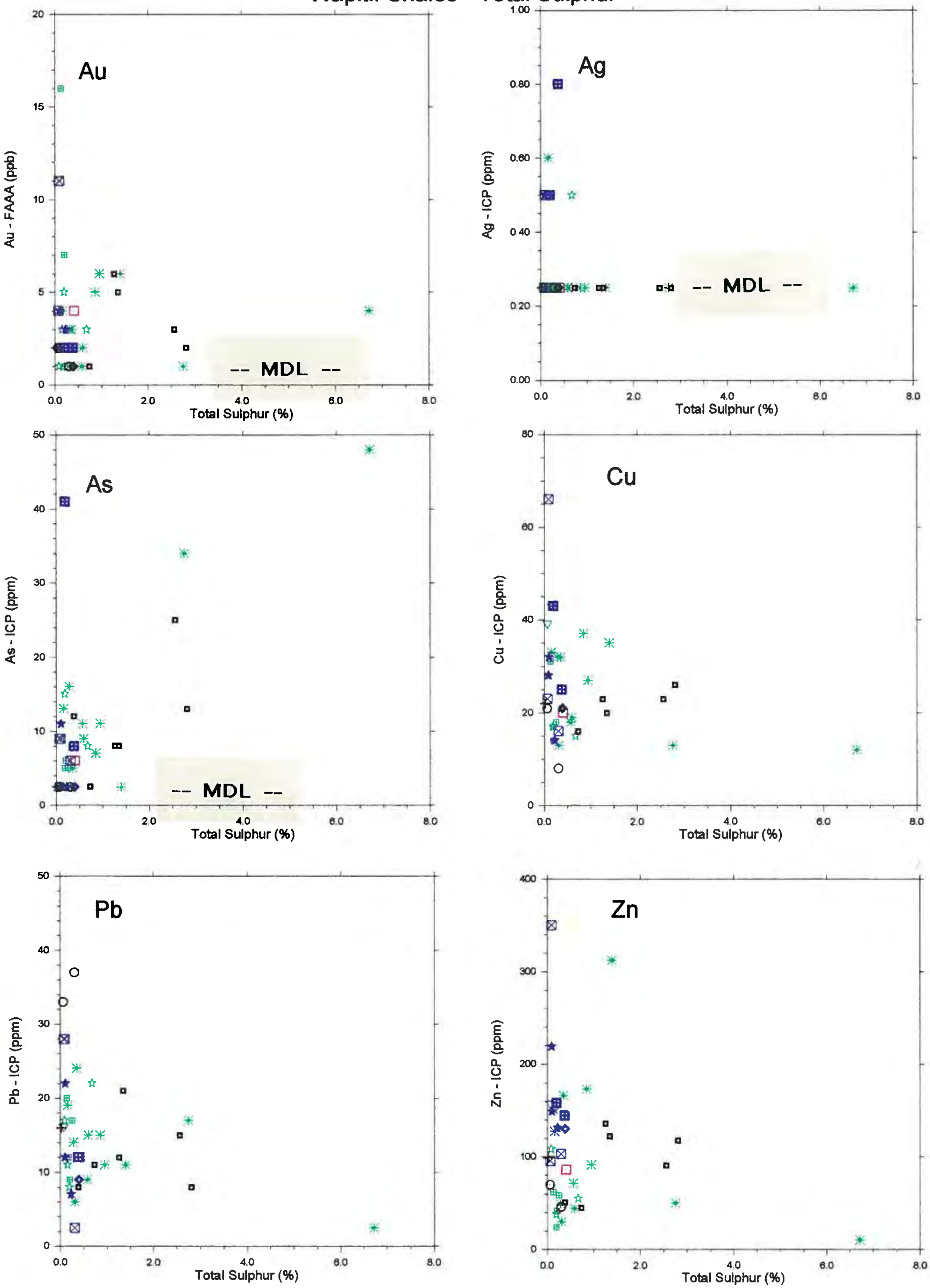
Wapiti: Shales -Phosphorus



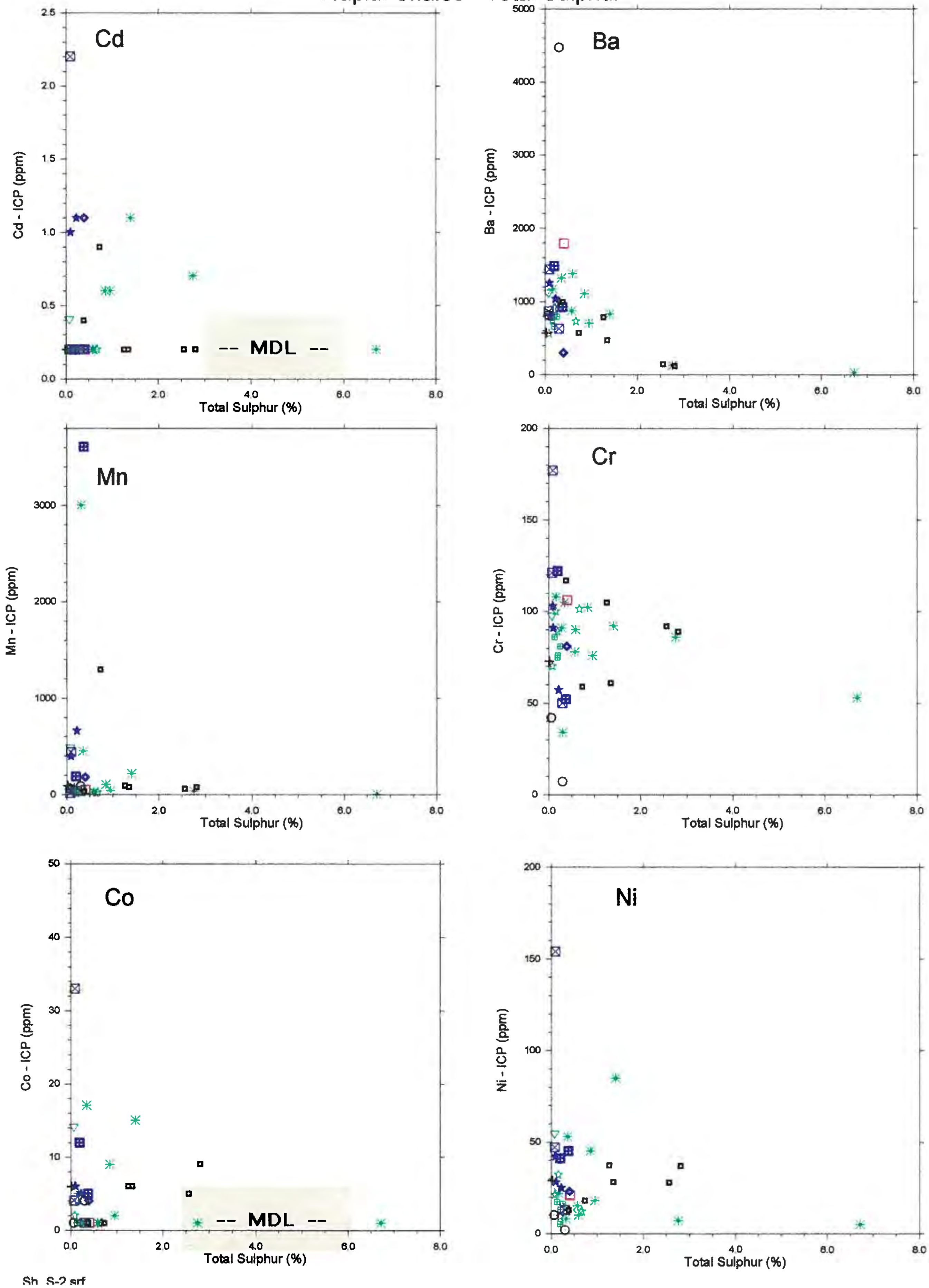
Sh_p-5.srf

Wapiti: Shales - Total Sulphur



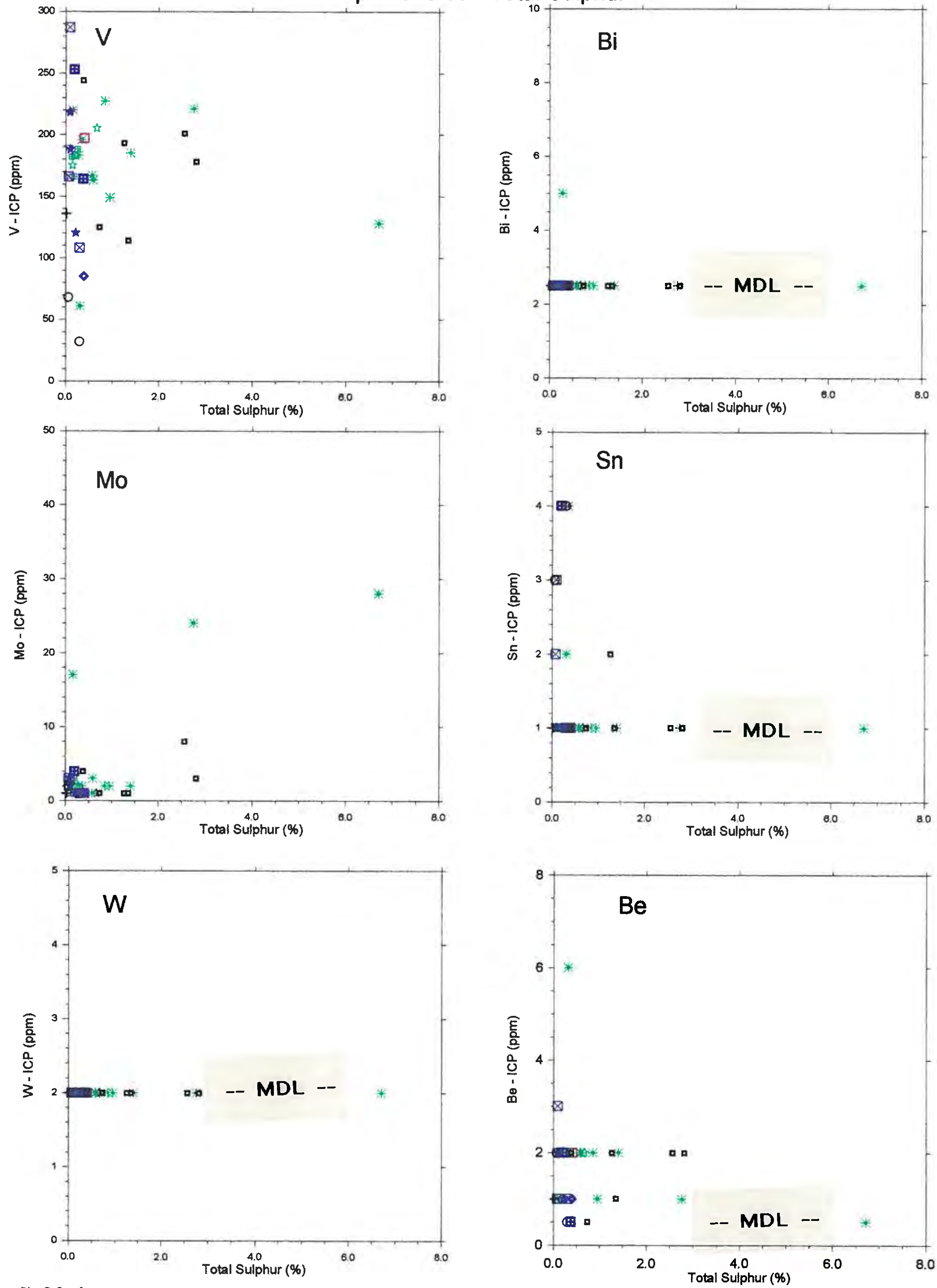
Sh_S-1.srf

Wapiti: Shales - Total Sulphur



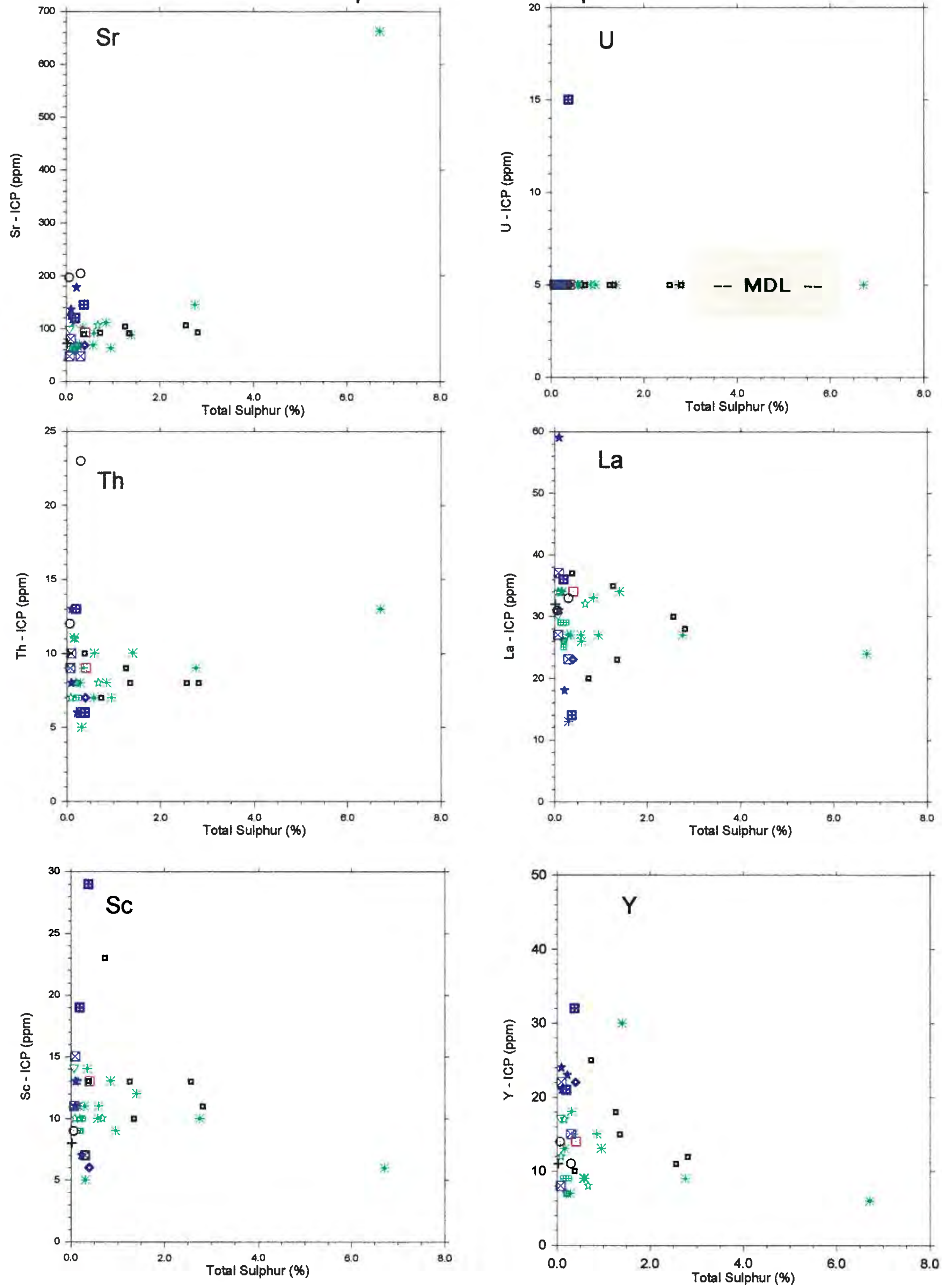
Sh_S-2.srf

Wapiti: Shales - Total Sulphur



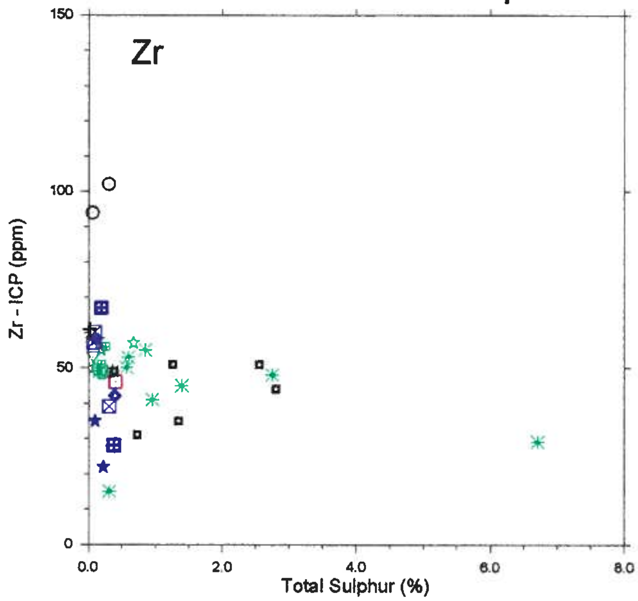
Sh_S-3.srf

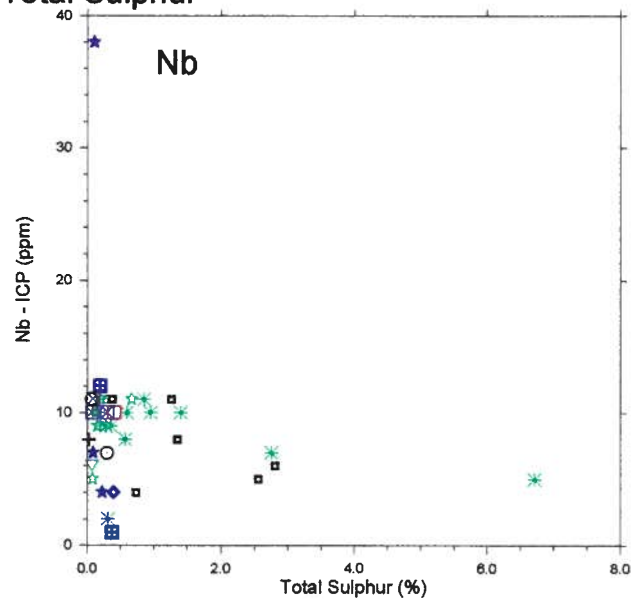
Wapiti: Shales - Total Sulphur

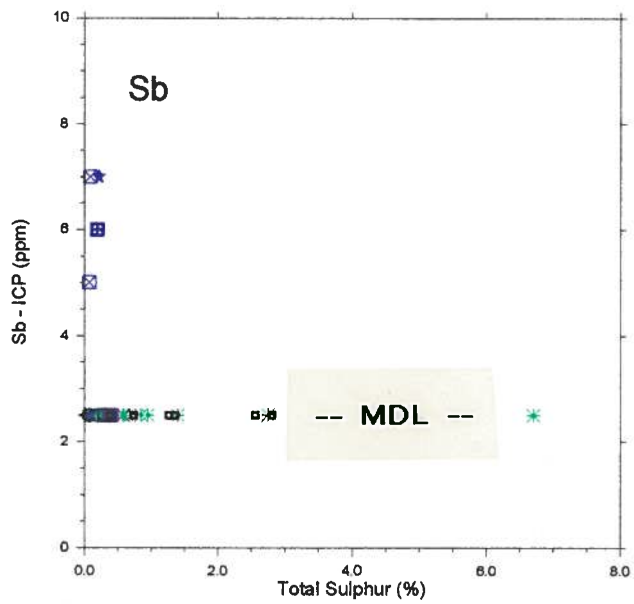


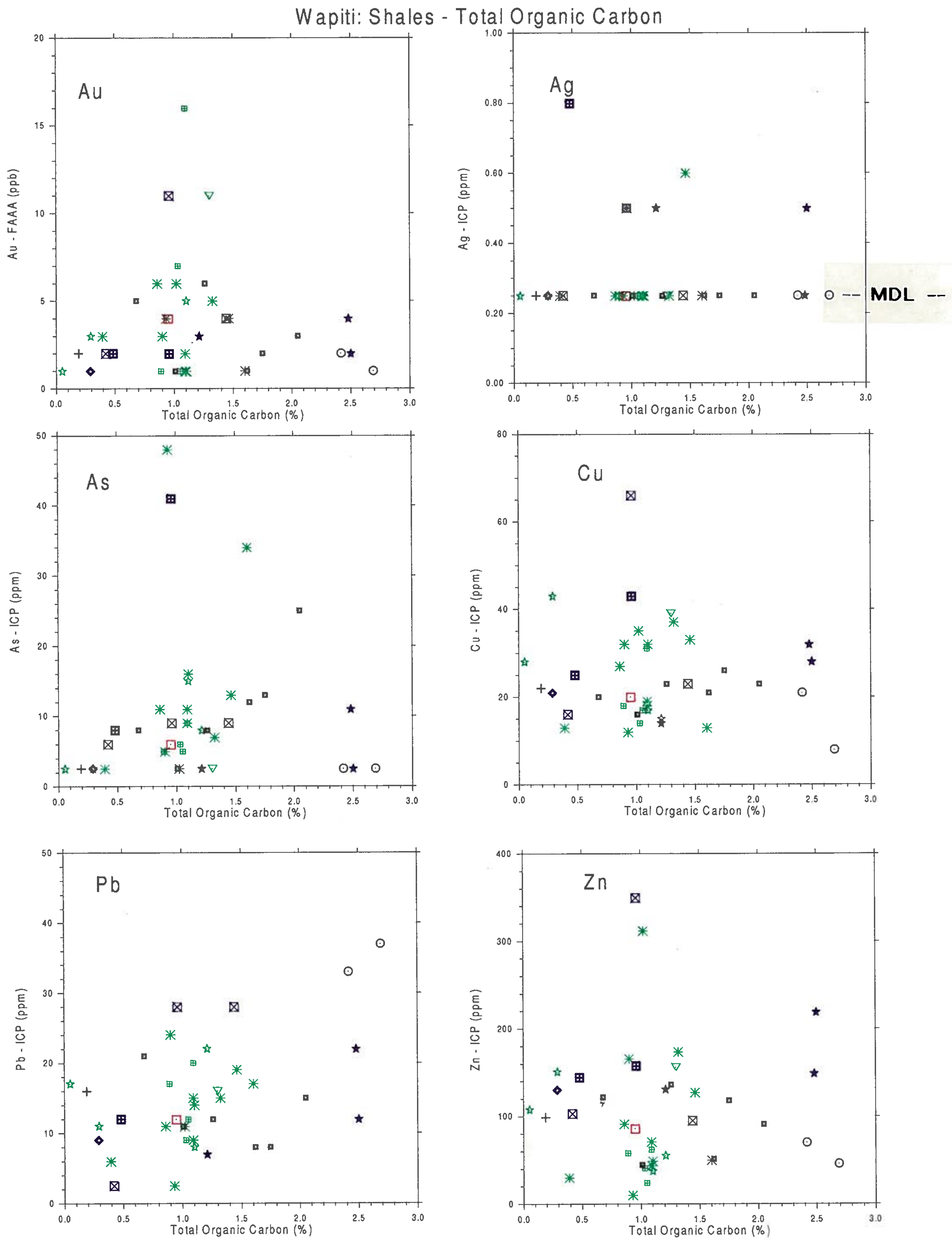
Sh_S-4.srf

Wapiti: Shales - Total Sulphur





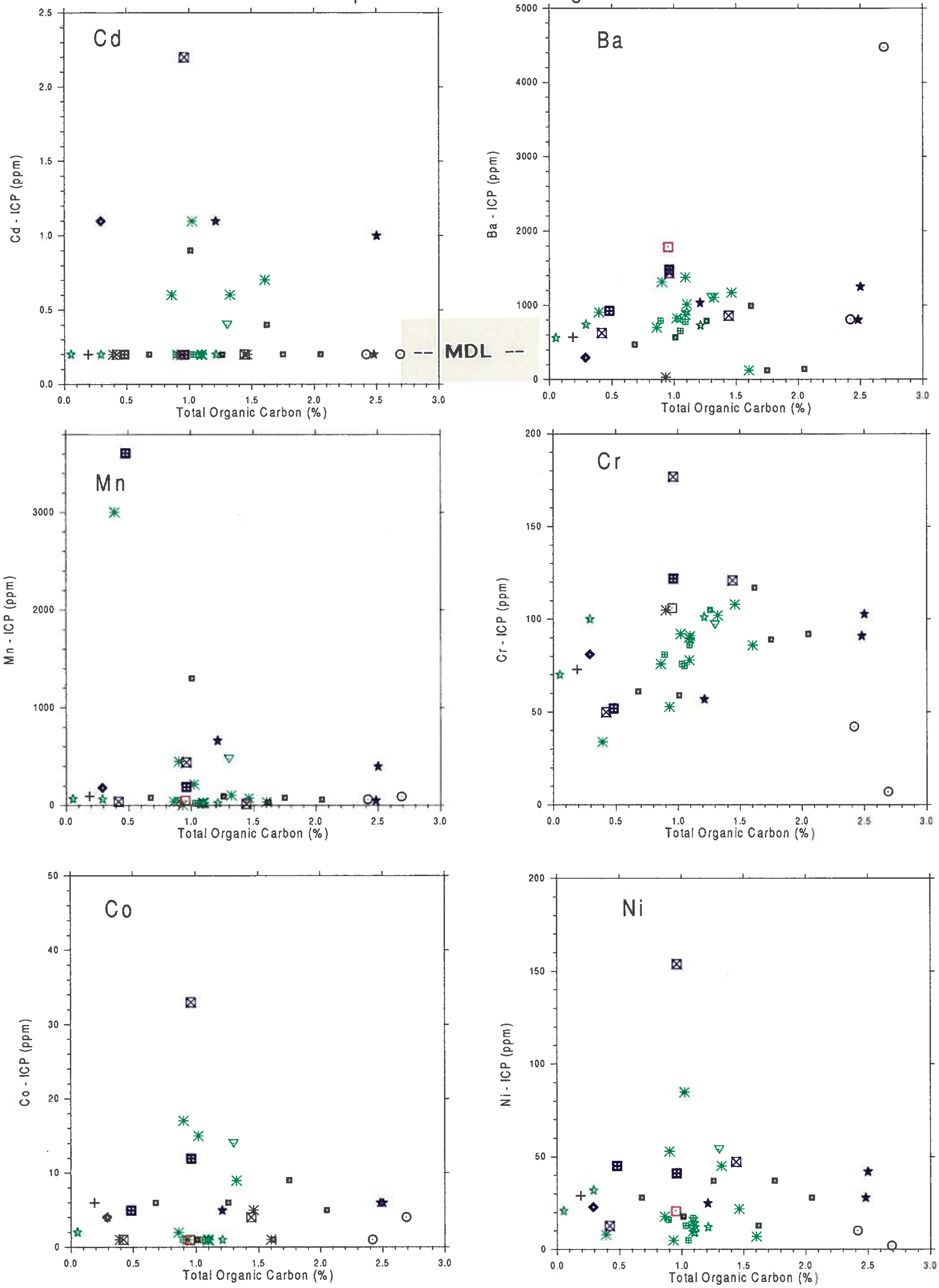




Wapiti: Shales - Total Organic Carbon
Au
Au - FAAA (ppb)
Ag
Ag - ICP (ppm)
MDL
As
As - ICP (ppm)
Cu
Cu - ICP (ppm)
Pb
Pb - ICP (ppm)
Zn
Zn - ICP (ppm)
Total Organic Carbon (%)

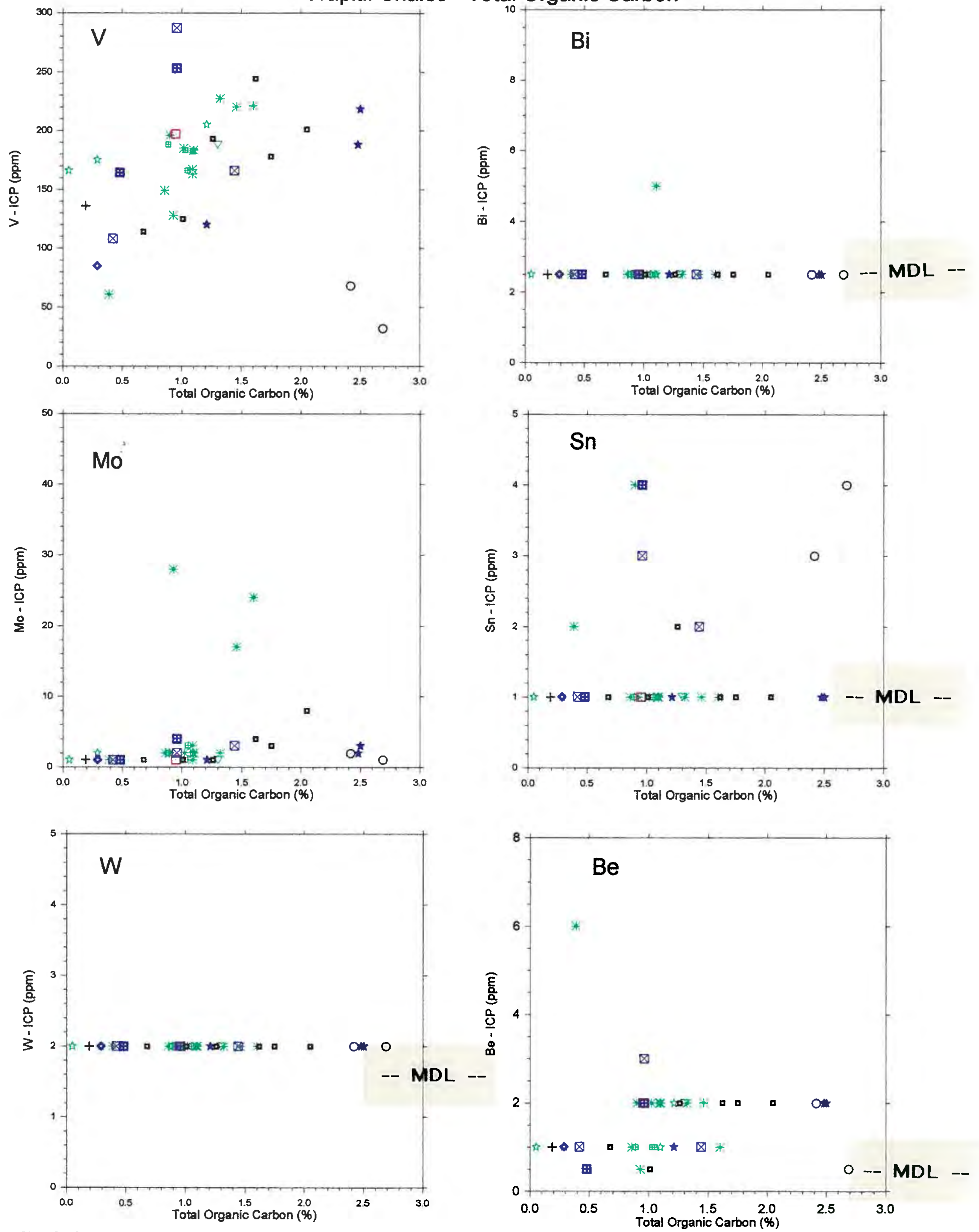
Sh_C-1.srf

Wapiti: Shales - Total Organic Carbon



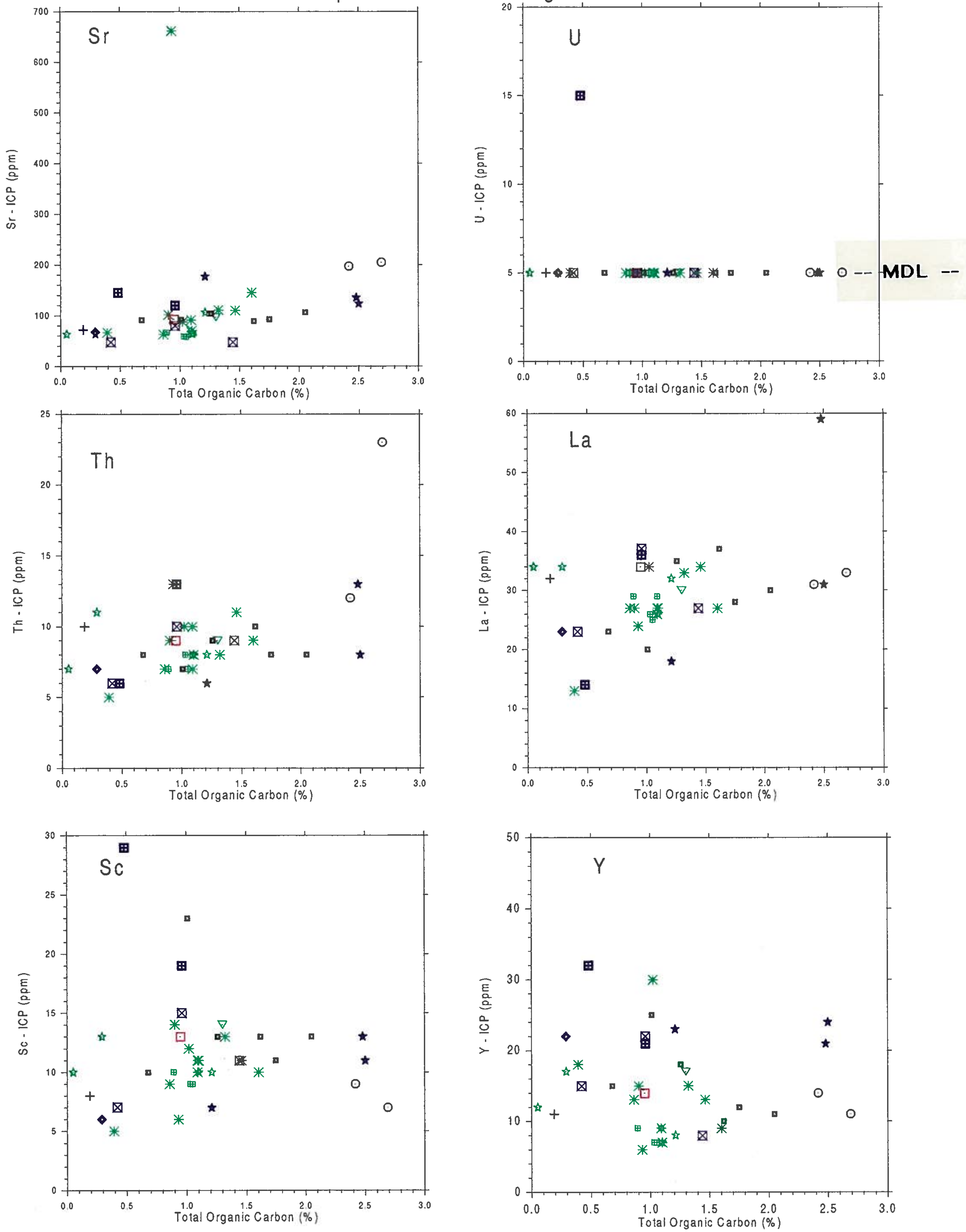
Sh_c-2.srf

Wapiti: Shales - Total Organic Carbon



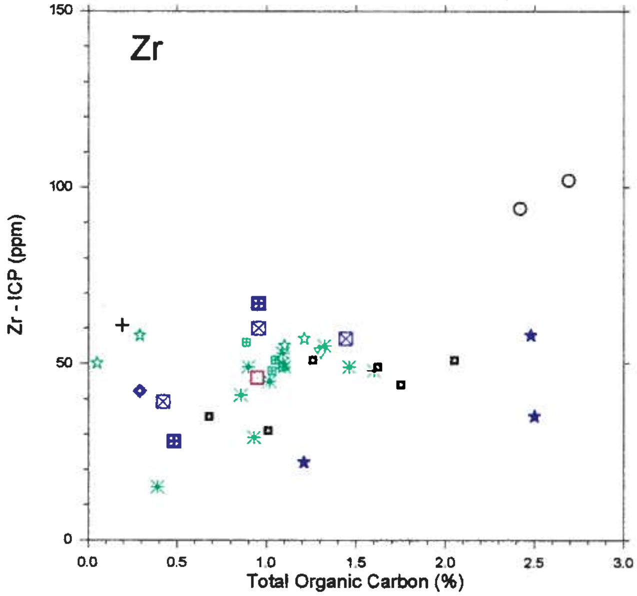
Sh_c-3.srf

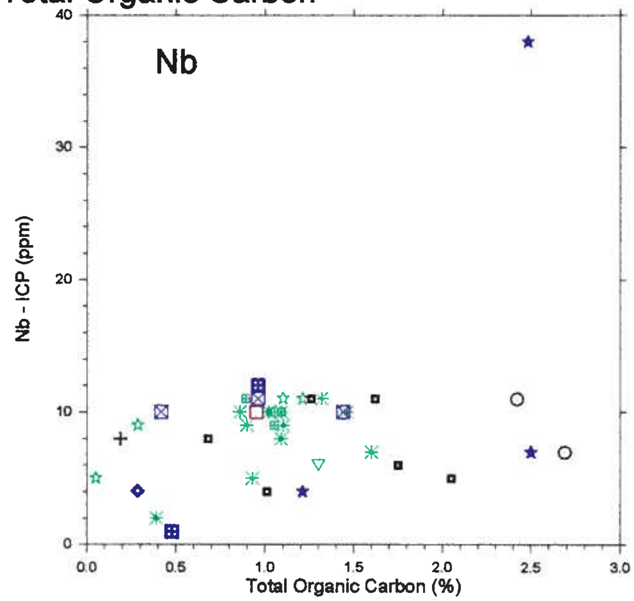
Wapiti: Shales - Total Organic Carbon

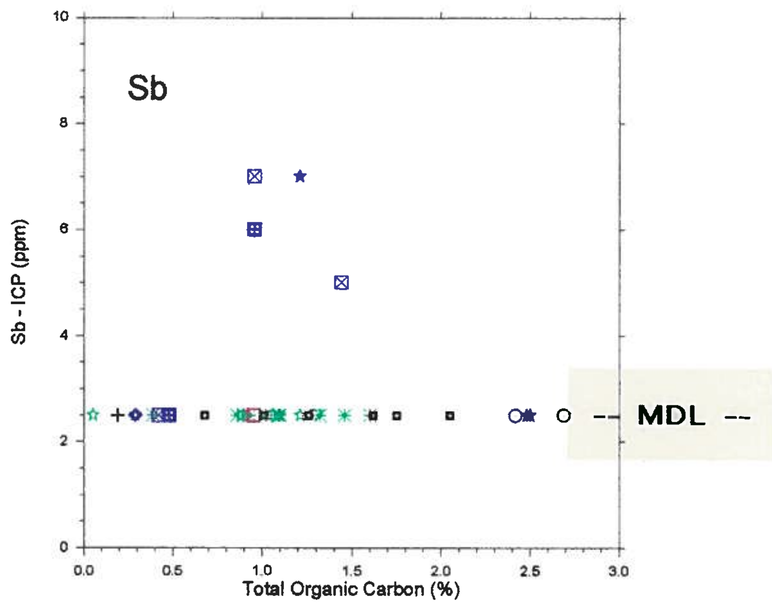


Sh_c-4.srf

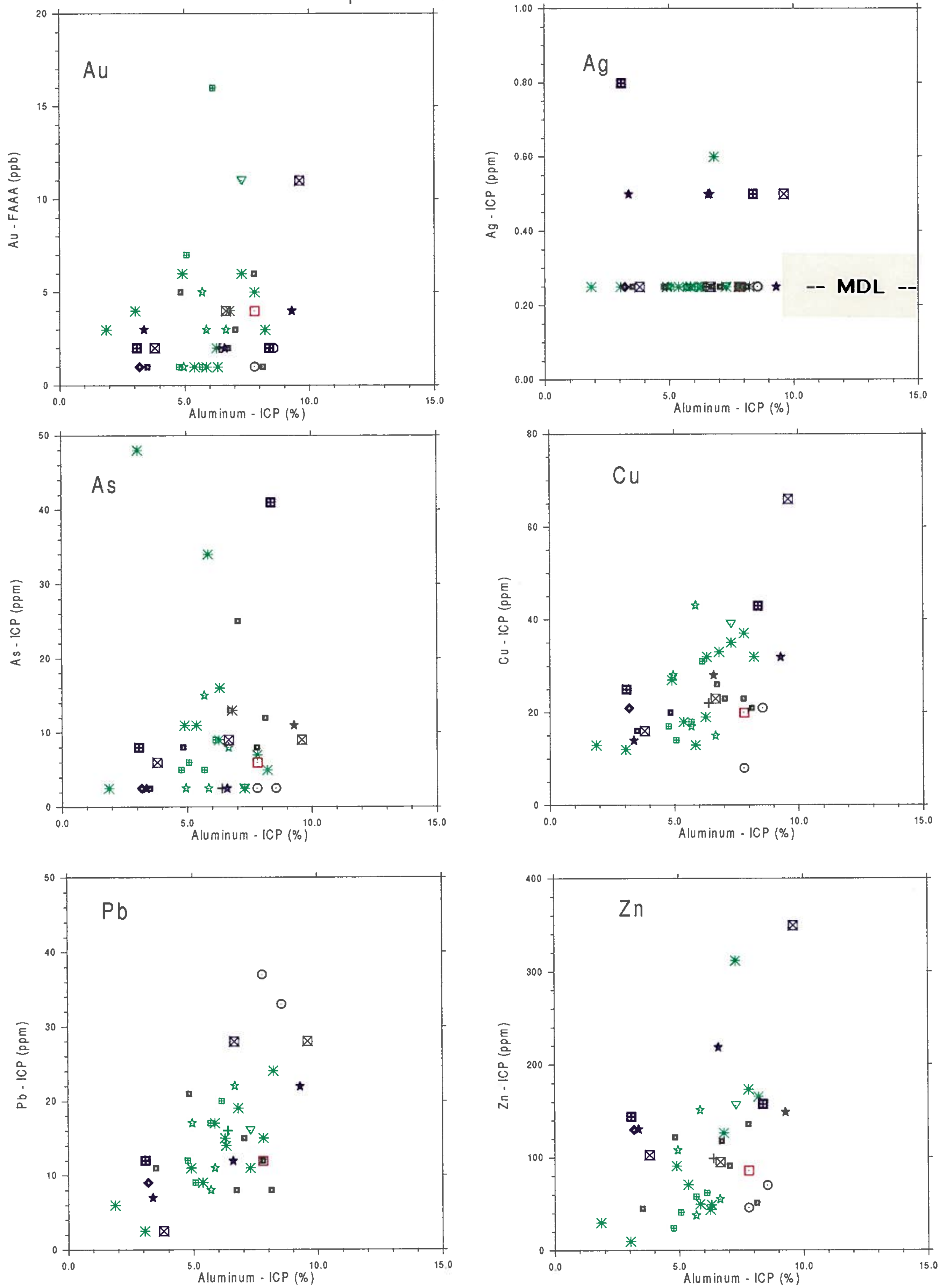
Wapiti: Shales - Total Organic Carbon





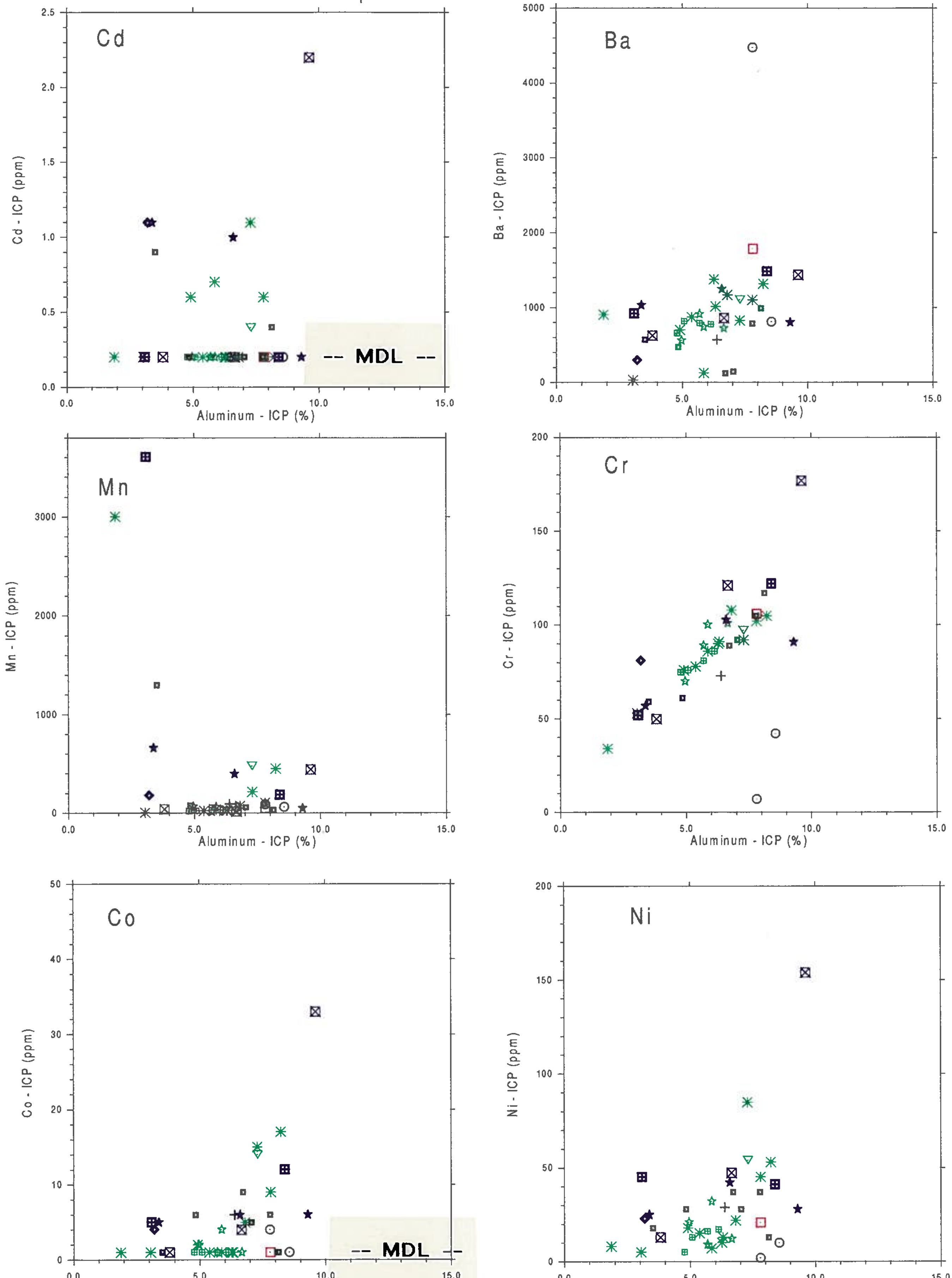


Wapiti: Shales - Aluminum



Sh_al-1.srf

Wapiti: Shales - Aluminum



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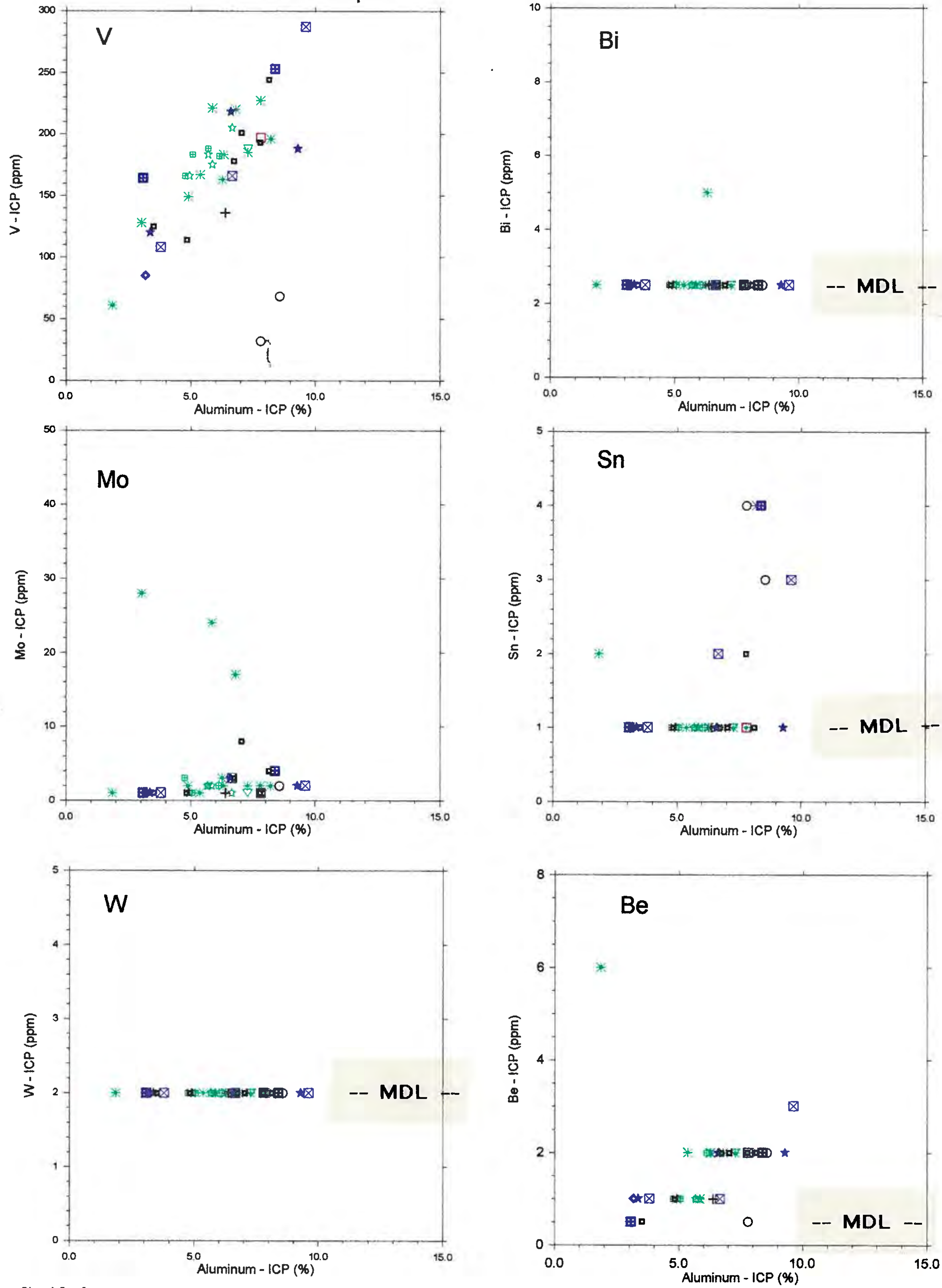
Wapiti: Shales - Aluminum



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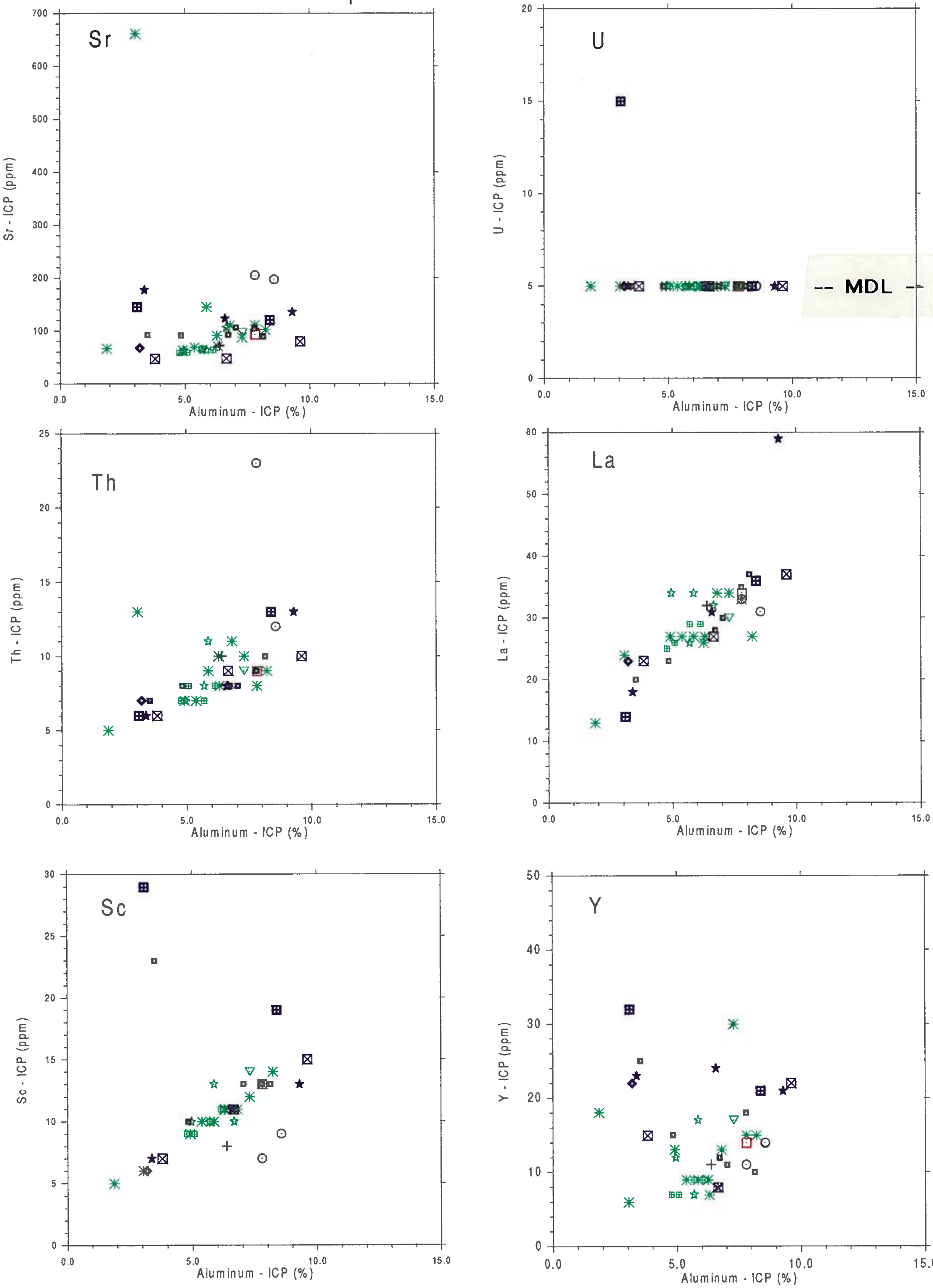
Wapiti: Shales - Aluminum



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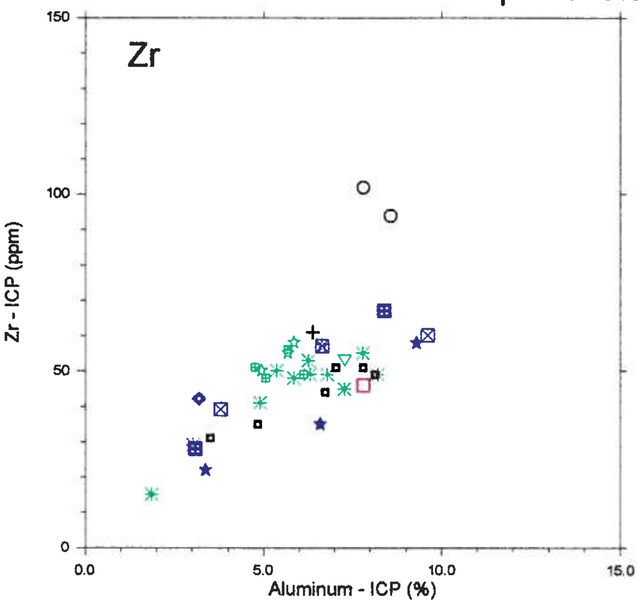
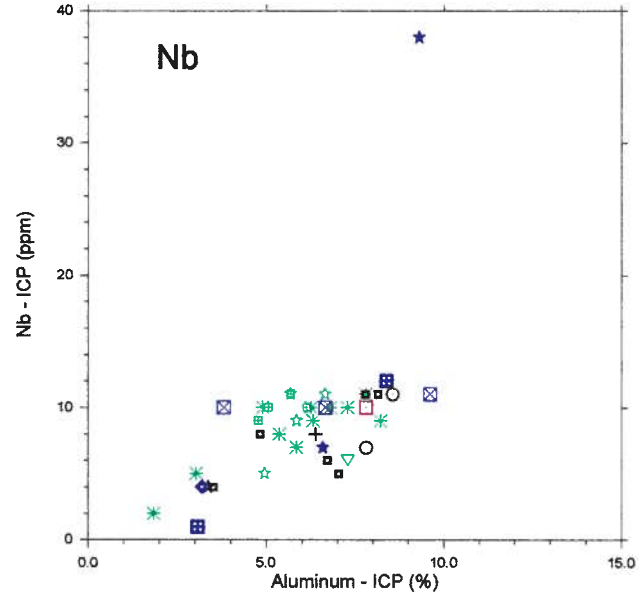
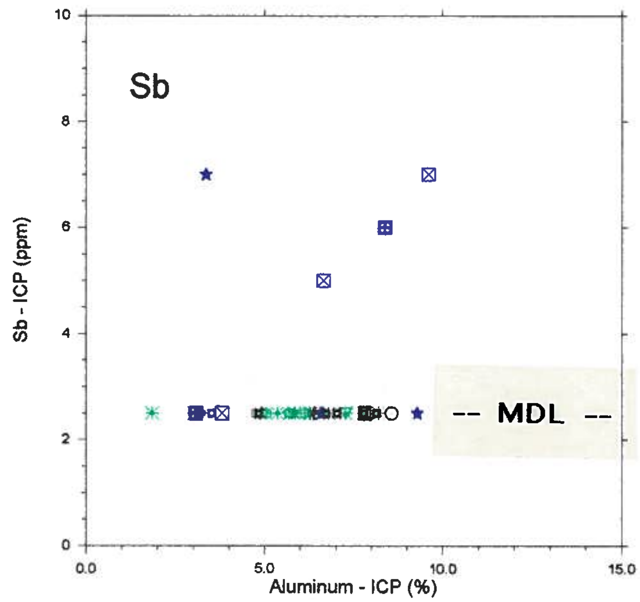
Wapiti: Shales - Aluminum

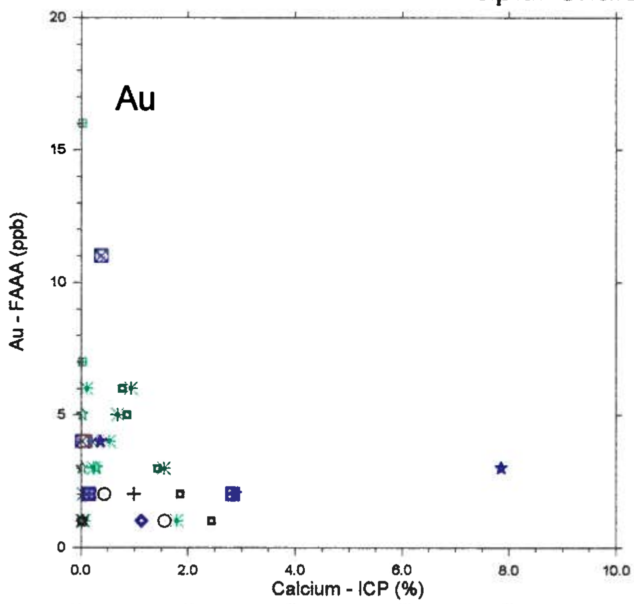


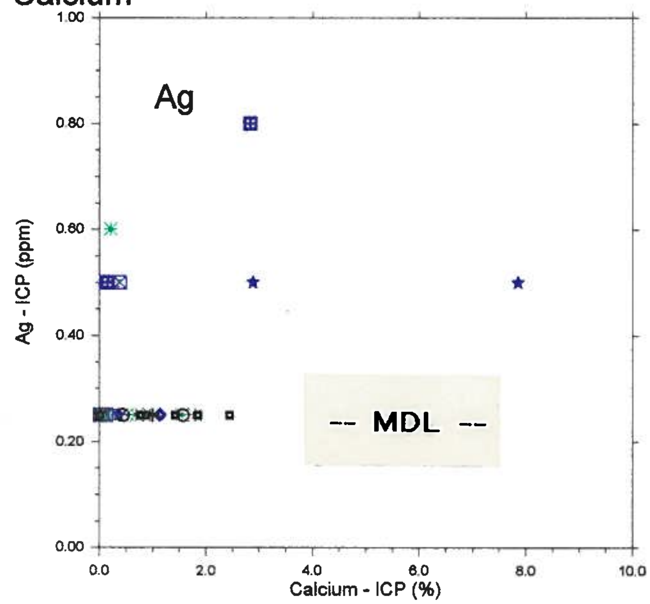


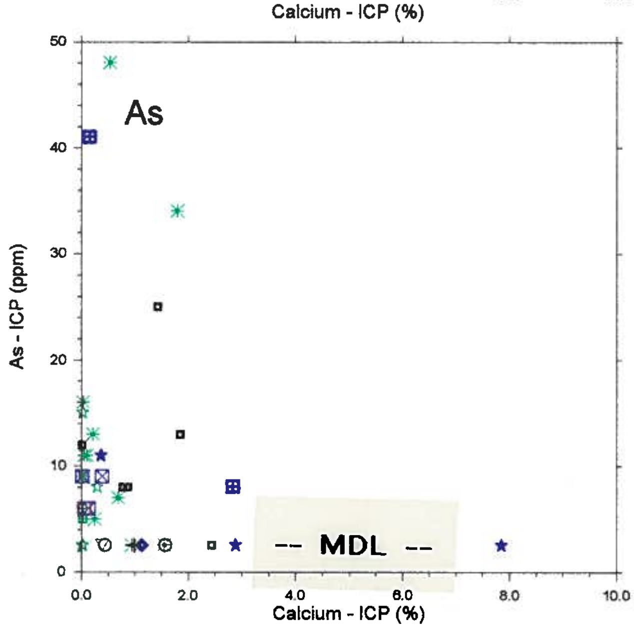


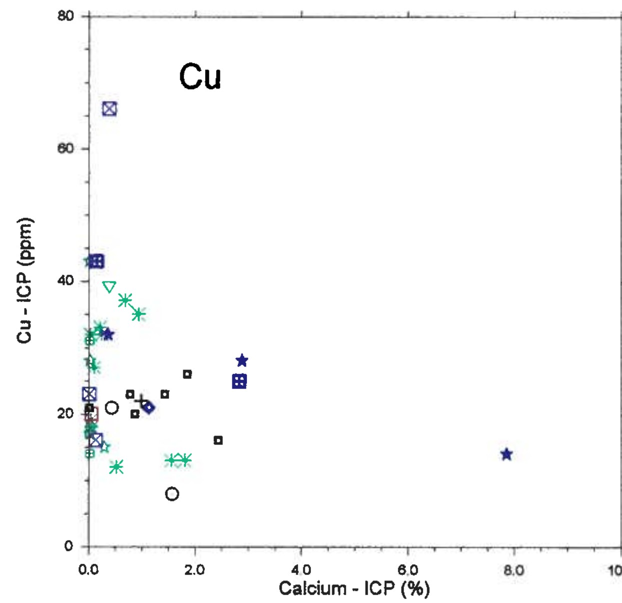
Sh_al-5.srf

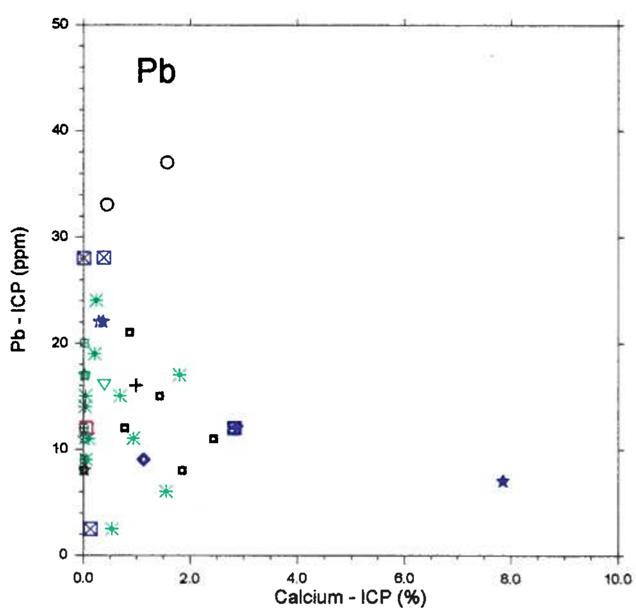
Wapiti: Shales - Calcium

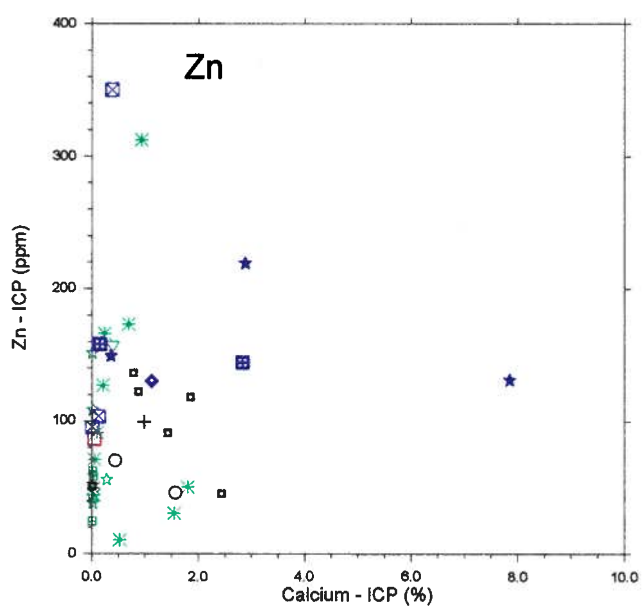






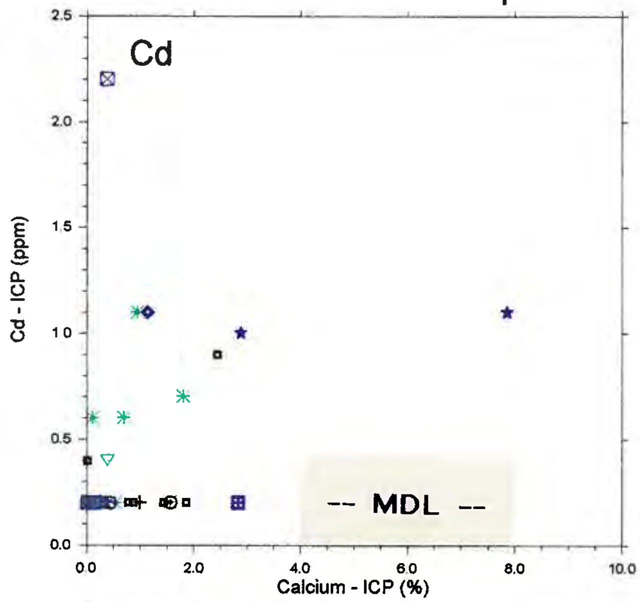


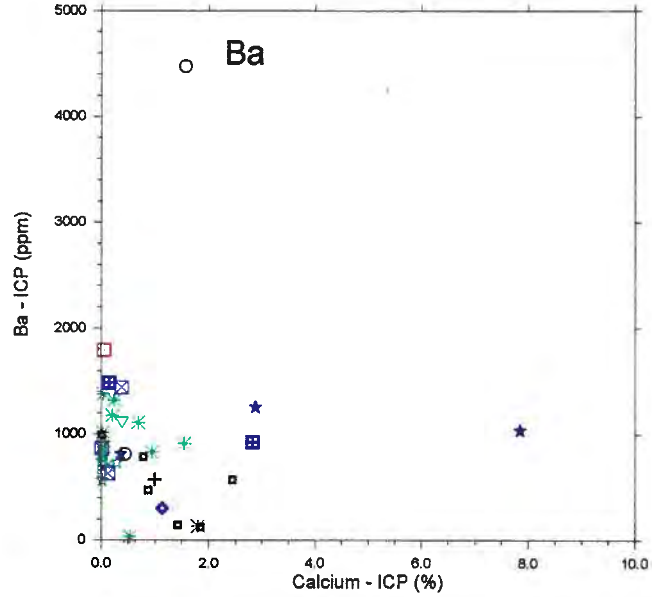


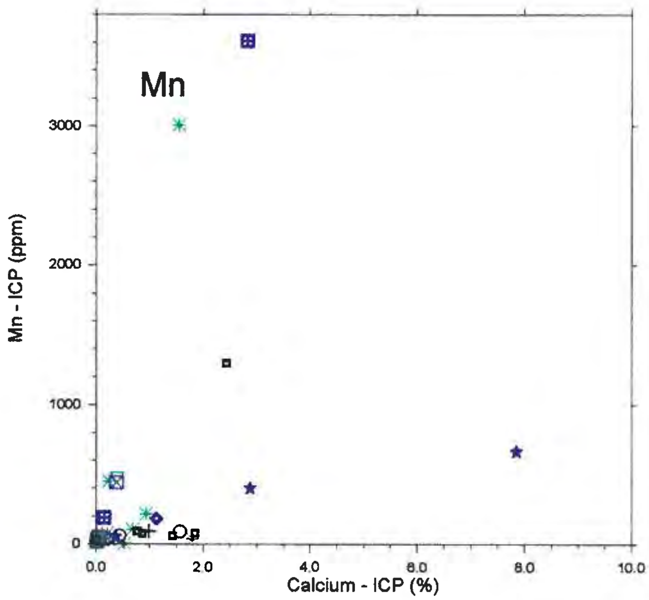


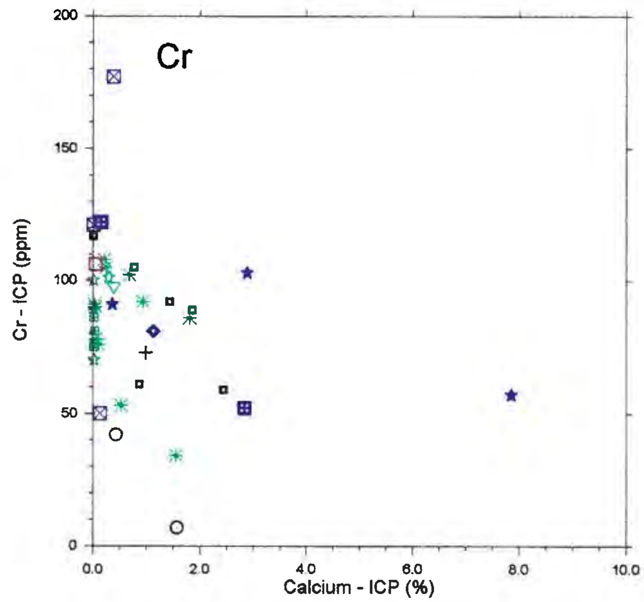
Sh_ca-1.srf

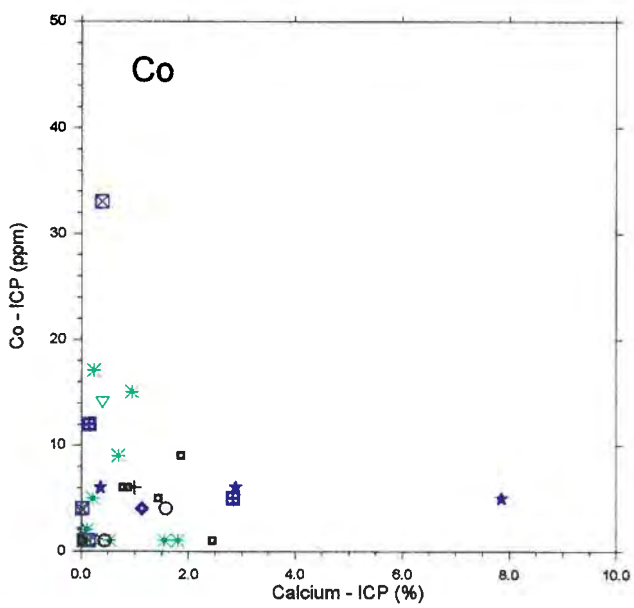
Wapiti: Shales - Calcium

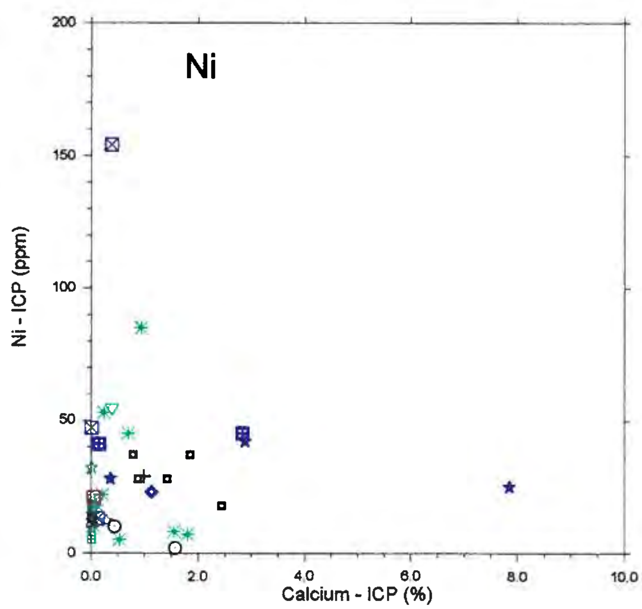






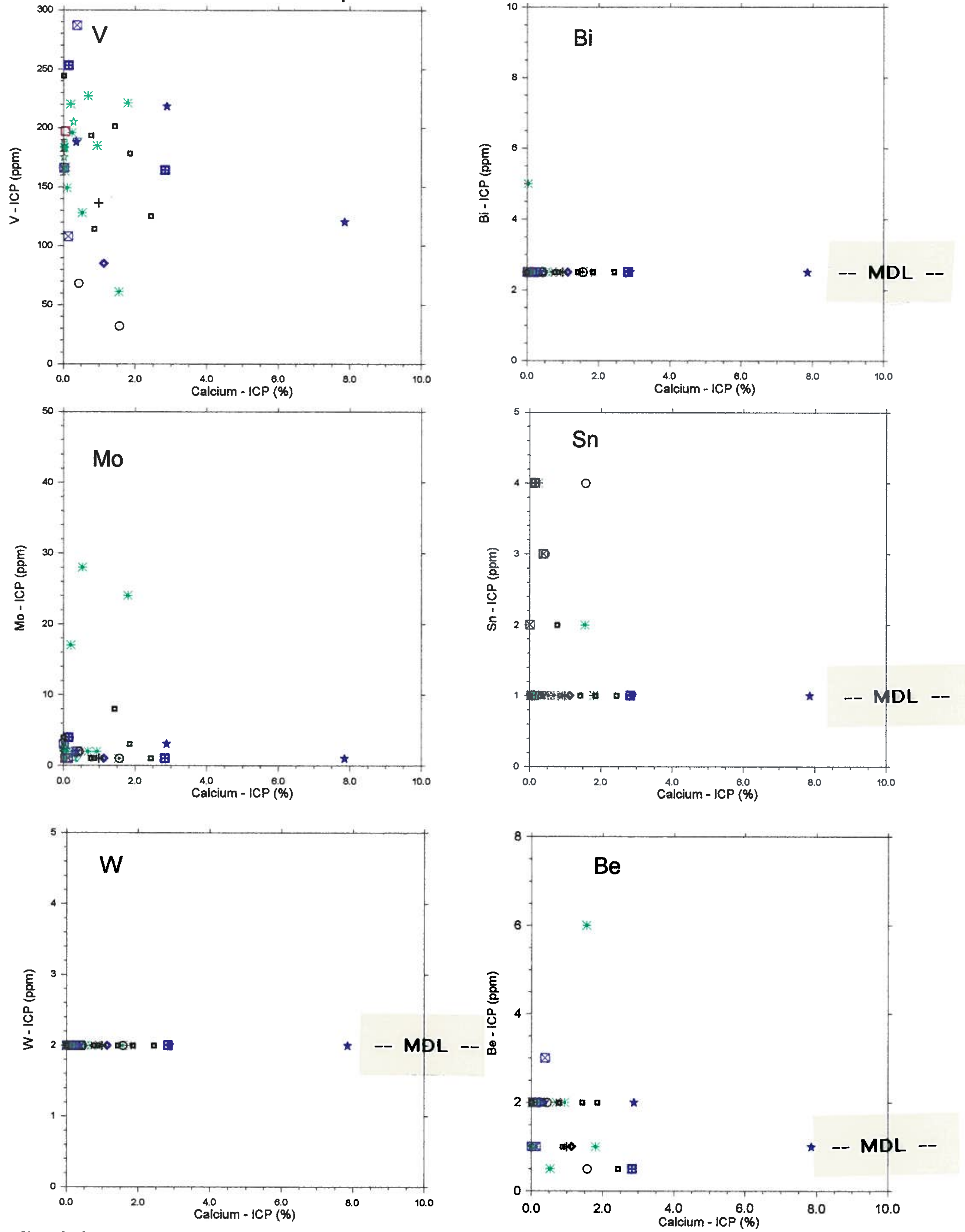






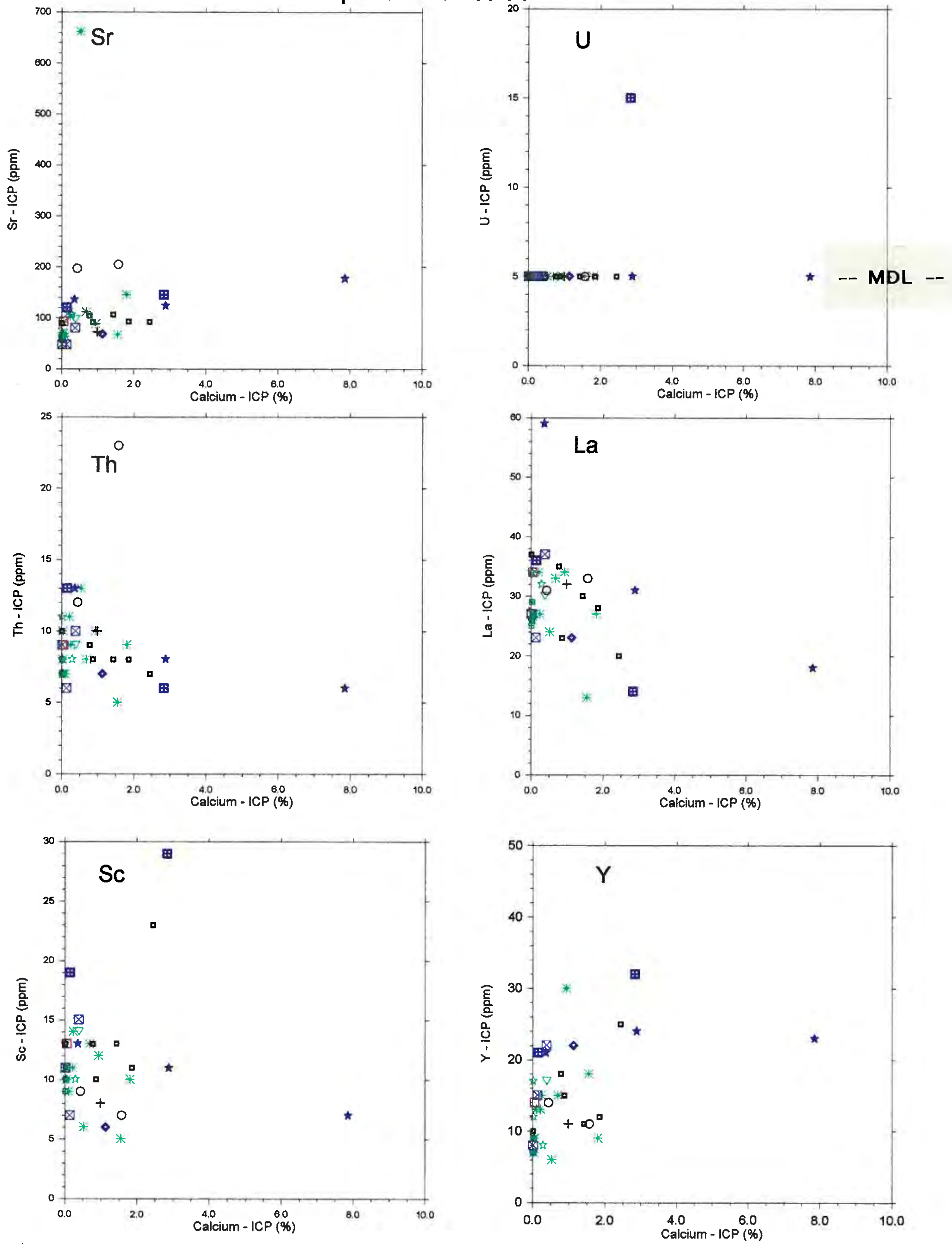
Sh_ca-2.srf

Wapiti: Shales - Calcium



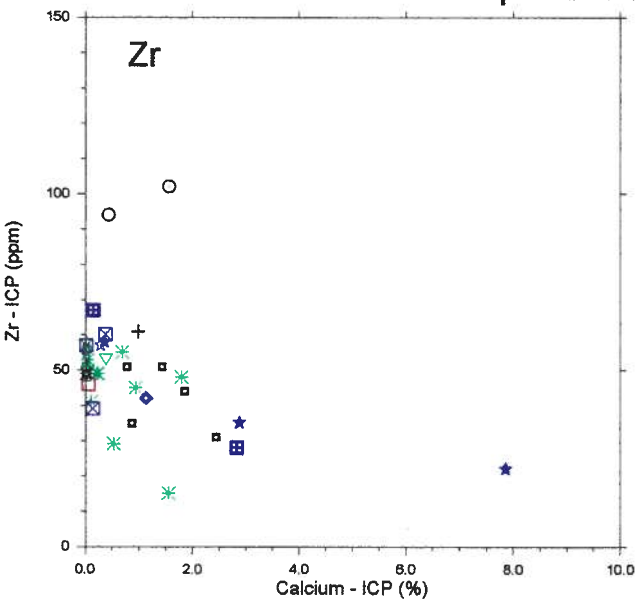
Sh_ca-3.srf

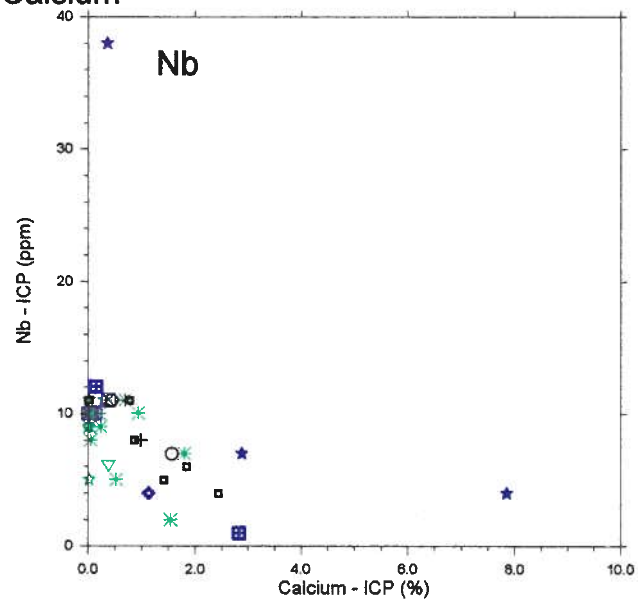
Wapiti: Shales - Calcium

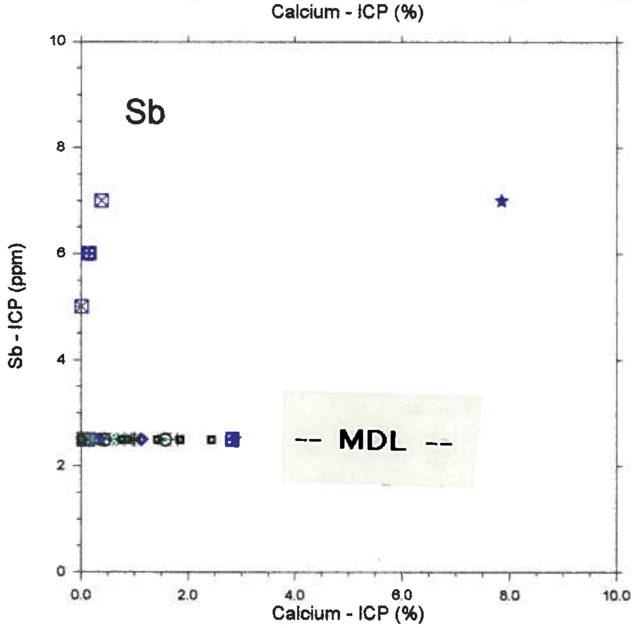


Sh_ca-4.srf

Wapiti: Shales - Calcium

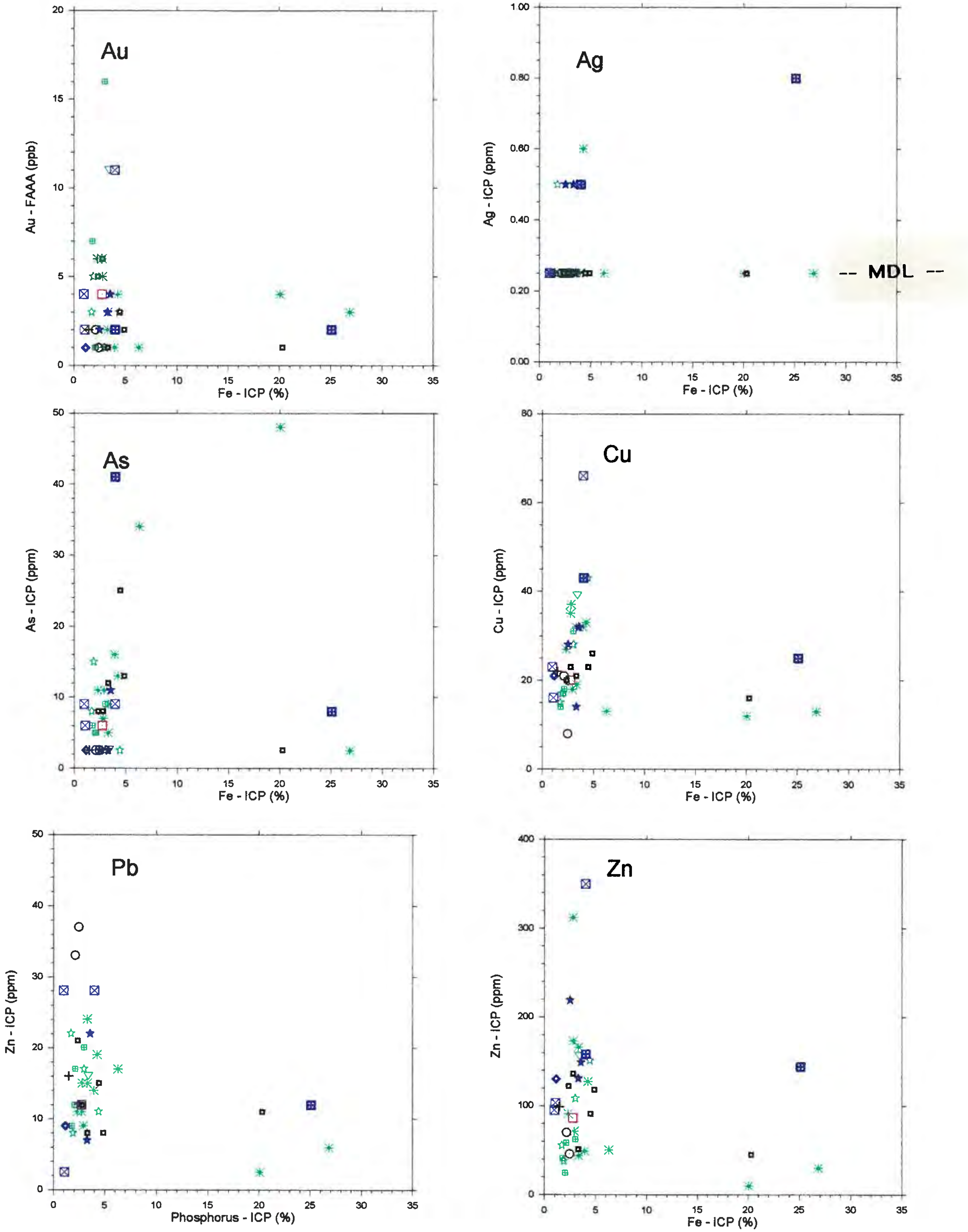






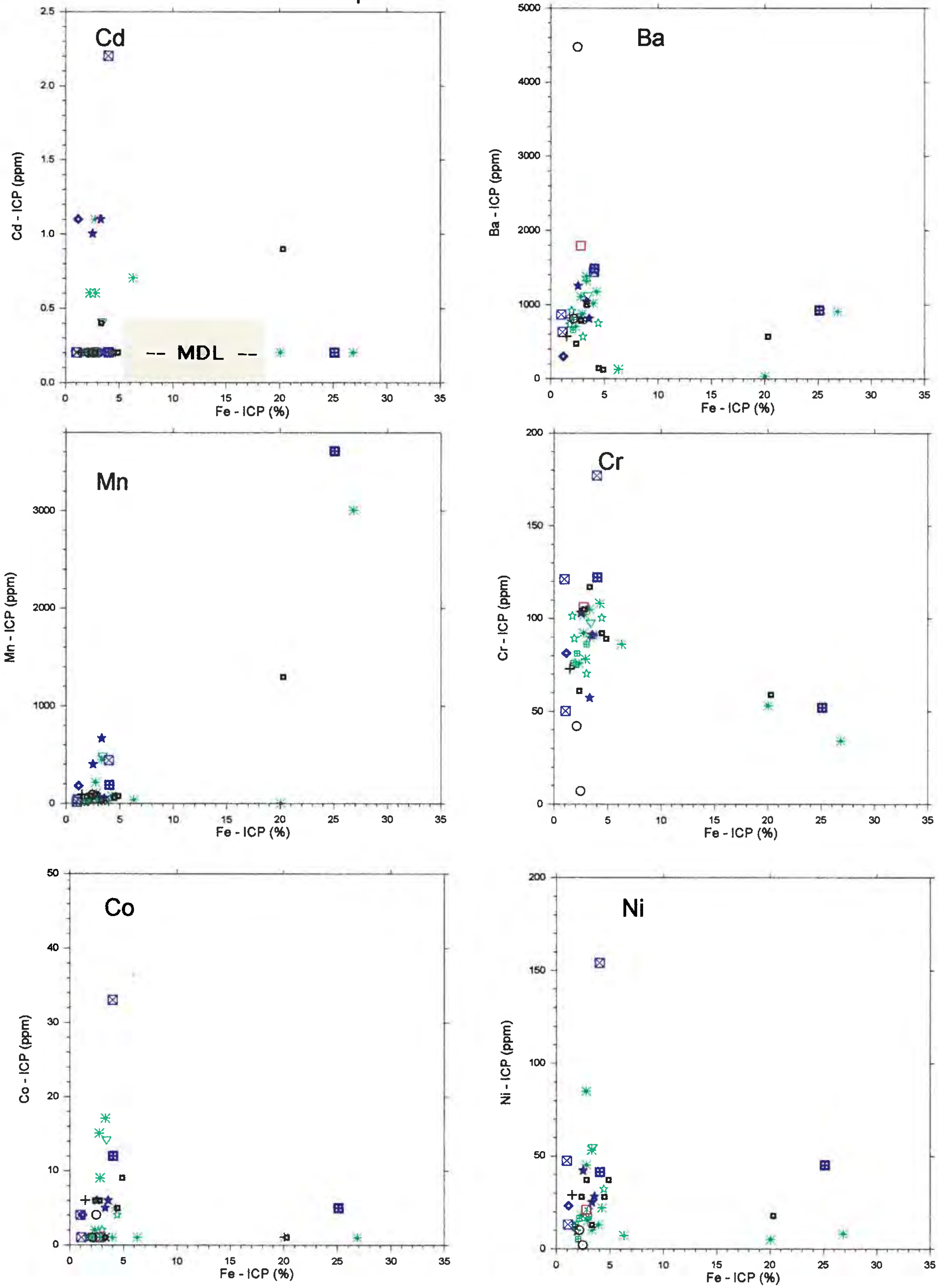
Sb_ca-5.srf

Wapiti: Shales - Fe



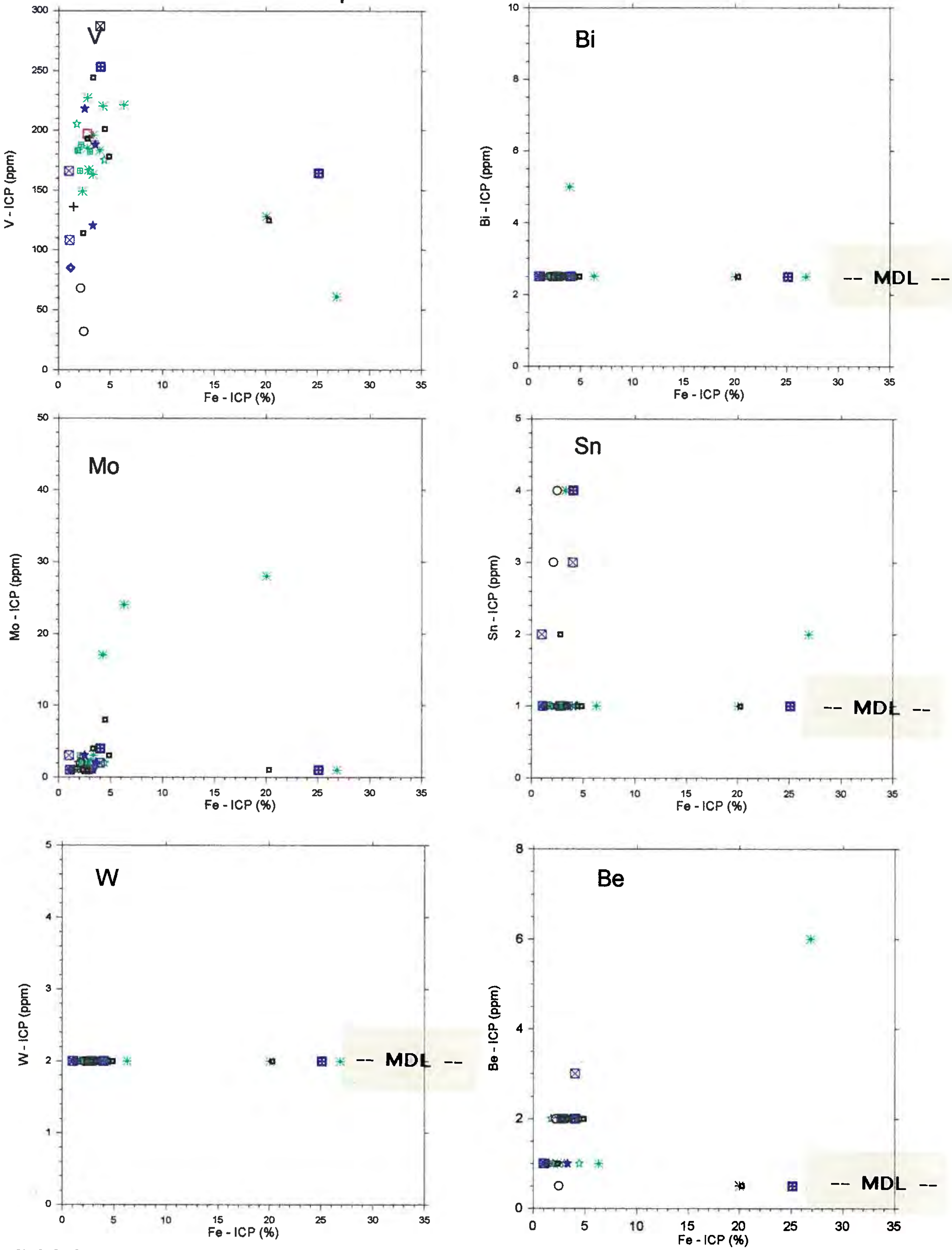
Sh_fe-1.srf

Wapiti: Shales - Fe



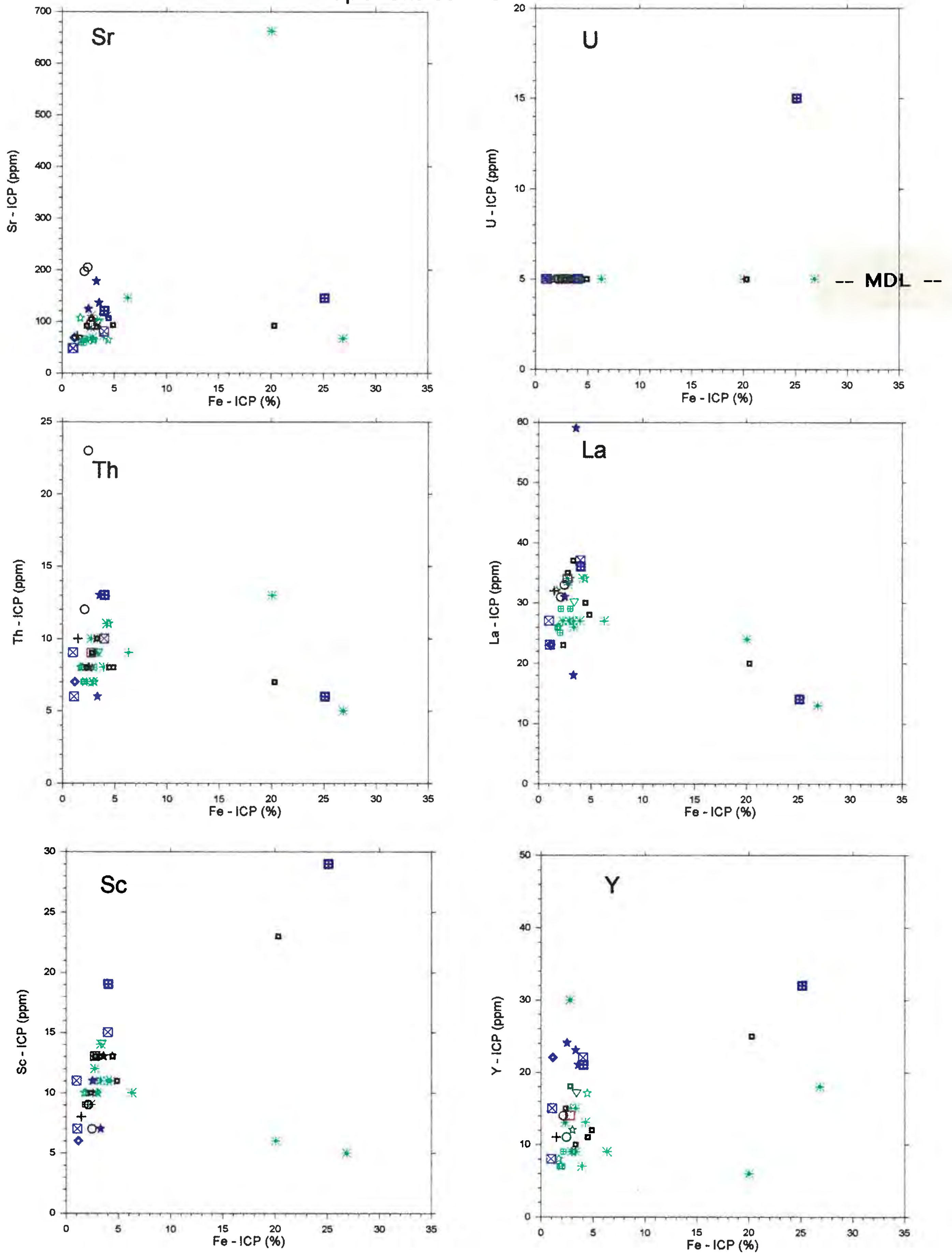
Sh_fe-2.srf

Wapiti: Shales -Fe



Sh_fe-3.srf

Wapiti: Shales - Fe



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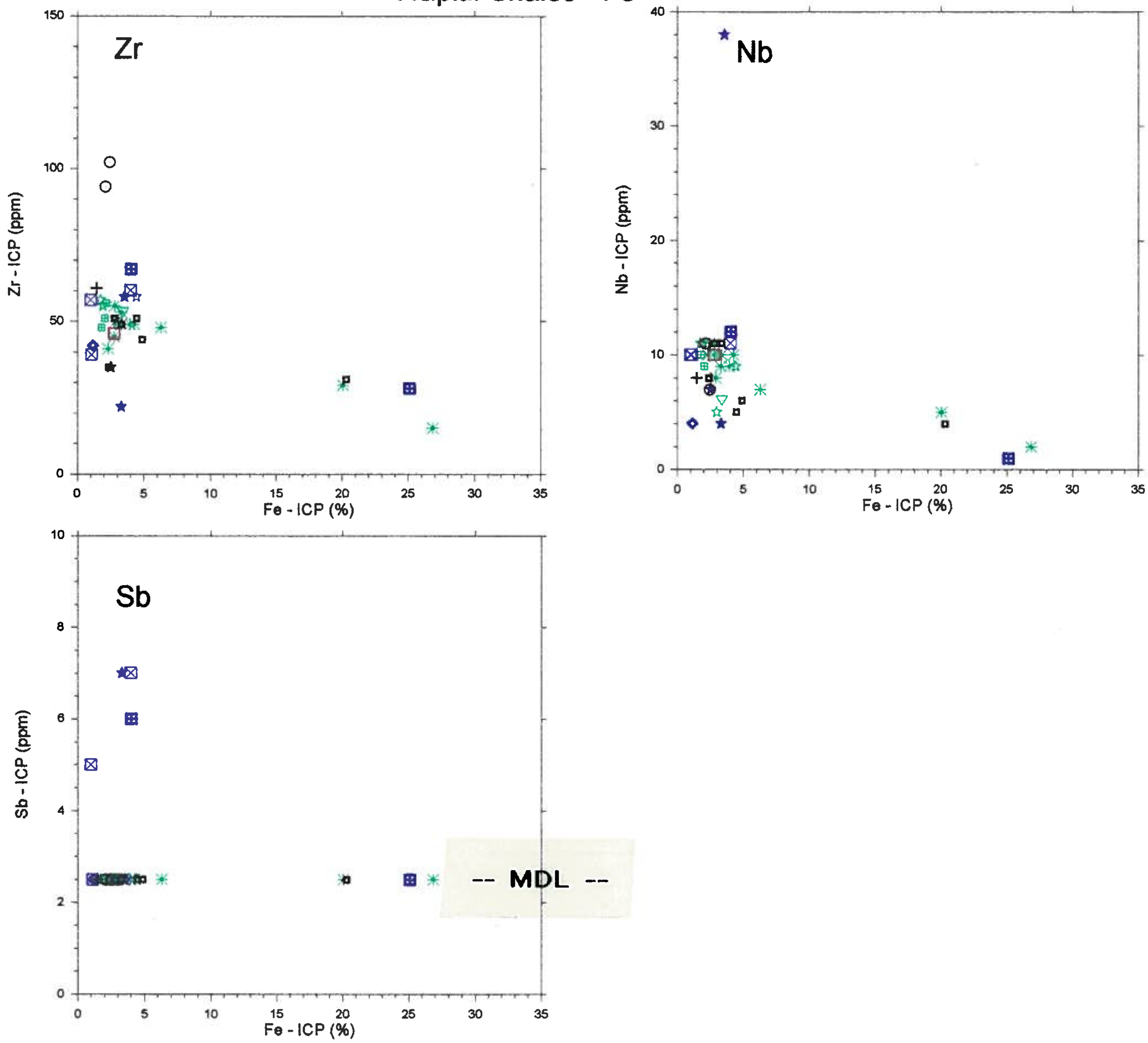
Wapiti: Shales - Fe



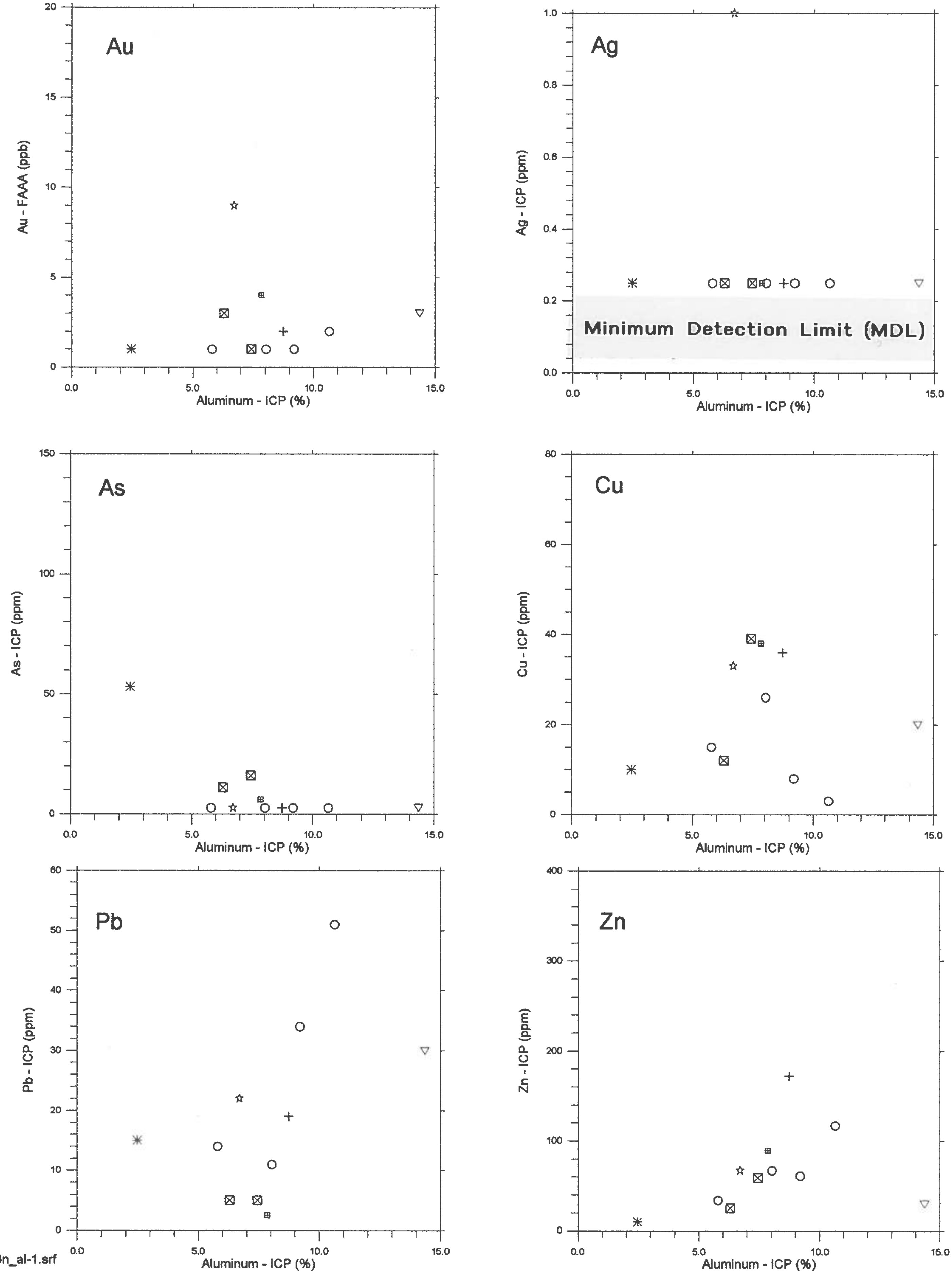
Sh_fe-5.srf

Bentonite Legend

Bentonites occur in the following formations:

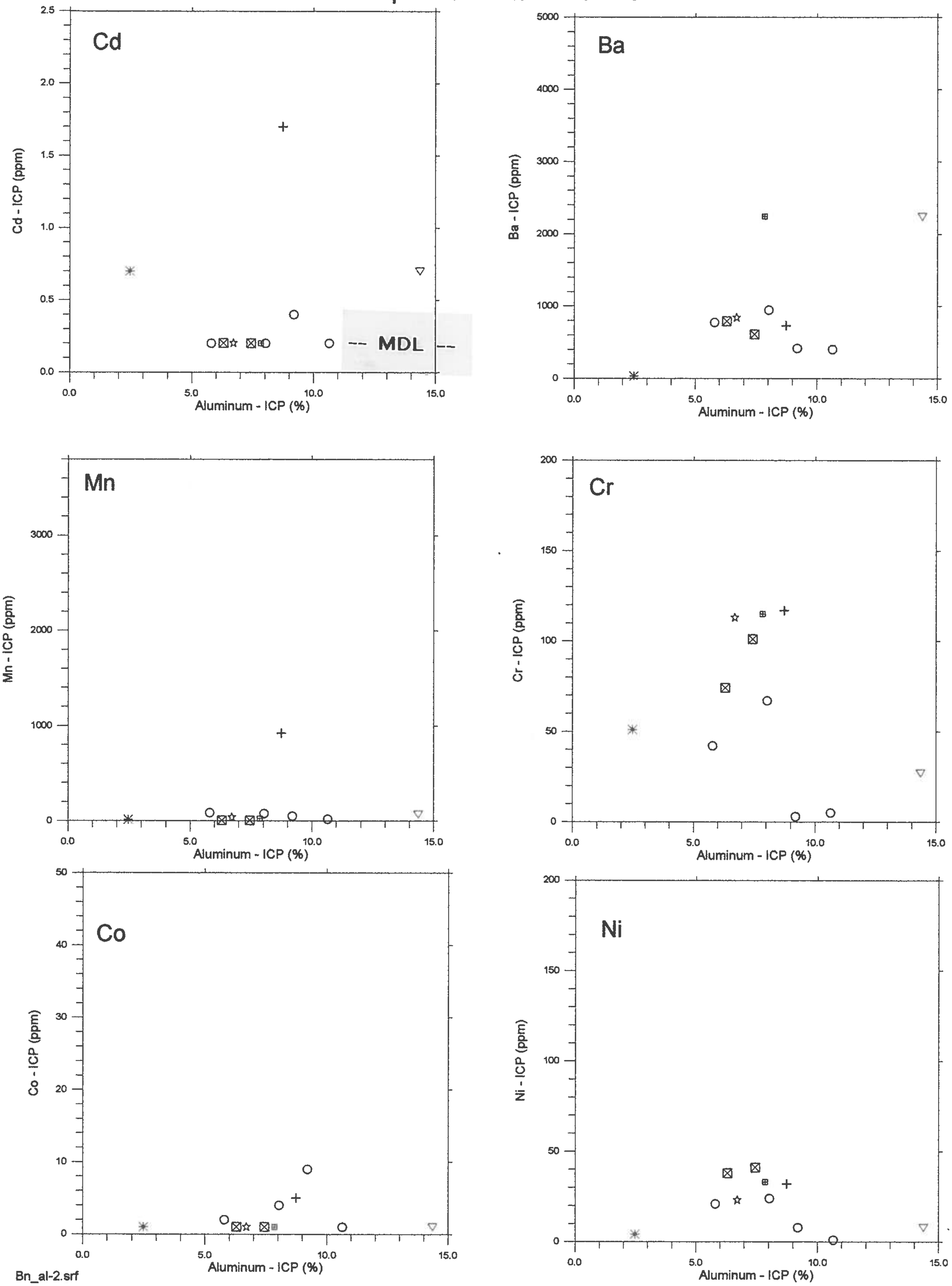
- ⊠ Boulder Creek
- ✳ Shaftesbury
- ✡ Westgate
- ⊞ Fish Scales
- ⊙ Brazeau/Wapiti
- + Coalspur

Wapiti: Bentonites - Aluminum

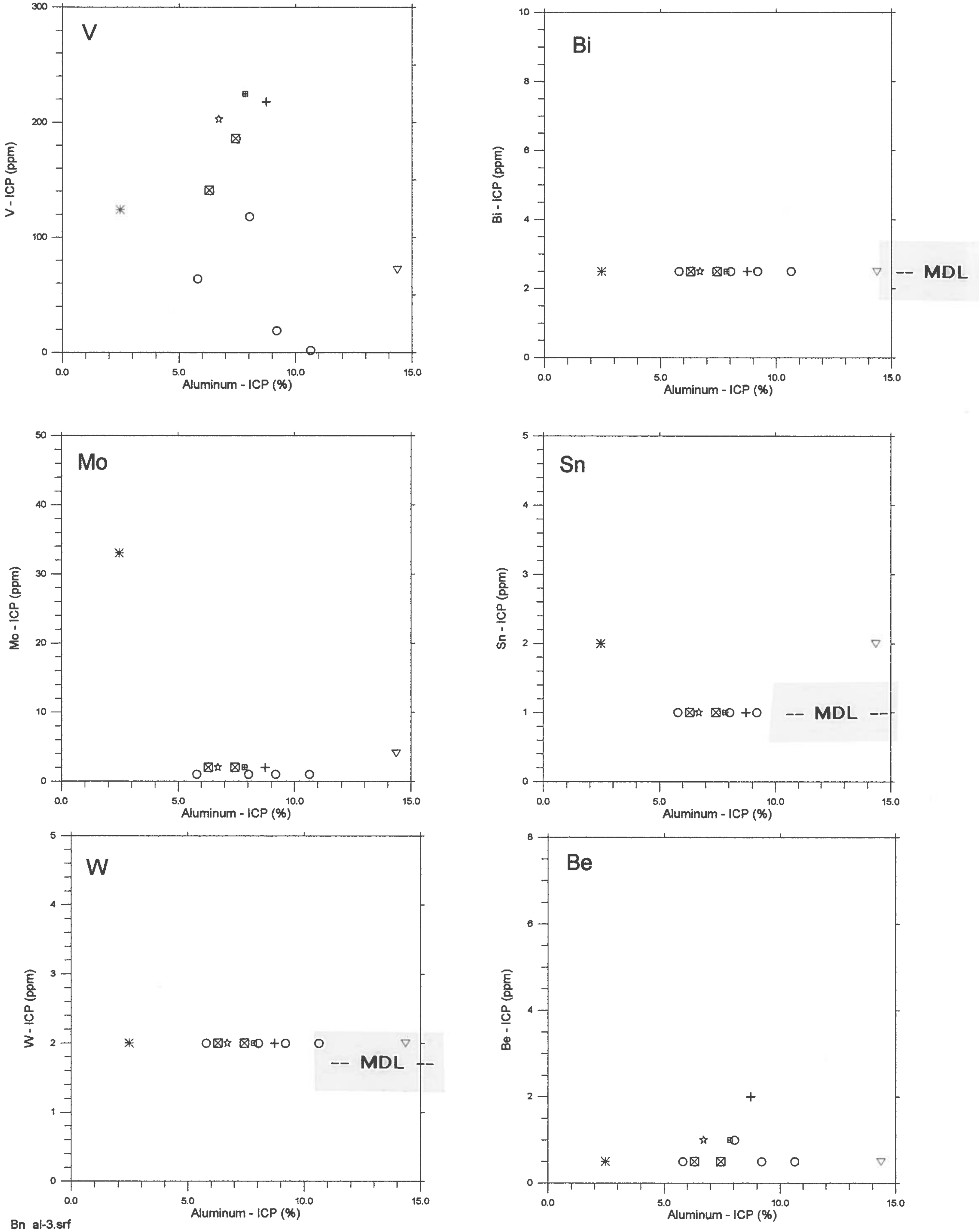


Bn_al-1.srf

Wapiti: Bentonites - Aluminum

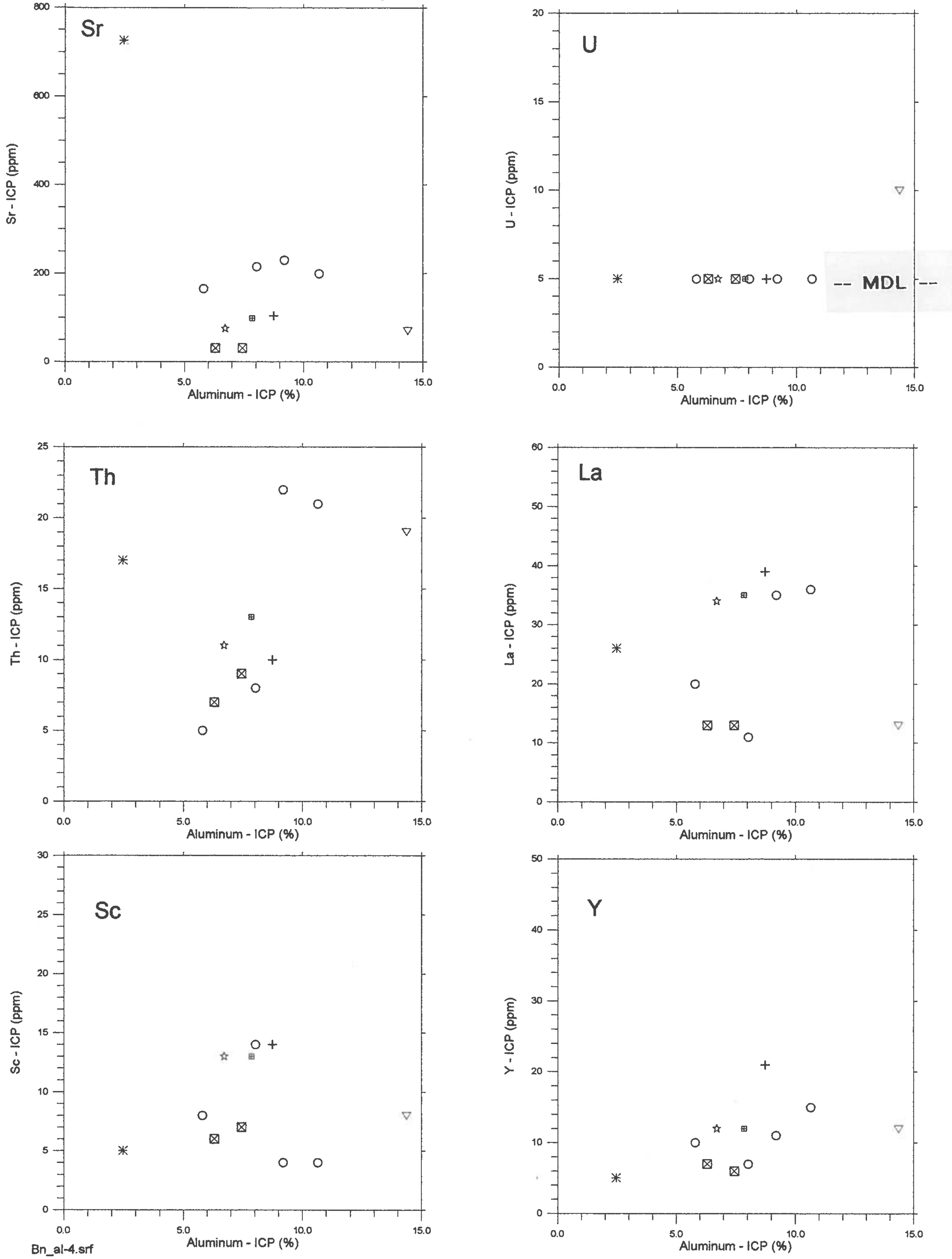


Wapiti: Bentonites - Aluminum

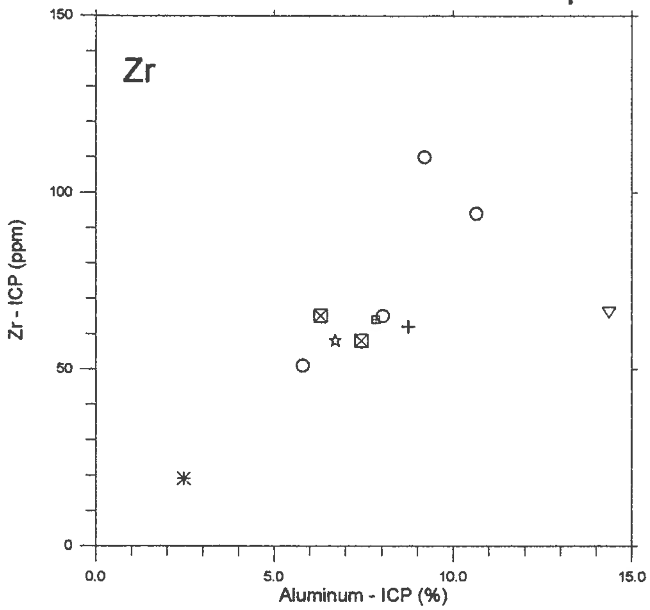


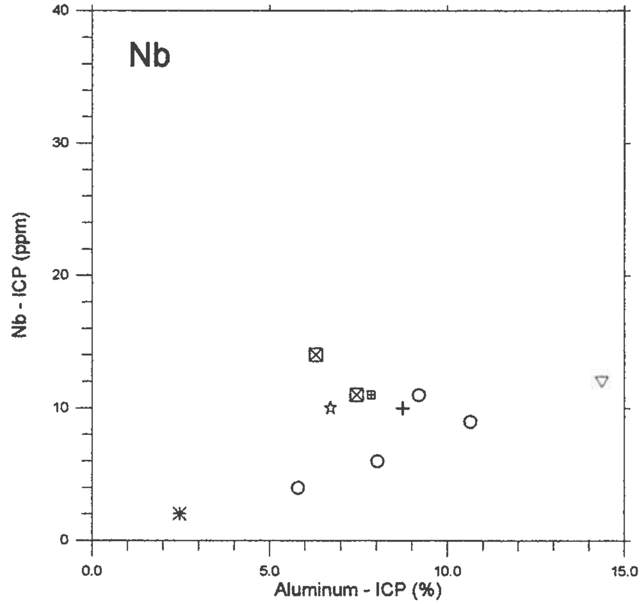
Bn al-3.srf

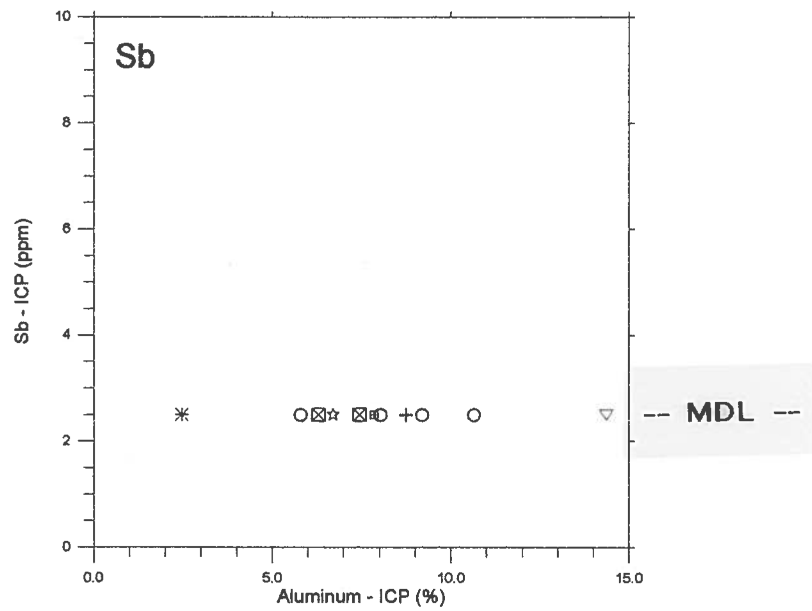
Wapiti: Bentonites - Aluminum



Wapiti: Bentonites - Aluminum







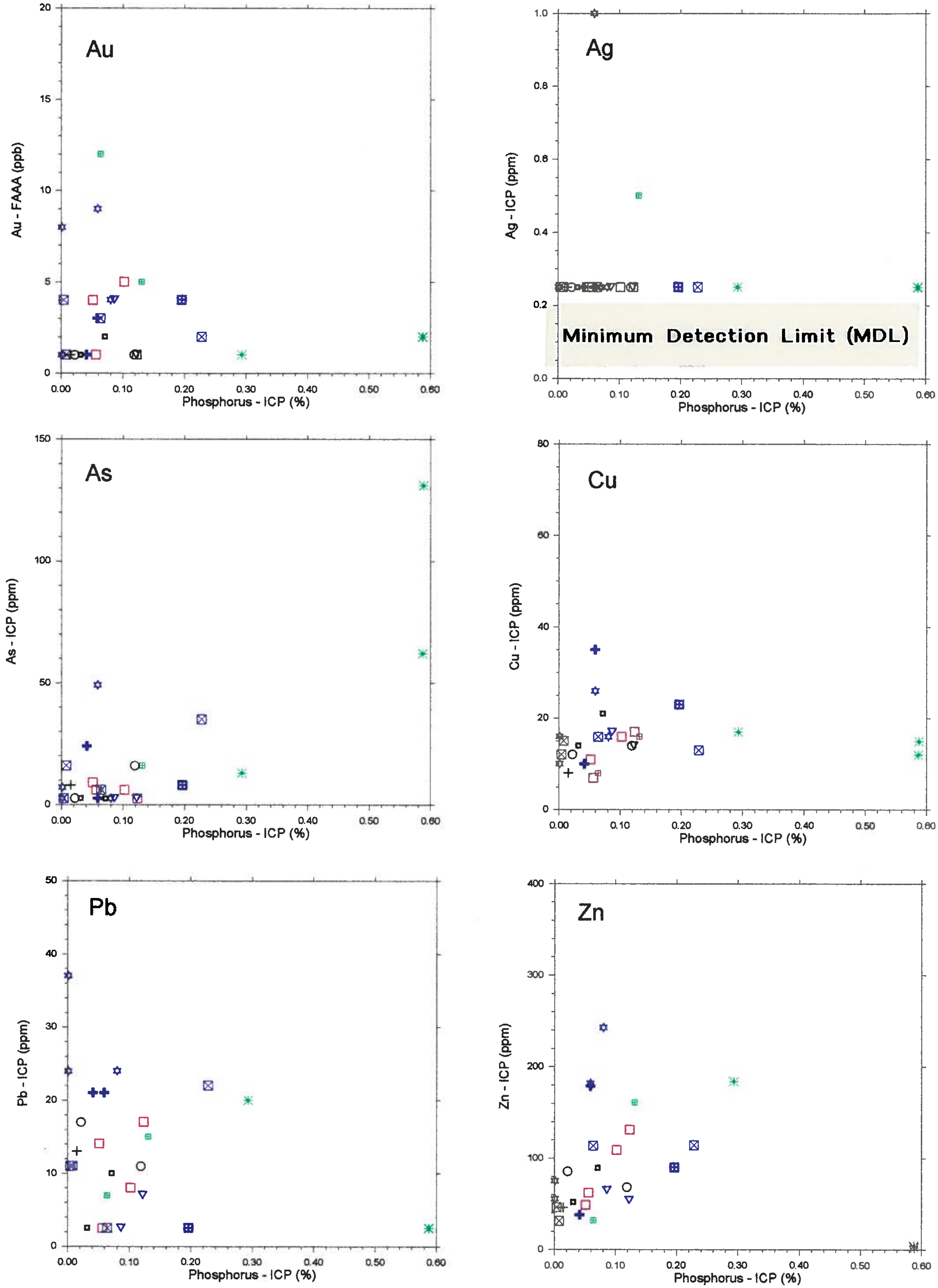
Bn_al-5.srf

Conglomerate, sandstone and siltstone legend

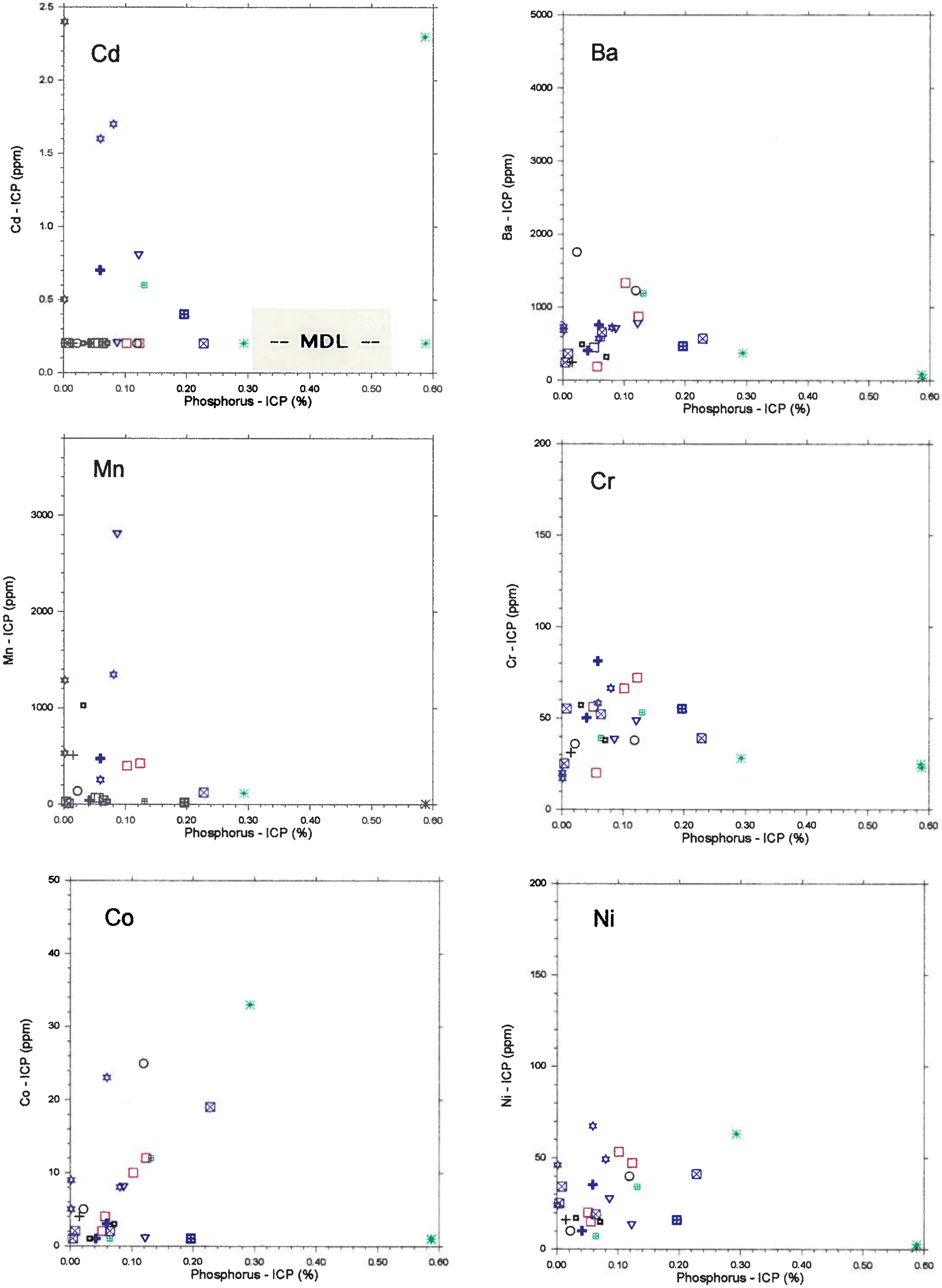
Clastic rocks occur in the following formations:

- ⊠ Boulder Creek
- ✳ Shaftesbury
- ⊞ Fish Scales
- ⊡ Dunvegan
- ▪ Kaskapau
- ⊙ Brazeau/Wapiti
- + Coalspur
- ▽ Nikanassin
- ⊞ Gorman Creek
- ✚ Cadomin
- ✡ Gladstone

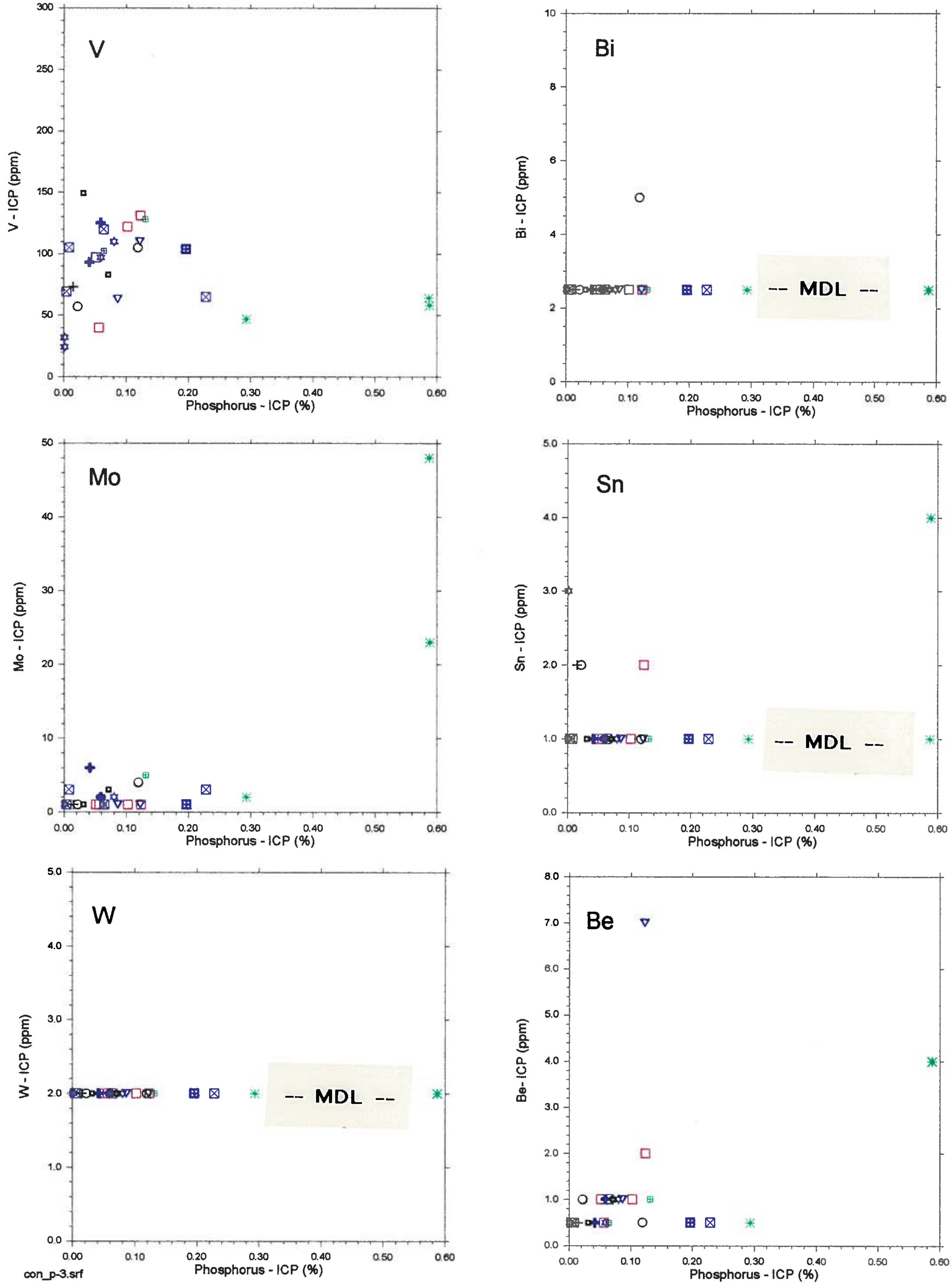
Conglomerates, Sandstones and Siltstones -Phosphorus



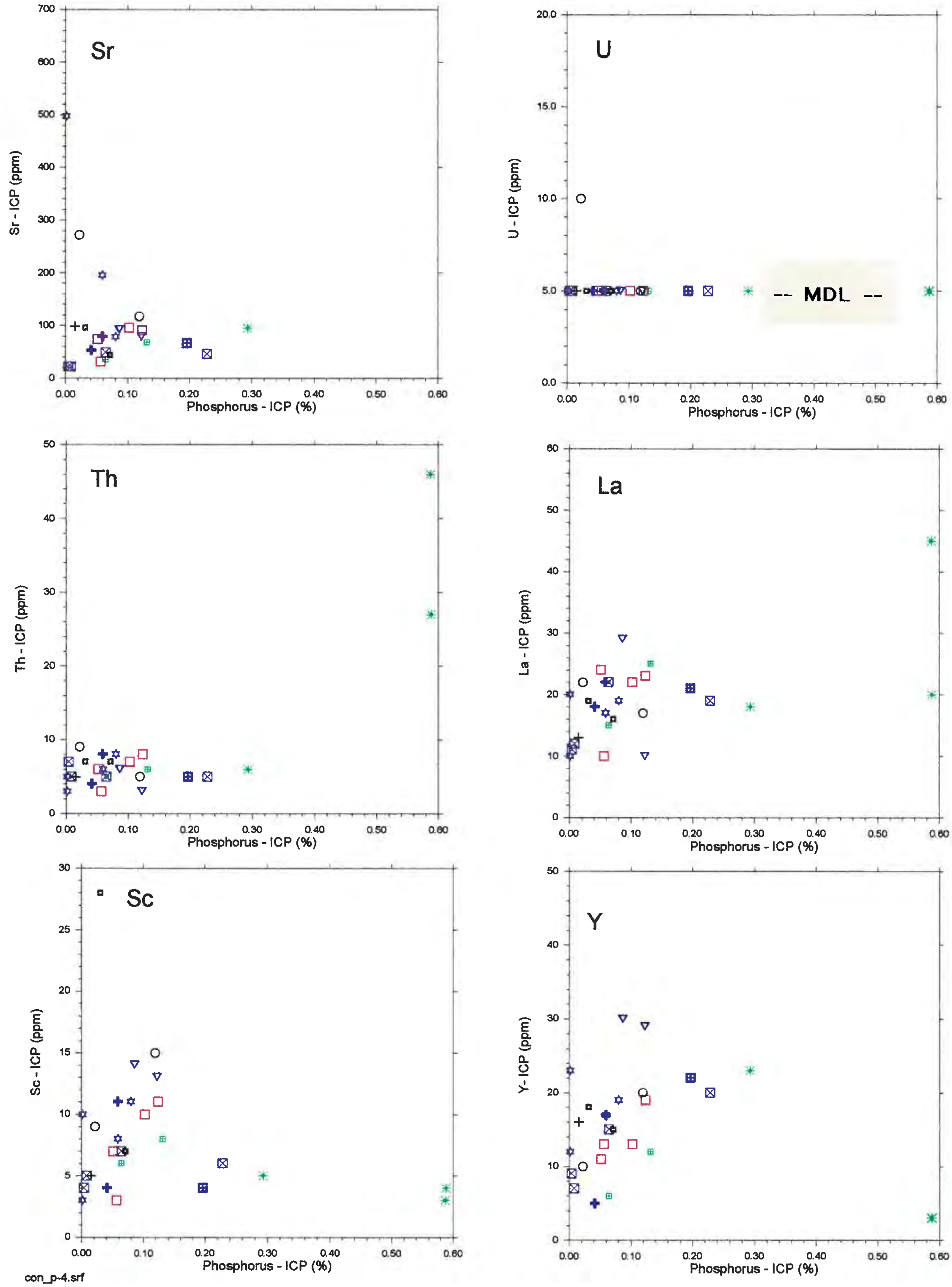
Conglomerates, Sandstones and Siltstones - Phosphorus



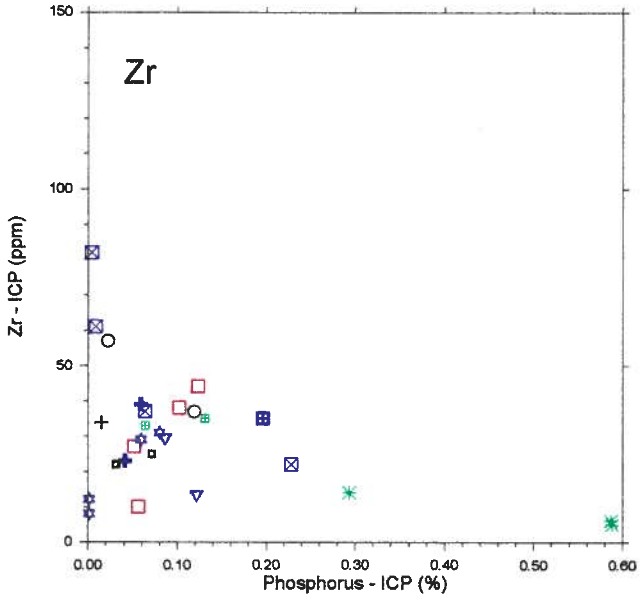
Conglomerates, Sandstones and Siltstones - Phosphorus

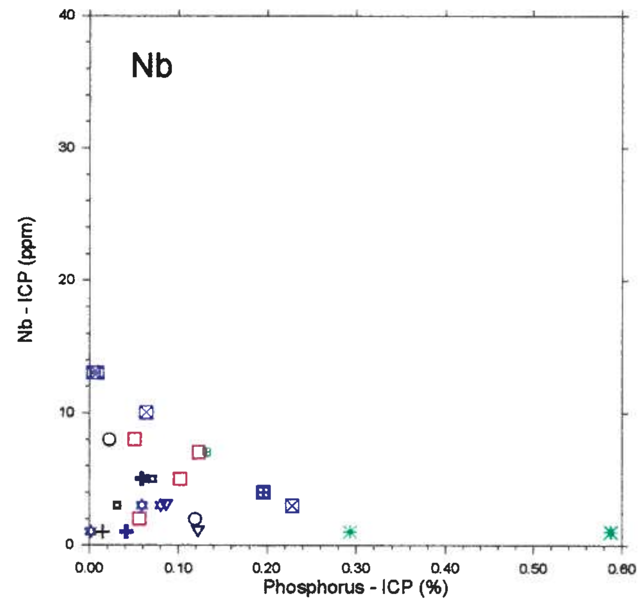


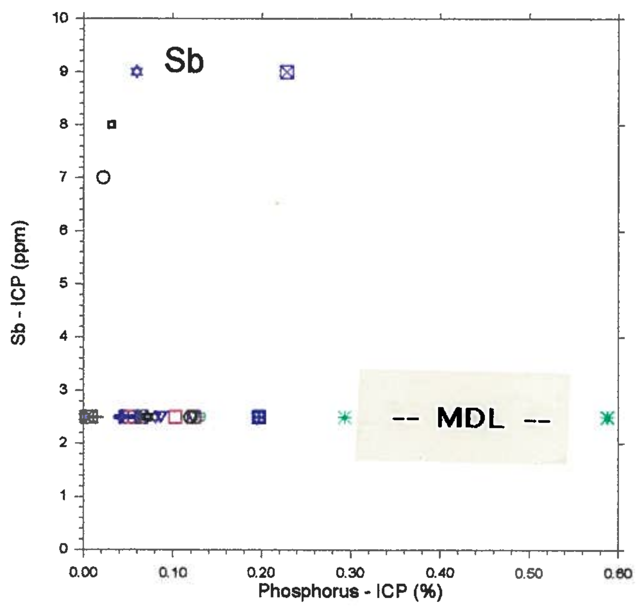
Conglomerates, Sandstones and Siltstones -Phosphorus



Conglomerates, Sandstones and Siltstones - Phosphorus

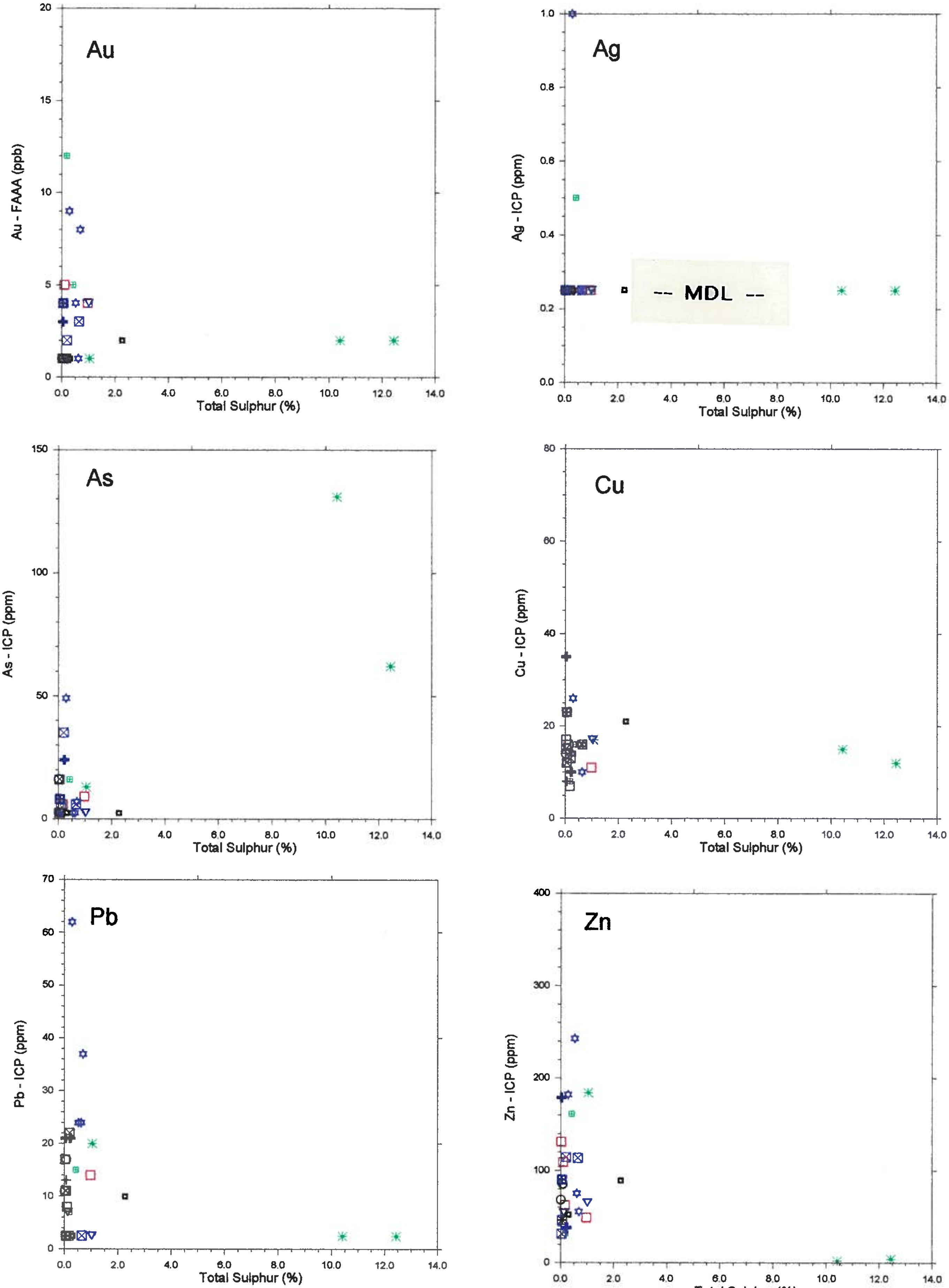






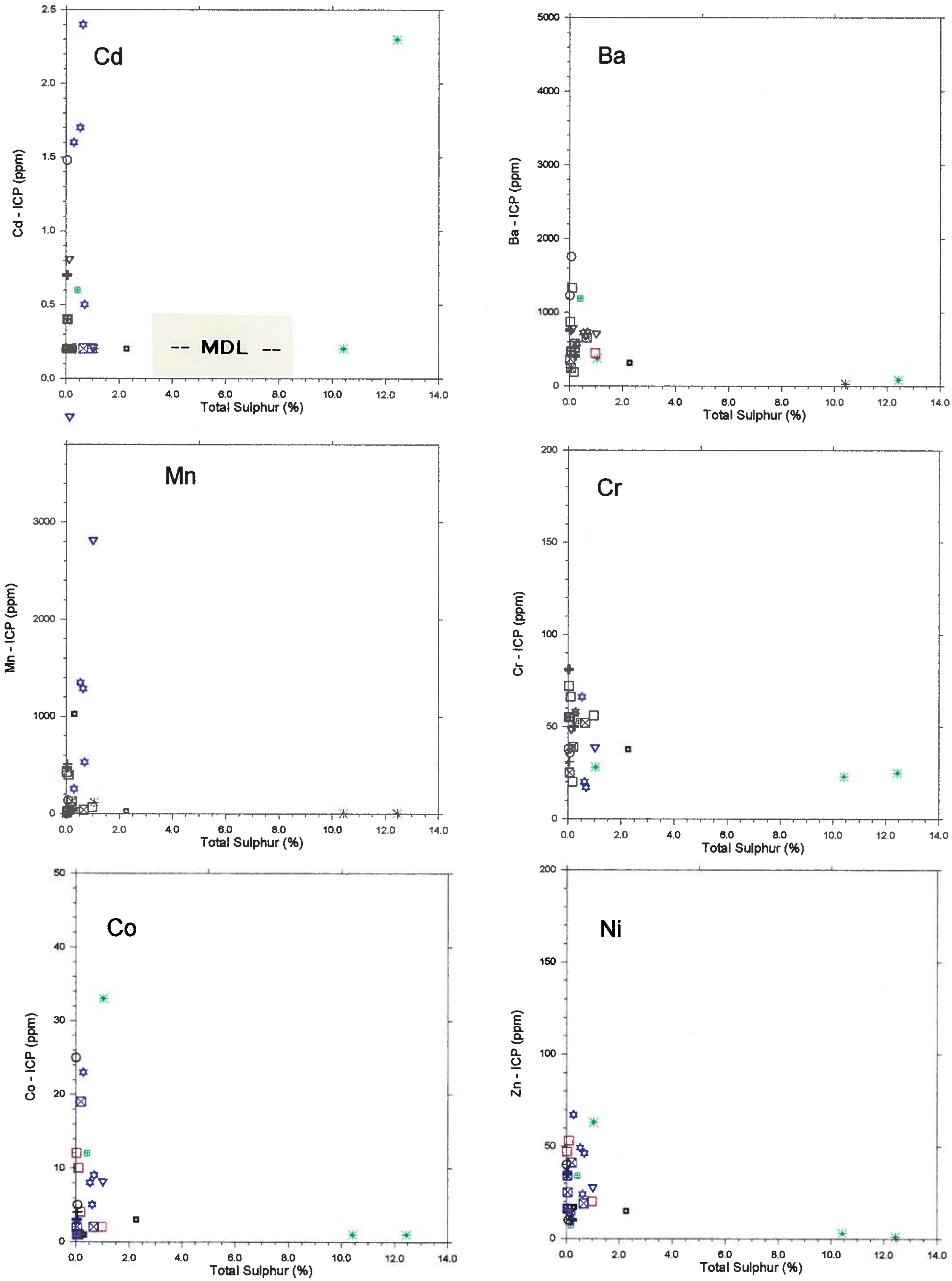
con_p-5.srf

Conglomerates, Sandstones and Siltstones - Total Sulphur



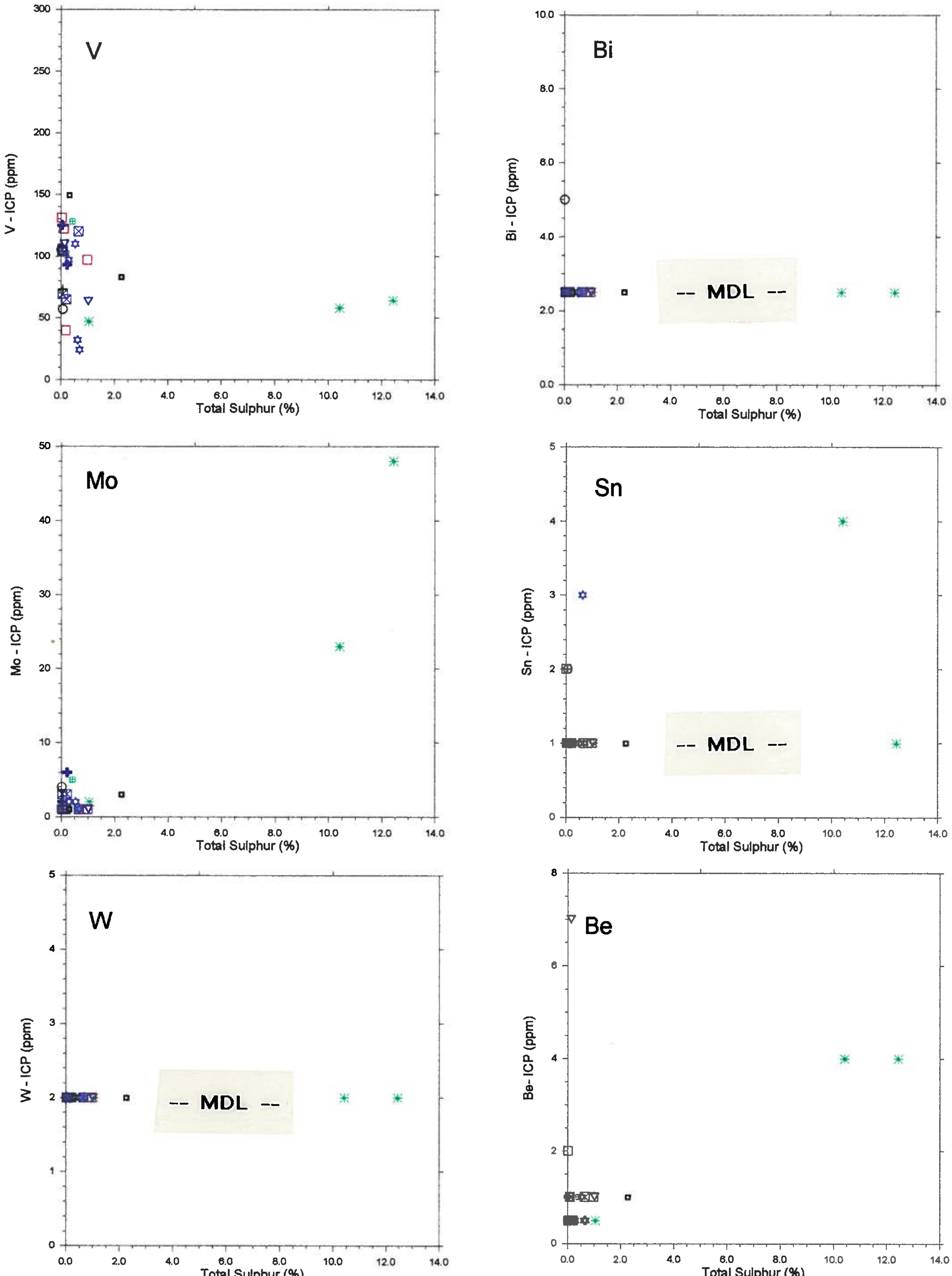
cong s-1.srf

Conglomerates, Sandstones and Siltstones - Total Sulphur



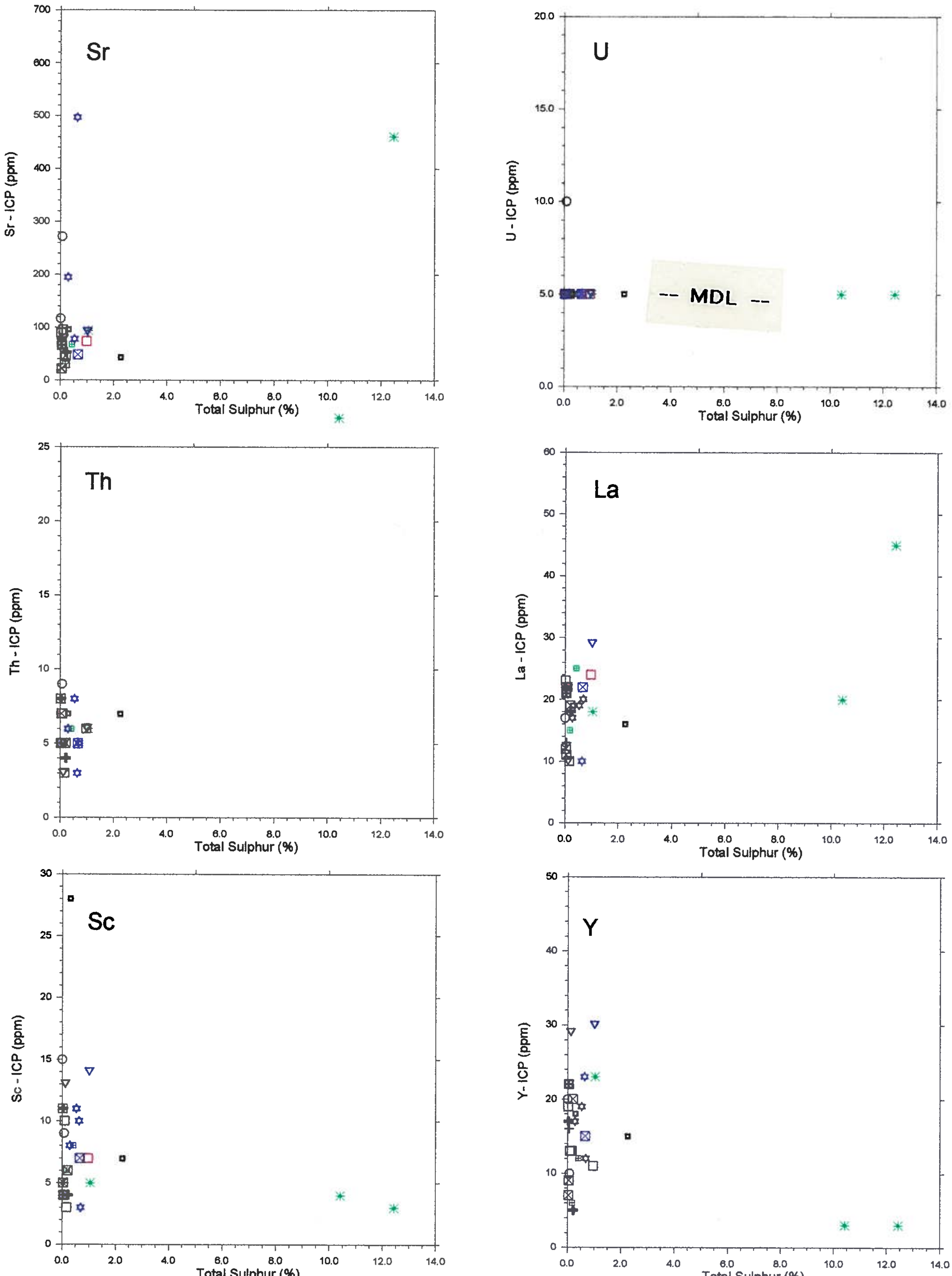
cong_s-2.srf

Conglomerates, Sandstones and Siltstones - Total Sulphur



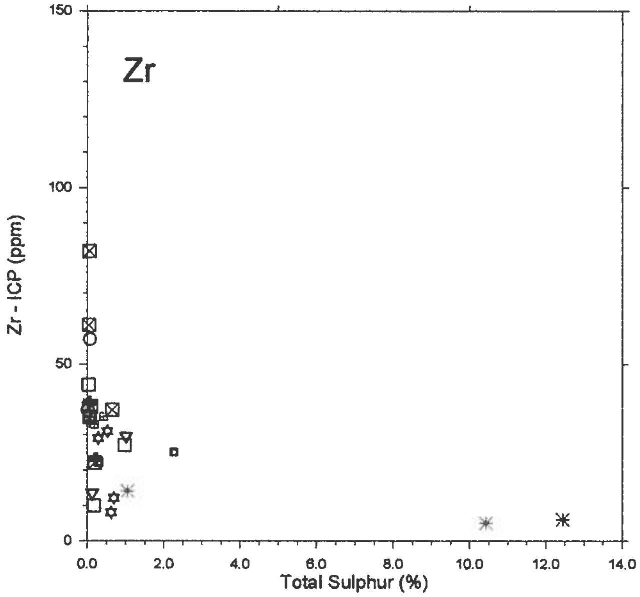
cong_s-3.srf

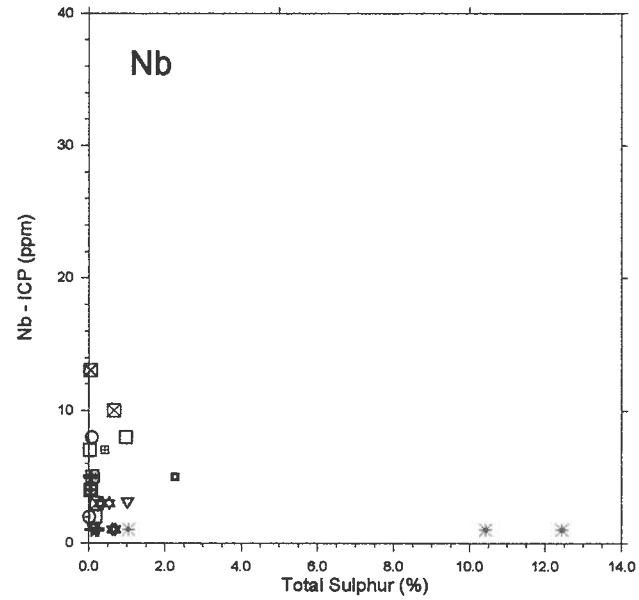
Conglomerates, Sandstones and Siltstones - Total Sulphur

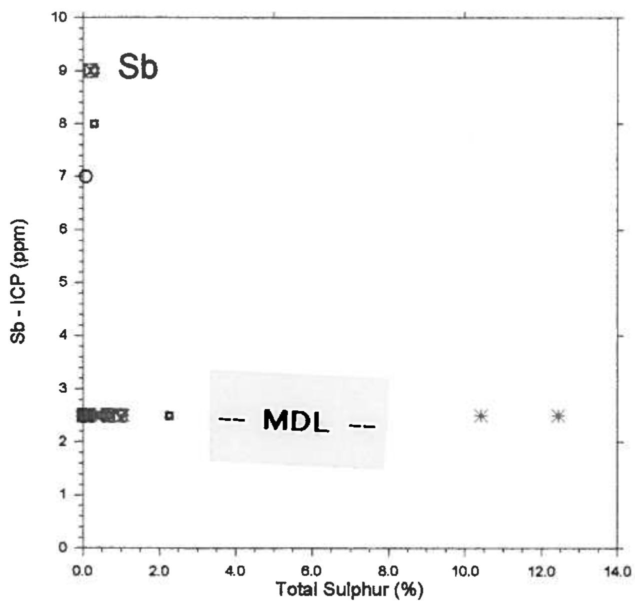


cong_s-4.srf

Conglomerates, Sandstones and Siltstones - Total Sulphur

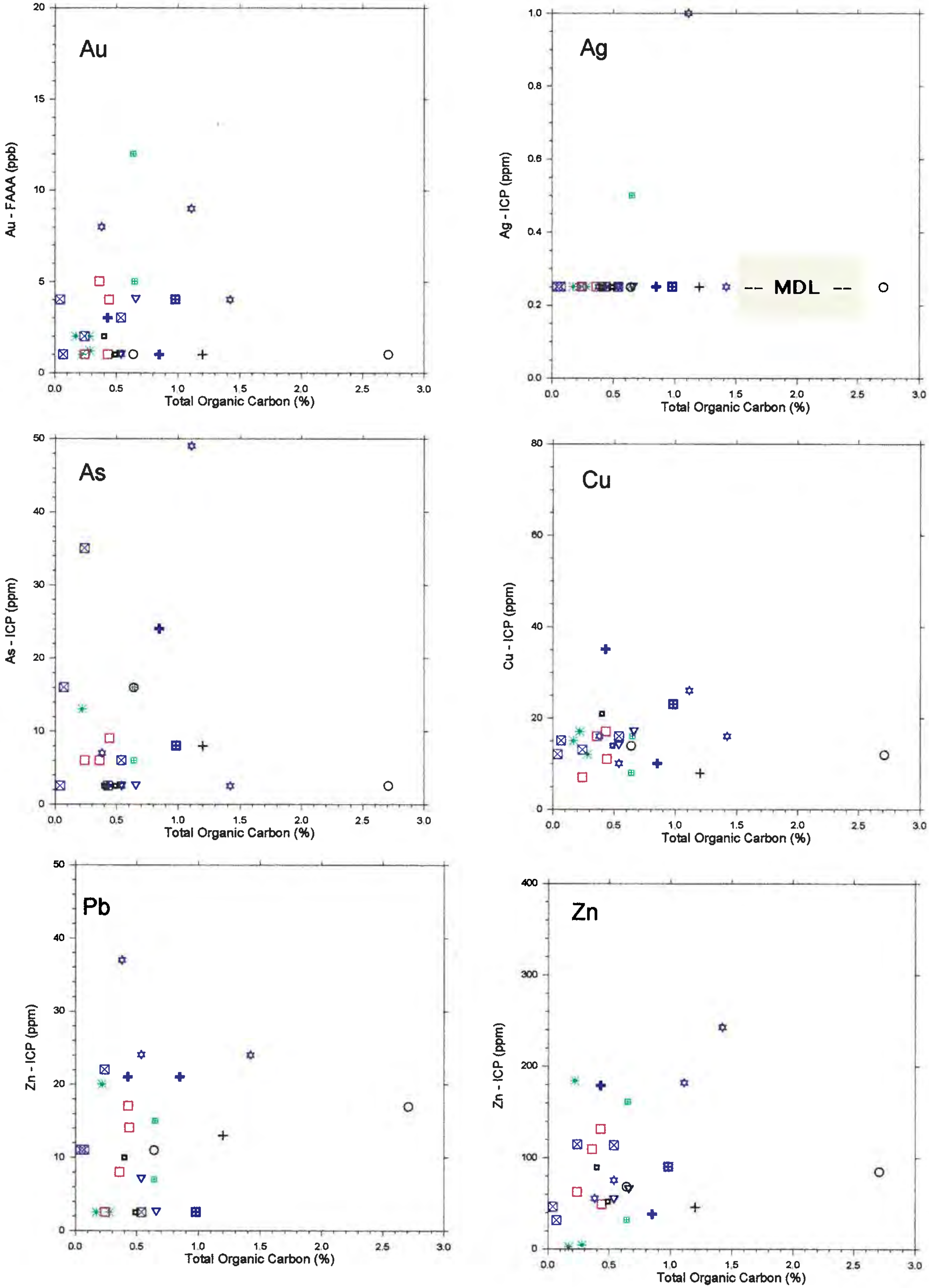




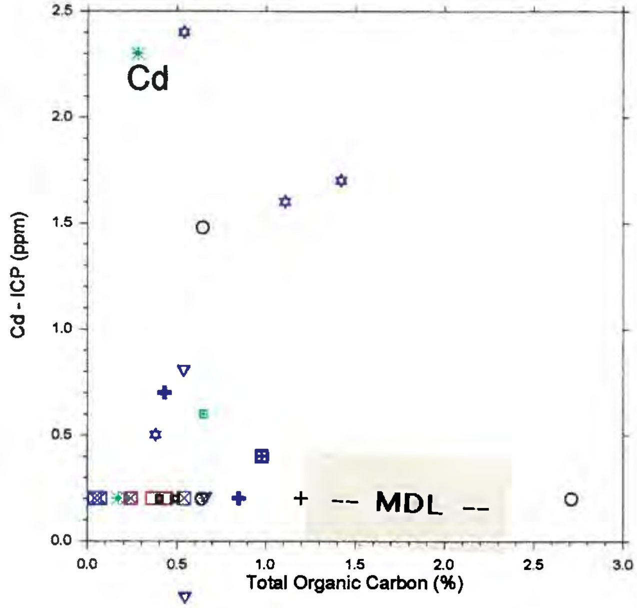


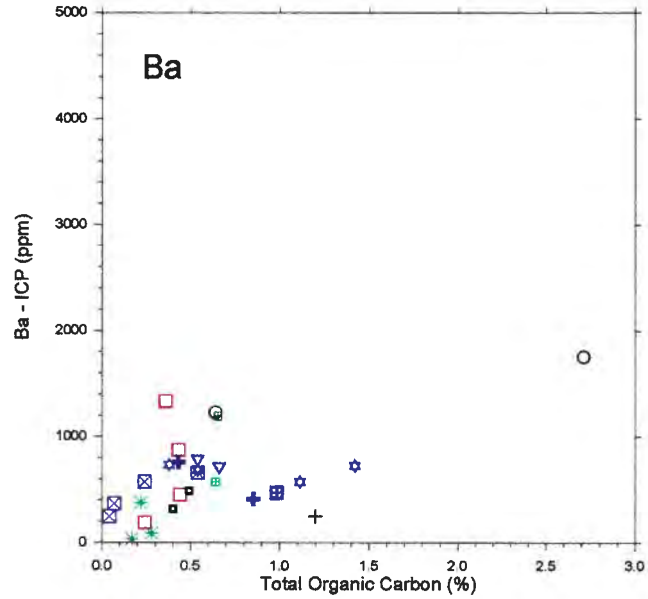
cong_s-5.srf

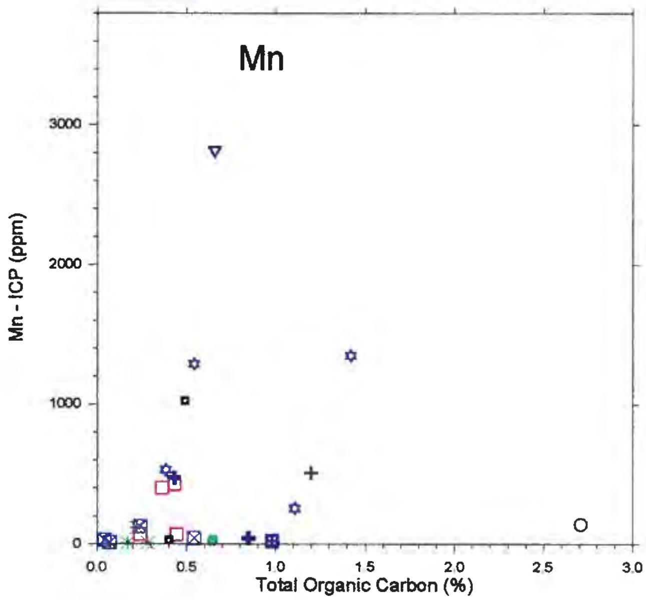
Conglomerates, Sandstones and Siltstones - Total Organic Carbon

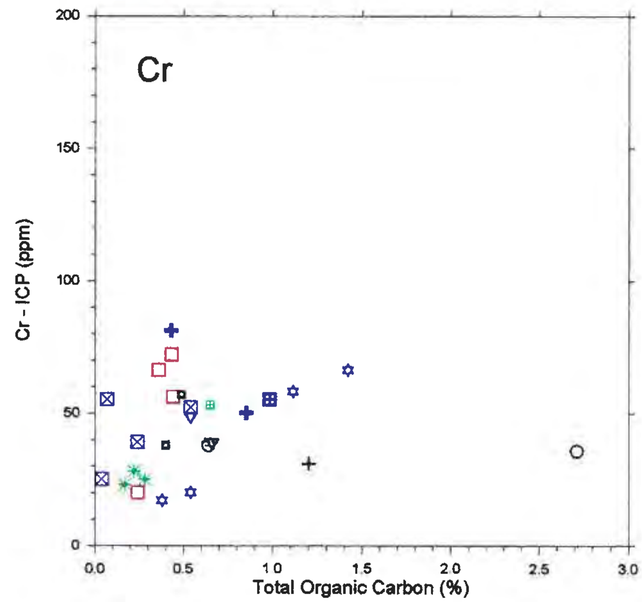


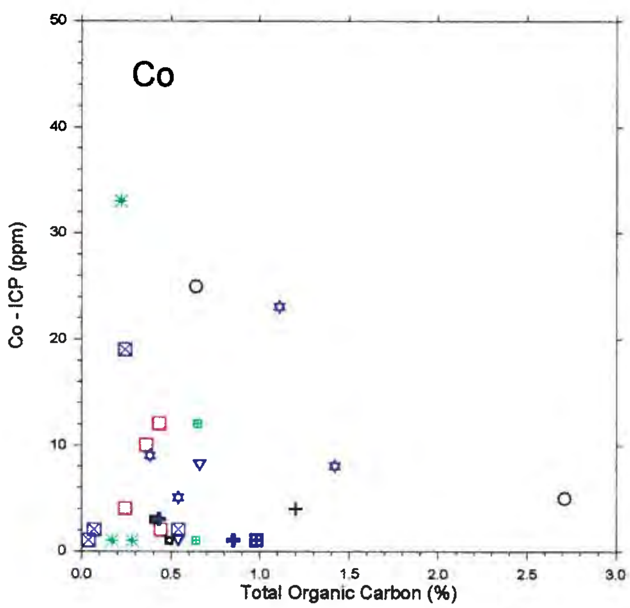
Conglomerates, Sandstones and Siltstones - Total Organic Carbon

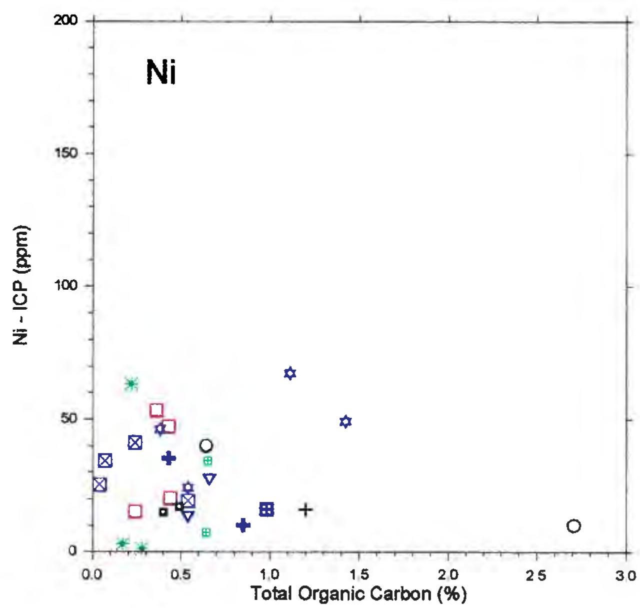




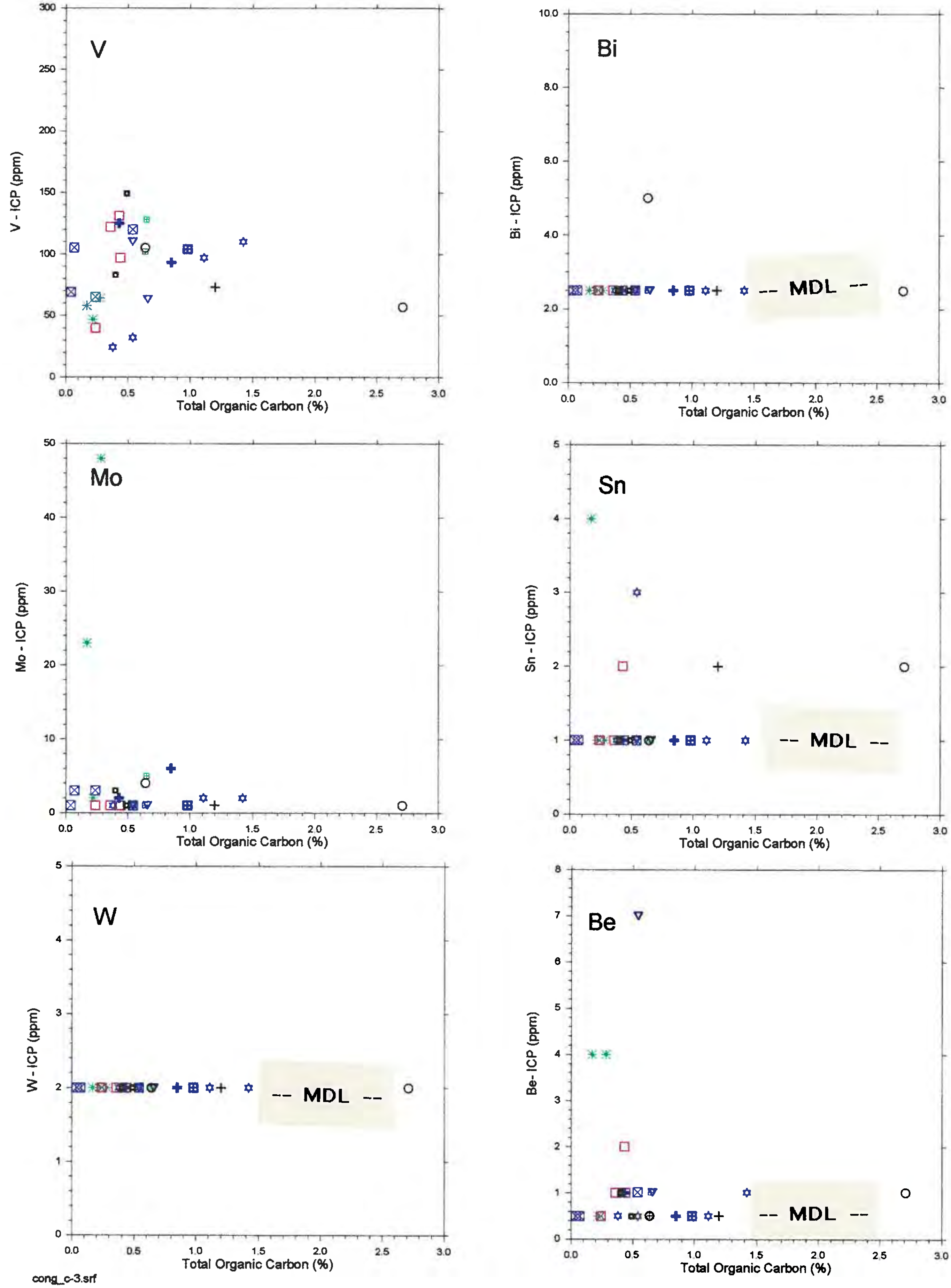




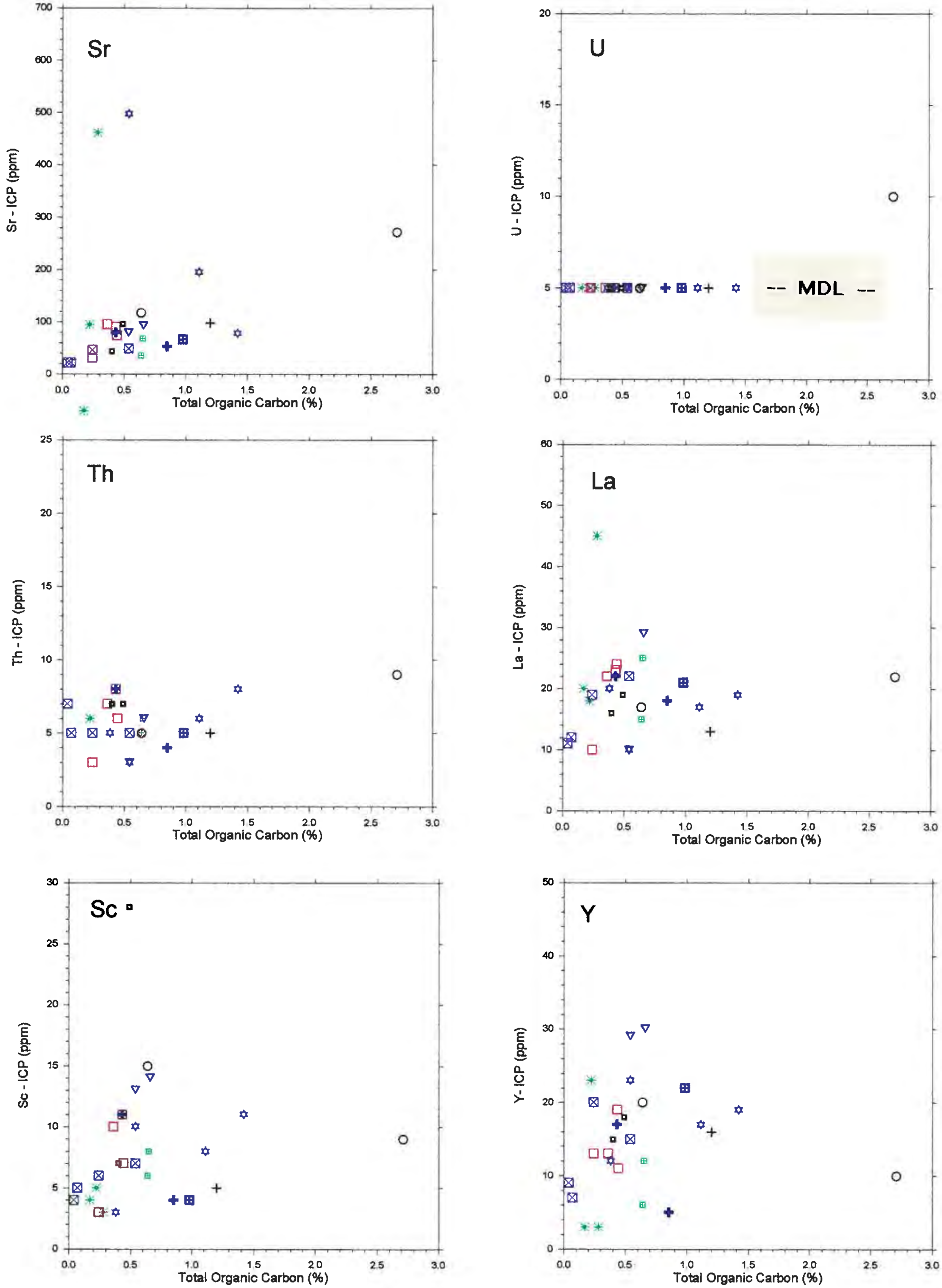




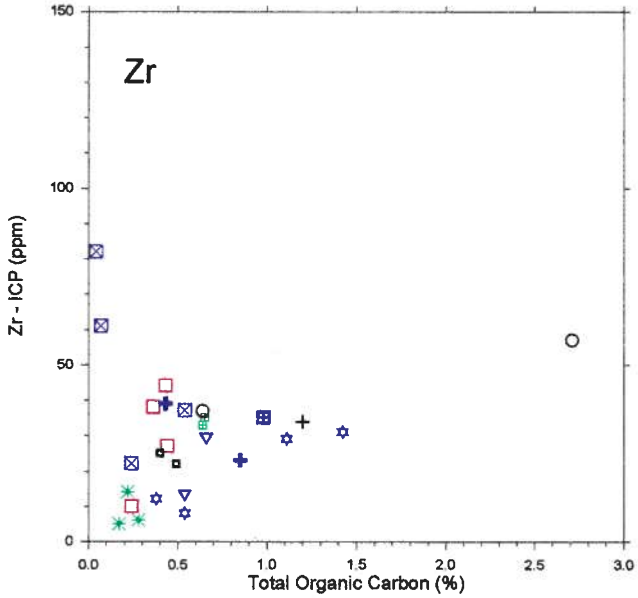
Conglomerates, Sandstones and Siltstones - Total Organic Carbon

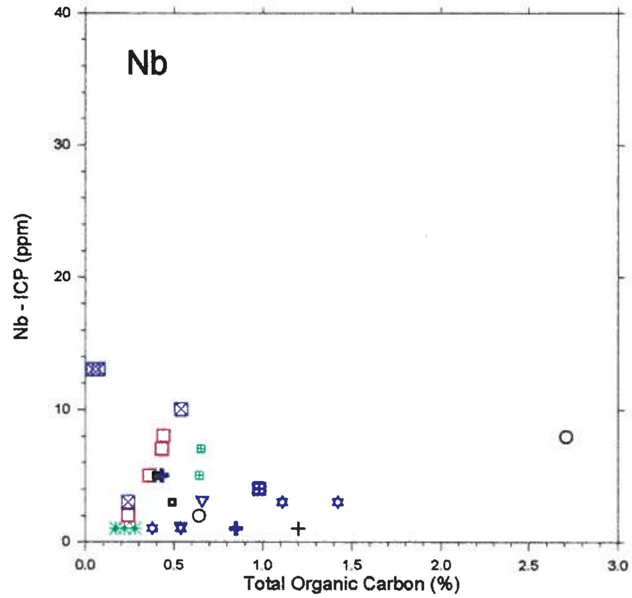


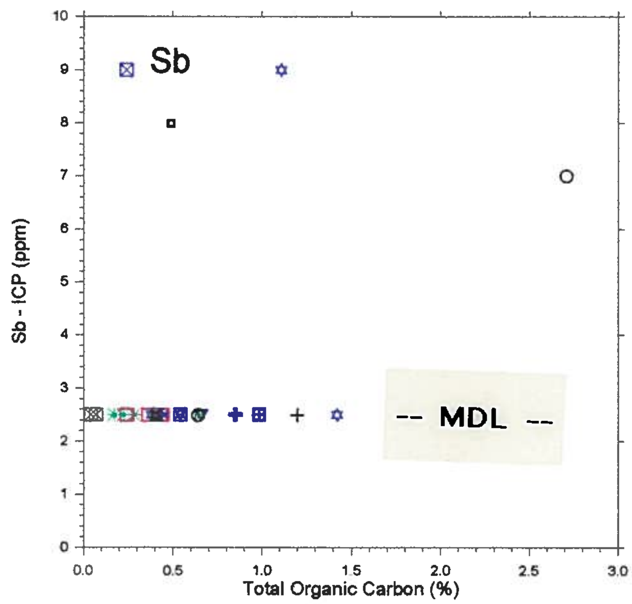
Conglomerates, Sandstones and Siltstones - Total Organic Carbon



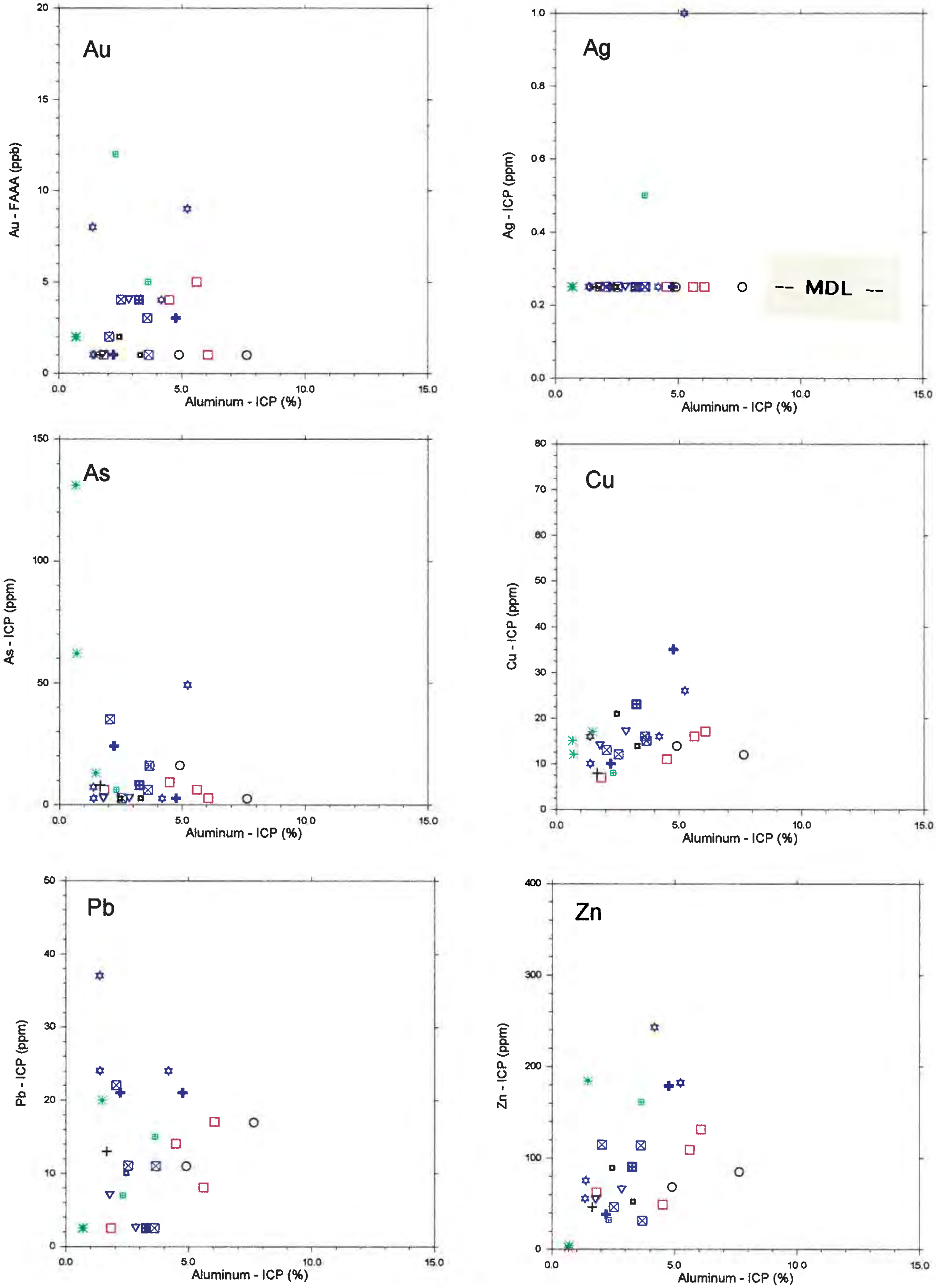
Conglomerates, Sandstones and Siltstones - Total Organic Carbon



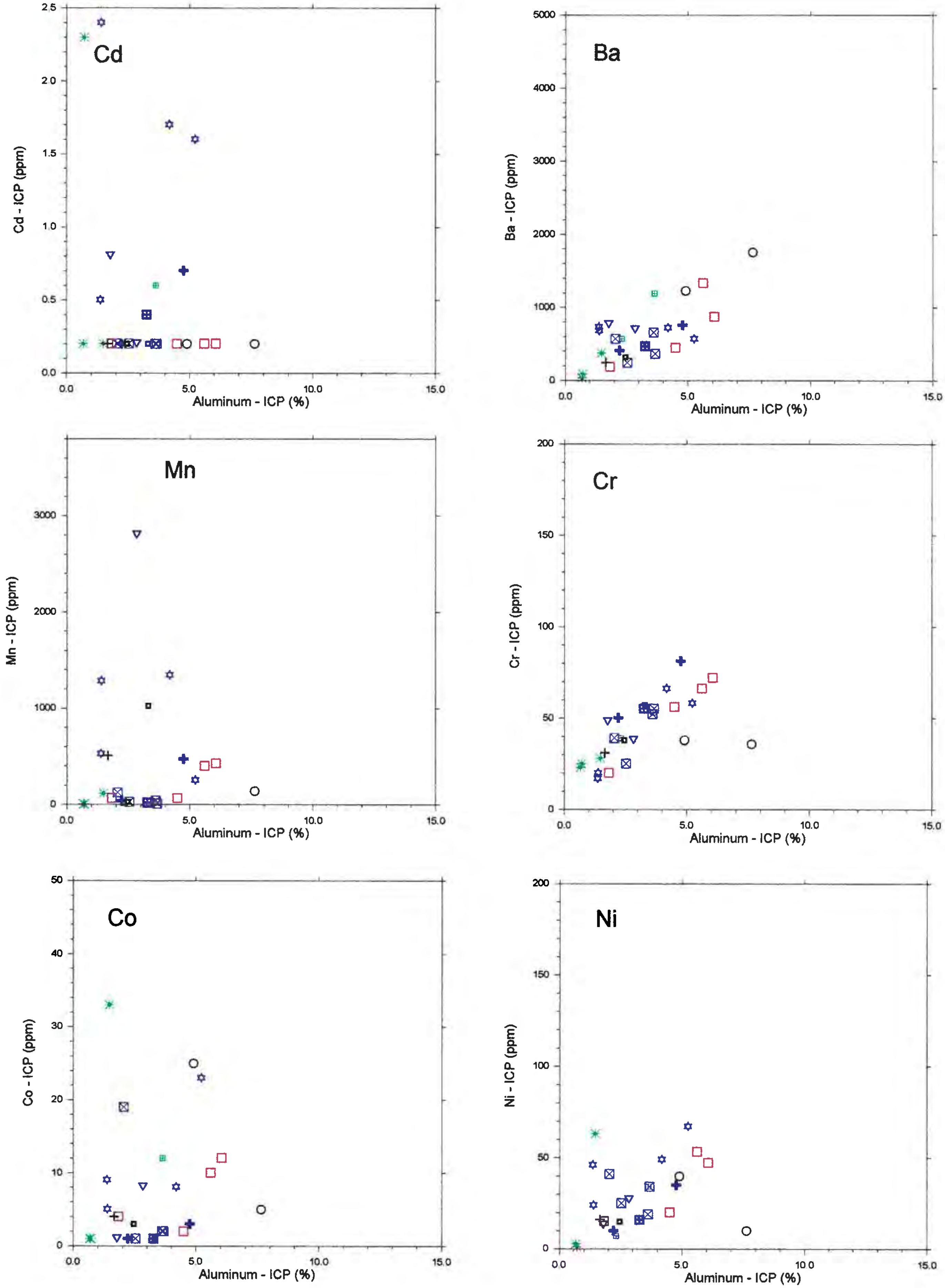




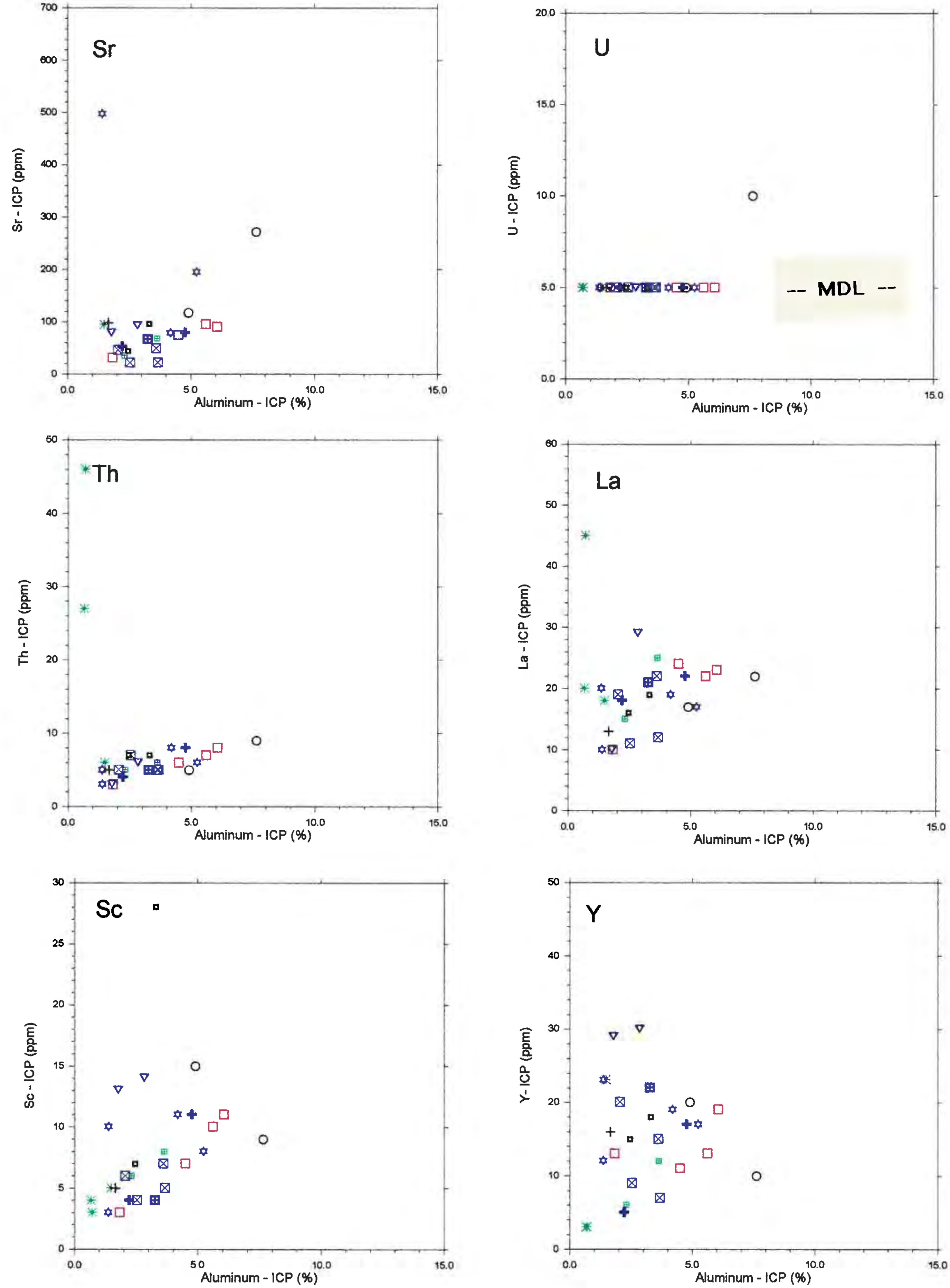
Conglomerates, Sandstones and Siltstones - Aluminum



Conglomerates, Sandstones and Siltstones - Aluminum



Conglomerates, Sandstones and Siltstones - Aluminum



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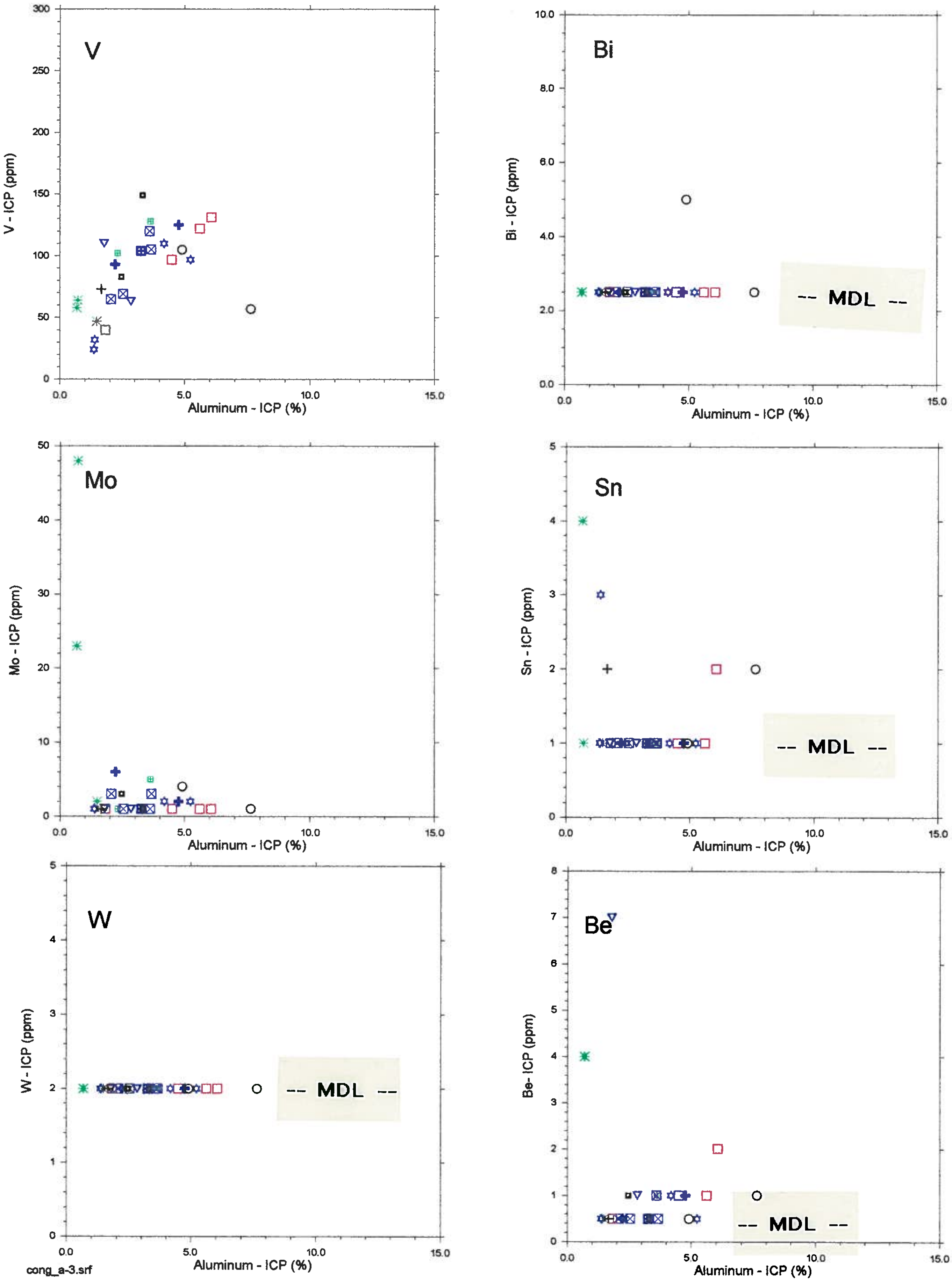

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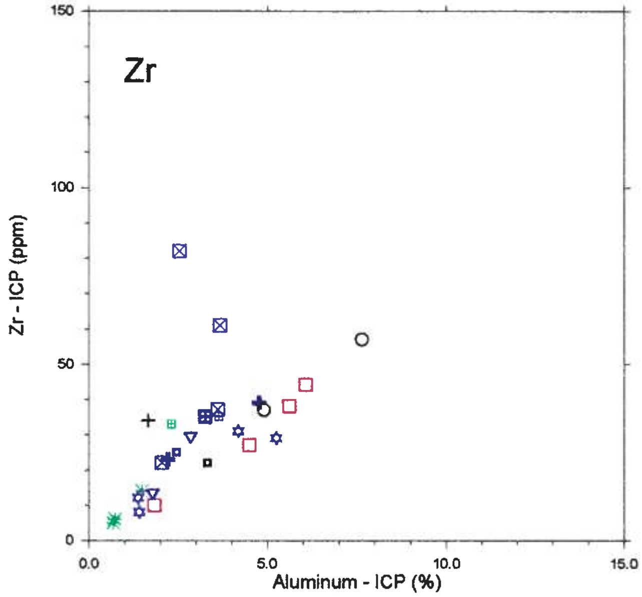

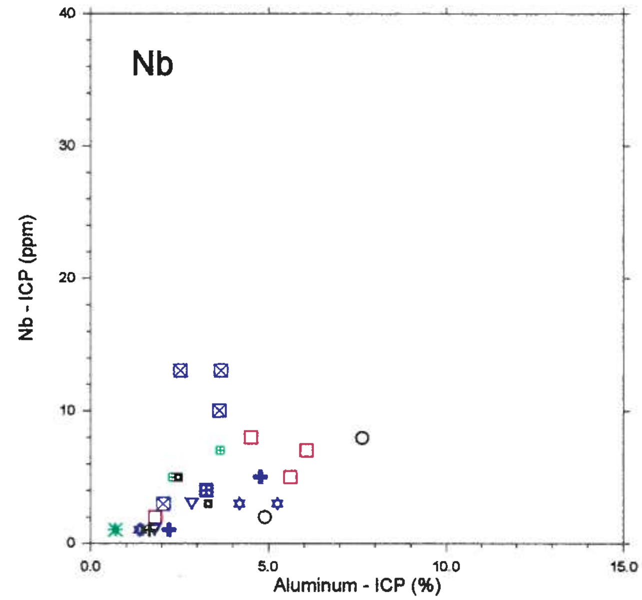

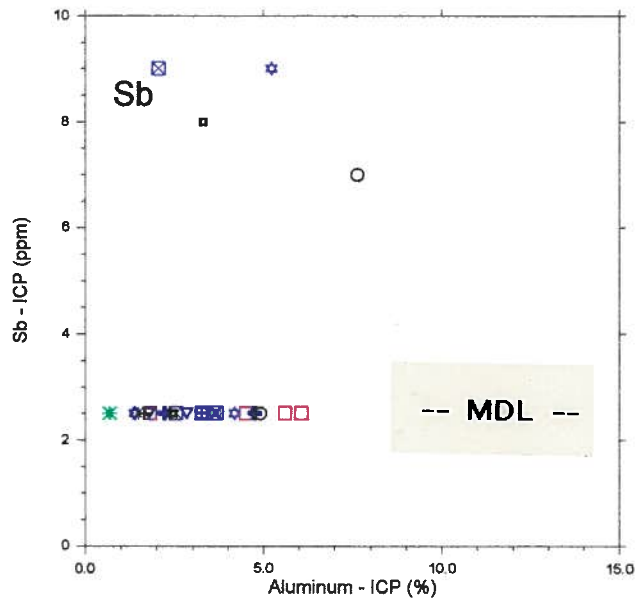

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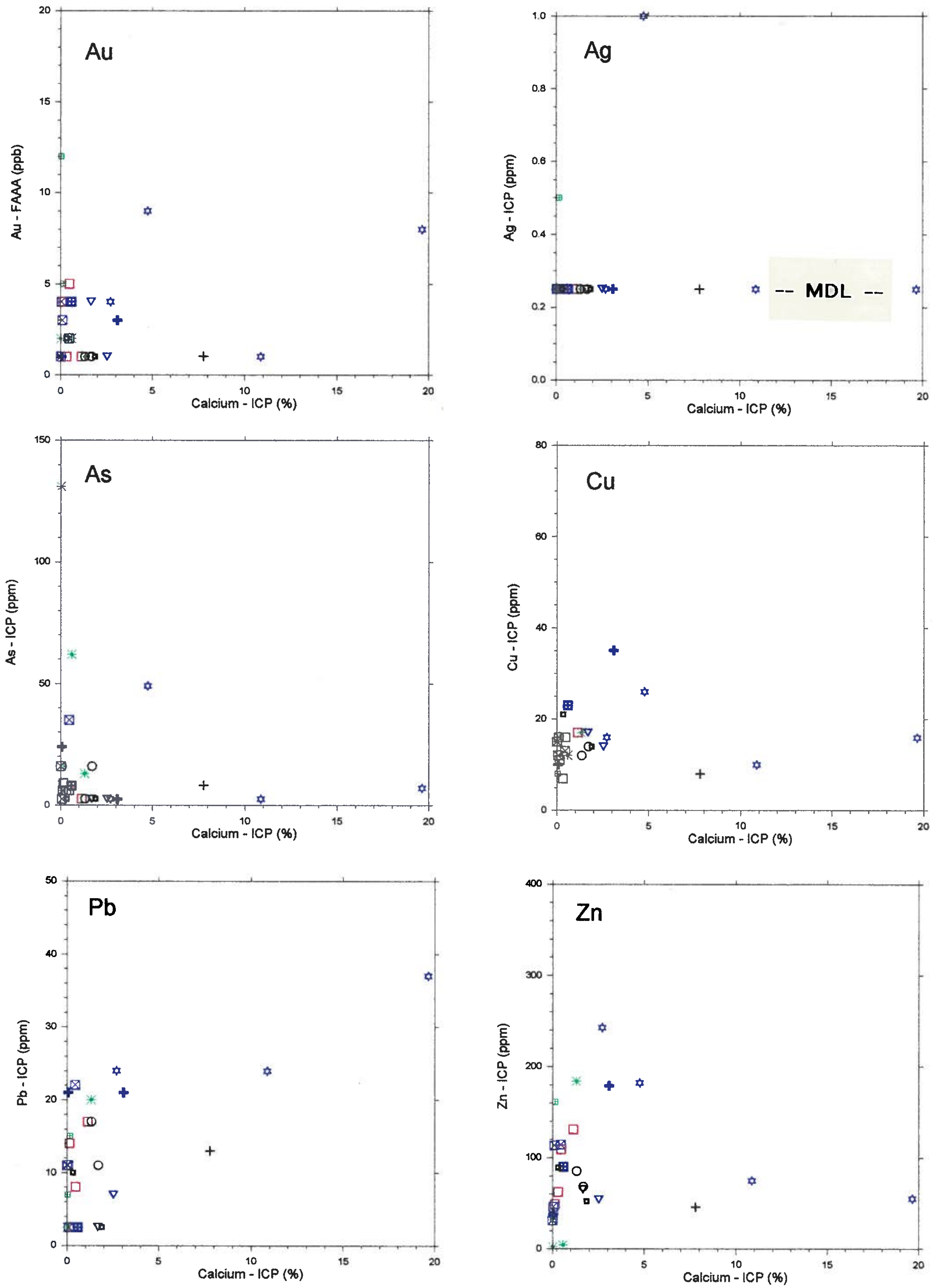
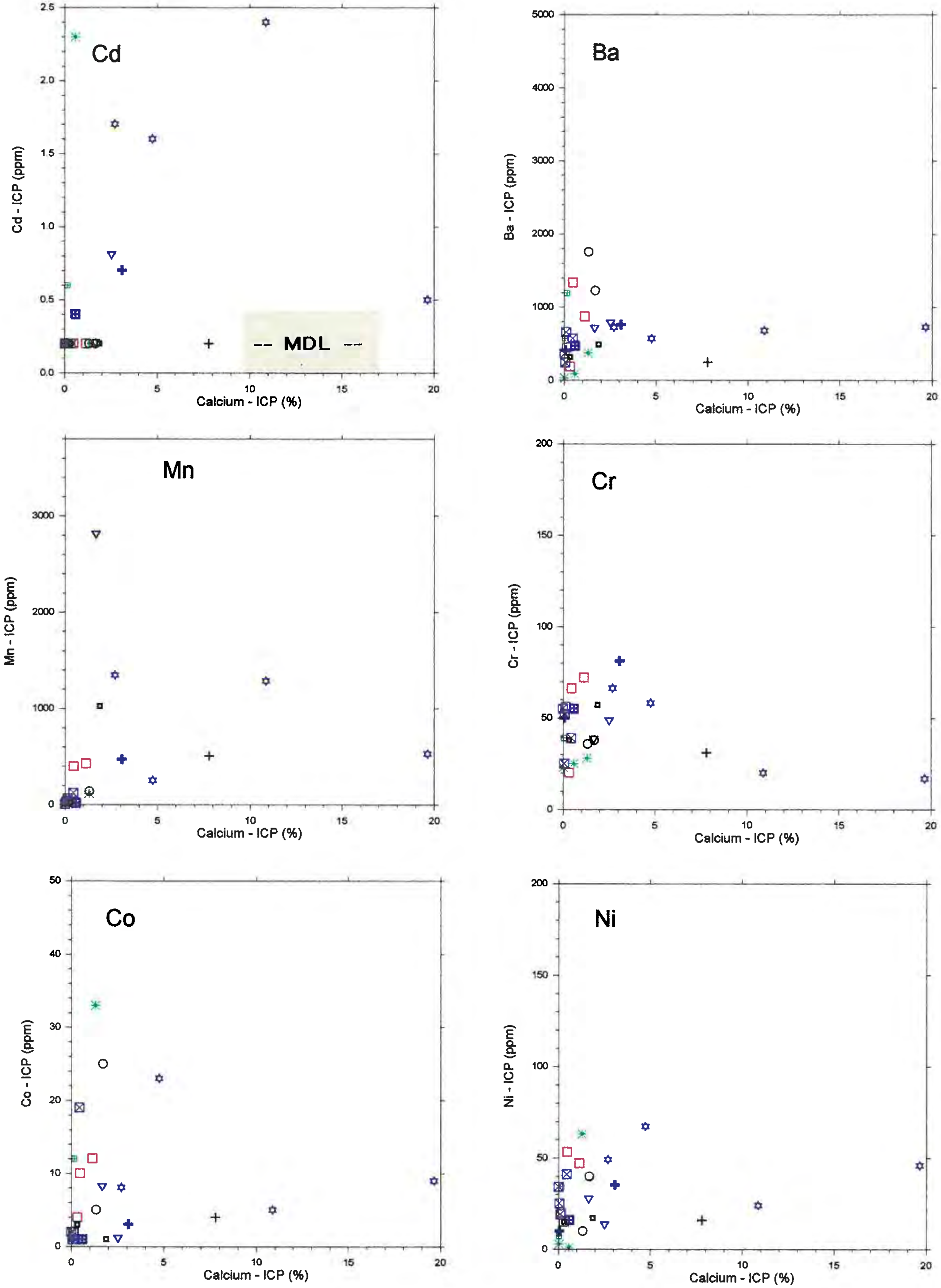
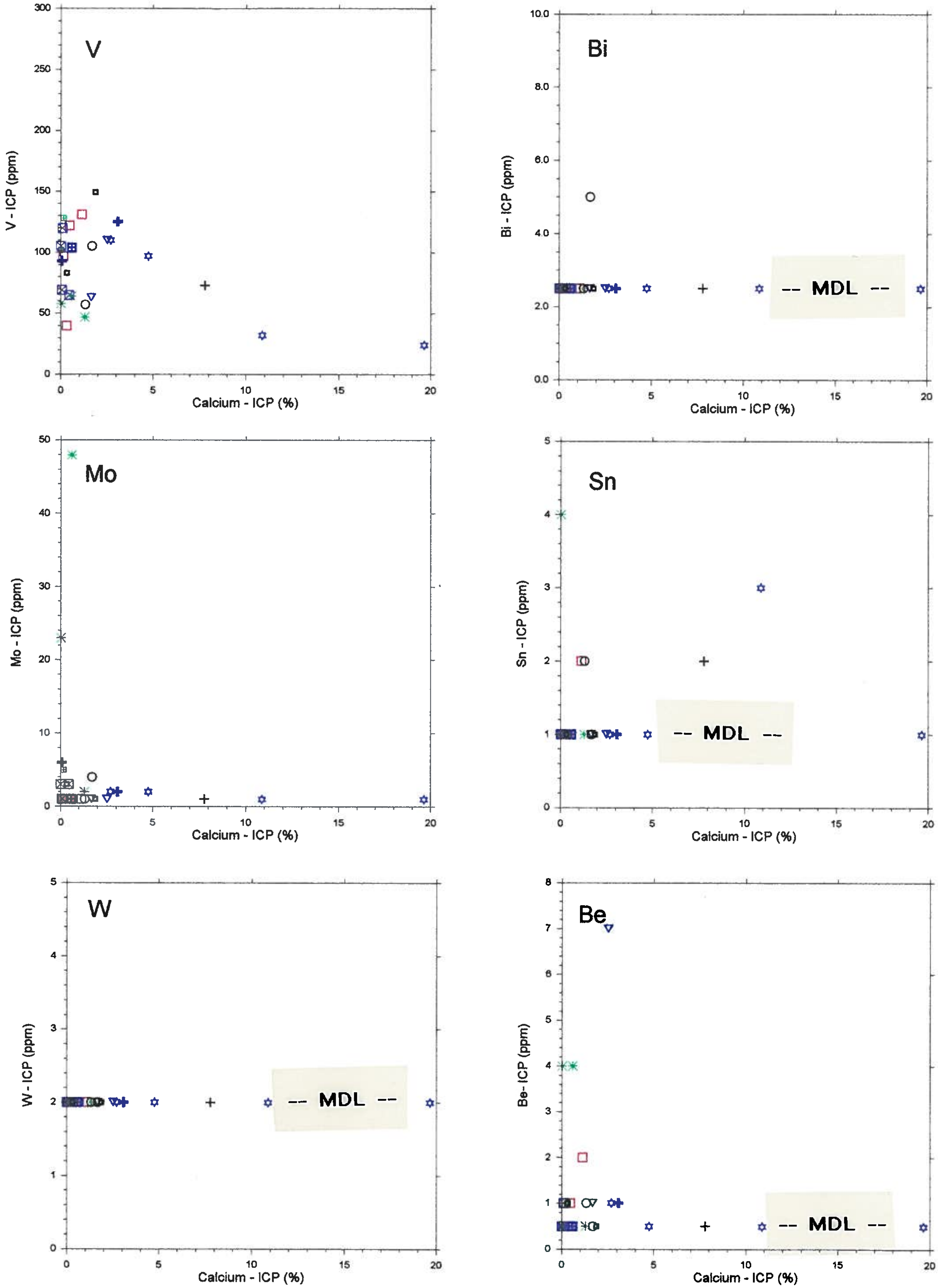
Conglomerates, Sandstones and Siltstones - Calcium



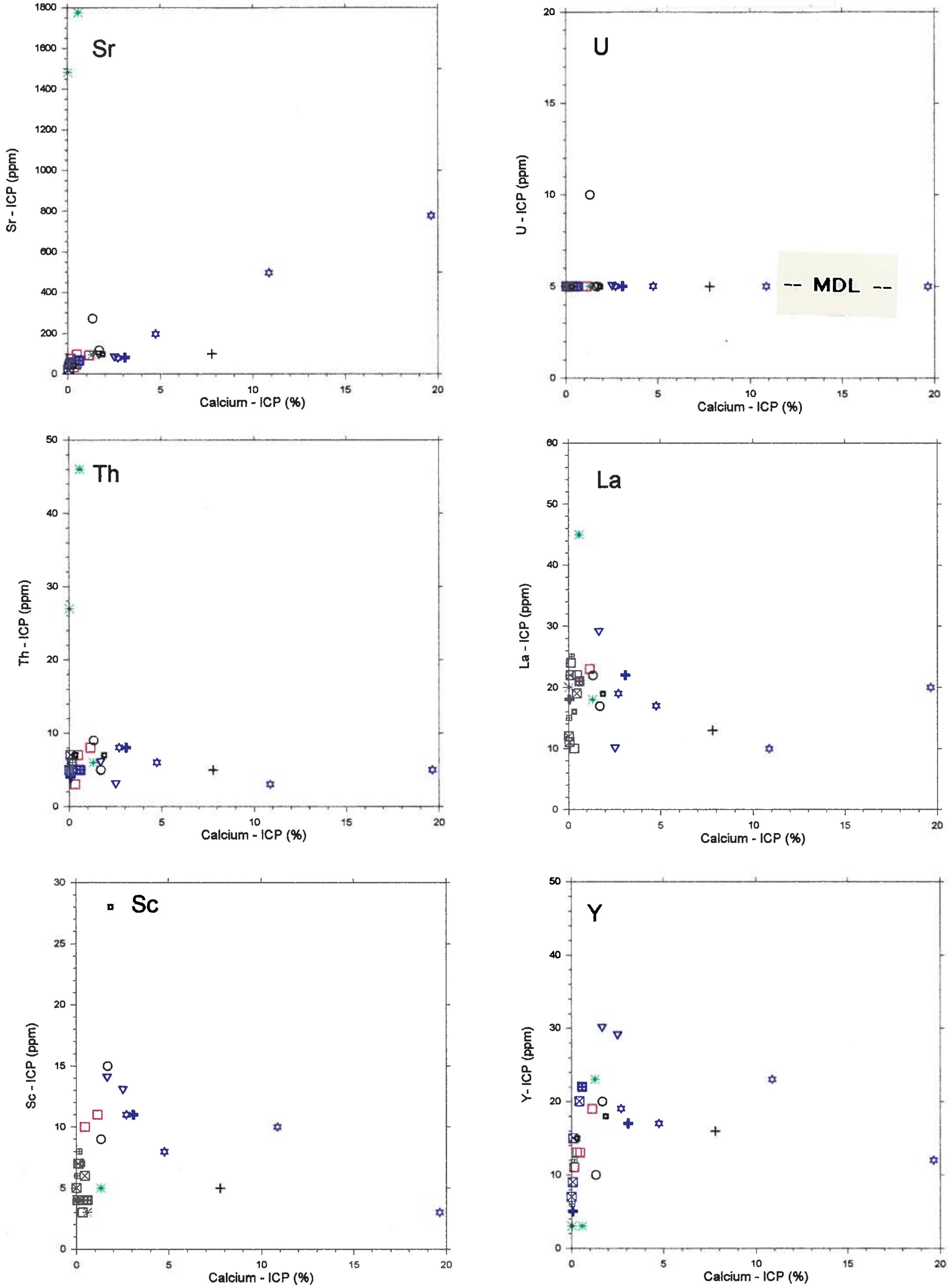
Conglomerates, Sandstones and Siltstones - Calcium



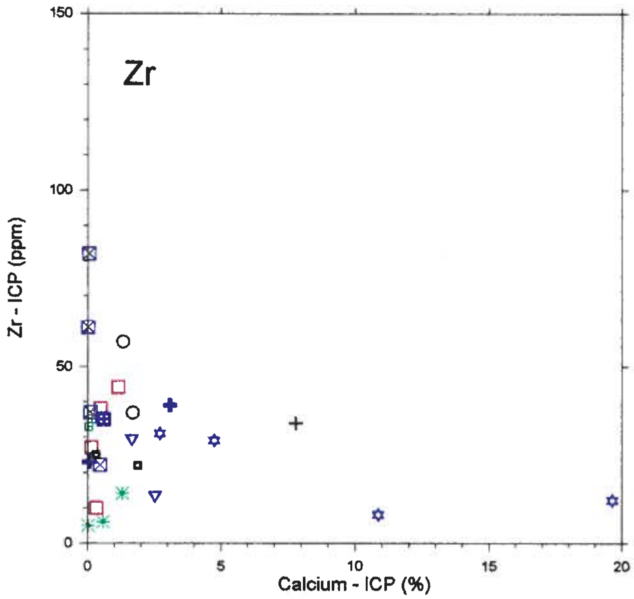
Conglomerates, Sandstones and Siltstones -Calcium

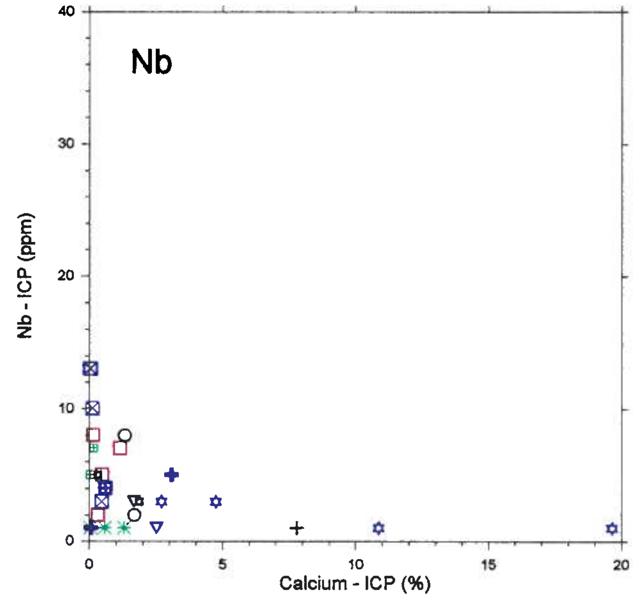


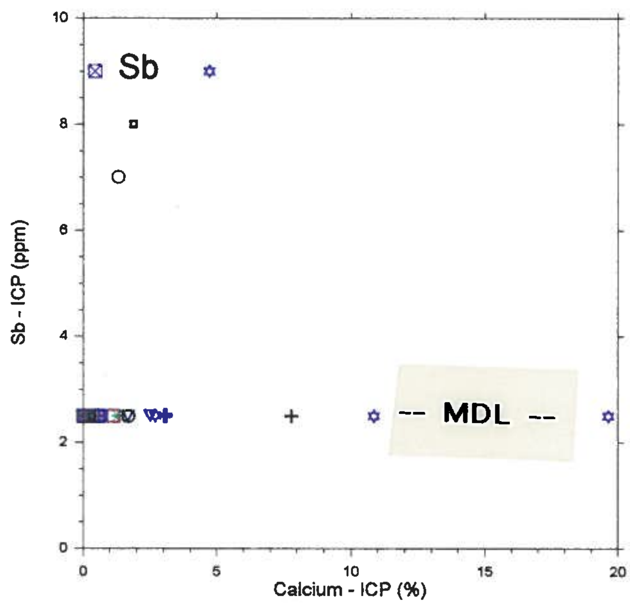
Conglomerates, Sandstones and Siltstones -Calcium



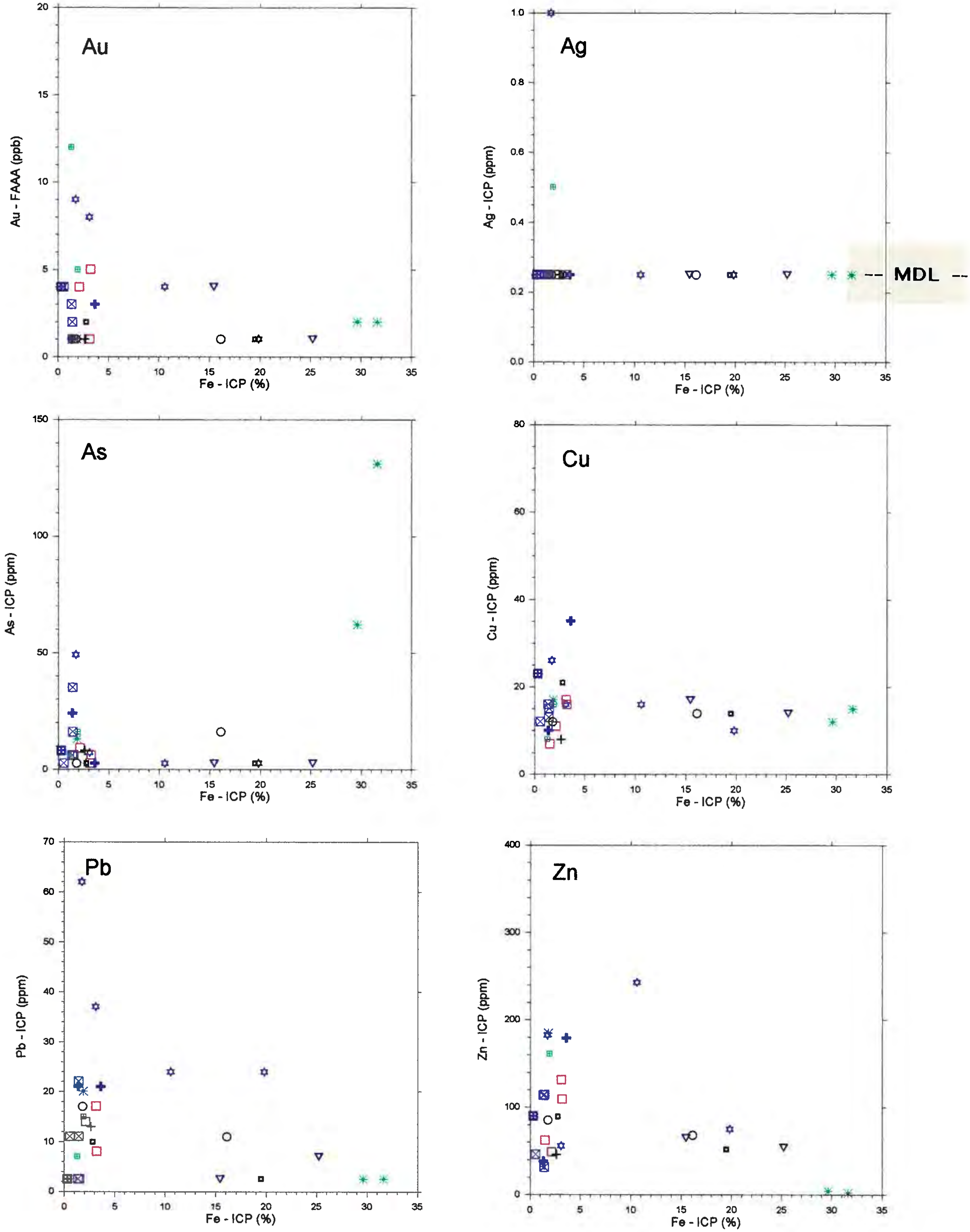
Conglomerates, Sandstones and Siltstones - Calcium



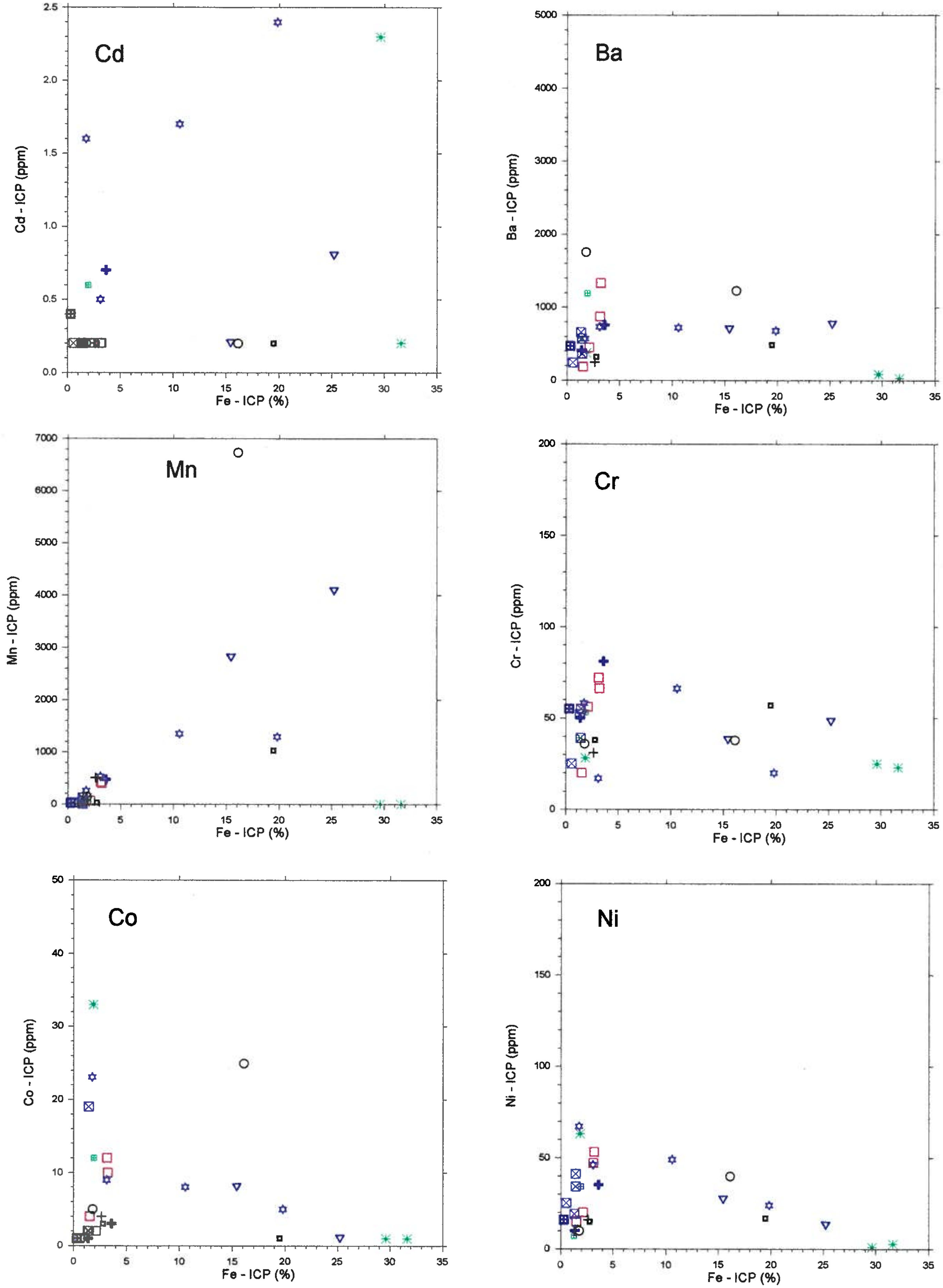




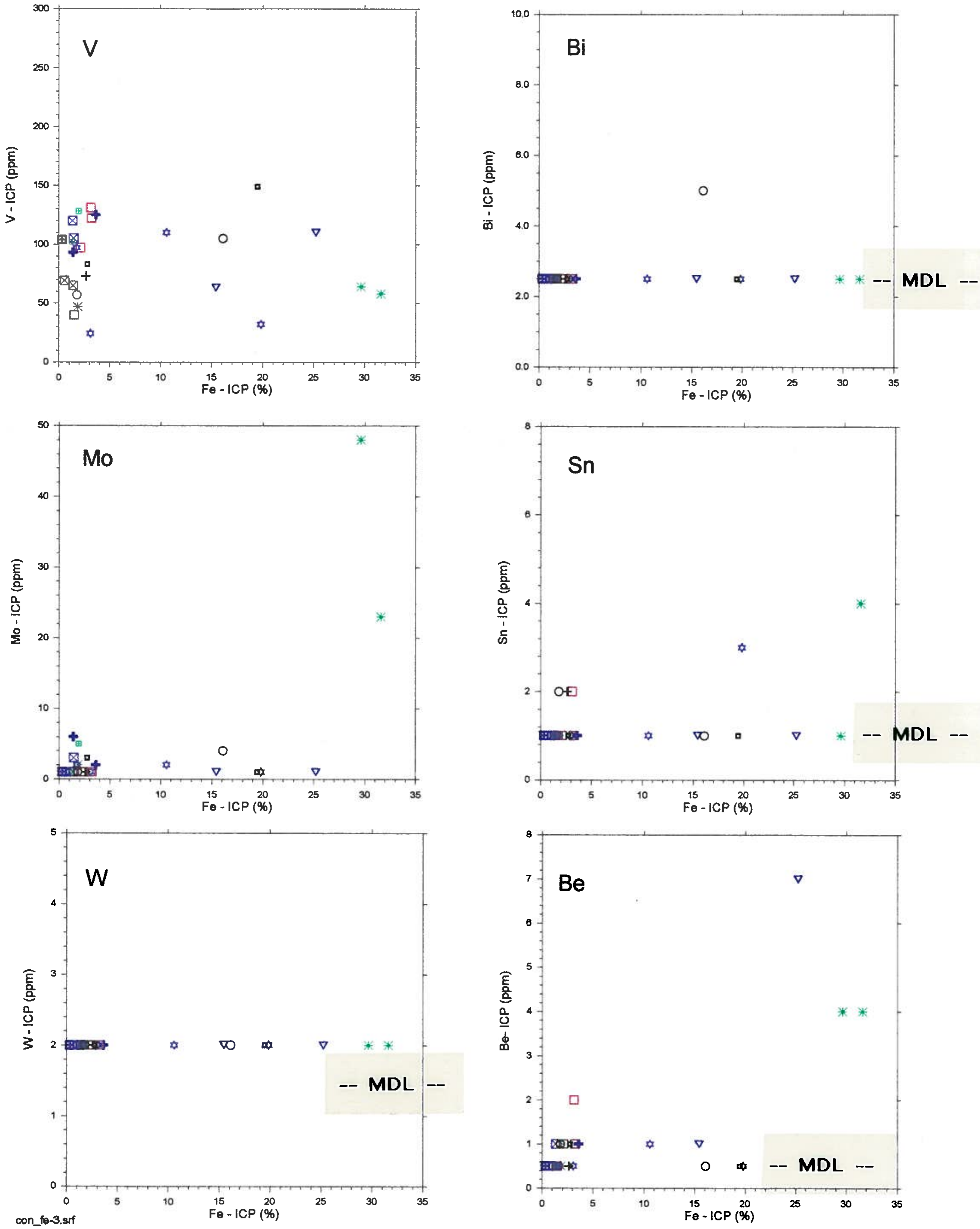
Conglomerates, Sandstones and Siltstones - Fe



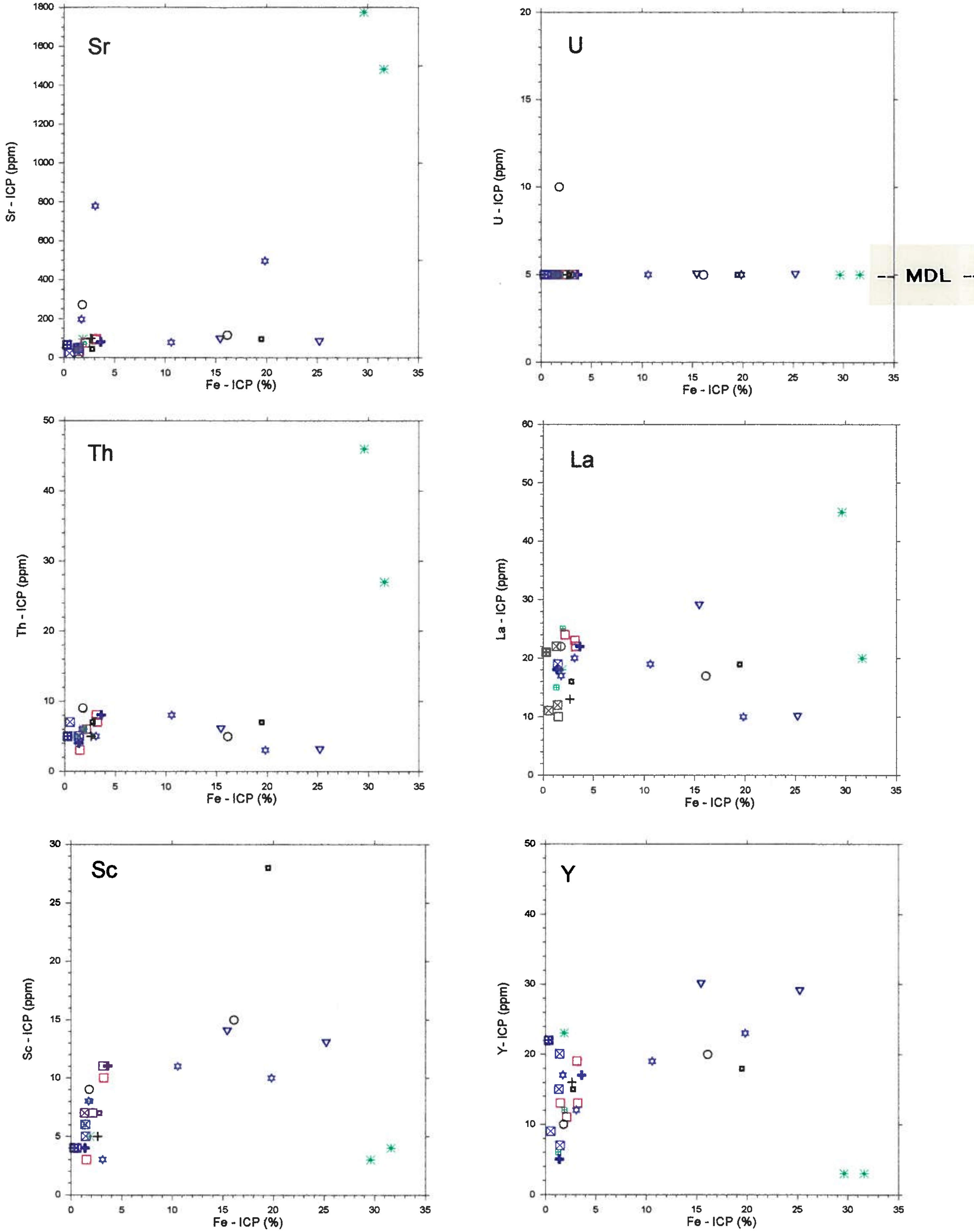
Conglomerates, Sandstones and Siltstones - Fe



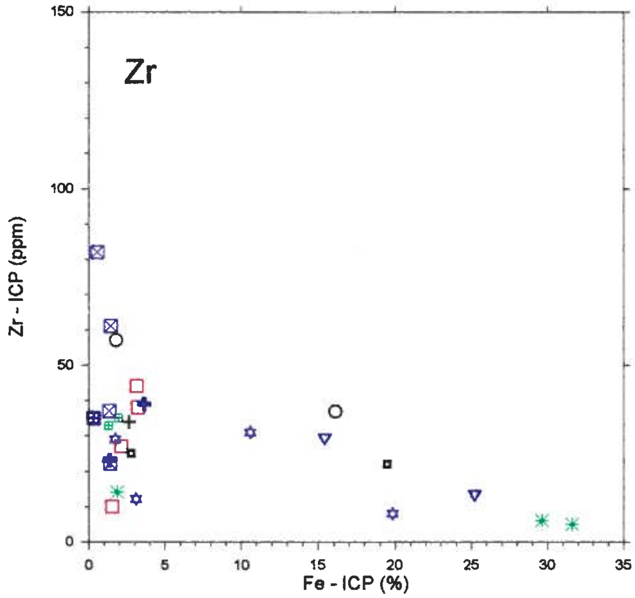
Conglomerates, Sandstones and Siltstones -Fe

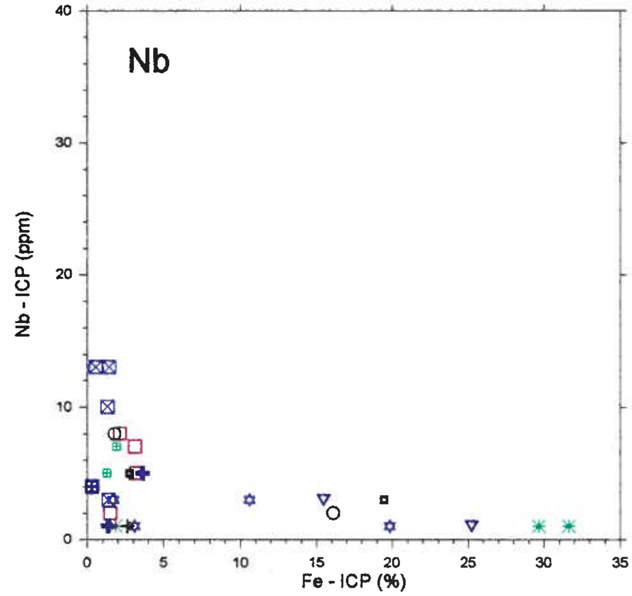


Conglomerates, Sandstones and Siltstones - Fe



Conglomerates, Sandstones and Siltstones - Fe





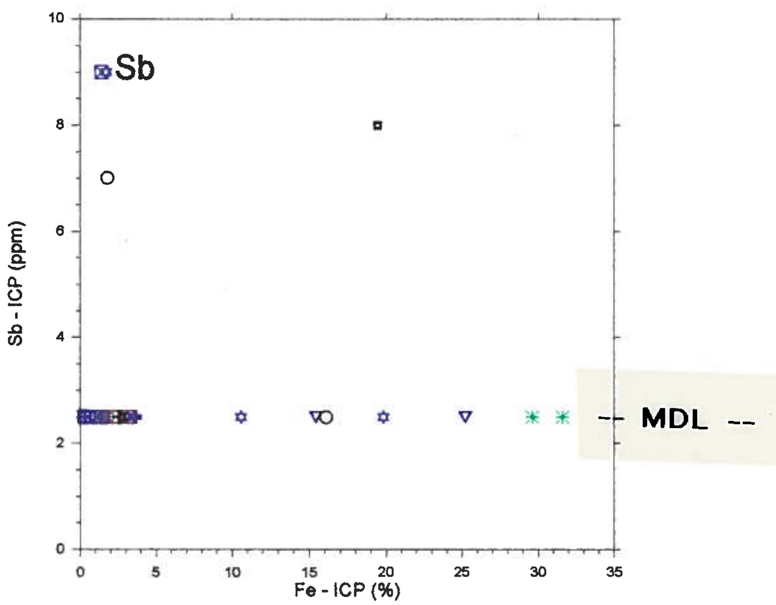
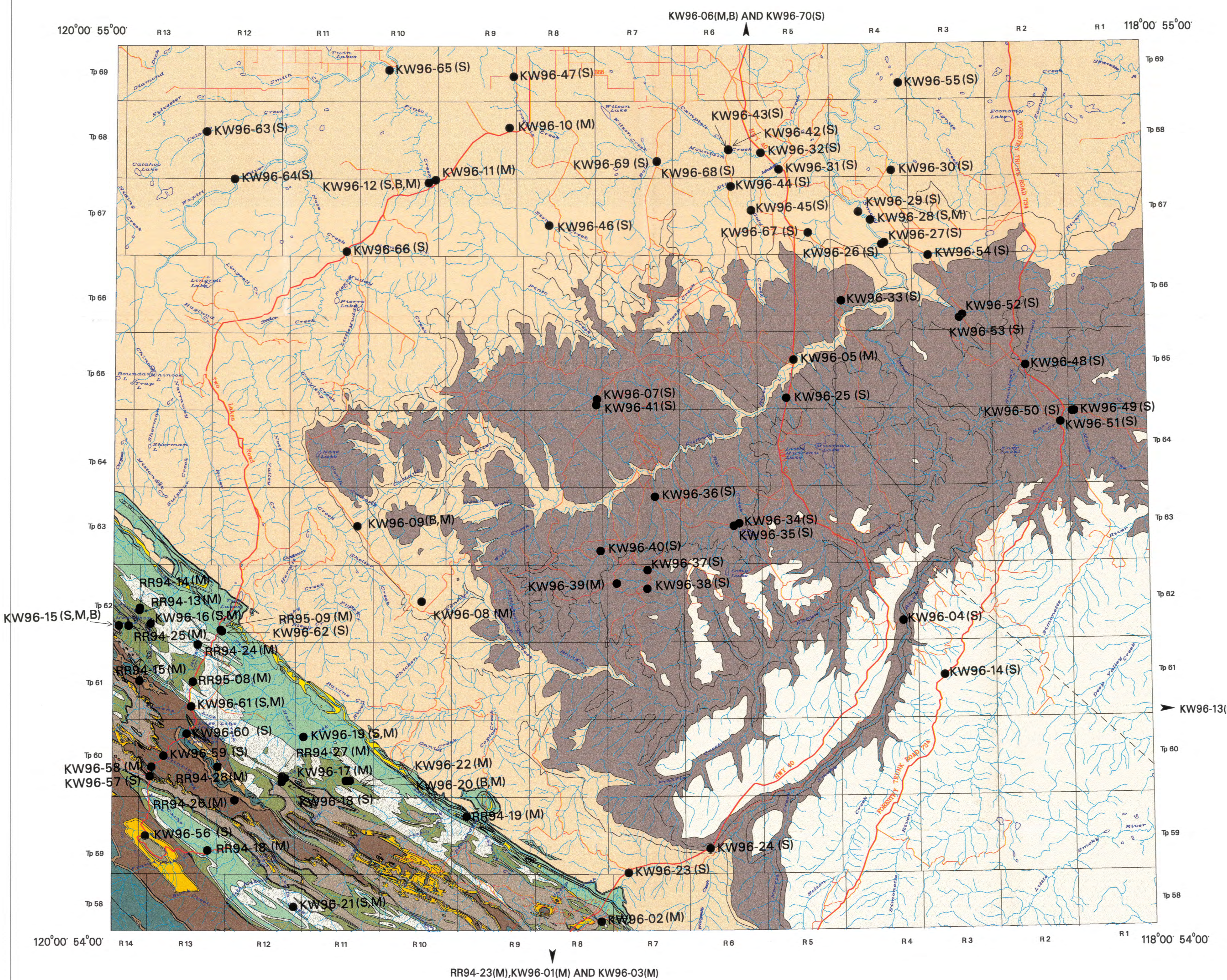


FIGURE 1. GENERAL GEOLOGY OF THE KAKWA/WAPITI AREA (NTS 83L) WITH STREAM AND BEDROCK SAMPLE LOCATIONS



Sample Number	Metallic Mineral Sample (M)	Stream Sediment Heavy Mineral Sample (S)	Bentonite Rare Earth Element Sample (B)	Formation(s)
KW96-01	YES(Y)	NO(N)	N	Nikanassin & Gladstone Formations
KW96-02	Y	N	N	Mountain Park & Shaftesbury Formations
KW96-03	Y	N	N	Cadomin Formation
KW96-04	N	Y	N	Gravel Pit
KW96-05	Y	N	N	Coalspur Formation
KW96-06	Y	N	Y	Lower Brazeau Formation
KW96-07	N	Y	N	Coalspur Formation
KW96-08	Y	N	N	Upper Brazeau Formation
KW96-09	Y	N	Y	Upper Brazeau Formation
KW96-10	Y	N	N	Lower Brazeau Formation
KW96-11	Y	N	N	Quaternary Lacustrine Till
KW96-12	Y	Y	Y	Lower Brazeau Formation
KW96-13	N	Y	N	Paskapoo Formation
KW96-14	N	Y	N	Paskapoo Formation
KW96-15	Y	Y	Y	Boulder Creek & Shaftesbury Formations
KW96-16	Y	Y	N	Shaftesbury Formation
KW96-17	Y	N	N	Shaftesbury Formation
KW96-18	N	Y	N	Shaftesbury Formation
KW96-19	Y	Y	N	Kaskapau Formation
KW96-20	Y	N	Y	Shaftesbury Formation
KW96-21	Y	Y	N	Shaftesbury Formation
KW96-22	Y	N	N	Shaftesbury Formation
KW96-23	N	Y	N	Lower Brazeau Formation
KW96-24	N	Y	N	Lower Brazeau & Coalspur Formations
KW96-25	N	Y	N	Coalspur Formation
KW96-26	N	Y	N	Lower Brazeau Formation
KW96-27	N	Y	N	Lower Brazeau Formation
KW96-28	Y	Y	N	Lower Brazeau Formation
KW96-29	N	Y	N	Lower Brazeau Formation
KW96-30	N	Y	N	Lower Brazeau Formation
KW96-31	N	Y	N	Lower Brazeau Formation
KW96-32	N	Y	N	Lower Brazeau Formation
KW96-33	N	Y	N	Coalspur Formation
KW96-34	N	Y	N	Coalspur Formation
KW96-35	N	Y	N	Coalspur Formation
KW96-36	N	Y	N	Coalspur Formation
KW96-37	N	Y	N	Coalspur Formation
KW96-38	N	Y	N	Coalspur Formation
KW96-39	Y	N	N	Coalspur Formation
KW96-40	N	Y	N	Coalspur Formation
KW96-41	N	Y	N	Coalspur Formation
KW96-42	N	Y	N	Lower Brazeau Formation
KW96-43	N	Y	N	Lower Brazeau Formation
KW96-44	N	Y	N	Lower Brazeau Formation
KW96-45	N	Y	N	Lower Brazeau Formation
KW96-46	N	Y	N	Lower Brazeau Formation
KW96-47	N	Y	N	Lower Brazeau Formation
KW96-48	N	Y	N	Coalspur Formation
KW96-49	N	Y	N	Coalspur Formation
KW96-50	N	Y	N	Coalspur Formation
KW96-51	N	Y	N	Coalspur Formation
KW96-52	N	Y	N	Coalspur Formation
KW96-53	N	Y	N	Coalspur Formation
KW96-54	N	Y	N	Upper Brazeau Formation
KW96-55	N	Y	N	Lower Brazeau Formation
KW96-56	N	Y	N	Gething Formation
KW96-57	N	Y	N	Cadomin Formation
KW96-58	Y	N	N	Gorman Creek Formation
KW96-59	N	Y	N	Gorman Creek Formation
KW96-60	N	Y	N	Whitehorse Formation
KW96-61	Y	Y	N	Gorman Creek & Dunvegan Formations
KW96-62	N	Y	N	Kaskapau Formation
KW96-63	N	Y	N	Lower Brazeau Formation
KW96-64	N	Y	N	Lower Brazeau Formation
KW96-65	N	Y	N	Lower Brazeau Formation
KW96-66	N	Y	N	Lower Brazeau Formation
KW96-67	N	Y	N	Lower Brazeau Formation
KW96-68	N	Y	N	Lower Brazeau Formation
KW96-69	N	Y	N	Lower Brazeau Formation
KW96-70	N	Y	N	Lower Brazeau Formation
RR94-13	Y	N	N	Shaftesbury Formation
RR94-14	Y	N	N	Shaftesbury Formation
RR94-15	Y	N	N	Monteith Formation
RR94-18	Y	N	N	Kaskapau Formation
RR94-19	Y	N	N	Muskiki Formation
RR94-23	Y	N	N	Boulder Creek & Shaftesbury Formations
RR94-24	Y	N	N	Dunvegan Formation
RR94-25	Y	N	N	Boulder Creek & Hulcross Formations
RR94-26	Y	N	N	Gorman Creek Formation
RR94-27	Y	N	N	Shaftesbury Formation
RR94-28	Y	N	N	Fernie Group
RR95-08	Y	N	N	Shaftesbury Formation
RR95-09	Y	N	N	Kaskapau Formation

TERTIARY
PASKAPOO FORMATION

UPPER CRETACEOUS TO EARLY TERTIARY
COALSPUR FORMATION

UPPER CRETACEOUS
BRAZEAU FORMATION
PASKWASKAU FORMATION
CARDIUM FORMATION
KASKAPAU FORMATION
DUNVEGAN FORMATION
SHAFTESBURY FORMATION

LOWER CRETACEOUS
GATES, BOULDER CREEK AND HULCROSS FORMATIONS
CADOMIN, GETHING, GLADSTONE, AND MOOSEBAR FORMATIONS

JURASSIC TO LOWER CRETACEOUS
GORMAN CREEK AND MONTEITH FORMATIONS
NIKANASSIN FORMATION

JURASSIC
FERNIE FORMATION

TRIASSIC
SPRAY RIVER GROUP

ALBERTA SYNCLINE (APPROXIMATE)

KW96-01(S,B,M) SAMPLE LOCATION, NUMBER & (TYPE)
S = STREAM SEDIMENT HEAVY MINERAL SAMPLE
B = BENTONITE RARE EARTH ELEMENT SAMPLE
M = METALLIC MINERAL SAMPLE

KW96-13 SAMPLE SITE OUTSIDE THE MAP AREA

References for the geology:

1. Geological Survey of Canada Bulletin 466 (NTS 83L)
2. Geological Survey of Canada Open File 2185 (NTS 83L/3)
3. Geological Survey of Canada Open File 1710 (NTS 83L/4 & 5)
4. McMechan, M.E. and Dawson, F.M. 1995: Geology and sturcture cross-section, Wapiti, Alberta; Geological Survey of Canada, Map 1875A, Scale 1:250,000

Scale 1:250,000

Kilometres

5 0 10 15

FIGURE 20. STREAM SEDIMENT DIAMOND INDICATOR ANOMALY SUMMARY MAP (ON SURFICIAL GEOLOGY BASE).