



**GEOLOGICAL SURVEY OF CANADA
OPEN FILE 6281**

**Petrology, Mineralogy and Geochemistry of
the Musquodoboit E-23 well, Scotian Shelf**

G. Pe-Piper, H. MacKie and D. J.W. Piper

2009



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Available from
Geological Survey of Canada
615 Booth Street
Ottawa, Ontario K1A 0E8

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**2009:Petrology, Mineralogy and Geochemistry of the Musquodoboit E-23 well, Scotian Shelf,
Geological Survey of Canada, Open File 6281, 88 p.**

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Preface

This Open File is one of a series on detrital and diagenetic mineralogy of the Lower Cretaceous rocks of the Scotian basin resulting from a collaborative program initiated in 2001 between Saint Mary's University and the Geological Survey of Canada. This report provides the results of a study of detrital mineralogy and geochemistry from Lower Cretaceous rocks of the Musquodoboit E-23 well in the western Sable sub-basin. It contributes to a growing database on the provenance of different parts of the Scotian basin. An understanding of provenance is an exploration tool for major sandstone distribution. Detrital minerals play an important role in influencing diagenesis and hence reservoir quality.

Acknowledgments

We thank the staff of the Encana for taking and providing us with the cutting samples while the Musquodoboit E-23 well was being drilled. We also thank Stavros Triantafyllidis, Emma Brown and Xiang Yang for providing us help with the SEM and electron microprobe work. This project has been funded by the Nova Scotia OETR Association. DJWP's work was through the ECOSEA project of the Secure Canadian Energy Supply Program. Manuscript reviewed by D. Calvin Campbell.

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ABSTRACT

Large cuttings samples were collected from key horizons at the time of drilling the Musquodoboit E-23 well. Most of the samples studied in detail were from the Logan Canyon and Missisauga formations. Single-lithology chips were separated from these cuttings and the samples that were large enough were analyzed geochemically for major and trace elements. Heavy minerals and lithic fragments were separated with tetrabromoethane and the compositions of heavy minerals including tourmaline, chromite and garnet were determined by electron microprobe.

Mudstone samples from the Logan Canyon and Missisauga formations are geochemically similar among themselves and resemble mudstones from the nearby Alma field. A muddy sandstone from the basal Banquereau Formation is geochemically distinct. The Logan Canyon and Upper Missisauga formations have a much higher proportion of low-Mg tourmaline, characteristic of a granitic source, than the Middle Missisauga Formation, in which tourmaline of metamorphic origin predominates. The absence of low-Mg tourmaline in the Glenelg and North Triumph fields suggests that this mineral was supplied by a Chaswood Formation river crossing central Nova Scotia from New Brunswick. Near the base of the Middle Missisauga Formation, many of the analyzed garnets closely match analyses from both the South Mountain batholith and Meguma Group metasedimentary rocks, but similar garnets are rare at higher stratigraphic levels. Tremolite and low-Fe diopside are each present at two horizons in Musquodoboit E-23, but have not been recognised elsewhere in the Lower Cretaceous of the Scotian basin, from which we have more than 4000 electron microprobe analyses of detrital minerals. They are sourced from thermally metamorphosed impure limestones, possibly from the inner Scotian Shelf. Lower Cretaceous sediments in Musquodoboit E-23 were supplied principally by a large Cabot Strait river that brought sediment to the entire Sable sub-basin. Detrital minerals provide some evidence for lesser local supply of sediment from the rivers that deposited the Chaswood Formation of central Nova Scotia.

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1 Introduction

The Pan-Canadian Petroleum–Murphy Musquodoboit E-23 well (Fig. 1) is a deviated well that was drilled by Pan-Canadian (now EnCana). It is located in the western part of the Sable sub-basin on the Scotian Shelf. The well was spudded on July 1st, 2001. The target for this exploration well was the reef margin of the Abenaki Formation (Baccaro Member), but it penetrated a thick overlying sequence of Cretaceous clastic terrigenous strata.

EnCana staff provided Saint Mary's University with large samples of well cuttings at selected intervals for a detailed study of the detrital petrology, mineralogy and geochemistry of the well section. This work is part of a larger cooperative study between Saint Mary's University and the Geological Survey of Canada on the dispersion and diagenesis of reservoir sandstones in the Lower Cretaceous of the Scotian basin.

Measured Depth (MD) and True Vertical Depth (TVD) for Musquodoboit E-23 are 3820 m and 3815.85 m respectively. Samples were provided from 960 m to 3415 m (Fig. 2), but only those to 2800 m were studied in detail. The shallowest sample at 960 m is at the extreme base of the Banquereau Formation. One sample is from the base of the Dawson Canyon Formation, three from the Logan Canyon Formation and three from the Missisauga Formation. The dominant lithologies are as follows: from 960–1000 m dark grey shale with sandstone beds up to 1 m thick (basal Banquereau Formation); 1000–1130 m limestone (Wyandot Formation); 1130–1280 m dark grey shale with thin interbedded limestone and sandstone (Dawson Canyon Formation); 1280–2395 m dark grey shale with occasional sandstone and limestone beds (Logan Canyon Formation); 2395–3100 m dark grey shale with abundant limestone and sandstone beds (Missisauga Formation); 3100–3346 m dark grey shales (Verrill Canyon Formation); 3346–3415 m limestone (Abenaki Formation).

2 Methods

2.1 Cutting sample preparation

Cutting samples from representative depths were collected for us by EnCana during the well drilling (Table 1). These cutting samples were washed with warm water through a 63 µm sieve to remove any unwanted material (mud and oil from the drilling). Samples were then sieved at 2 mm, allowing the separation of the grains into two classes: >63 µm to <2 mm and >2 mm. “Heavy mineral” separation was performed on all sub-samples for the >63 µm to <2 mm fraction using the heavy liquid tetrabromoethane, which has density of 2.9 g/ml (Table 2). The heavy separates of this fraction were then used to make polished thin sections. Sample numbers refer to the depths (in metres below RT) at which the samples were obtained.

2.2 Identification of cuttings >2 mm

Cuttings larger than 2 mm were identified using a binocular microscope and were separated based on lithology/mineralogy, grain size, colour or apparent cement. Each group of cuttings was placed into separate vials and labelled with the depth and lithology. A numerical summary of the cuttings and clasts >2 mm and their lithologies are given in Table 3. This table lists the quantity of rock cuttings and clasts for each identified lithology found at each sample depth. These data are used to describe how the petrography of the studied samples change with depth and stratigraphy (Table 4). Representative unidentified cuttings were used to make polished thin sections and analysed under a polarized/reflected light petrographic microscope and an electron microprobe.

2.3 Identification of heavy fraction of cuttings <2 mm

Polished thin sections of the heavy separates of the >63 µm to <2 mm grains were made for all available samples. For samples with bimodal sizes and enough heavy separates from both size classes, two polished thin sections were made, one for the finer fraction (F) and one for the coarser fraction (C). The grain size and preliminary identification of mineralogy/lithology of cutting grains was done using a polarized/reflected light petrographic microscope and subsequently refined with the use of an electron microprobe.

2.4 Microprobe analysis

Polished thin sections were analysed at the Regional Electron Microprobe Centre located at Dalhousie University to find composition of both detrital and diagenetic minerals (Table 6). The microprobe used is a JEOL-8200 electron microprobe with five wavelength spectrometers and a Noran 133 eV energy dispersion detector. The beam was operated at 15kV and 20nA, with an average beam diameter of 5 µm. Elements set up to be measured were Si, Al, Ti Cr, Fe, Mn, Mg, Ca, Na, K, P, Zr, and Ba. The energy dispersive spectrometer (EDS) was used for fast and easy identification of minerals such as quartz, calcite, barite, rutile, and staurolite. It was also used to find elements not set up to be measured by the microprobe, such as S to identify pyrite, Zn and S to identify sphalerite, and Pb and S to identify galena. Cuttings and minerals (detrital or diagenetic) of interest were also documented as back-scattered electron (BSE) images.

2.5 Scanning electron microscopy

The Scanning Electron Microscope (SEM) at the Regional Analytical Centre at Saint Mary's University was used to locate grains of both detrital and diagenetic minerals for future analyses on the electron microprobe. It is a LEO 1450 VP SME with a maximum resolution up to 3.5 nm at 30 kV. Detection limit is >0.1 %. The SEM uses a tungsten filament to supply electrons to produce a back-scattered electron image of the grains on the polished thin section and return an atomic number. The SEM was also used to confirm the mineral identification of minerals that were not easily identified by petrographic microscope through the use of electron dispersion spectroscopy (EDS). However only analyses from the electron microprobe are used to evaluate detailed mineral chemistry in this report.

2.6 Whole rock chemical analyses

Representative lithologies (Table 3) for which >20 g of cuttings were available were analysed for whole-rock geochemistry (Table 7). The cuttings were brushed vigorously with a toothbrush, rinsed in deionized water and dried with Kimwipes. The dried cuttings were pulverized using a shatterbox with an iron bowl at the Minerals Engineering Centre of Dalhousie University. Major and trace elements were determined by Activation Laboratories according to their code

4Lithoresearch and Code 4B1 packages, combining lithium metaborate/tetraborate fusion ICP whole rock analysis with trace elements by ICP-MS (Activation Laboratories, 2006).

3 Petrography and mineralogy

3.1 Petrography

Twenty-one samples were taken from the depths indicated by the operator in Table 1; however, for the purpose of this project only the first ten have been included (to a depth of 2800 m). The number of cuttings counted ranges from 58 in sample 2600B to 458 in sample 2190 (Table 3). The dominant two cutting lithologies counted for the majority of samples are very fine sandstone and shale/mudstone respectively (Table 4). Samples down to 1800 m show only very fine sandstone or both very fine sandstone and shale/mudstone. At 2190 m samples start to show inputs of coarser quartz grains which gradually increase downcore to 2500 m, below which they were not found. Sample 2190 m also shows a significant input of coal/shaly coal with minor amounts of coarse and medium sandstone, calcareous sandstone and shell fragments; whereas samples at 2500 m only show minor medium sandstone and shell fragments.

At 2600 m the very fine siliciclastic sandstone component diminishes until it is completely replaced at 2800 m by calcareous sandstone. The shale/mudstone component continues through these depths. Sample 2600A also shows a minor amount of silty shale, white calcareous mudstone/chalk, and limestone, but these are absent from samples 2600B and 2800. Samples 2500B and 2600B show minor amounts of pyritized fossils and pyrite, and sample 2500A shows ten counted cuttings of a common unknown lithology (oxidized grains).

Three polished thin sections, of 2–6 cuttings (>2 mm), have also been made for the following samples: 1800, 2500A and 2800 (Table 4). The thin sections for 1800 and 2500A consist of two carbonate sandstone cuttings and six quartz grains respectively. The 2800 m thin section appears to be mostly quartz with grains showing interlocking textures typical of crystalline rocks. These grains could be igneous with some possible feldspar crystals.

3.2 Mineralogy

3.2.1 Introduction

In order to study the mineralogy of the cuttings for the Musquodoboit E-23 well, polished thin sections of the heavy "mineral" fraction (Table 2) were made from the first ten sample depths (Table 1). The percentages of light versus heavy "minerals" can also be found in Table 2.

Sandstones are consistently the most common cutting, with siltstone and mudstone cuttings gradually increasing from rare at 960 m to common at 2800 m. Identified cuttings show no distinct variation with depth. Identified minerals within the cuttings (Table 5) are: carbonates, glauconite, quartz, calcite, zircon, chromite, garnet, and carbonate bioclasts. Glauconite, quartz and carbonates are the most common minerals throughout the studied interval. Bioclasts consist of shell fragments and forams.

Several different types of forams are abundant in the upper portion of the studied interval. Their abundance declines below 1800 m, and fossilized wood (pyrite-replaced) can be found at 2500 m and 2800 m. The majority of opaque minerals in these samples are massive pyrite or frambooidal pyrite along with ilmenite and magnetite.

3.2.2 Detrital Mineralogy

Table 5 shows the variation of both detrital and diagenetic minerals with depth. The most commonly identified individual detrital minerals in all depths are: tourmaline, garnet, zircon, quartz, and feldspars. Identified tourmaline grains are most commonly blue and green and rarely brown in colour. Garnet is mostly almandine, with only two out of almost 90 garnet analyses being spessartine (Table 6). Both chromite and chromian spinel are very common in most studied samples of Logan Canyon and Missisauga formations, but they are more rare in the sample from Dawson Canyon Formation with only chromian spinel being present. Ilmenite, which is often altered to TiO_2 minerals, is also very common detrital mineral. Magnetite has been identified in most samples from both Logan and Missisauga Formations and clinopyroxene (diopside) and amphibole (tremolite) are only common in few samples from both of these formations. The minerals, diopside and tremolite, together with phlogopite are all present in sample 2600 of the Missisauga Formation. Chloritoid has only been found in sample 960 from the Banquereau Formation. The identified feldspar is mostly

K-feldspar, but plagioclase is also present in sample 960.

Tourmaline, zircon and garnet are the most abundant translucent heavy detrital minerals, in all depths studied. However, chromian spinels and chromite are also common. All these minerals are transport-resistant minerals and therefore their occurrence and abundance may indicate second or multi-cycle origin. The unstable minerals phlogopite, clinopyroxene and amphibole have been identified at present only in certain samples (1375 and 1800 for Logan Canyon and 2600 for Missisauga Formations). These unstable minerals probably have a relatively local origin.

Several minerals are diagnostic of a particular type of source terrane. Chloritoid indicates a metamorphic origin. Chromian spinel and chromite with a wide range of textures and colours (Appendices 1 and 2) and chemical compositions (discussed below) indicate an ophiolitic source. It may be important that the majority of the analysed crystals of these two minerals have a subhedral habit that argues in favour of first cycle origin for these minerals. Almandine garnet is the typical garnet of metamorphic rocks ranging from garnetiferous schists to granulite facies rocks. Almandine garnet is also known from igneous rocks, although usually only locally. Spessartine garnet is rather less common than many of the garnet species. It mostly occurs in skarn deposits and metasomatised rocks. The amphibole tremolite is an early product of the thermal metamorphism of dolomite containing silica impurities, but is also found in regionally metamorphosed carbonate rocks and it is characteristic mineral of low grade regionally metamorphosed ultramafic rocks. The pyroxene diopside is also typical mineral of many metamorphic rocks. It is particularly characteristic of thermally metamorphosed calcium-rich sediments, but are also common constituents of calcium- and magnesium rich schists of both igneous and sedimentary protolith. Thus the assemblage almandine, diopside and tremolite, which is present in sample 2600 (Middle Missisauga Formation) suggests a metamorphic source.

3.2.3 Chemical composition of detrital minerals

Tourmaline

Tourmaline compositions (Fig. 3) are compared with the source fields identified by Henry and Guidotti (1985) and Kassoli-Fournaraki and Michailidis (1994). The majority of tourmaline analyses from the Dawson Canyon, Logan Canyon and Missisauga formations have compositions typical of derivation from clastic metasediments (Fields 4, 5, 6, and 10 in Fig. 3a). However, some

analyses also suggest Li-poor granites as a source (Field 2 in Fig. 3) and only two analyses from the Missisauga Formation suggest source from Li-rich pegmatite and aplite (Field 1 in Fig. 3b)

Chromian spinel and chromite

The total range of chemical composition of chromite and chromian spinel for all samples studied from Logan Canyon and Missisauga Formations (Fig. 4) falls in all three compositional fields distinguished by Pearce et al. (2000): MORB, island-arc tholeiite and boninite. The two analyses from sample 960 m from the Banquereau Formation plot in the MORB field. Chromian spinel and chromites have also been analysed for the Alma K-85, Glenelg N-49 and North Triumph B-52 wells (Fig. 5; Pe-Piper et al., 2004). These analyses also show the same compositional range as those from E-23 well. A similar wide compositional spread to that of the Scotian Basin wells is shown by chromian spinel and chromite analyses we have collected from the literature for the Newfoundland Appalachians (western Newfoundland ophiolites, Fig. 5). Overall the compositional variation of the Scotian Basin chromian spinels and chromites compares better with that of the Newfoundland Appalachians rather with that of the Quebec Appalachians (Figs. 4, 5).

Garnet

The analysed garnets are plotted in Fig. 6. The garnet analyses come mainly from the Logan Canyon and Missisauga Formations. We have a substantial number of comparison analyses from potential igneous and metamorphic sources. When the Musquodoboit E-23 garnet compositions are compared with those of potential sources, both granites and metamorphic rocks may be source lithologies (Fig. 6).

Clinopyroxene

The Musquodoboit E-23 well is the only well in Scotian Basin that we have studied in which diopside has been found in appreciable amounts, with the exception of some wells in the Orpheus Graben. The chemical composition of the clinopyroxene in Musquodoboit E-23 is very different compared with the clinopyroxenes analysed from the Lower Cretaceous sandstones of the Orpheus Graben wells Argo F-38 and Jason C-20 (Weir-Murphy, 2002). The concentrations of TiO_2 , Al_2O_3 and FeO_t are much higher in clinopyroxenes from the Orpheus Graben wells, whereas MgO and CaO

concentrations are much higher in the Musquodoboit E-23 well. Clinopyroxenes from the Orpheus Graben wells resemble those from the Cretaceous alkaline mafic rocks from the same wells (see e.g. Pe-Piper and Jansa, 1987), and very different compared with the E-23 well clinopyroxenes. The latter clinopyroxenes are in general chemically similar to the clinopyroxenes from thermal metamorphic rocks (e.g. Deer et al., 1992).

Amphibole and mica

The amphibole analysed in the studied rocks is tremolite (Table 6, Fig. 7). Tremolite is an early product of the thermal metamorphism of impure carbonate rocks.

The micas analysed in the studied rocks include muscovite and phlogopite (Table 6). Phlogopite is a common mineral in thermal metamorphic impure carbonate rocks. Phlogopite is also a characteristic product of regional metamorphism of impure magnesium limestone. Thus, amphibolite facies siliceous magnesium limestones may contain phlogopite together with tremolite and diopside. Phlogopite may also be present in metasomatically altered ultramafic rocks and as primary mineral in some mafic igneous rocks.

3.2.4 Diagenetic minerals

Identified diagenetic minerals include glauconite, which is present in all studied samples, pyrite, frambooidal pyrite and beige to pale brown carbonates, which are mostly siderite. Calcite has also been identified at 1270 m, 1375 m, and 2800 m, whereas chlorite has been identified only occasionally.

4. Whole Rock Geochemistry

4.1 Determination of the degree of chemical weathering of the hinterland and the amount of sorting and recycling of detrital minerals

4.1.1 Screening for significant diagenesis or dilution by carbonate

Nine samples from the Musquodoboit E-23 well were selected for whole rock chemical analyses. These analyses include four mudstones from the Logan Canyon Formation (Cree Member); three mudstones from the Missisauga Formation (upper member); two calcareous mudstones from the Abenaki Formation; as well as one muddy sandstone from the base of the Banquereau Formation. Geochemical data have been plotted as reported (Table 7) and are not plotted on a volatile-free basis. (Note when comparing with the Scotian basin data of Pe-Piper et al., 2008, that the latter are reported and plotted on a volatile-free basis).

Inspection of the geochemical data in Table 7 shows that three samples do not lie on the normal linear trend of detrital terrigenous sediments on a SiO_2 vs. Al_2O_3 plot (Pe-Piper et al., 2008). The two samples from the Abenaki Formation have 30–40 wt % CaO , principally in carbonate, and correspondingly high LOI (loss on ignition). Sample 2190 (3) has exceptionally high Fe_2O_{3t} and high LOI, suggesting significant siderite cementation. Ca and Mg, also concentrated in siderite (Karim et al., 2008), are also elevated in this sample compared with normal mudstone from the same level, whereas most trace elements are rather lower probably due to dilution. Siderophile elements, except for Mn, do not appear concentrated in this Fe-rich sample.

In general, these three samples with high carbonate contents cannot be evaluated by the terrigenous provenance discrimination diagrams discussed below, except where element ratios are used that are not influenced by dilution by carbonate minerals. The data for these three samples are plotted on most of the diagrams, but no comment is made in the text unless the variation might be significant.

4.1.2 Weathering of hinterland rocks

The degree of weathering of the hinterland rocks and the effect of diagenesis on the analyzed samples will be determined using a variety of geochemical plots from the literature. The determination of these variables is important because the chemistry of these sedimentary rocks will

later be used to determine provenance and tectonic setting. If the hinterland rocks were significantly affected by weathering and the analyzed samples by diagenesis, then their chemistry will not accurately reflect their provenance and tectonic setting and alternative methods will need to be employed to determine their geologic history.

The dominant process during chemical weathering of the upper crust is the formation of secondary clay minerals through the degradation of feldspars. As weathering increases the proportion of alumina to alkalis typically increases due to the removal of calcium, sodium, and potassium by aggressive soil solutions (Nesbitt and Young, 1982). Using the molecular proportions of Al_2O_3 - Na_2O + CaO - K_2O , Nesbitt and Young (1982) derived a chemical index of alteration, which allows for the numerical expression of the degree of weathering:

$$\text{CIA} = [\text{Al}_2\text{O}_3 / (\text{Al}_2\text{O}_3 + \text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O})] \times 100$$

CaO represents the amount of CaO that is incorporated into the silicate fraction of the rock and a correction must be made for the apatite and carbonate contents. A CIA value of 50 is typical of unaltered albite, anorthite and potassic feldspar, while idealized muscovite produces a value of 75. Average shales range from 70–75, while illite ranges from 75–85, and kaolinite and chlorite yield the highest values close to that of 100 (Nesbitt and Young 1982).

The CIA values for the analyzed samples are: 72 to 82 for the Logan Canyon Formation mudstones (excluding the sample with siderite cement), 67 to 78 for the Missisauga Formation mudstones, and 44 for the Banquereau Formation sandstone suggesting that the hinterland rocks for the Logan Canyon Formation mudstones have undergone slightly more weathering than the Missisauga Formation, and the Banquereau Formation sandstone respectively. When the molecular proportions of Al_2O_3 - Na_2O + CaO - K_2O are plotted on a ternary diagram (Fig. 8), analyzed samples from the Logan Canyon Formation, Missisauga Formation and the Banquereau Formation sandstone lie on a linear trend from plagioclase to illite.

The degree of weathering in sedimentary rocks can also be assessed using Th/U ratios, which will increase along with the degree of weathering. McLennan et al. (1995) suggested that a ratio near 3.8 indicates a relatively unweathered source, but the precise value will vary according to local hinterland geology (Pe-Piper et al., 2008). The Logan Canyon samples, which plot closest to the illite field on Fig 8, also show the highest Th/U ratios (Fig. 9), with lower but overlapping values in the Missisauga Formation mudstones, and the Banquereau Formation sandstone with the lowest

Th/U ratio. The range of Th/U for Lower Cretaceous mudstones at Musquodoboit E-23 falls within the range of most mudstone samples from the Alma field (3.4–4.8). At Alma, a Th/U ratio > 5 is found only at the extreme top of the Missisauga Formation (Fig. 9b). In the fluvial Chaswood Formation, where the source rocks may have a lower Th/U ratio, a Th/U ratio > 5 is found only in the units with well-developed paleosols (Fig. 9c), in contrast to more rapidly deposited fluvial lithologies, confirming the role of weathering in creating a high Th/U ratio. Otherwise, the U/Th ratio does not change significantly at unconformities, below which Sr and P are concentrated (Piper et al., 2008).

4.1.3 Sorting and recycling of detrital minerals

Trace and rare earth elements, such as zircon and titanite, are minerals that can often effectively resist sedimentary processes such as weathering and transport. If these heavy minerals accumulate within sedimentary beds, through sorting, their chemistry will no longer accurately reflect the provenance and/or tectonic setting of their hinterland rocks. La Flèche and Camiré (1996) developed a ternary plot (Al_2O_3 -Hf*36.2-TiO₂*300) to determine whether there has been any significant accumulation of either zircon or titanite which would be represented by a trend towards the Hf apex. When plotted (Fig. 10), samples suggest little to no accumulation of zircon or titanite, except that the siderite-cemented mudstone sample (2190(3)) from the Logan Canyon Formation and the Banquereau Formation sandstone show a weak trend towards the Hf apex. This suggests low to moderate concentration of heavy minerals in these samples.

4.2 Provenance of Cretaceous rocks of the Musquodoboit E-23 well

4.2.1 Geochemical identification of provenance

Whole-rock geochemistry is attractive as an indicator of provenance, because it might be expected in some manner to integrate contributions from a variety of rock types in the hinterland. In contrast, the use of indicator minerals may identify only a particular minor source of that mineral (ophiolite for chromite; calc-silicate rock for tremolite) and is further complicated by the reworking of minerals from polycyclic sediments. In the literature, many attempts have been made to use relative abundance of particular elements to draw conclusions about the composition of the rocks

that were a source of detrital sediment. We apply some of these techniques to the samples analyzed from the Musquodoboit E-23 well. Work elsewhere in the Scotian basin, including at the nearby Alma field, has shown that many of the techniques proposed in the literature are not of universal application, but nevertheless provide useful insight into the character of detritus supplied to the basin (Pe-Piper et al., 2008). The Scotian basin detritus is unusually rich in TiO_2 (concentrated in the heavy mineral ilmenite and its titania weathering products) and low in CaO (Pe-Piper et al., 2008) and this has an important influence on its bulk geochemical characteristics.

4.2.2 Nature of the hinterland rocks

Relatively immobile elements, such as Ti and Ni, can be used to determine the original lithological composition of the hinterland rock and to separate immature sediments derived from a magmatic source from normal mature sediments (Floyd et al., 1989). The mudstone samples from the Missisauga Formation and three samples from the Logan Canyon Formation have high Ni and Ti that Floyd et al. (1989) propose are characteristic of mafic rocks (Fig. 11a). The Banquereau Formation sandstone plots within the field of an acidic or felsic source.

The sources of a sedimentary rock suite can be determined using K versus Rb ratios that are generally analogous to standard continental crust values (Floyd et al., 1989). On Fig. 11b, the Missisauga, Logan Canyon and Banquereau formation rocks show high K and Rb abundances that are typical of hinterland rocks of a felsic to intermediate composition.

Floyd and Leveridge (1987) also used La/Th versus Hf trace element data to estimate the sources of detrital rocks of volcanic arc provenance. Values are low and uniform for sediments derived from acid-dominated arcs usually containing Hf values between 3-7 ppm (Floyd and Leveridge, 1987). As erosion of the arcs plutonic roots and continental metasedimentary basement increases, the Hf content increases due to its release from its main host zircon (Floyd and Leveridge, 1987). Mudstone samples from the Missisauga and Logan Canyon Formations indicate a felsic source while the Banquereau Formation sandstone sample shows a high Hf component typical of a passive margin source with an increasing old sediment component (Fig. 12a). The high Hf might also result from the concentration of heavy minerals by sorting.

Co/Th versus La/Sc ratios have also been proposed as a provenance indicator (Fig. 12b; Gu et al., 2002). All plotted samples show a Co/Th ratio near that of 1.27 suggesting a felsic to andesitic

source or mixed felsic/andesitic source.

Totten et al. (2000) showed that Th/Sc ratios near a value of 1.0 are typical of the upper continental crust which tends to be more enriched in the incompatible element Th; whereas, a more mafic component has a ratio near 0.6 and tends to be more enriched in the compatible element Sc (Fig. 13a). The Missisauga Formation and Logan Canyon samples suggest an intermediate source. The Banquereau Formation sandstone shows a Th/Sc ratio close to 1, higher than the other samples, suggesting a more felsic source. This still suggests an intermediate source but with more of a felsic component. The Abenaki Formation carbonates show low amounts of both Th and Sc components, due to dilution, but their ratio of below 0.6 suggests a more mafic source. A similar approach uses a plot of La/Sc vs. Th/Sc (Fig 13b). This plot, after Totten et al. (2000) may be used where there is mixing between a mafic source enriched in the compatible element Sc, and a more continental source enriched in the incompatible elements La and Th. Included for reference are the North American shale composite (NASC). All of the plotted samples cluster along the curve suggesting a mixing of a felsic and mafic sources.

When plotted on the Th-Hf-Co ternary diagram (Fig. 14) after Taylor and McLennan (1985), samples from the Logan Canyon, Missisauga, and Abenaki formations plot within the field for the upper continental crust. The Banquereau Formation sandstone plots outside of the upper continental crust field, closer to the Hf apex which suggests a moderate accumulation of minerals rich in Hf (e.g. zircon), as noted above (Fig. 10).

Based on the data obtained from the previously discussed diagrams it can be concluded that the Logan Canyon and Missisauga mudstones have been derived from a hinterland with sources of intermediate to felsic composition. There might have been more mafic input to the terrigenous component of the Abenaki Formation (Figs. 12a, 13), but the evidence is not strong. The Banquereau Formation sandstone is more difficult to interpret because of the effects of heavy mineral concentration by sorting. It shows a greater component of older reworked sediments and suggests an intermediate to felsic hinterland rock.

4.2.3 Tectonic setting

Bulk geochemistry has also been used in the literature to infer the tectonic setting of the source area for the detrital sediment. On the passive continental margin, identification of tectonic setting is essentially an assessment of the original tectonic setting of particular basement terranes that have contributed detrital sediment to the Scotian basin.

Using the ratios of K_2O/Na_2O versus SiO_2 (Fig. 15a) Roser and Korsch (1986) have proposed the following tectonic settings: passive margin (PM), active continental margin (ACM), and oceanic island arc (ARC). The mudstone samples from the Missisauga and Logan Canyon formation cluster mostly in the PM, close to and just crossing the boundary with the ACM field. Using the ratios of SiO_2/Al_2O_3 versus K_2O/Na_2O , Roser and Korsch (1986) distinguished the following four tectonic settings: passive margin (PM), active continental margin (ACM), arc setting basaltic and andesitic detritus (A1), and evolved arc setting felsic plutonic detritus (A2). Once again, most of the samples cluster on the boundary of the PM and ACM fields.

Ti/Zr versus La/Sc plots (Fig. 16) have been used to determine tectonic setting while at the same time considering the degree of sorting (Bhatia and Crook, 1986). High La/Sc ratios are characteristic of active continental margin and passive margin greywackes respectively. Passive margin settings also show low Ti/Zr ratios (Bhatia and Crook, 1986). The fields described in this diagram were originally characterized based on sandstones. Sandstones usually show higher La/Sc and lower Ti/Zr ratios than associated shales due to the process of sorting. Four fields are shown on this plot: oceanic island arc (OIA), continental island arc (CIA), active continental margin (ACM), and passive margin (PM). When plotted the majority of samples from Logan Canyon and Missisauga fall within the ACM field.

Bhatia and Crook (1986) have also designed three ternary plots ($La-Th-Sc$, $Th-Co-Zr/10$, and $Th-Sc-Zr/10$) to determine tectonic setting while at the same time considering the degree of sorting. The fields defined are as follows: Oceanic island arc (A), continental island arc (B), active continental margin (C), and passive margin (D). Note that on Fig 17a fields C and D are combined. For the $La-Th-Sc$ plot (Fig. 17a) all analyzed samples cluster within field B, continental island arc source, and show no obvious sorting trend. On the $Th-Co-Zr/10$ plot (Fig. 17b) the majority of samples from the Logan Canyon and Missisauga Formations also plot within field B. For the $Th-Sc-Zr/10$ plot (Fig. 17c) samples from Missisagua and Logan Canyon formations again cluster within

field B.

In summary, tectonic discrimination diagrams do not consistently identify the Lower Cretaceous Scotian basin sediments as passive margin sediments, despite the fact that their tectonic setting was on a passive margin. Most discrimination diagrams suggest an active continental margin source.

4.2.4 Rare earth elements

Rare earth element (REE) plots (Fig. 18) are useful in determining provenance and tectonic environment due to the fact that heavy minerals tend to sequester and transport REEs (Totten et al., 2000). All samples show a moderate slope in the light rare earth elements (LREE) with little to no slope in the heavy rare earth elements (HREE) suggesting they are weakly fractionated. They also all show weak negative Eu anomalies. Thus, this type of pattern is characteristic of average upper crust and shows no evidence for unusual sources.

The REE abundances for the Abenaki Formation samples are about three times lower compared with the younger terrigenous sediments, suggesting dilution of the clastic component that carries the REE elements by the carbonate. The samples also show a slight fractionation for the HREE in contrast to the younger samples. This suggests there might have been a different source for the clastic component of the Abenaki Formation mudstones.

5 Discussion: provenance of the Cretaceous sediments

5.1 The regional context in the Early Cretaceous

A variety of geochronological and mineralogical studies have shown that the supply of detrital sediment to the Sable sub-basin (Pe-Piper et al., 2004) was of different composition and hence provenance compared to the eastern Scotian basin (e.g. Peskowesk A-99: Pe-Piper et al., 2006b); to the wells on the La Have platform in the west (Pe-Piper and Piper, 2007); and to the Chaswood Formation (Pe-Piper and MacKay, 2006; Piper et al., 2007). This distinction was also confirmed by bulk geochemical studies (Pe-Piper et al. 2008). The most pronounced differences between the wells of the Sable sub-basin compared with the Chaswood Formation on land are (a)

the virtual absence of detrital chromite-spinel in the Chaswood Formation, whereas it is a common heavy mineral offshore and (b) the predominance of Silurian–Ordovician ages for detrital monazite in the Chaswood Formation, whereas Devonian and Precambrian ages predominate in the offshore. These observations suggest that rivers draining through Cabot Strait and receiving sediment from western Newfoundland supplied sediment to the central and eastern Scotian basin. The Chaswood Formation was probably supplied by at least three discrete rivers draining from northern New Brunswick (Pe-Piper and MacKay, 2006). These rivers may at times have supplied sediment directly to the Scotian Shelf, or may have been tributaries of the main Cabot Strait river(s), perhaps flowing along the Cobequid-Chedabucto fault zone.

Detrital muscovite in the Sable sub-basin is principally of Carboniferous–Permian age, implying a source from Meguma Group metasediments on the inner Scotian Shelf that were thermally reset in the Alleghenian orogeny (Reynolds et al., 2009). Detrital muscovite, monazite and zircon in the Upper Missisauga Formation from the Naskapi N-30 well all indicate a source exclusively from the Meguma terrane, including the South Mountain batholith (Reynolds et al., 2009), suggesting that at that time the Chaswood river in central Nova Scotia was diverted along the Cobequid-Chedabucto fault zone.

Detrital minerals from the Upper Missisauga Formation in the Glenelg and North Triumph fields are very similar, but the Alma field farther to the west differs in detail in mineral composition (Pe-Piper et al., 2004). For example, granitic tourmaline is more abundant at Alma. These observations might imply that supply from a trunk Cabot Strait river was diluted at Alma by local supply from Chaswood Formation rivers including erosion of the inner Scotian Shelf. Musquodoboit E-23 is located 16 km inboard of the Alma field , for which mineralogy and geochemistry have been studied in both the Logan Canyon and Upper Missisauga formations. As discussed below, there are close similarities between Alma and Musquodoboit wells.

5.2 The mineralogical evidence

The minerals tourmaline and garnet in the Musquodoboit E-23 well are particularly useful in understanding sources. The Logan Canyon and Upper Missisauga formations have a much higher proportion of low-Mg tourmaline, characteristic of a granitic source, than the Middle Missisauga

Formation, in which tourmaline of metamorphic origin predominates (Fig. 3). Although this might be interpreted as resulting from progressive unroofing of plutonic rocks, it more likely results from a change in provenance. Low-Mg tourmalines are similarly abundant in the lower member of the Chaswood Formation of central Nova Scotia, likely co-eval with the Middle and Upper Missisauga Formation, and this may have been the transport route for tourmaline during deposition of the Upper Missisauga and Logan Canyon formations.

As noted above, garnet data are difficult to interpret because many compositional clusters observed in Lower Cretaceous rocks are not matched well by available analyses from potential onshore sources. The best match is from sample 2800 near the base of the Middle Missisauga Formation, where many of the analyzed garnets closely match analyses from both the South Mountain batholith and Meguma Group metasedimentary rocks. The only other sample with garnets resembling those of the South Mountain batholith is 2190 (Lower Cree Member). Samples 2600 and 2500 from the Middle Missisauga Formation have abundant low-Mn almandine with some grossular substitution; our closest matches are from mafic to intermediate plutonic rocks. Sample 1800 from the Upper Cree Member has several distinctive almandine garnets with considerable spessartine (Mn) and grossular (Ca) substitution, close in composition to garnet from the Wedgeport granite of SW Nova Scotia. Almandine garnets with 20–50% spessartine substitution predominate in the Chaswood Formation of central Nova Scotia, but are found only in small amounts in samples 2800 and 2600 in the Middle Missisauga Formation. This possible evidence for a source from the central Nova Scotia Chaswood river in the Middle Missisauga Formation contradicts the evidence from tourmaline that such a source was present only after the Middle Missisauga. It thus emphasises the need for more information on mineral compositions in potential sources on land.

Variations in chromite-spinel abundance and chemistry suggest that the differences between Alma and Musquodoboit in the west and Glenelg and North Triumph to the east are not solely the result of more Chaswood river input in the west. At least in the Upper Missisauga Formation, the proportion of MORB-sourced chromite in Musquodoboit and Alma is greater and the proportion of boninitic chromite less than in the Glenelg and North Triumph fields (Figs. 5, 6). This might be the chance result of different supply at different stratigraphic levels within the Upper Missisauga Formation. If the difference is real, then it cannot be accounted for by sediment supply by a Chaswood river, because of the lack of chromite in Chaswood Formation sandstones and its paucity

in Appalachian bedrock of Nova Scotia.

Two detrital minerals are found at more than one horizon in Musquodoboit E-23, but have not been recognised elsewhere in the Lower Cretaceous of the Scotian basin, from which we have more than 4000 electron microprobe analyses of detrital minerals. These minerals are tremolite in samples 1375 (top Logan Canyon) and 2600 (Middle Missisauga) and low Fe-diopside in 1800 (upper Cree Member) and 2600. As discussed above, this mineral assemblage together with the phlogopite found in sample 2600 is characteristic of thermal metamorphism of impure carbonate rocks. Sample 2600, in which the minerals are most abundant, contains unusually low amounts of chromite, and the rare tourmaline is mostly of metasedimentary origin. We suggest two hypotheses for these observations. It is possible that the tremolite and diopside have a distant source, perhaps from the George River Group of Cape Breton Island, and it is chance that it has been recognised only from Musquodoboit E-23 and not from other wells in the Sable sub-basin. Alternatively, the tremolite and diopside had a local source on the inner Scotian shelf, perhaps from Windsor Group carbonates intruded by an Alleghanian pluton analogous to the German Bank pluton (cf. Pe-Piper et al., 2009).

5.3 The geochemical evidence

Geochemically, the samples analysed from the Logan Canyon and Missisauga formations are very similar to one another (except for the siderite-cemented mudstone 2190(3), and also closely resemble mudstones of similar age from the Alma field, 16 km to the south (e.g., Fig. 9; see also Pe-Piper et al. 2008).

Tectonic discrimination diagrams mostly suggest an active continental margin source for the Lower Cretaceous Scotian basin sediments, despite the fact that their tectonic setting was on a passive margin. There may be several reasons for this identification. The sedimentological and petrographic character of the Chaswood Formation (Pe-Piper and MacKay, 2006; Piper et al., 2007) indicates that much of the Scotian basin was sourced proximally from reactivated horsts of Appalachian basement. There is no evidence that a continent-scale passive margin river supplied sediment to the basin. Were there such a river, its sedimentary contribution was masked by the local Appalachian and Grenville sources. Rapid erosion of local basement, much of which was formed

on an active continental margin in the Neoproterozoic and early Paleozoic, would thus mimic the sediment supply from a contemporary active continental margin. Furthermore, Early Cretaceous volcanism supplied ash to the Scotian basin and Chaswood Formation (Pe-Piper et al., 2006a, 2008) that would have included elements normally lost during passive margin weathering and fluvial supply.

More specific interpretations of sediment source based on geochemistry do not appear possible. Minor variations in chemical composition observed between the Logan Canyon and Missisauga formations are within the range of normal variation (e.g. Fig. 9b) and should not be over-interpreted from the limited database in this report.

6 Conclusions

1. Mudstone samples from the Logan Canyon and Missisauga formations are geochemically similar among themselves and resemble mudstones from the nearby Alma field. A muddy sandstone from the basal Banquereau Formation is geochemically distinct.
2. Mudstone geochemistry is consistent with a source from re-activated Appalachian and Grenville basement. Geochemistry of the terrigenous fraction of the Abenaki Formation may indicate a greater proportion of mafic detritus.
3. The predominant mineral assemblage at Musquodoboit E-23 is similar to that elsewhere in the Lower Cretaceous of the Sable sub-basin. The presence of chromite and Grenville monazite has been previously used as evidence that this sediment was supplied by a river flowing through Cabot Strait, likely including sediment derived from western Newfoundland.
4. The Logan Canyon and Upper Missisauga formations have a much higher proportion of low-Mg tourmaline, characteristic of a granitic source, than the Middle Missisauga Formation, in which tourmaline of metamorphic origin predominates. The absence of low-Mg tourmaline in the Glenelg and North Triumph fields suggests that this mineral might have been supplied by a Chaswood Formation river crossing central Nova Scotia from New Brunswick.
4. Near the base of the Middle Missisauga Formation, many of the analyzed garnets closely match analyses from both the South Mountain batholith and Meguma Group metasedimentary rocks, but

similar garnets are rare at higher stratigraphic levels.

5. Tremolite and low-Fe diopside are each present at two horizons in Musquodoboit E-23, but have not been recognised elsewhere in the Lower Cretaceous of the Scotian basin, from which we have more than 4000 electron microprobe analyses of detrital minerals. They are sourced from thermally metamorphosed impure limestones, possibly from the inner Scotian Shelf.

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M.Sc. Thesis, Saint Mary's University, Halifax, N.S., Canada, 168 p.

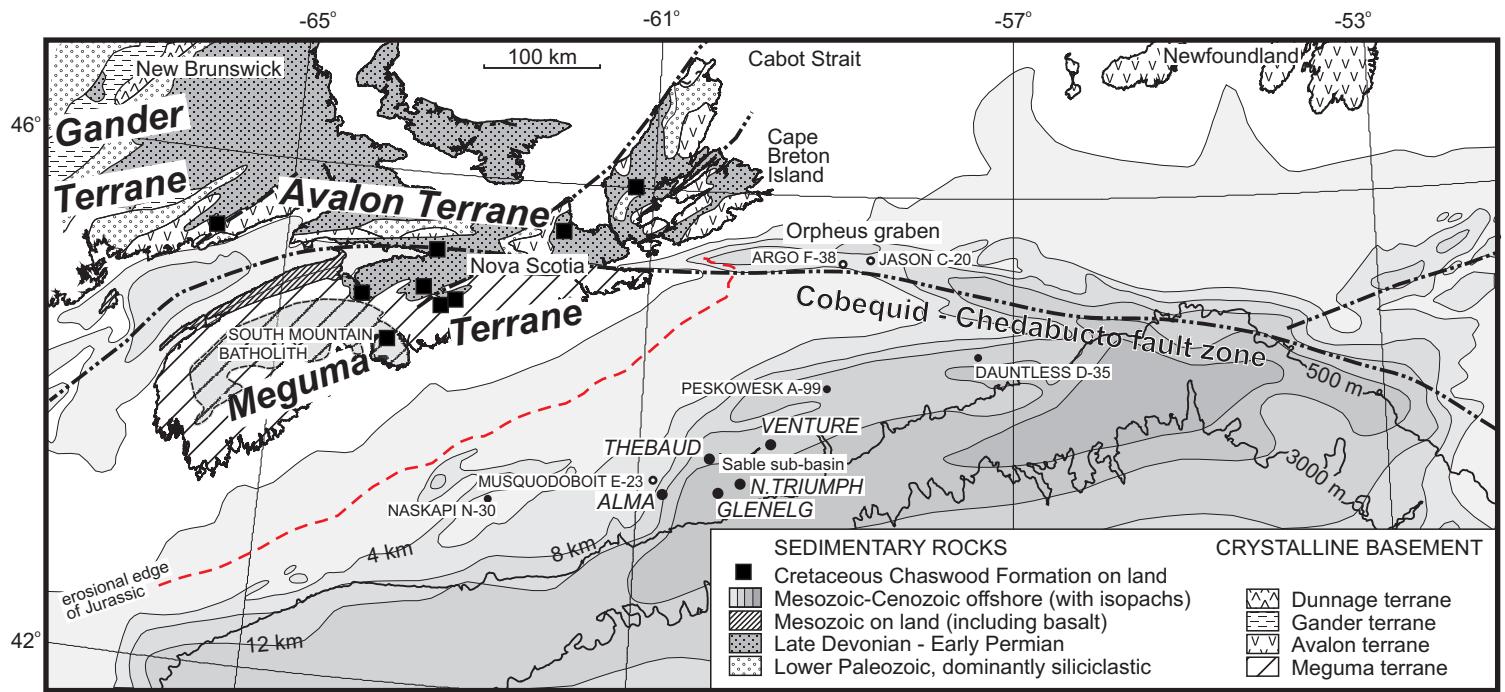


Figure 1: Location of Musquodoboit E-23 well, other wells and fields on the Scotian Shelf with detailed petrographic studies, and Chaswood Formation localities on land. Also shows isopachs of Scotian basin (from Williams and Grant, 1998), erosional edge of Jurassic (from Wade and MacLean, 1990) and generalized geology on land.

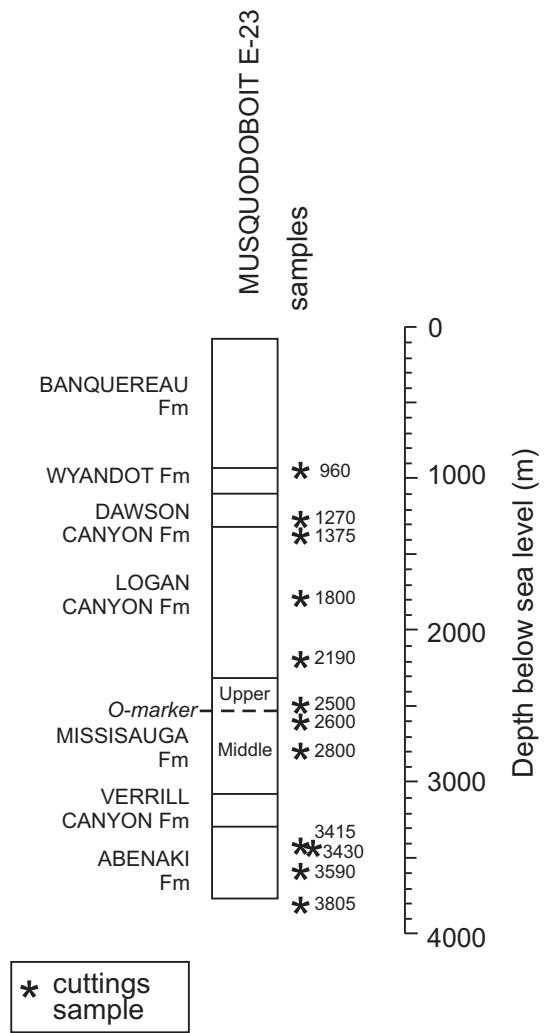


Fig. 2: Simplified stratigraphic column for the Musquodoboit E-23 well, with location of studied samples (Table 1)

Musquodoboit E-23 Tourmaline

KEY TO FIELDS (Kassoli-Fournaraki & Michailidis 1994, after Henry & Guidotti 1985)	
1.	Li-rich pegmatite, aplite
2.	Li-poor granite
3.	Fe-rich qz-tourmaline rock
4.	Metapelite, -psammite with Al saturating phase
5.	Metapelite, -psammite lacking Al saturating phase
6.	Metapelite, calc-silicate rock, or type 3
7.	Meta-ultramafic rock; Cr, V-rich metasedimentary rock
8.	Metacarbonate and metapyroxenite
9.	Ca-rich metapelite
10.	Ca-poor metapelite, -psammite, or type 3

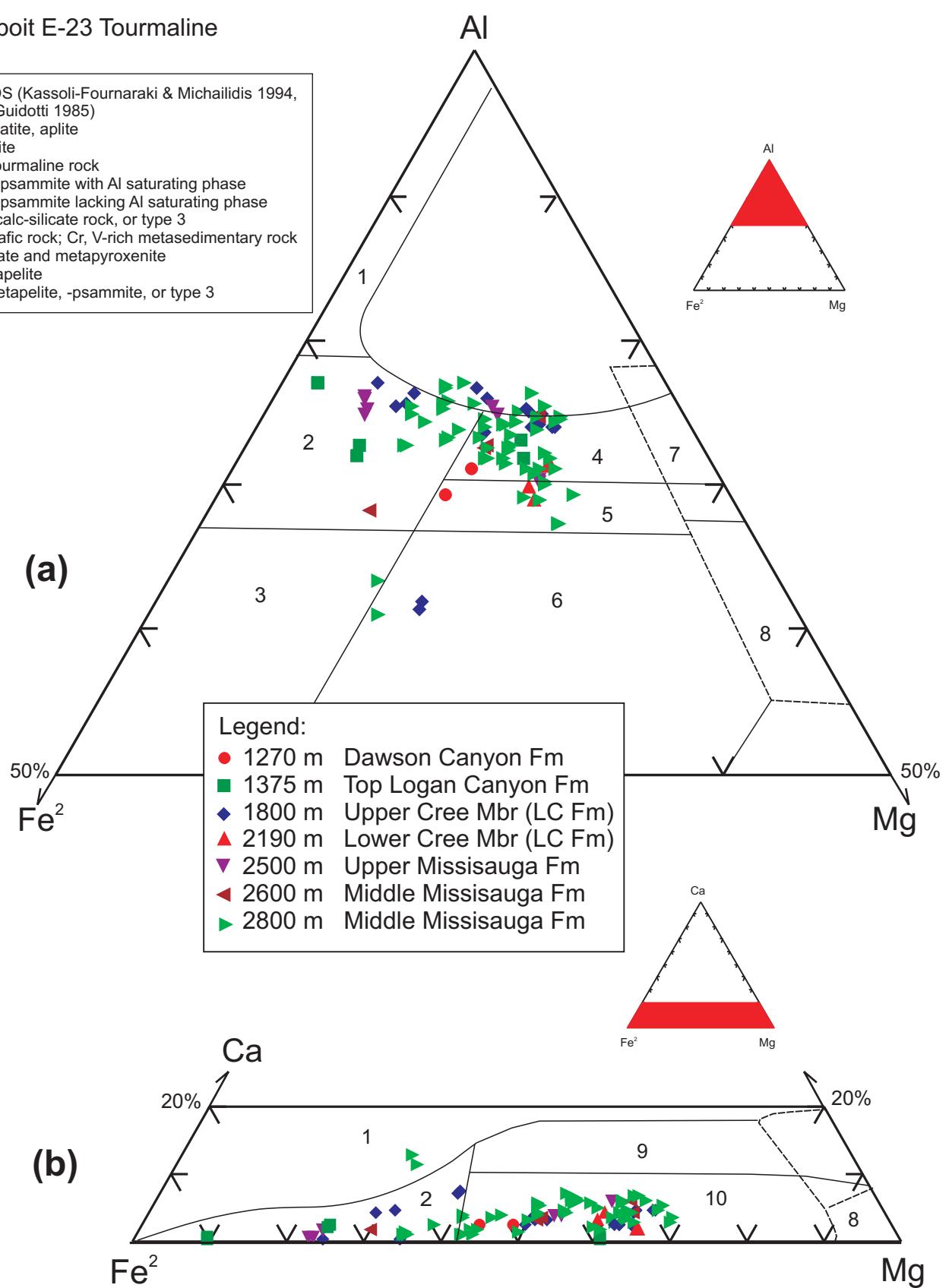


Figure 3: Composition of tourmaline from Musquodoboit E-23.

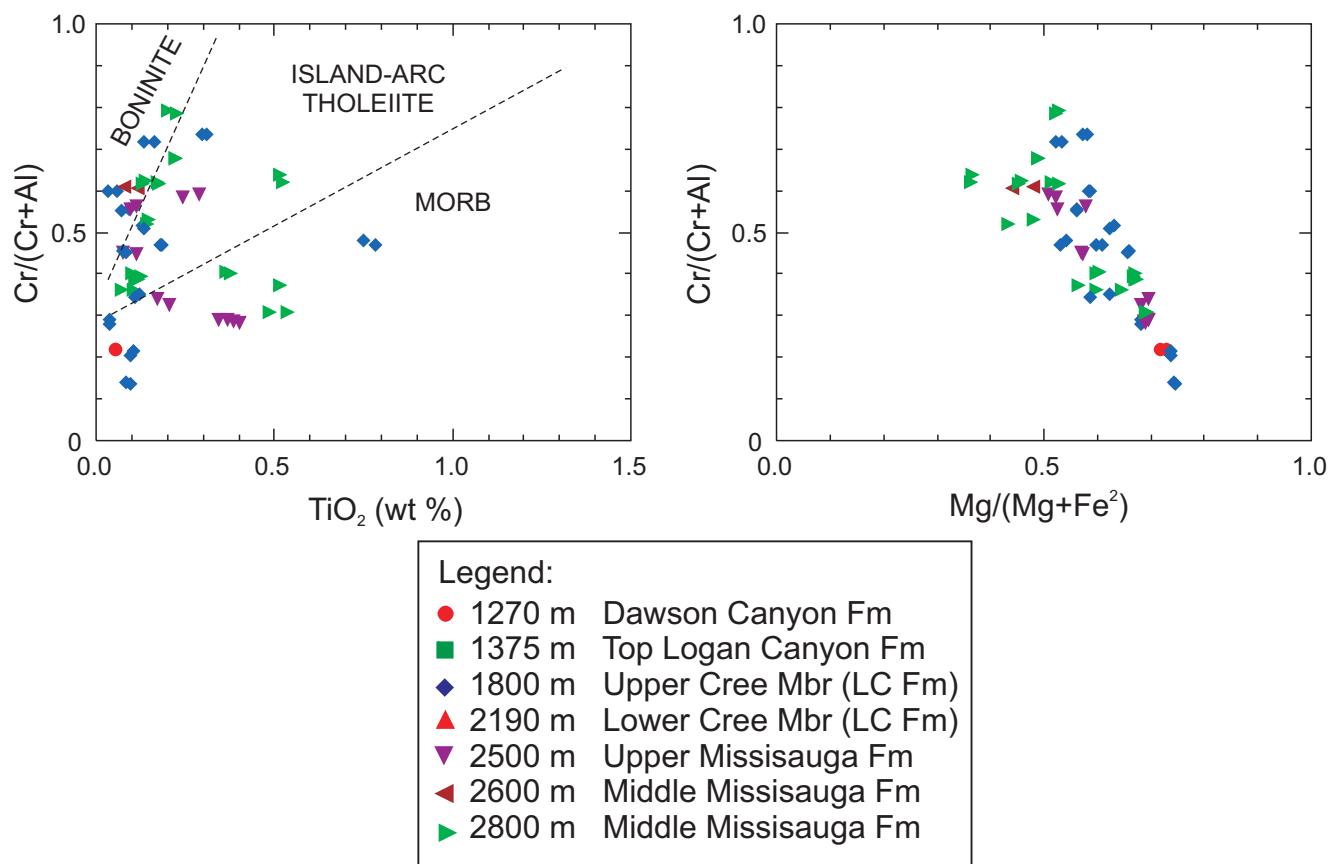


Figure 4: Composition of spinel – chromite from Musquodoboit E-23

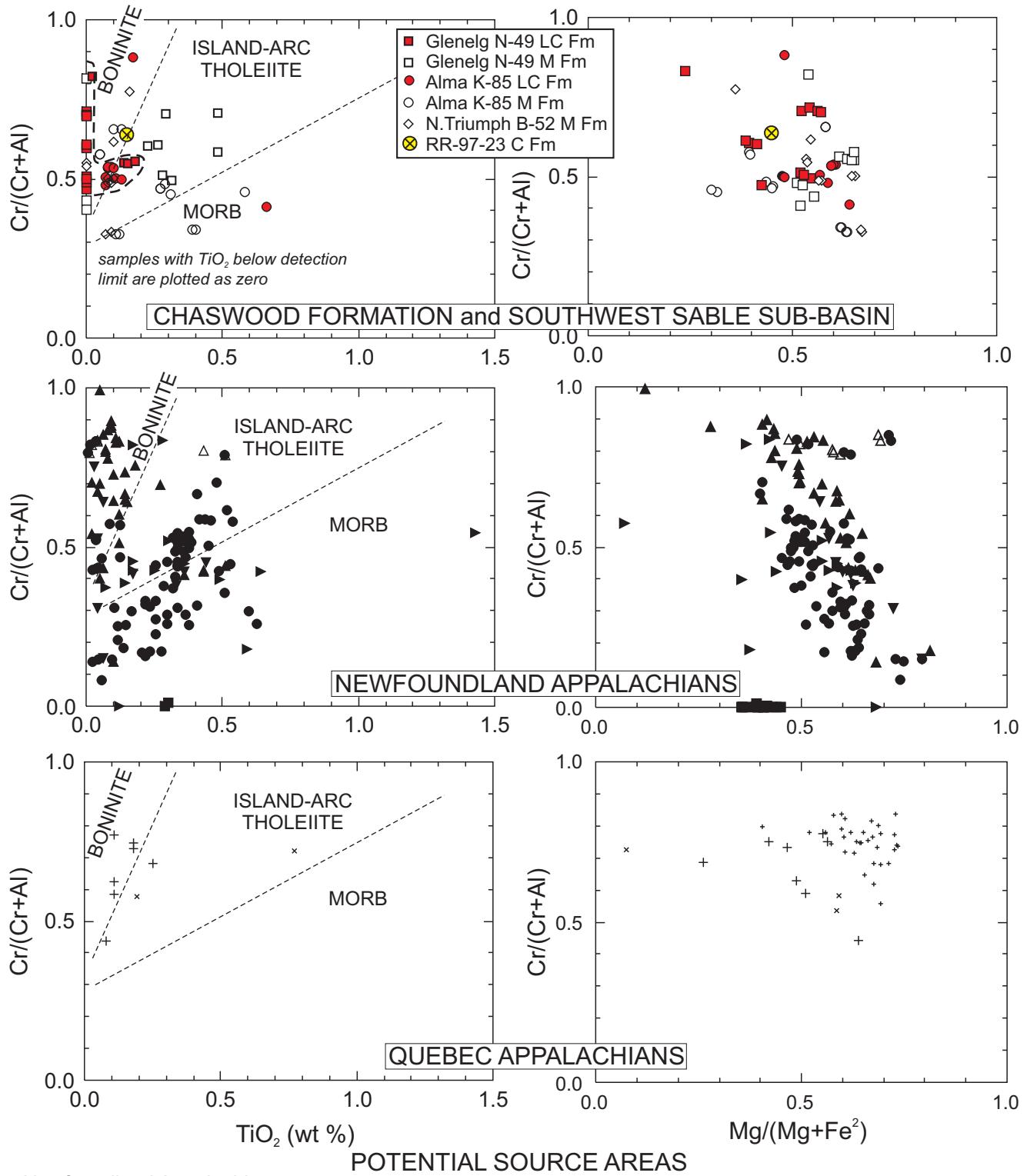


Figure 5: Composition of spinel – chromite from other wells in the Sable sub-basin and from potential Appalachian sources

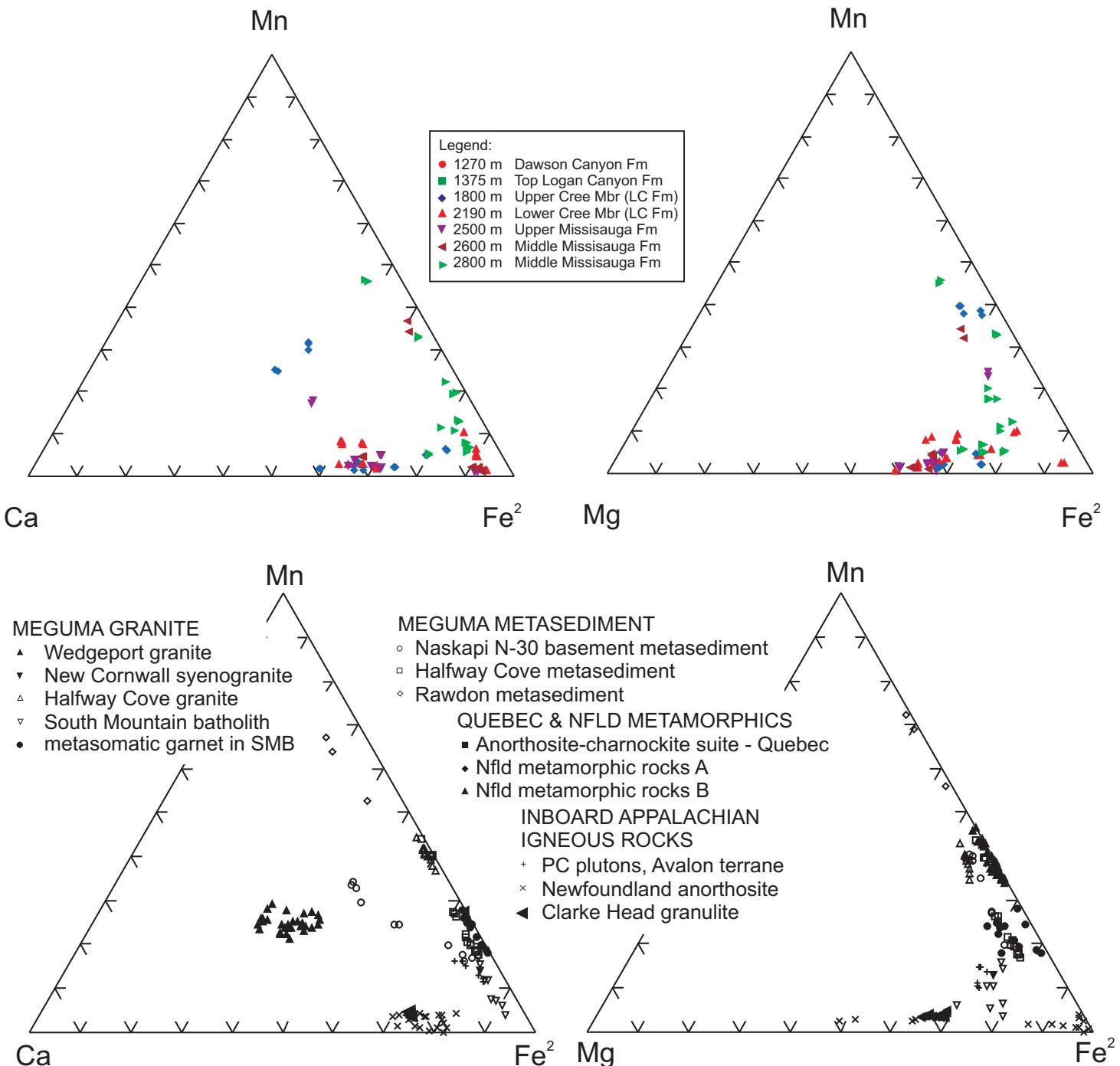


Figure 6: Chemical variation in garnet from Musquodoboit E-23 and comparison with garnets from potential Appalachian source areas. Source rock compositions from Pe-Piper & Ingram (2002); Ham (1988); Allan and Clarke (1981); Feetham (1995); and unpublished data of G. Pe-Piper.

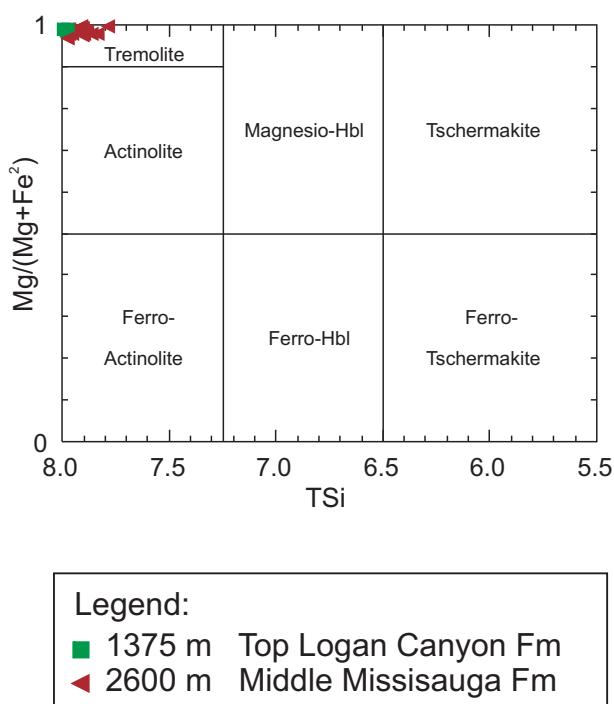


Figure 7: Composition of amphibole from Musquodoboit E-23.
Nomenclature after Leake et al. (1997)

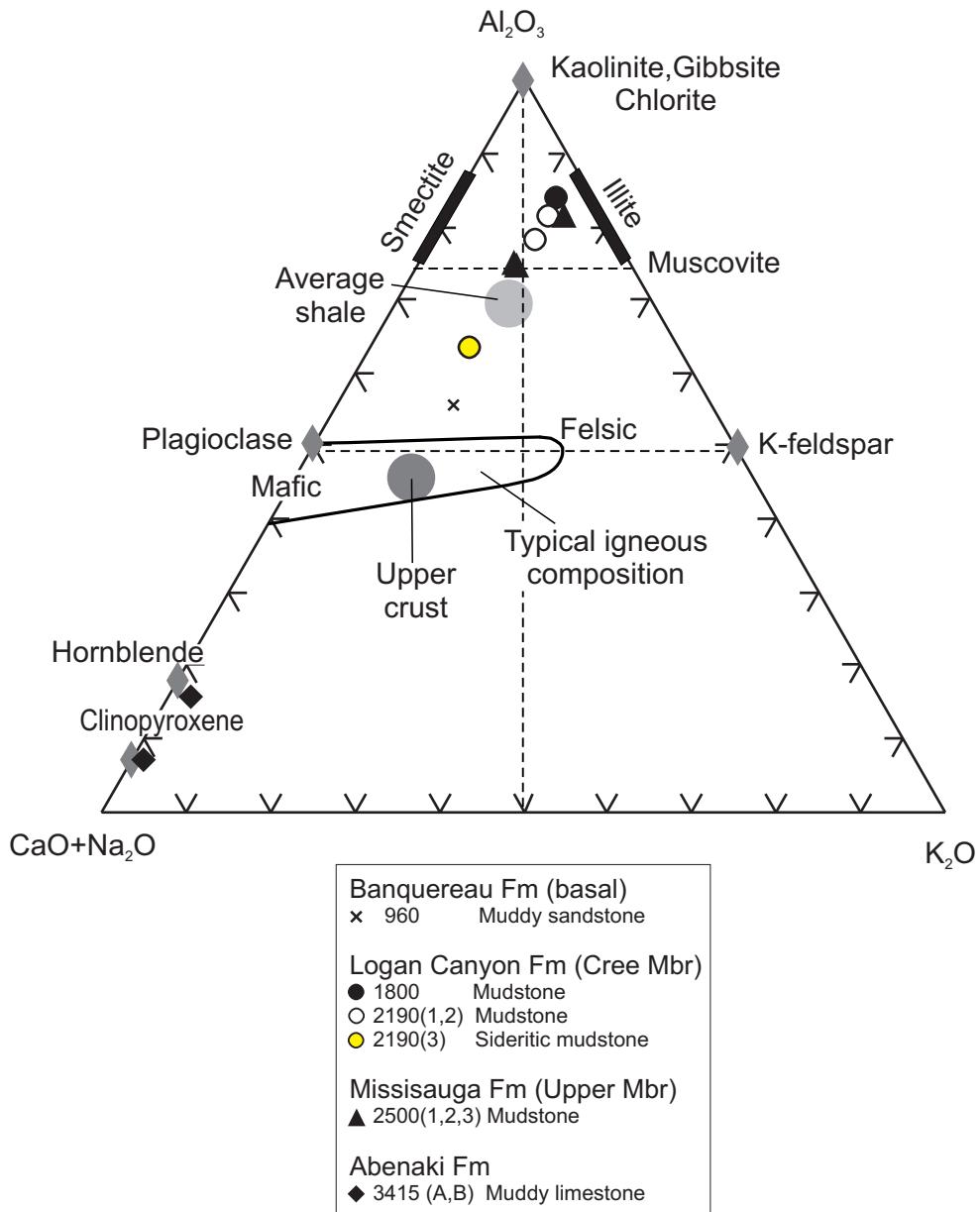


Figure 8: Ternary plot of molecular proportions of Al₂O₃ - Na₂O+CaO - K₂O. Fields from Gu et al. (2002). Idealized clinopyroxene and hornblende compositions from Taylor and McLennan (1985).

Banquereau Fm (basal)
\times 960 Muddy sandstone
Logan Canyon Fm (Cree Mbr)
● 1800 Mudstone
○ 2190(1,2) Mudstone
● 2190(3) Sideritic mudstone
Missisauga Fm (Upper Mbr)
▲ 2500(1,2,3) Mudstone
Abenaki Fm
◆ 3415 (A,B) Muddy limestone

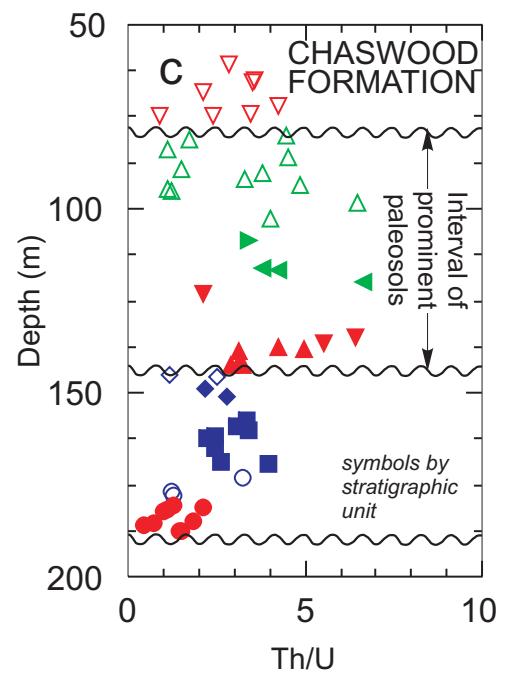
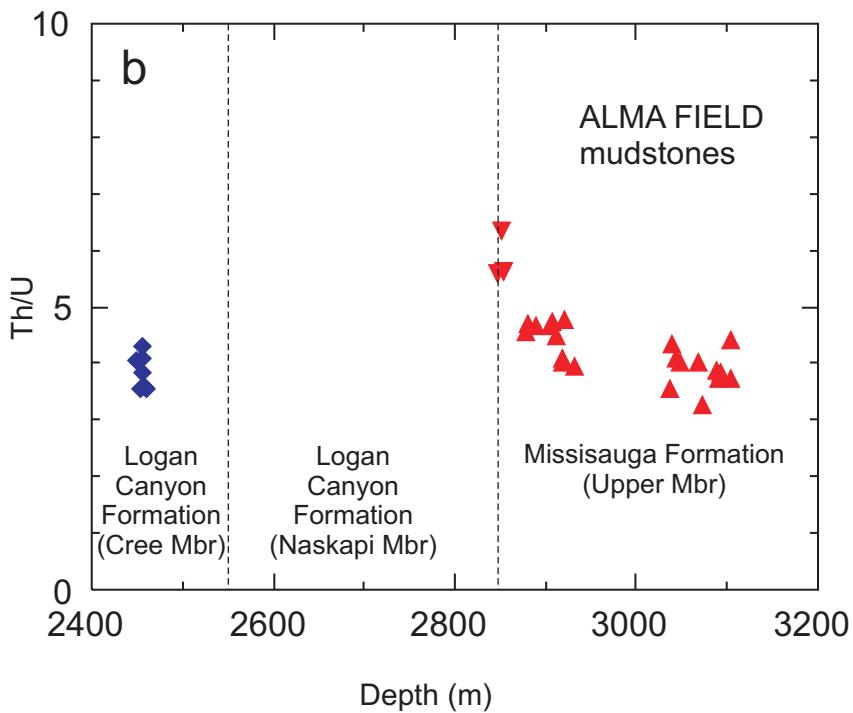
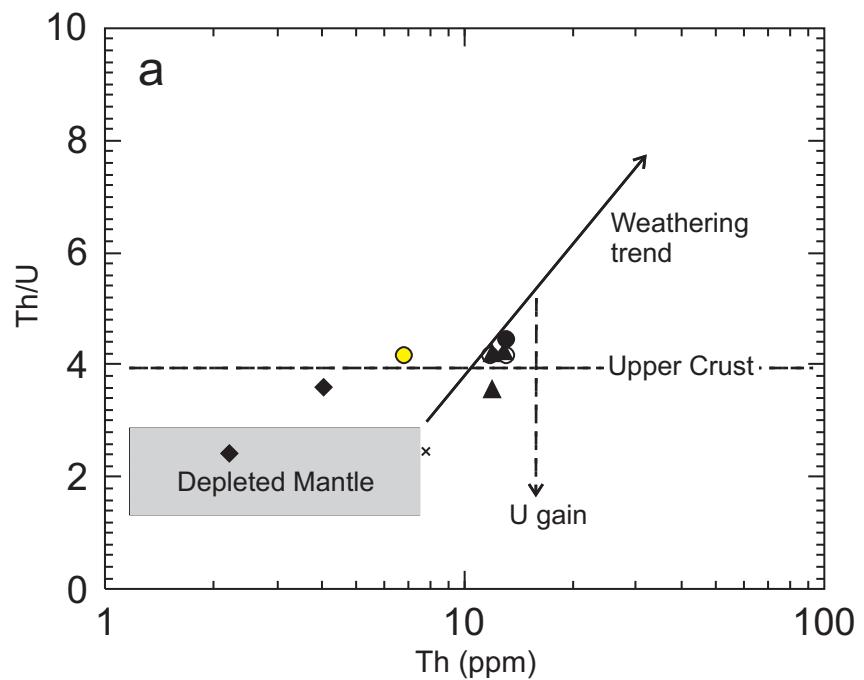
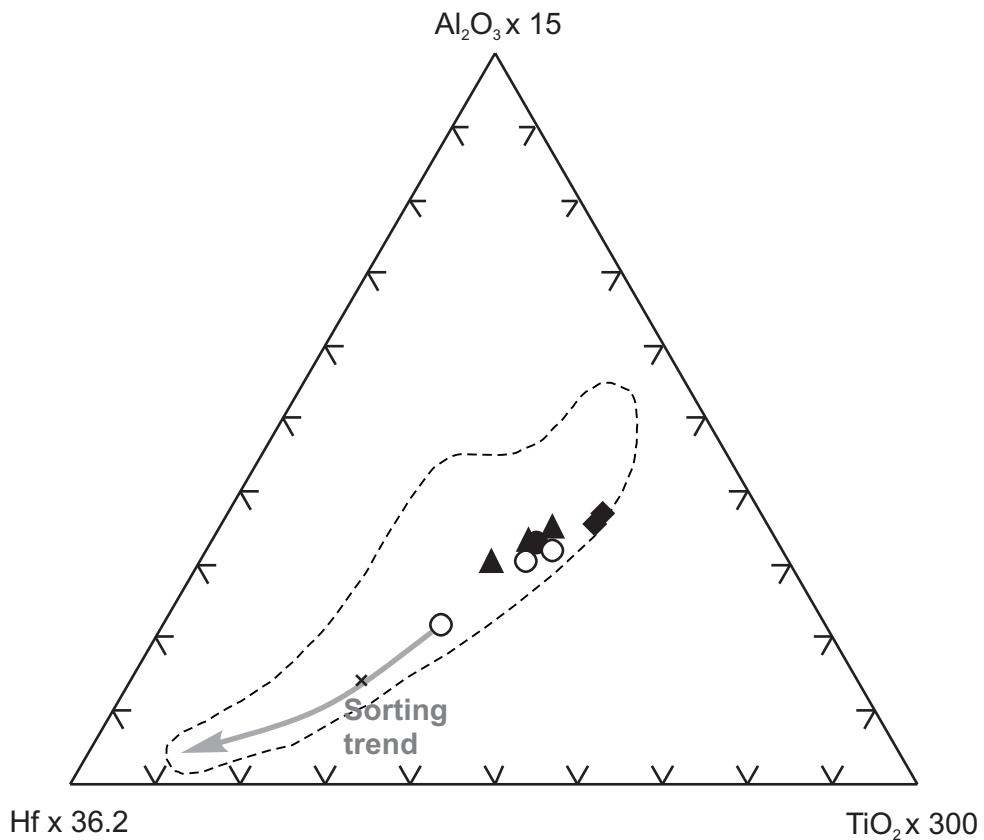


Figure 9: (a) Th/U vs. Th plot for Musquodoboit E-23. Fields and trends from Gu et al. (2002). (b) Comparison with Th/U ratio for mudstones from the Alma field. (c) Comparison with Th/U ratio



Banquereau Fm (basal)		
x 960	Muddy sandstone	
Logan Canyon Fm (Cree Mbr)		
● 1800	Mudstone	
○ 2190(1,2)	Mudstone	
● 2190(3)	Sideritic mudstone	
Missisauga Fm (Upper Mbr)		
▲ 2500(1,2,3)	Mudstone	
Abenaki Fm		
◆ 3415 (A,B)	Muddy limestone	

Figure 10: $\text{Al}_2\text{O}_3 \times 15$ - $\text{Hf} \times 36.2$ - $\text{TiO}_2 \times 300$ plot. Field after La Fléche and Camiré (1996) and Garcia et al. (1994).

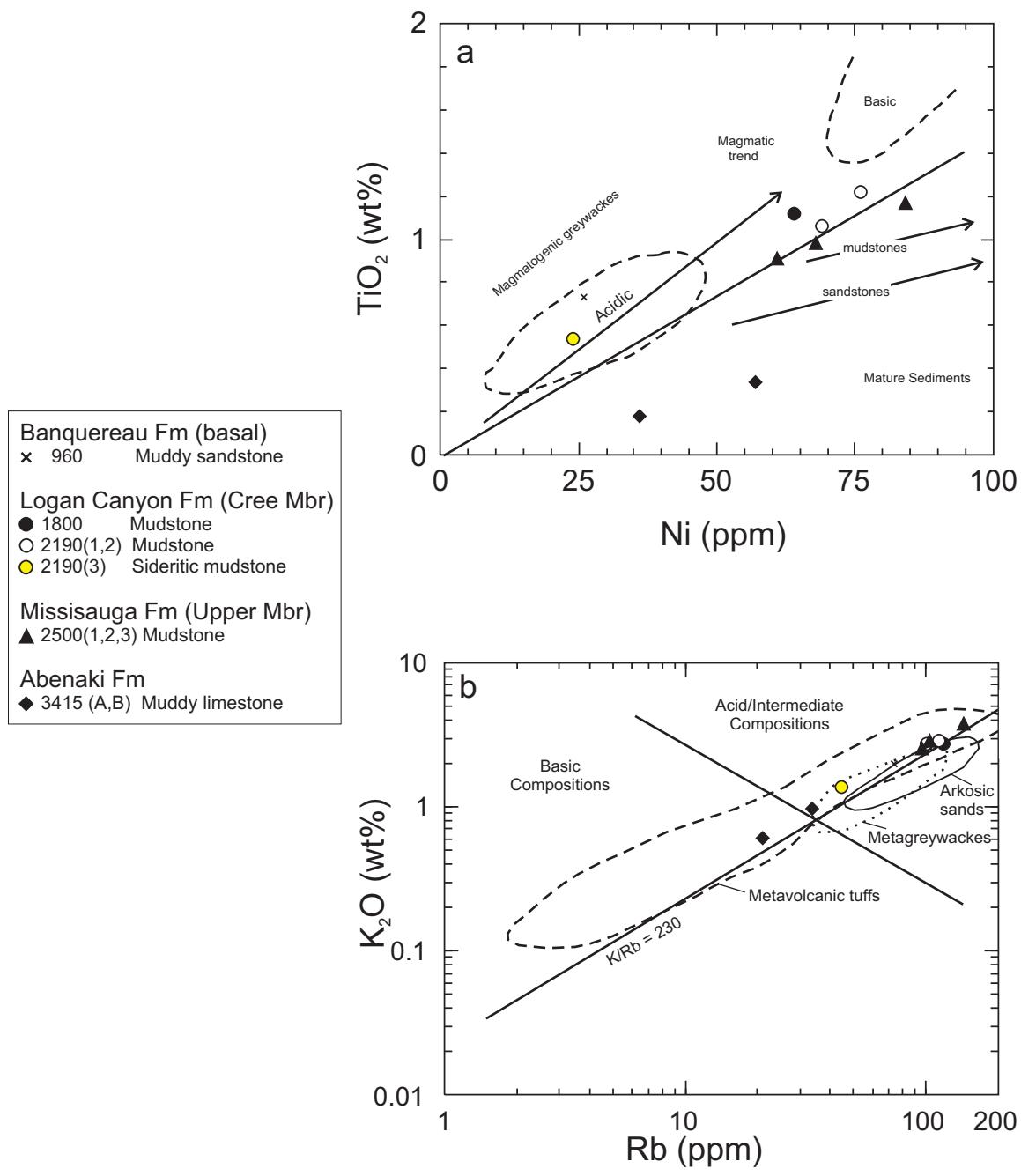


Figure 11: (a) TiO_2 vs. Ni plot. Fields and trends after Gu et al., 2002 and Floyd et al. (1989). (b) K_2O vs. Rb plot. Fields after Floyd and Leveridge (1987).

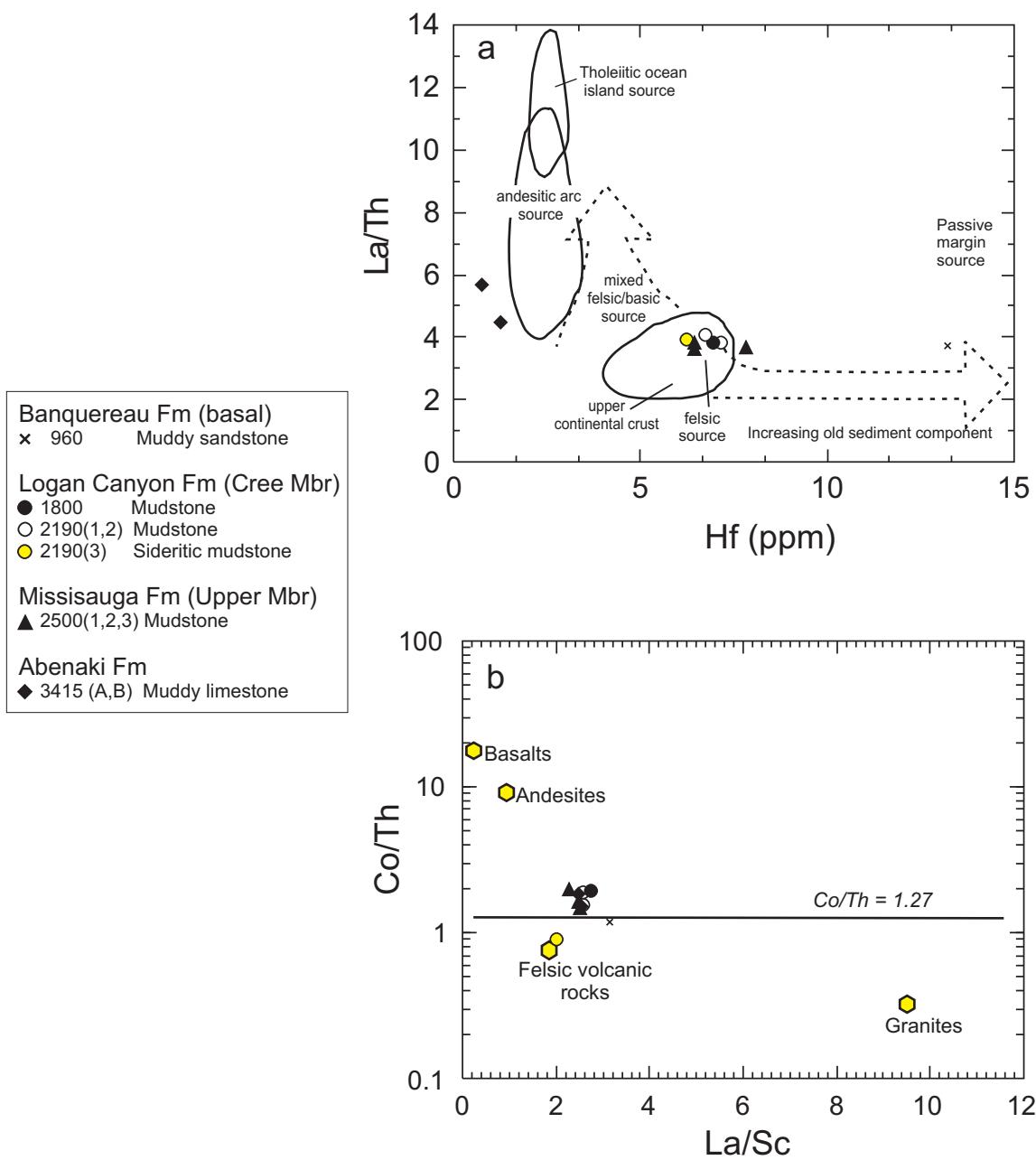


Figure 12: (a) La/Th ratio vs. Hf plot. Fields after Floyd and Leveridge (1987) and Gu et al. (2002). (b) Co/Th ratio vs. La/Sc ratio plot. Average compositions of igneous rocks from Condie (1993) and Gu et al. (2002).

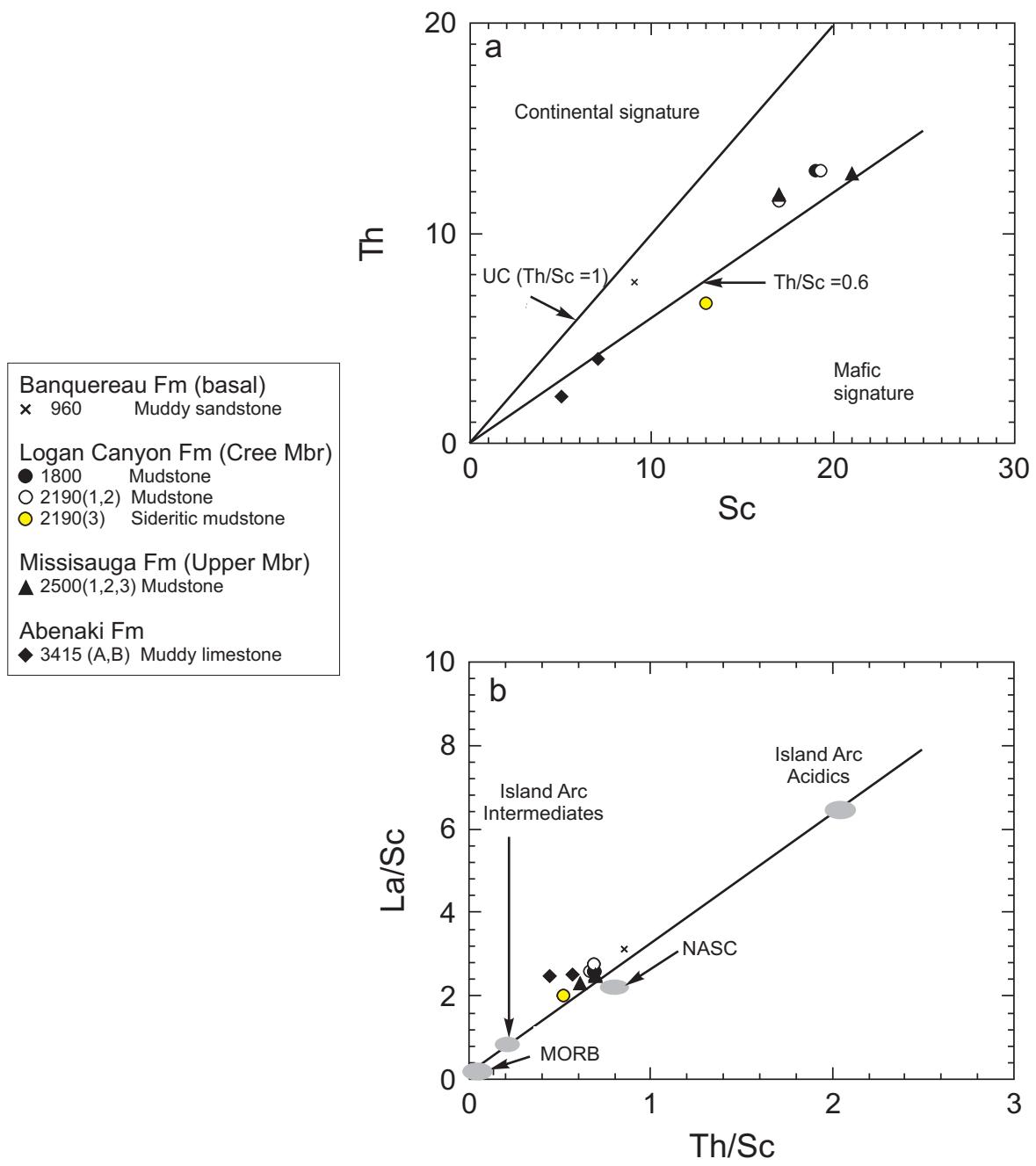
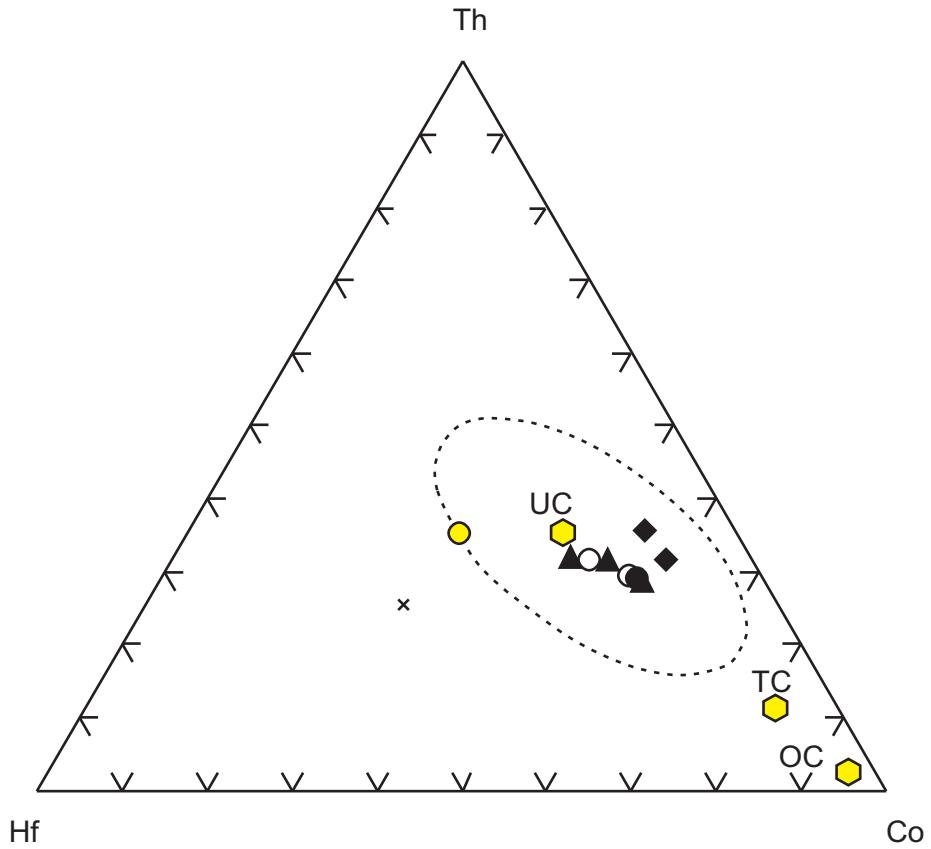


Figure 13: (a) Th vs. Sc plot. Fields and trends from Totten et al. (2000). (b) La/Sc vs. Th/Sc ratio plot. Fields from Totten et al. (2000). Values of different igneous rock types and the North American shale composite (NASC) are included for reference (Taylor and McLennan, 1985; Sun and McDonough, 1989; Gromet and Silver, 1983).



Banquereau Fm (basal)	
x 960	Muddy sandstone
Logan Canyon Fm (Cree Mbr)	
● 1800	Mudstone
○ 2190(1,2)	Mudstone
● 2190(3)	Sideritic mudstone
Missisauga Fm (Upper Mbr)	
▲ 2500(1,2,3)	Mudstone
Abenaki Fm	
◆ 3415 (A,B)	Muddy limestone

Figure 14: Th-Hf-Co plot. Fields after Taylor and McLennan (1985). UC = Upper continental crust; TC = bulk continental crust; OC = average oceanic crust.

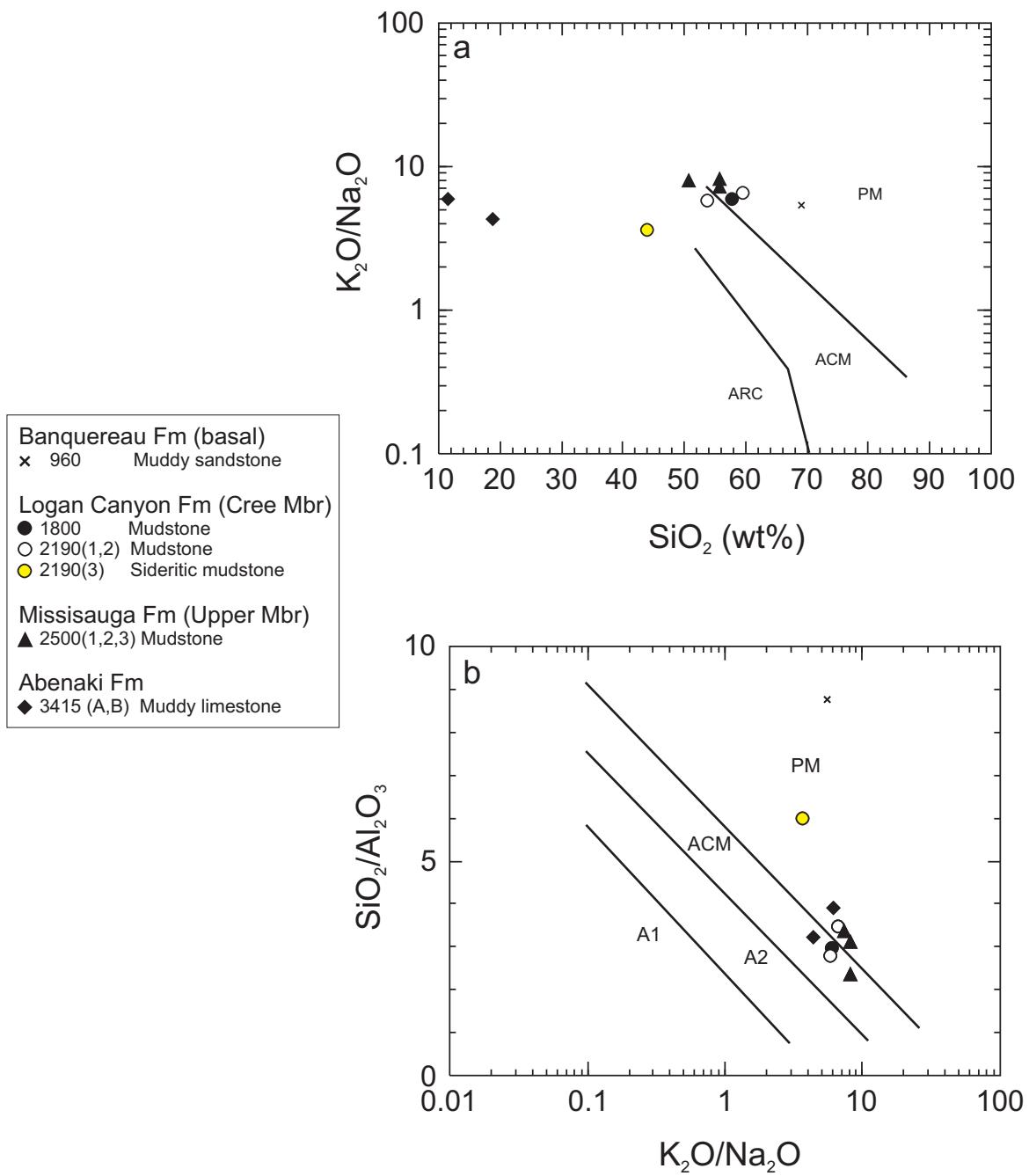


Figure 15: (a) K_2O/Na_2O ratio versus SiO_2 plot. Fields after Roser and Korsch (1986): passive margin = PM, active continental margin = ACM and oceanic island arc = ARC.

(b) SiO_2/Al_2O_3 ratio versus K_2O/Na_2O ratio plot. Fields and boundary lines after Roser and Korsch (1986) : passive margin = PM, active continental margin = ACM, arc setting, basaltic and andesitic detritus = A1 and evolved arc setting

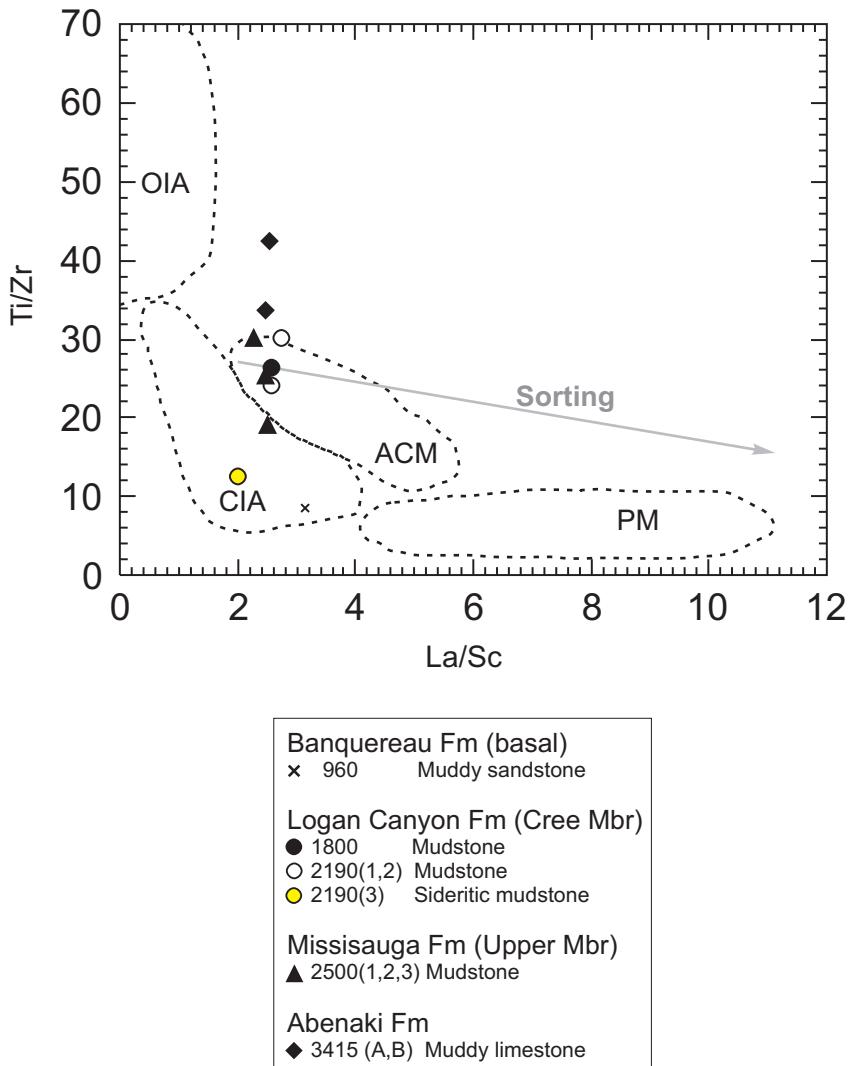


Figure 16: Ti/Zr ratio versus La/Sc ratio plot. Fields after Bhatia and Crook (1986): oceanic island arc = OIA, continental island arc = CIA, active continental margin = ACM and passive margin = PM. The sorting trend after Gu et al. (2002).

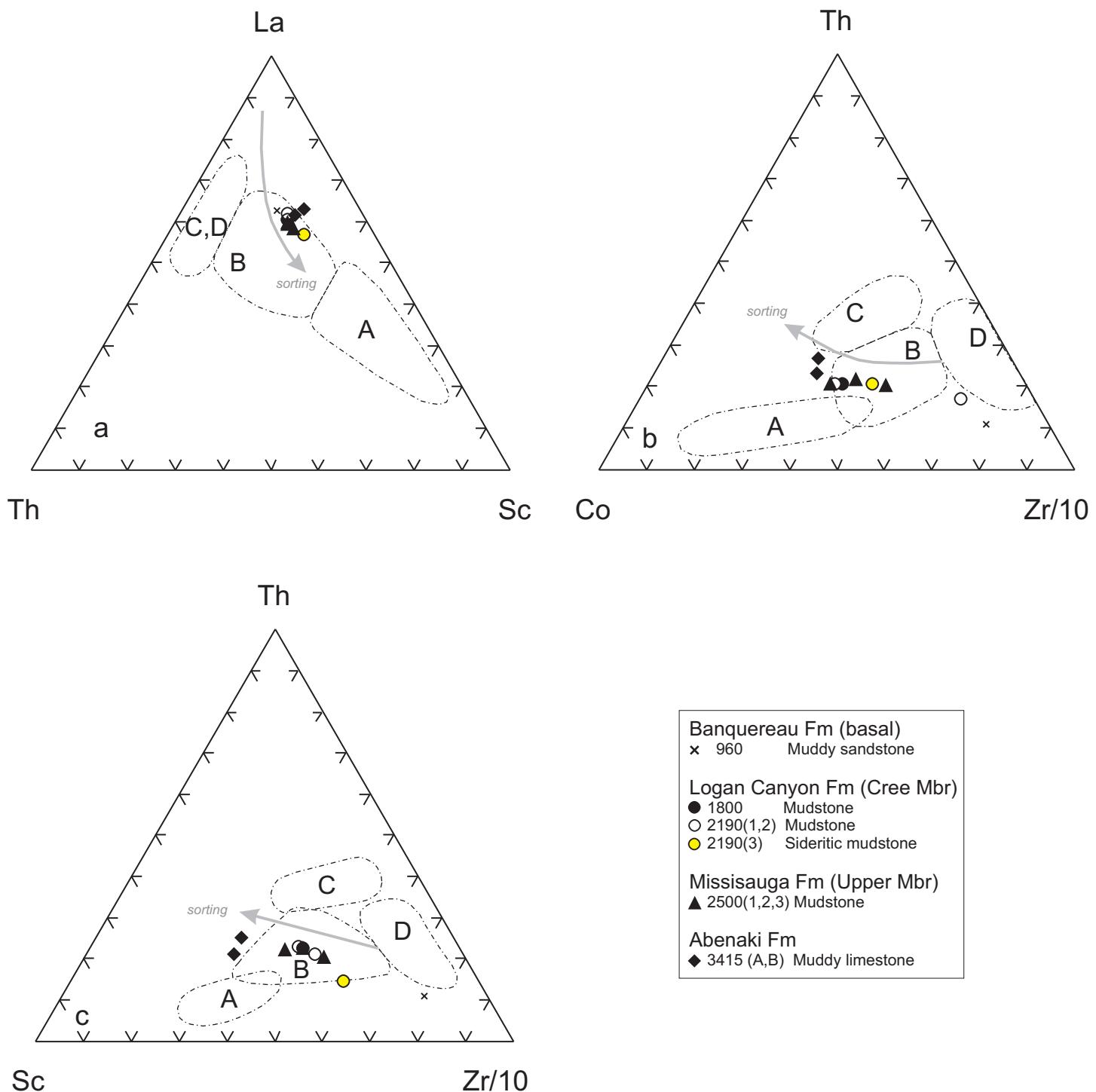


Figure 17: (a) La - Th - Sc plot; (b) Th - Co - Zr/10 plot; and (c) Th - Sc - Zr/10 plot.
 All fields from Bhatia and Cook (1986): A = oceanic island arc; B = continental island arc; C = active continental margin; D = passive margin. Sorting curves from Gu et al. (2002).

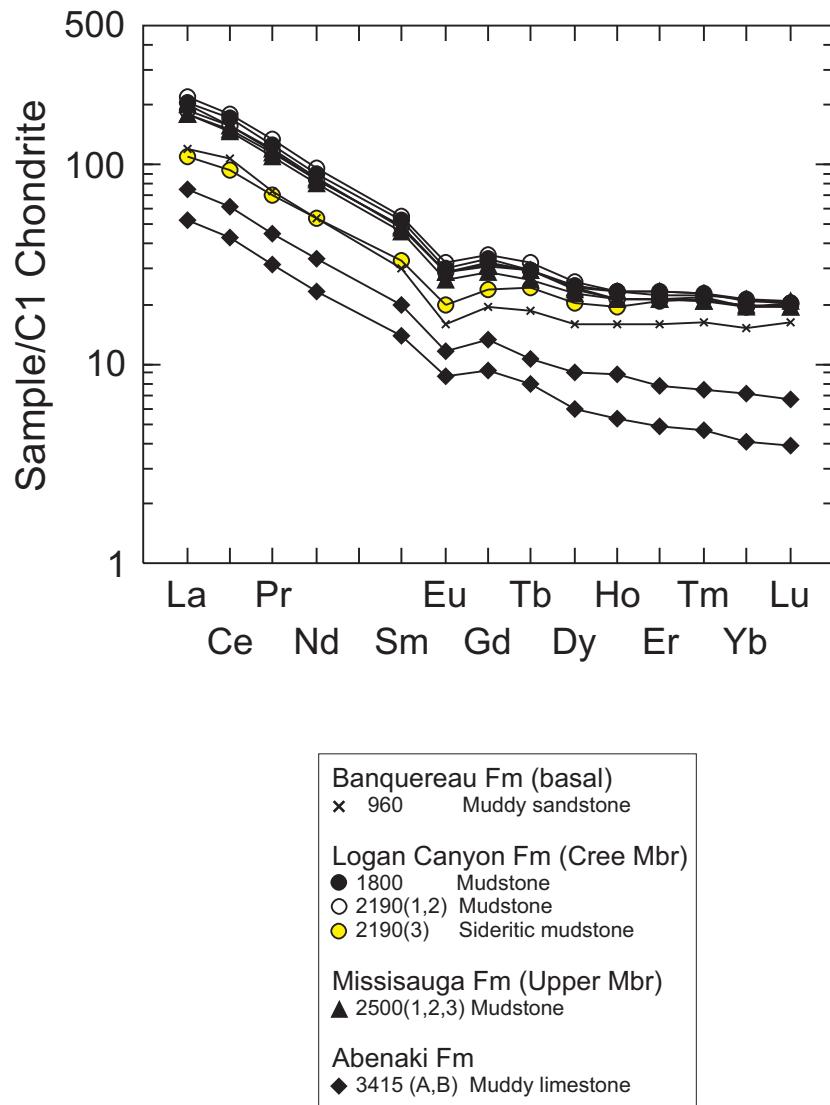


Figure 18: Rare earth element plot normalized to C1 Chondrite values.

Table 1. Sample depths and lithostratigraphic units for the Musquodoboit E-23 well.

Sample	Depth (m)	Formation
1	960	Basal Banquereau
2	1270	Dawson Canyon
3	1375	Top Logan Canyon
4	1800	Logan Canyon (Cree Mbr.)
5	2190	Logan Canyon (Lower Cree Mbr.)
6	2500A	Upper Missisauga
7	2500B	Upper Missisauga
8	2600A	Middle Missisauga
9	2600B	Middle Missisauga
10	2800	Middle Missisauga
11	3415A	Abenaki
12	3415B	Abenaki
13	3430A	Abenaki
14	3430B	Abenaki
15	3430C	Abenaki
16	3590A	Abenaki
17	3590B	Abenaki
18	3805A	Abenaki
19	3805B	Abenaki
20	3805C	Abenaki
21	3805D	Abenaki

A-D are subsamples from the same depth

Table 2. Weight of heavy mineral separates from the Musquodoboit E-23 Well

							<2mm Fraction In Ttbn*	
SAMPLE	Bulk Sample	>2mm	<2mm	>2mm	<2mm	Sink (heavies)	Float (lights)	
Depth (m)	Wt (g)	Wt (g)	Wt (g)	Wt%	Wt%	Wt (g)	Wt (g)	
960	52.16	4.58	47.51	8.78%	91.09%	2.07	97.93	
1270	18.09	6.11	11.99	33.78%	66.28%	10.58	89.42	
1375	30.32	12.02	18.30	39.64%	60.36%	5.39	94.61	
1800	90.54	39.31	51.15	43.42%	56.49%	2.45	97.55	
2190	152.81	47.42	105.16	31.03%	68.82%	6.24	93.76	
2500A	101.13	29.52	71.55	29.19%	70.75%	2.90	97.10	
2500B	105.44	48.37	57.01	45.87%	54.07%	3.07	96.93	
2600A	114.00	23.11	90.77	20.27%	79.62%	2.82	97.18	
2600B	36.00	7.43	28.61	20.64%	79.47%	2.96	97.04	
2800	103.90	5.38	98.26	5.18%	94.57%	0.63	99.37	
3415A	89.61	43.36	45.38	48.39%	50.64%	4.72	95.28	
3415B	102.38	28.52	73.82	27.86%	72.10%	4.36	95.64	
3430A	109.11	1.66	107.31	1.52%	98.35%	0.82	99.18	
3430B	94.26	1.62	92.54	1.72%	98.18%	0.97	99.03	
3430C	54.16	0.94	53.16	1.74%	98.15%	0.70	99.30	
3590A	96.69	3.48	93.36	3.60%	96.56%	0.17	99.83	
3590B	120.67	5.33	115.30	4.42%	95.55%	0.19	99.81	
3805A	147.36	42.46	104.87	28.81%	71.17%	0.12	99.88	
3805B	96.45	23.19	73.17	24.04%	75.86%	0.06	99.94	
3805C	124.12	33.22	90.86	26.76%	73.20%	0.10	99.90	
3805D	104.52	28.59	76.25	27.35%	72.95%	0.10	99.90	

* = tetrabromoethane

Table 3. Counts of cuttings > 2 mm

top depth (m)	960	1270	1375	1800	2190	2500A	2500B	2600A	2600B	2800
total number of cuttings	162	90	93	223	458	301	287	100	58	126
Sandstone, vf.-fine	162	46	90	92	194	122	86	20	39	
Sandstone, medium					1	9	6			
Sandstone, coarse-v.crs					4					
Calcareous sandstones					2			1		69
Shell fragments			3	1	2	1	2	13		2
Coal and shaly coal					50				2	1
Silty shale								2		1
Shale/mudstone	44		130	200	107	108	57	16	53	
White calcareous mudstone/chalk					1			2		
Limestone								5		
Granules-white qz				3	41	28				
Granules-pink qz					2	3				
Granules-yellow qz					1	8				
Granules-dark qz				1	8	45				
Pyritized fossil/pyrite							1		1	
Rust contaminant					10					

Table 4. Interpreted petrography of cuttings samples, Musquodoboit E-23 well

Table 5. Minerals present in cuttings samples

Depth	Formation	Identified individual detrital minerals	Identified diagenetic minerals	Identified Minerals within Cuttings	Abundance of types of cuttings	Comments
960m	Banquereau	Tur, Gt, Pl, Zrn, Cld, Ap	Glt, Py, Carb	Carb, BioCl, Qtz, Glt	sst = vcom; slt = r; mst = r	Qtz is common; abundance of foram fossils (few different species); opaques consist of Py and fairly common Phosphates, possibly bone.
1270m	Dawson Canyon Formation	Feld (Ksp), Gt, Tur, ?Amph, Chspl	Glt, Py, Fram Py, Cal	Glt, Carb, Qtz, Cal	sst = vcom; slt = com; mst = com	Several different species of forams; opaques consist of Py and Fram Py.
1375m	Top Logan Canyon	Tur, ?Bt, Gt, Zrn, Mag, Chl, Amph, Ap	Glt, Py, Fram Py, Cal	Qtz, BioCl, Glt, Carb, ?Chrom,	sst = vcom; slt = com; mst = com	Opaques consist of Py; fram Py, and Mag; Phosphates are also present (?bone); forams, and possible ?Bryzoan
1800m	Logan Canyon (Cree member)	Tur, Chr, Zrn, Gt (Alm), ?Mag, Chspl, Cpx (Di), Ap, Ilm	Glt, Py, Fram Py, Carb, Cal	Qtz, Carb, Glt	sst = vcom; slt = com; mst = rare	Opaques consist of common Py and ?Mag with rare Fram Py; Phosphates are also present (possibly bone); foram fossils are common; one rare fossil possible ?foram
2190m	Logan Canyon (lower Cree)	Tur, Gt (Alm), Zrn, Feld (Ksp), St	Glt, Py, Fram Py	Qtz, Carb	sst = com; slt = com; mst = com	Slide consists of large percentage of cuttings which appear to be carb in nature; Opaques consist of ?Mag, Py (common) and Fram Py (very common); forams are present
2500A	Upper Mississauga	Chr, Tur, Zrn, Gt (Alm), Mag, Chspl	Glt, Py, Fram Py, Carb	Qtz, Carb, Glt	sst = com; slt = com; mst = com	Opaques consist of very common Py and Fram Py as well as common Mag; forams are rare;
2500B	Upper Mississauga	Tur, Chspl, Zrn, Gt (Alm)	Glt, Py, Fram Py, Carb	Glt, Qtz, Carb, Zr	sst = vcom; slt = com; mst = com	Opaques consist of very common Py and common Fram Py; Also ?Mag; Some Py-replaced material-possibly fossilized wood
2600m	Middle Mississauga	Feld, Chr, Tur, Gt(Alm), Zrn, Gl, Mag, Cpx (Di), amph, Chspl, Phl	Glt, Py, Fram Py, Carb	Glt, Qtz, Carb	sst = com; slt = com; mst = v. com	Other minerals present: rare muscovite; opaques consist of very common Py and common Fram Py with common Mag
2800m	Middle Mississauga	Tur, ?Feld, Chr, Gt (Alm, Sps), Zrn, ?Mag, Chspl, Ms	Glt, Py, Fram Py, Cal	Carb, Qtz, Glt	sst = com; slt = com; mst = com	Slide consists of a large percentage of grains; opaques consist of very common Py and Fram Py with rare ?Mag; Also presence of fossilized wood and forams

Tur = tourmaline; Gt = garnet; Chr = chromite; Zrn = zircon; Qtz = quartz; Glt = glauconite; Carb = carbonates; Feld = feldspar; Mag = magnetite; Py = pyrite; Fram = frambooidal; Cal = calcite; Amph = amphibole (tremolite); Bt = biotite; Plag = plagioclase; Phos = phosphates; Cld = chloritoid; Chspl = chromian spinel; Chl = chlorite; St = staurolite; Ms = muscovite; Phl = Phlogopite; Sps = spessartine garnet; Alm = almandine garnet; BioCl = bioclast; Br = brown; Bl = blue; Gr = green; com = common; vcom = very common; sst = sandstone; silt = siltstone; mst = mudstone

Table 6: Electron microprobe chemical analyses of minerals.

Well	Depth (m)	Formation	Analysis No	File No	Mineral	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO _t	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SrO	NiO	BaO	Total
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	42	Min 30-640	apatite	0.16	0.00	0.00	0.03	0.19	0.07	0.04	54.78	0.05	0.02	39.08	0.05	0.35	0.01	94.8316 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	43	Min 30-641	apatite	0.17	0.00	0.01	0.03	0.19	0.10	0.07	54.06	0.07	0.02	39.02	0.05	0.32	0.00	94.0977 (lt)
Musquodoboit E-23	1375	Top Logan Canyon	3	Min 30-761	chlorite	29.02	0.10	14.04	0.04	34.69	0.09	3.14	0.58	0.03	0.73	0.07	0.07	0.08	0.06	82.73
Musquodoboit E-23	1375	Top Logan Canyon	4	Min 30-762	chlorite	30.17	0.10	15.04	0.06	32.68	0.06	3.23	0.45	0.06	0.96	0.03	0.02	0.06	0.03	82.97
Musquodoboit E-23	960	Banquereau	1	Min 30-891	chloritoid	24.03	0.00	40.88	0.06	19.85	3.91	3.31	0.00	0.00	0.01	0.00	0.00	0.11	0.02	92.18
Musquodoboit E-23	960	Banquereau	2	Min 30-892	chloritoid	24.08	0.00	40.79	0.02	19.97	3.92	3.17	0.00	0.00	0.01	0.00	0.00	0.09	0.00	92.07
Musquodoboit E-23	1270	Dawson Canyon	5	Min 30-893	Chromian Spinel	0.00	0.05	48.78	20.23	14.05	0.18	17.99	0.02	0.00	0.01	0.00	0.27	0.00	0.02	101.6053 (ht)
Musquodoboit E-23	1270	Dawson Canyon	6	Min 30-896	Chromian Spinel	0.00	0.05	49.16	20.48	13.99	0.16	17.78	0.00	0.01	0.03	0.00	0.25	0.00	0.02	101.9505 (ht)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	3	Min 30-601	Chromian Spinel	0.00	0.07	31.66	39.38	13.77	0.28	14.76	0.05	0.02	0.02	0.03	0.16	0.23	0.07	100.50
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	4	Min 30-602	Chromian Spinel	0.00	0.08	31.84	39.23	13.92	0.30	14.66	0.07	0.03	0.02	0.00	0.13	0.15	0.08	100.51
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	7	Min 30-605	Chromian Spinel	0.00	0.10	50.66	19.50	12.08	0.14	18.36	0.06	0.03	0.02	0.01	0.25	0.00	0.00	101.20
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	8	Min 30-606	Chromian Spinel	0.00	0.10	49.93	20.22	12.18	0.15	18.25	0.04	0.03	0.02	0.00	0.23	0.04	0.03	101.24
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	9	Min 30-607	Chromian Spinel	0.30	0.11	39.19	30.96	13.28	0.22	13.04	0.07	0.01	0.04	0.04	0.16	0.12	0.00	97.5385 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	10	Min 30-608	Chromian Spinel	0.00	0.12	39.21	31.44	13.54	0.23	14.18	0.08	0.01	0.03	0.01	0.22	0.12	0.05	99.24
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	21	Min 30-619	Chromian Spinel	0.00	0.14	26.81	41.70	17.22	0.31	13.55	0.07	0.03	0.04	0.00	0.17	0.22	0.11	100.36
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	22	Min 30-620	Chromian Spinel	0.00	0.13	26.49	42.18	17.08	0.31	13.74	0.07	0.02	0.04	0.00	0.17	0.23	0.09	100.55
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	33	Min 30-631	Chromian Spinel	0.00	0.08	55.53	13.36	12.54	0.14	18.82	0.05	0.03	0.02	0.00	0.29	0.00	0.00	100.88
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	34	Min 30-632	Chromian Spinel	0.00	0.10	55.85	13.11	12.10	0.14	18.88	0.04	0.02	0.01	0.00	0.32	0.00	0.00	100.56
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	35	Min 30-633	Chromian Spinel	0.00	0.75	27.30	37.71	21.76	0.37	11.57	0.07	0.02	0.03	0.00	0.22	0.19	0.09	100.07
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	36	Min 30-634	Chromian Spinel	0.00	0.78	27.82	36.72	22.27	0.39	11.29	0.06	0.02	0.05	0.02	0.21	0.16	0.05	99.84
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	37	Min 30-635	Chromian Spinel	0.00	0.18	29.57	39.03	17.41	0.34	13.33	0.07	0.03	0.02	0.00	0.18	0.18	0.13	100.47
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	38	Min 30-636	Chromian Spinel	0.00	0.18	29.48	38.80	17.77	0.34	13.05	0.07	0.02	0.02	0.00	0.14	0.20	0.08	100.14
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	58	Min 30-656	Chromian Spinel	0.00	0.04	42.18	25.57	15.54	0.18	16.01	0.03	0.00	0.02	0.00	0.13	0.06	0.00	99.75
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	59	Min 30-657	Chromian Spinel	0.00	0.04	43.03	24.90	15.78	0.20	16.17	0.00	0.02	0.01	0.01	0.13	0.01	0.00	100.30
Musquodoboit E-23	2500A	Upper Missisauga	1	Min 30-873	Chromian Spinel	0.00	0.20	40.74	29.30	12.40	0.22	15.77	0.03	0.01	0.02	0.01	0.22	0.06	0.04	99.02
Musquodoboit E-23	2500A	Upper Missisauga	2	Min 30-874	Chromian Spinel	0.00	0.17	39.88	30.64	12.18	0.20	16.14	0.04	0.01	0.03	0.00	0.22	0.07	0.09	99.66
Musquodoboit E-23	2500A	Upper Missisauga	15	Min 30-887	Chromian Spinel	0.00	0.11	31.81	38.87	14.05	0.28	12.29	0.09	0.01	0.03	0.02	0.15	0.12	0.15	97.96
Musquodoboit E-23	2500A	Upper Missisauga	16	Min 30-888	Chromian Spinel	0.00	0.07	31.44	38.82	13.82	0.28	12.15	0.07	0.00	0.03	0.00	0.16	0.11	0.06	97.0223 (lt)
Musquodoboit E-23	2500B	Upper Missisauga	9	Min 30-833	Chromian Spinel	0.00	0.40	42.70	25.43	15.74	0.25	16.47	0.02	0.00	0.03	0.01	0.26	0.08	0.10	101.49
Musquodoboit E-23	2500B	Upper Missisauga	10	Min 30-834	Chromian Spinel	0.00	0.37	42.07	25.44	15.59	0.25	16.43	0.04	0.01	0.04	0.01	0.26	0.02	0.06	100.57
Musquodoboit E-23	2500B	Upper Missisauga	11	Min 30-835	Chromian Spinel	0.00	0.34	42.16	25.53	15.56	0.25	16.45	0.01	0.01	0.04	0.00	0.24	0.03	0.05	100.68
Musquodoboit E-23	2500B	Upper Missisauga	12	Min 30-836	Chromian Spinel	0.00	0.39	42.15	25.16	15.56	0.23	16.23	0.02	0.01	0.02	0.02	0.25	0.04	0.05	100.13
Musquodoboit E-23	2800	Middle Missisauga	5	Min 30-666	Chromian Spinel	0.00	0.37	32.98	33.67	20.67	0.28	13.66	0.06	0.04	0.05	0.03	0.19	0.12	0.12	102.2253 (ht)
Musquodoboit E-23	2800	Middle Missisauga	6	Min 30-667	Chromian Spinel	0.00	0.38	33.52	33.28	20.57	0.33	13.56	0.06	0.03	0.05	0.04	0.20	0.12	0.12	102.2472 (ht)
Musquodoboit E-23	2800	Middle Missisauga	25	Min 30-686	Chromian Spinel	0.00	0.10	38.12	32.57	15.25	0.24	15.04	0.06	0.02	0.04	0.04	0.14	0.12	0.08	101.8253 (ht)
Musquodoboit E-23	2800	Middle Missisauga	26	Min 30-687	Chromian Spinel	0.00	0.07	38.61	32.63	15.25	0.21	13.68	0.05	0.02	0.04	0.00	0.19	0.10	0.07	100.90
Musquodoboit E-23	2800	Middle Missisauga	59	Min 30-720	Chromian Spinel	0.02	0.11	36.72	34.64	14.48	0.28	15.61	0.05	0.03	0.04	0.03	0.19	0.18	0.07	102.4521 (ht)
Musquodoboit E-23	2800	Middle Missisauga	60	Min 30-721	Chromian Spinel	0.01	0.13	35.74	39.47	14.87	0.30	15.42	0.03	0.02	0.03	0.01	0.21	0.12	0.10	101.958 (ht)
Musquodoboit E-23	2800	Middle Missisauga	73	Min 30-734	Chromian Spinel	0.04	0.53	39.68	26.38	18.62	0.24	16.46	0.03	0.02	0.03	0.05	0.31	0.12	0.09	102.6132 (ht)
Musquodoboit E-23	2800	Middle Missisauga	74	Min 30-735	Chromian Spinel	0.03	0.49	39.68	26.43	18.64	0.25	16.37	0.04	0.02	0.03	0.30	0.13	0.05	102.4871 (ht)	
Musquodoboit E-23	2800	Middle Missisauga	77	Min 30-738	Chromian Spinel	0.02	0.10	35.53	35.41	14.70	0.29	15.51	0.04	0.04	0.04	0.03	0.19	0.19	0.04	102.1271 (ht)
Musquodoboit E-23	2800	Middle Missisauga	78	Min 30-739	Chromian Spinel	0.04	0.12	36.75	34.44	14.56	0.27	15.68	0.04	0.04	0.02	0.05	0.20	0.17	0.02	102.3926 (ht)
Musquodoboit E-23	2800	Middle Missisauga	89	Min 30-750	Chromian Spinel	0.04	0.51	36.87	32.67	15.92	0.27	12.57	0.04	0.03	0.04	0.04	0.20	0.15	0.09	99.45
Musquodoboit E-23	2800	Middle Missisauga	94	Min 30-755	Chromian Spinel	0.62	0.15	26.73	44.84	13.57	0.30	9.70	0.19	0.12	0.05	0.04	0.21	0.27	0.12	96.8951 (lt)
Musquodoboit E-23	2800	Middle Missisauga	95	Min 30-756	Chromian Spinel	0.43	0.14	28.50	46.02	13.32	0.30	8.87	0.10	0.13	0.04	0.04	0.16	0.26	0.04	98.35
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	5	Min 30-603	chromite	0.01	0.13	14.56	55.15	17.87	0.41	10.62	0.10	0.04	0.04	0.02	0.13	0.33	0.18	99.59
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	6	Min 30-604	chromite	0.03	0.16	14.70	55.31	18.50	0.40	10.44	0.13	0.03	0.04	0.00	0.14	0.32	0.18	100.37
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	23	Min 30-621	chromite	0.00	0.09	23.72	44.22	18.80	0.35	11.79	0.09	0.02	0.03	0.04	0.14	0.22	0.10	99.61
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	24	Min 30-622	chromite	0.00	0.07	24.03	44.11	18.94	0.40	11.85	0.09	0.03	0.04	0.03	0.16	0.25	0.10	100.09
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	50	Min 30-648	chromite	0.00	0.31	13.72	56.50	16.71	0.41	11.75	0.08	0.04	0.04	0.02	0.17	0.31	0.12	100.17
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	51	Min 30-649	chromite	0.00	0.30	13.78	56.56	17.00	0.40	11.54	0.09	0.00	0.03	0.03	0.128 (l)	0.35	0.09	100.32
Musquodoboit E-23	1800	Logan Canyon (C																		

Table 6: Electron microprobe chemical analyses of minerals.

Well	Depth (m)	Formation	Analysis No	File No	Mineral	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO _t	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SrO	NiO	BaO	Total
Musquodoboit E-23	2800	Middle Missisauga	47	Min 30-708	chromite	0.02	0.13	20.79	49.51	17.82	0.40	9.07	0.06	0.03	0.04	0.02	0.17	0.23	0.11	98.39
Musquodoboit E-23	2800	Middle Missisauga	48	Min 30-709	chromite	0.04	0.14	20.36	50.07	17.80	0.37	9.15	0.06	0.04	0.06	0.02	0.18	0.23	0.15	98.67
Musquodoboit E-23	2800	Middle Missisauga	75	Min 30-736	chromite	0.10	0.22	16.24	51.20	23.19	0.49	9.94	0.05	0.03	0.05	0.06	0.18	0.34	0.14	102.2271 (lt)
Musquodoboit E-23	2800	Middle Missisauga	76	Min 30-737	chromite	0.07	0.22	16.30	50.97	23.36	0.44	9.97	0.05	0.02	0.02	0.04	0.20	0.32	0.13	102.13 (ht)
Musquodoboit E-23	2800	Middle Missisauga	81	Min 30-742	chromite	0.11	0.20	10.56	59.68	18.94	0.56	10.41	0.07	0.04	0.05	0.03	0.19	0.33	0.18	101.34
Musquodoboit E-23	2800	Middle Missisauga	82	Min 30-743	chromite	0.07	0.22	10.96	59.81	18.87	0.51	10.36	0.05	0.05	0.05	0.06	0.18	0.38	0.13	101.72
Musquodoboit E-23	2800	Middle Missisauga	90	Min 30-751	chromite	0.09	0.52	16.05	42.01	34.78	0.54	7.31	0.06	0.04	0.05	0.03	0.24	0.29	0.16	102.1867 (ht)
Musquodoboit E-23	2800	Middle Missisauga	91	Min 30-752	chromite	0.08	0.53	16.50	40.36	34.96	0.54	7.19	0.06	0.03	0.06	0.08	0.24	0.32	0.19	101.12
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	27	Min 30-625	diopside (cpx)	54.52	0.02	0.44	0.00	0.70	0.01	17.90	25.48	0.24	0.00	0.00	0.00	0.36	0.00	99.66
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	28	Min 30-626	diopside (cpx)	54.61	0.00	0.45	0.00	0.68	0.00	17.79	25.54	0.27	0.00	0.00	0.00	0.38	0.00	99.73
Musquodoboit E-23	2600	Middle Missisauga	3	Min 30-775	diopside (cpx)	53.88	0.00	0.15	0.00	0.46	0.02	17.80	25.98	0.07	0.00	0.01	0.00	0.34	0.00	98.71
Musquodoboit E-23	2600	Middle Missisauga	4	Min 30-776	diopside (cpx)	53.70	0.00	0.16	0.00	0.40	0.00	18.05	26.39	0.07	0.02	0.02	0.02	0.33	0.00	99.17
Musquodoboit E-23	2600	Middle Missisauga	10	Min 30-782	diopside (cpx)	48.08	0.02	0.73	0.00	0.97	0.02	15.10	28.85	0.37	0.03	0.02	0.01	0.30	0.00	94.4841 (lt)
Musquodoboit E-23	2600	Middle Missisauga	11	Min 30-783	diopside (cpx)	53.87	0.00	0.11	0.00	0.69	0.02	17.65	26.13	0.05	0.03	0.03	0.00	0.35	0.00	98.93
Musquodoboit E-23	2600	Middle Missisauga	12	Min 30-784	diopside (cpx)	53.53	0.00	0.08	0.00	0.65	0.00	17.65	26.43	0.03	0.01	0.01	0.01	0.34	0.00	98.75
Musquodoboit E-23	2600	Middle Missisauga	19	Min 30-791	diopside (cpx)	53.82	0.00	0.41	0.00	0.40	0.00	17.54	26.04	0.20	0.01	0.01	0.01	0.34	0.00	98.79
Musquodoboit E-23	2600	Middle Missisauga	20	Min 30-792	diopside (cpx)	53.65	0.00	0.56	0.00	0.37	0.01	17.61	25.87	0.26	0.02	0.03	0.00	0.36	0.00	98.74
Musquodoboit E-23	2600	Middle Missisauga	23	Min 30-795	diopside (cpx)	53.14	0.02	0.88	0.00	0.58	0.00	17.59	25.73	0.29	0.01	0.00	0.01	0.36	0.00	98.62
Musquodoboit E-23	2600	Middle Missisauga	24	Min 30-796	diopside (cpx)	54.01	0.00	0.38	0.00	0.54	0.01	17.38	26.19	0.17	0.02	0.00	0.00	0.36	0.00	99.07
Musquodoboit E-23	2600	Middle Missisauga	29	Min 30-801	diopside (cpx)	53.66	0.00	0.32	0.00	0.44	0.03	17.72	25.93	0.15	0.01	0.04	0.00	0.35	0.00	98.64
Musquodoboit E-23	2600	Middle Missisauga	30	Min 30-802	diopside (cpx)	54.31	0.01	0.39	0.02	0.42	0.04	17.93	25.90	0.18	0.02	0.00	0.01	0.34	0.00	99.56
Musquodoboit E-23	2600	Middle Missisauga	34	Min 30-806	diopside (cpx)	54.07	0.03	0.41	0.00	0.52	0.03	18.14	25.90	0.14	0.03	0.00	0.00	0.30	0.00	99.56
Musquodoboit E-23	2600	Middle Missisauga	36	Min 30-808	diopside (cpx)	54.05	0.00	0.16	0.00	0.48	0.03	18.16	26.29	0.09	0.01	0.00	0.00	0.34	0.00	99.61
Musquodoboit E-23	2600	Middle Missisauga	38	Min 30-810	diopside (cpx)	54.20	0.00	0.23	0.00	0.42	0.03	18.10	26.11	0.10	0.03	0.00	0.03	0.35	0.00	99.61
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	1	Min 30-599	Garnet (almandine)	37.04	0.04	20.65	0.03	28.55	1.95	6.62	2.73	0.03	0.05	0.04	0.04	0.26	0.02	98.04
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	2	Min 30-600	Garnet (almandine)	36.92	0.05	20.47	0.02	28.62	2.06	6.65	2.79	0.01	0.02	0.03	0.01	0.27	0.03	97.9629 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	11	Min 30-609	Garnet (almandine)	36.86	0.05	20.09	0.02	24.54	1.05	6.23	8.33	0.01	0.02	0.02	0.02	0.24	0.00	97.4786 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	12	Min 30-610	Garnet (almandine)	36.45	0.11	19.90	0.01	24.35	1.03	6.19	8.57	0.01	0.04	0.03	0.02	0.24	0.01	96.9696 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	13	Min 30-611	Garnet (almandine)	36.68	0.11	20.40	0.02	29.99	1.69	4.76	4.36	0.01	0.03	0.03	0.01	0.24	0.01	98.35
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	14	Min 30-612	Garnet (almandine)	36.03	0.07	20.18	0.02	29.82	1.76	4.74	4.35	0.00	0.02	0.06	0.05	0.25	0.00	97.3529 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	15	Min 30-613	Garnet (almandine)	37.13	0.02	20.54	0.00	24.86	0.49	6.17	8.16	0.00	0.03	0.04	0.01	0.21	0.01	97.6693 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	16	Min 30-614	Garnet (almandine)	37.00	0.07	20.81	0.01	24.30	0.49	5.94	8.78	0.00	0.02	0.04	0.03	0.24	0.01	97.7683 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	17	Min 30-615	Garnet (almandine)	35.61	0.27	18.24	0.03	18.28	10.95	0.68	12.65	0.02	0.03	0.03	0.05	0.27	0.06	97.1797 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	18	Min 30-616	Garnet (almandine)	35.68	0.18	18.70	0.01	17.87	11.20	0.66	12.79	0.03	0.03	0.02	0.02	0.19	0.00	97.3815 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	39	Min 30-637	Garnet (almandine)	35.58	0.11	19.48	0.02	18.45	13.12	1.44	8.61	0.04	0.03	0.05	0.01	0.22	0.06	97.1977 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	40	Min 30-638	Garnet (almandine)	35.55	0.11	19.17	0.02	18.92	12.39	1.41	8.97	0.03	0.03	0.02	0.06	0.28	0.05	97.0014 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	41	Min 30-639	Garnet (almandine)	35.56	0.16	19.41	0.02	18.57	13.08	1.43	8.65	0.02	0.03	0.04	0.05	0.30	0.07	97.3881 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	52	Min 30-650	Garnet (almandine)	37.41	0.03	20.63	0.05	22.55	0.57	5.38	11.20	0.02	0.01	0.05	0.00	0.27	0.02	98.18
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	53	Min 30-651	Garnet (almandine)	37.23	0.07	20.49	0.01	22.81	0.63	5.29	11.13	0.00	0.03	0.01	0.01	0.21	0.07	97.9873 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	54	Min 30-652	Garnet (almandine)	36.62	0.07	20.24	0.07	28.58	0.73	4.50	6.73	0.00	0.02	0.03	0.03	0.25	0.00	97.8773 (lt)
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	55	Min 30-653	Garnet (almandine)	36.47	0.05	20.34	0.08	28.66	0.71	4.42	6.86	0.00	0.03	0.03	0.03	0.26	0.00	97.9384 (lt)
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	3	Min 30-843	Garnet (almandine)	36.19	0.12	20.23	0.08	31.10	0.82	0.87	8.99	0.01	0.04	0.04	0.04	0.32	0.00	98.86
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	4	Min 30-844	Garnet (almandine)	36.44	0.10	20.44	0.05	31.06	0.75	0.95	8.82	0.02	0.03	0.00	0.04	0.28	0.00	98.99
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	5	Min 30-845	Garnet (almandine)	37.43	0.08	20.91	0.04	24.68	0.82	7.30	7.02	0.01	0.04	0.02	0.03	0.28	0.00	98.66
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	6	Min 30-846	Garnet (almandine)	37.42	0.05	20.84	0.06	24.51	0.84	7.29	6.92	0.01	0.03	0.04	0.05	0.31	0.00	98.38
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	7	Min 30-847	Garnet (almandine)	37.79	0.03	21.65	0.07	27.55	0.33	10.06	1.09	0.01	0.04	0.08	0.00	0.27	0.00	98.96
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	8	Min 30-848	Garnet (almandine)	37.58	0.03	21.52	0.06	27.27	0.34	9.97	1.11	0.00	0.03	0.07	0.02	0.25	0.00	98.26
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	9	Min 30-849	Garnet (almandine)	36.16	0.03	20.63	0.07	33.64	3.93	2.41	1.46	0.00	0.06	0.03	0.06	0.27	0.00	98.75
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	10	Min 30-850	Garnet (almandine)	36.01	0.01	20.54	0.10	33.66	3.88	2.57	1.50	0.01	0.05	0.03	0.05	0.30	0.00	98.70
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	11	Min 30-851	Garnet (almandine)	36.18	0.07	21.15	0.14	28.80	0.53	8.61	1.37	0.03	0.04	0.03	0.04	0.27	0.00	97.2468 (lt)
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	12	Min 30-852	Garnet (almandine)	35.49	0.02	20.74	0.11	28.43	0.60	8.59	1.32	0.00	0.03	0.09	0.00	0.26	0.00	95.68 (lt)
Musquodoboit E																				

Table 6: Electron microprobe chemical analyses of minerals.

Well	Depth (m)	Formation	Analysis No	File No	Mineral	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO _t	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SrO	NiO	BaO	Total	
Musquodoboit E-23	2190	Logan Canyon (lower Creek)	23	Min 30-863	Garnet (almandine)	36.47	0.04	20.70	0.10	33.10	2.28	4.21	1.26	0.01	0.05	0.05	0.04	0.31	0.00	98.62	
Musquodoboit E-23	2190	Logan Canyon (lower Creek)	24	Min 30-864	Garnet (almandine)	36.34	0.03	20.74	0.06	33.06	2.27	4.19	1.31	0.00	0.04	0.05	0.05	0.28	0.00	98.42	
Musquodoboit E-23	2190	Logan Canyon (lower Creek)	27	Min 30-867	Garnet (almandine)	37.52	0.06	20.74	0.07	23.81	1.01	6.15	8.98	0.00	0.03	0.03	0.03	0.28	0.00	98.71	
Musquodoboit E-23	2190	Logan Canyon (lower Creek)	28	Min 30-868	Garnet (almandine)	37.26	0.09	20.56	0.07	23.37	1.02	5.97	9.64	0.00	0.03	0.03	0.01	0.31	0.00	98.36	
Musquodoboit E-23	2190	Logan Canyon (lower Creek)	31	Min 30-871	Garnet (almandine)	37.29	0.05	20.68	0.06	22.89	2.96	5.65	8.83	0.00	0.05	0.01	0.02	0.29	0.00	98.77	
Musquodoboit E-23	2190	Logan Canyon (lower Creek)	32	Min 30-872	Garnet (almandine)	37.36	0.03	20.79	0.05	22.63	2.74	5.93	8.77	0.01	0.04	0.00	0.00	0.27	0.00	98.62	
Musquodoboit E-23	2500A	Upper Missisauga	3	Min 30-875	Garnet (almandine)	37.56	0.04	20.84	0.05	24.09	1.30	6.22	8.43	0.00	0.04	0.01	0.01	0.25	0.00	98.83	
Musquodoboit E-23	2500A	Upper Missisauga	4	Min 30-876	Garnet (almandine)	37.40	0.08	20.84	0.03	23.98	1.30	6.08	8.51	0.00	0.03	0.00	0.03	0.25	0.00	98.54	
Musquodoboit E-23	2500A	Upper Missisauga	11	Min 30-883	Garnet (almandine)	37.56	0.06	20.34	0.00	23.82	0.75	6.46	8.58	0.01	0.02	0.00	0.00	0.26	0.00	97.8742 (lt)	
Musquodoboit E-23	2500A	Upper Missisauga	12	Min 30-884	Garnet (almandine)	37.56	0.06	20.41	0.01	23.61	0.78	6.39	9.00	0.00	0.02	0.00	0.00	0.23	0.00	98.09	
Musquodoboit E-23	2500A	Upper Missisauga	17	Min 30-889	Garnet (almandine)	37.12	0.03	21.08	0.00	30.02	0.31	7.61	1.69	0.01	0.02	0.01	0.01	0.20	0.00	98.11	
Musquodoboit E-23	2500A	Upper Missisauga	18	Min 30-890	Garnet (almandine)	37.04	0.00	21.00	0.01	29.81	0.32	7.52	1.83	0.01	0.03	0.00	0.00	0.24	0.00	97.8032 (lt)	
Musquodoboit E-23	2500B	Upper Missisauga	1	Min 30-825	Garnet (almandine)	37.59	0.04	20.66	0.05	25.19	0.86	6.38	7.48	0.00	0.04	0.05	0.02	0.25	0.00	98.61	
Musquodoboit E-23	2500B	Upper Missisauga	2	Min 30-826	Garnet (almandine)	37.58	0.08	20.73	0.08	25.14	0.84	6.39	7.61	0.01	0.03	0.03	0.04	0.28	0.00	98.84	
Musquodoboit E-23	2500B	Upper Missisauga	3	Min 30-827	Garnet (almandine)	36.53	0.09	19.59	0.04	22.04	7.09	1.76	10.83	0.01	0.03	0.04	0.06	0.28	0.00	98.42	
Musquodoboit E-23	2500B	Upper Missisauga	4	Min 30-828	Garnet (almandine)	36.48	0.08	19.64	0.07	21.93	7.46	1.68	10.62	0.02	0.03	0.01	0.06	0.27	0.00	98.35	
Musquodoboit E-23	2500B	Upper Missisauga	5	Min 30-829	Garnet (almandine)	37.20	0.05	20.42	0.05	25.95	1.75	5.93	6.86	0.02	0.03	0.02	0.02	0.26	0.00	98.55	
Musquodoboit E-23	2500B	Upper Missisauga	6	Min 30-830	Garnet (almandine)	37.11	0.07	20.55	0.05	26.23	1.78	5.90	6.82	0.00	0.04	0.04	0.04	0.27	0.00	98.89	
Musquodoboit E-23	2500B	Upper Missisauga	15	Min 30-839	Garnet (almandine)	37.83	0.05	21.13	0.05	23.78	0.63	8.39	6.48	0.00	0.02	0.06	0.00	0.25	0.00	98.67	
Musquodoboit E-23	2500B	Upper Missisauga	16	Min 30-840	Garnet (almandine)	37.80	0.08	21.09	0.05	23.67	0.55	8.34	6.51	0.01	0.02	0.01	0.00	0.27	0.00	98.40	
Musquodoboit E-23	2600	Middle Missisauga	1	Min 30-773	Garnet (almandine)	37.67	0.02	21.21	0.04	30.14	0.35	8.15	1.44	0.00	0.01	0.03	0.01	0.27	0.01	99.35	
Musquodoboit E-23	2600	Middle Missisauga	2	Min 30-774	Garnet (almandine)	37.67	0.02	21.29	0.04	30.02	0.40	8.14	1.42	0.01	0.03	0.05	0.03	0.20	0.05	99.37	
Musquodoboit E-23	2600	Middle Missisauga	5	Min 30-777	Garnet (almandine)	37.68	0.01	21.33	0.00	28.27	0.60	8.67	1.82	0.03	0.03	0.04	0.00	0.23	0.00	98.71	
Musquodoboit E-23	2600	Middle Missisauga	6	Min 30-778	Garnet (almandine)	37.47	0.00	21.39	0.03	28.10	0.59	8.80	1.69	0.01	0.03	0.08	0.00	0.22	0.01	98.43	
Musquodoboit E-23	2600	Middle Missisauga	7	Min 30-779	Garnet (almandine)	37.92	0.02	21.35	0.00	28.38	0.61	9.05	1.39	0.01	0.03	0.02	0.00	0.22	0.04	99.03	
Musquodoboit E-23	2600	Middle Missisauga	31	Min 30-803	Garnet (almandine)	36.02	0.07	20.57	0.05	24.76	12.97	2.42	1.42	0.02	0.03	0.01	0.03	0.27	0.02	98.66	
Musquodoboit E-23	2600	Middle Missisauga	32	Min 30-804	Garnet (almandine)	36.06	0.13	20.47	0.02	24.27	14.09	2.37	1.02	0.03	0.03	0.08	0.01	0.25	0.02	98.85	
Musquodoboit E-23	2600	Middle Missisauga	50	Min 30-822	Garnet (almandine)	37.47	0.17	20.29	0.01	24.55	1.58	6.30	7.93	0.03	0.03	0.02	0.03	0.26	0.03	98.70	
Musquodoboit E-23	2600	Middle Missisauga	51	Min 30-823	Garnet (almandine)	37.48	0.15	20.22	0.02	24.60	1.56	6.26	7.94	0.03	0.03	0.02	0.00	0.24	0.02	98.54	
Musquodoboit E-23	2600	Middle Missisauga	52	Min 30-824	Garnet (almandine)	37.41	0.18	20.10	0.03	24.44	1.54	6.23	7.90	0.01	0.03	0.01	0.02	0.23	0.00	98.14	
Musquodoboit E-23	2800	Middle Missisauga	1	Min 30-662	Garnet (almandine)	37.19	0.01	21.17	0.00	32.48	2.07	4.70	1.87	0.02	0.04	0.00	0.00	0.15	0.00	99.69	
Musquodoboit E-23	2800	Middle Missisauga	2	Min 30-663	Garnet (almandine)	37.38	0.00	21.06	0.04	32.76	2.02	4.60	1.92	0.03	0.02	0.00	0.00	0.18	0.00	100.04	
Musquodoboit E-23	2800	Middle Missisauga	15	Min 30-676	Garnet (almandine)	36.61	0.00	20.94	0.00	31.98	7.43	2.58	0.87	0.01	0.01	0.04	0.00	0.26	0.00	100.73	
Musquodoboit E-23	2800	Middle Missisauga	16	Min 30-677	Garnet (almandine)	36.38	0.09	20.77	0.03	30.35	8.47	2.70	0.92	0.03	0.03	0.06	0.00	0.22	0.00	100.05	
Musquodoboit E-23	2800	Middle Missisauga	39	Min 30-700	Garnet (almandine)	36.69	0.00	21.10	0.00	32.07	1.92	3.45	4.42	0.02	0.01	0.00	0.00	0.18	0.00	99.85	
Musquodoboit E-23	2800	Middle Missisauga	40	Min 30-701	Garnet (almandine)	36.62	0.02	20.97	0.00	32.15	1.98	3.41	4.51	0.02	0.03	0.00	0.00	0.22	0.00	99.93	
Musquodoboit E-23	2800	Middle Missisauga	45	Min 30-706	Garnet (almandine)	36.97	0.05	21.22	0.01	32.23	2.76	4.54	1.67	0.00	0.02	0.00	0.00	0.17	0.00	99.63	
Musquodoboit E-23	2800	Middle Missisauga	46	Min 30-707	Garnet (almandine)	36.80	0.01	21.00	0.01	32.52	2.83	4.45	1.63	0.02	0.01	0.00	0.03	0.19	0.00	99.51	
Musquodoboit E-23	2800	Middle Missisauga	51	Min 30-712	Garnet (almandine)	36.34	0.01	20.86	0.00	33.09	4.99	2.43	1.54	0.03	0.02	0.00	0.01	0.17	0.02	99.50	
Musquodoboit E-23	2800	Middle Missisauga	52	Min 30-713	Garnet (almandine)	36.72	0.03	20.81	0.01	33.26	4.86	2.40	1.50	0.02	0.02	0.00	0.00	0.20	0.00	99.84	
Musquodoboit E-23	2800	Middle Missisauga	61	Min 30-722	Garnet (almandine)	36.70	0.01	20.80	0.00	31.85	4.38	3.05	2.75	0.01	0.02	0.01	0.00	0.19	0.00	99.77	
Musquodoboit E-23	2800	Middle Missisauga	62	Min 30-723	Garnet (almandine)	36.62	0.02	20.94	0.00	32.65	4.03	3.22	2.06	0.01	0.02	0.00	0.00	0.20	0.00	99.78	
Musquodoboit E-23	2800	Middle Missisauga	63	Min 30-724	Garnet (almandine)	37.10	0.15	21.14	0.17	31.02	2.24	5.85	1.53	0.00	0.02	0.04	0.00	0.22	0.02	99.50	
Musquodoboit E-23	2800	Middle Missisauga	64	Min 30-725	Garnet (almandine)	37.08	0.15	21.12	0.18	31.06	2.33	5.62	1.60	0.02	0.02	0.03	0.00	0.15	0.00	99.38	
Musquodoboit E-23	2800	Middle Missisauga	65	Min 30-726	Garnet (almandine)	36.33	0.01	20.83	0.00	31.16	7.47	3.06	0.59	0.07	0.03	0.06	0.00	0.23	0.00	99.84	
Musquodoboit E-23	2800	Middle Missisauga	66	Min 30-727	Garnet (almandine)	36.37	0.00	21.04	0.01	31.08	7.32	3.01	0.82	0.02	0.01	0.01	0.00	0.21	0.00	99.91	
Musquodoboit E-23	2800	Middle Missisauga	92	Min 30-753	Garnet (almandine)	35.97	0.01	20.57	0.13	27.76	13.38	0.75	1.09	0.02	0.02	0.00	0.00	0.20	0.00	99.90	
Musquodoboit E-23	2800	Middle Missisauga	93	Min 30-754	Garnet (almandine)	35.87	0.02	20.48	0.03	27.63	13.61	0.77	0.99	0.04	0.01	0.03	0.00	0.18	0.00	99.64	
Musquodoboit E-23	2800	Middle Missisauga	13	Min 30-674	Garnet (spessartine)	36.14	0.07	20.55	0.00	19.65	18.56	1.91	2.33	0.04	0.02	0.00	0.00	0.19	0.00	99.46	
Musquodoboit E-23	2800	Middle Missisauga	14	Min 30-675	Garnet (spessartine)	36.33	0.03	20.80	0.00	19.76	18.33	2.06	2.17	0.05	0.02	0.00	0.00	0.22	0.00	99.77	
Musquodoboit E-23	2800	Middle Missisauga	37	Min 30-698	muscovite	45.54	0.40	32.59	0.00	3.70	0.00	1.08	0.01	0.39	9.49	0.00	0.00	0.00	0.02	0.00	93.21
Musquodoboit E-23	2800	Middle Missisauga	38	Min 30-699	muscovite	45.17	0.38	32.88	0.00	3.83	0.00										

Table 6: Electron microprobe chemical analyses of minerals.

Well	Depth (m)	Formation	Analysis No	File No	Mineral	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO _t	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SrO	NiO	BaO	Total
Musquodoboit E-23	1375	Top Logan Canyon	12	Min 30-770	tourmaline	34.08	0.12	35.20	0.00	13.29	0.16	0.78	0.05	1.75	0.06	0.02	0.00	0.14	0.00	85.65
Musquodoboit E-23	1375	Top Logan Canyon	13	Min 30-771	tourmaline	35.90	0.36	33.84	0.00	6.85	0.02	6.00	0.06	2.03	0.03	0.00	0.00	0.16	0.00	85.24
Musquodoboit E-23	1375	Top Logan Canyon	14	Min 30-772	tourmaline	36.03	0.89	32.93	0.00	7.08	0.02	6.22	0.10	2.28	0.04	0.02	0.00	0.15	0.00	85.75
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	19	Min 30-617	tourmaline	36.09	0.88	35.06	0.00	6.00	0.00	5.74	0.29	1.85	0.02	0.00	0.00	0.17	0.00	86.10
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	20	Min 30-618	tourmaline	36.21	0.82	35.09	0.00	5.93	0.00	5.85	0.31	1.84	0.03	0.00	0.00	0.15	0.00	86.24
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	25	Min 30-623	tourmaline	34.39	0.35	34.94	0.00	10.50	0.05	2.97	0.58	1.73	0.05	0.00	0.00	0.15	0.00	85.73
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	26	Min 30-624	tourmaline	34.70	0.42	34.78	0.00	11.02	0.08	2.76	0.54	1.75	0.04	0.00	0.00	0.14	0.00	86.25
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	29	Min 30-627	tourmaline	35.66	0.53	34.04	0.00	8.12	0.01	5.03	0.41	1.99	0.02	0.00	0.00	0.17	0.00	85.97
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	30	Min 30-628	tourmaline	35.43	0.48	34.07	0.00	8.25	0.00	5.06	0.51	2.01	0.03	0.00	0.00	0.18	0.00	86.01
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	31	Min 30-629	tourmaline	35.65	0.84	34.89	0.00	5.56	0.00	6.15	0.61	1.66	0.02	0.00	0.00	0.20	0.00	85.59
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	32	Min 30-630	tourmaline	36.15	0.78	34.68	0.01	5.74	0.00	6.18	0.56	1.65	0.00	0.00	0.00	0.14	0.00	85.89
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	44	Min 30-642	tourmaline	36.00	0.66	34.44	0.00	5.29	0.00	6.60	0.63	1.84	0.02	0.00	0.00	0.12	0.00	85.61
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	45	Min 30-643	tourmaline	35.92	0.70	34.84	0.00	5.38	0.00	6.61	0.65	1.85	0.01	0.00	0.00	0.16	0.00	86.12
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	46	Min 30-644	tourmaline	35.30	0.81	35.07	0.00	7.17	0.01	4.71	0.38	1.80	0.04	0.00	0.00	0.13	0.00	85.43
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	47	Min 30-645	tourmaline	35.83	0.65	35.80	0.00	7.47	0.00	4.37	0.30	1.77	0.04	0.00	0.00	0.16	0.00	86.39
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	48	Min 30-646	tourmaline	34.46	0.62	27.18	0.00	13.63	0.11	5.57	1.52	1.95	0.10	0.00	0.00	0.17	0.00	85.30
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	49	Min 30-647	tourmaline	34.44	0.62	27.08	0.00	13.99	0.11	5.62	1.42	1.97	0.09	0.00	0.00	0.18	0.00	85.52
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	60	Min 30-658	tourmaline	35.37	0.55	34.69	0.00	9.87	0.06	2.96	0.03	1.78	0.03	0.01	0.00	0.13	0.00	85.49
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	61	Min 30-659	tourmaline	35.41	0.12	35.29	0.00	11.14	0.04	2.06	0.04	1.64	0.02	0.00	0.00	0.12	0.00	85.87
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	62	Min 30-660	tourmaline	35.83	0.69	34.31	0.00	6.17	0.00	6.05	0.33	1.94	0.02	0.00	0.00	0.15	0.00	85.50
Musquodoboit E-23	1800	Logan Canyon (Cree Mbr)	63	Min 30-661	tourmaline	35.88	0.66	34.40	0.00	5.80	0.00	6.18	0.30	1.98	0.00	0.00	0.00	0.15	0.00	85.34
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	1	Min 30-841	tourmaline	35.56	0.24	31.80	0.00	7.63	0.05	7.01	0.70	2.00	0.05	0.00	0.00	0.14	0.00	85.17
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	2	Min 30-842	tourmaline	35.21	0.26	32.32	0.00	7.64	0.07	6.70	0.52	2.07	0.06	0.00	0.00	0.14	0.00	85.00
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	29	Min 30-869	tourmaline	35.59	0.42	32.84	0.00	6.42	0.01	6.87	0.25	2.33	0.05	0.00	0.00	0.12	0.00	84.89
Musquodoboit E-23	2190	Logan Canyon (lower Cree)	30	Min 30-870	tourmaline	35.75	0.38	32.94	0.00	6.25	0.01	6.86	0.22	2.32	0.03	0.00	0.00	0.11	0.00	84.88
Musquodoboit E-23	2500A	Upper Missisauga	5	Min 30-877	tourmaline	35.18	0.20	33.10	0.00	7.20	0.04	6.96	1.01	1.83	0.06	0.00	0.00	0.15	0.00	85.72
Musquodoboit E-23	2500A	Upper Missisauga	6	Min 30-878	tourmaline	35.00	0.20	32.81	0.00	7.20	0.06	6.96	1.01	1.81	0.04	0.00	0.00	0.15	0.00	85.24
Musquodoboit E-23	2500A	Upper Missisauga	13	Min 30-885	tourmaline	34.46	0.10	34.25	0.00	11.98	0.06	2.16	0.20	1.91	0.06	0.05	0.00	0.09	0.00	85.32
Musquodoboit E-23	2500A	Upper Missisauga	14	Min 30-886	tourmaline	34.32	0.13	34.17	0.00	12.23	0.10	2.19	0.22	1.91	0.05	0.02	0.00	0.15	0.00	85.48
Musquodoboit E-23	2500B	Upper Missisauga	7	Min 30-831	tourmaline	34.97	0.17	34.76	0.00	11.84	0.15	1.96	0.08	1.74	0.05	0.00	0.00	0.12	0.00	85.85
Musquodoboit E-23	2500B	Upper Missisauga	8	Min 30-832	tourmaline	34.94	0.20	34.76	0.00	11.89	0.16	2.02	0.10	1.86	0.05	0.00	0.00	0.11	0.00	86.09
Musquodoboit E-23	2500B	Upper Missisauga	13	Min 30-837	tourmaline	35.34	0.93	34.73	0.00	7.19	0.03	5.13	0.53	1.82	0.05	0.00	0.00	0.10	0.00	85.85
Musquodoboit E-23	2500B	Upper Missisauga	14	Min 30-838	tourmaline	35.44	0.88	34.78	0.00	7.21	0.05	4.94	0.50	1.79	0.05	0.00	0.00	0.12	0.00	85.75
Musquodoboit E-23	2600	Middle Missisauga	39	Min 30-811	tourmaline	35.13	0.98	33.53	0.00	8.22	0.07	5.29	0.52	1.91	0.04	0.00	0.00	0.11	0.00	85.81
Musquodoboit E-23	2600	Middle Missisauga	40	Min 30-812	tourmaline	35.20	0.95	33.37	0.00	8.39	0.09	5.27	0.48	1.95	0.05	0.00	0.00	0.08	0.00	85.82
Musquodoboit E-23	2600	Middle Missisauga	43	Min 30-815	tourmaline	35.62	0.45	35.37	0.00	5.68	0.02	6.13	0.56	1.88	0.04	0.00	0.00	0.08	0.00	85.83
Musquodoboit E-23	2600	Middle Missisauga	44	Min 30-816	tourmaline	35.23	0.60	35.38	0.00	5.75	0.00	6.22	0.84	1.90	0.05	0.00	0.00	0.09	0.00	86.06
Musquodoboit E-23	2600	Middle Missisauga	45	Min 30-817	tourmaline	33.76	2.24	30.26	0.01	13.78	0.03	3.44	0.25	1.99	0.03	0.00	0.01	0.24	0.00	86.03
Musquodoboit E-23	2800	Middle Missisauga	7	Min 30-668	tourmaline	35.21	0.33	36.60	0.00	8.05	0.00	4.13	0.50	1.72	0.09	0.01	0.00	0.11	0.00	86.75
Musquodoboit E-23	2800	Middle Missisauga	8	Min 30-669	tourmaline	36.01	0.26	34.34	0.00	8.51	0.01	5.08	0.42	1.91	0.07	0.04	0.00	0.13	0.00	86.80
Musquodoboit E-23	2800	Middle Missisauga	9	Min 30-670	tourmaline	35.53	0.35	33.58	0.00	8.71	0.12	5.47	0.62	1.95	0.07	0.00	0.00	0.12	0.00	86.51
Musquodoboit E-23	2800	Middle Missisauga	10	Min 30-671	tourmaline	35.32	0.33	33.46	0.00	8.78	0.10	5.47	0.60	1.92	0.07	0.00	0.00	0.11	0.00	86.16
Musquodoboit E-23	2800	Middle Missisauga	11	Min 30-672	tourmaline	35.54	0.40	34.89	0.00	10.32	0.02	3.69	0.32	2.06	0.07	0.01	0.00	0.12	0.00	87.44
Musquodoboit E-23	2800	Middle Missisauga	12	Min 30-673	tourmaline	35.34	0.93	34.57	0.00	9.17	0.00	4.50	0.51	2.08	0.07	0.00	0.00	0.09	0.00	87.26
Musquodoboit E-23	2800	Middle Missisauga	17	Min 30-678	tourmaline	35.91	1.13	33.53	0.00	7.50	0.01	5.77	0.81	1.75	0.05	0.00	0.00	0.12	0.00	86.57
Musquodoboit E-23	2800	Middle Missisauga	18	Min 30-679	tourmaline	35.41	1.23	33.76	0.00	7.68	0.02	5.85	0.92	1.75	0.06	0.00	0.00	0.14	0.00	86.81
Musquodoboit E-23	2800	Middle Missisauga	19	Min 30-680	tourmaline	35.02	0.71	35.31	0.23	8.66	0.00	3.62	0.48	1.71	0.05	0.00	0.00	0.13	0.00	85.94
Musquodoboit E-23	2800	Middle Missisauga	20	Min 30-681	tourmaline	35.37	0.71	35.45	0.45	8.62	0.00	3.62	0.43	1.70	0.05	0.00	0.00	0.16	0.00	86.56
Musquodoboit E-23	2800	Middle Missisauga	21	Min 30-682	tourmaline	36.48	0.12	35.84	0.00	9.00	0.00	3.99	0.14	1.05	0.04	0.01	0.00	0.22	0.00	86.90
Musquodoboit E-23	2800	Middle Missisauga	22	Min 30-683	tourmaline	36.49	0.14	35.92	0.00	8.10	0.00	4.56	0.19	1.20	0.01	0.00	0.00	0.29	0.00	86.91
Musquodoboit E-23	2800	Middle Missisauga	23	Min 30-684	tourmaline	35.43	0.81	34.97	0.00	7.39	0.01	5.48	1.02	1.67	0.05	0.00	0.00	0.11	0.00	86.94
Musquodoboit E-23	2800	Middle Missisauga	24	Min 30-685	tourmaline	35.34	0.84	34.99	0.00	7.29	0.00	5.56	0.99	1.66	0.06	0.00	0.00	0.16	0.00	86.90
Musquodoboit E-23	2800	Middle Missisauga	27	Min 30-688	tourmaline	35.57</td														

Table 6: Electron microprobe chemical analyses of minerals.

Well	Depth (m)	Formation	Analysis No	File No	Mineral	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO _t	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SrO	NiO	BaO	Total
Musquodoboit E-23	2800	Middle Missisauga	36	Min 30-697	tourmaline	35.85	0.73	34.71	0.00	6.16	0.00	6.30	0.89	1.88	0.06	0.00	0.00	0.13	0.00	86.71
Musquodoboit E-23	2800	Middle Missisauga	41	Min 30-702	tourmaline	36.04	0.66	33.94	0.00	6.36	0.00	6.80	0.66	1.92	0.03	0.00	0.00	0.17	0.00	86.58
Musquodoboit E-23	2800	Middle Missisauga	42	Min 30-703	tourmaline	35.81	0.48	35.35	0.00	5.32	0.00	6.67	0.63	1.81	0.03	0.00	0.00	0.14	0.00	86.23
Musquodoboit E-23	2800	Middle Missisauga	43	Min 30-704	tourmaline	35.77	0.40	32.59	0.00	6.09	0.00	7.95	0.90	2.17	0.12	0.00	0.00	0.14	0.00	86.13
Musquodoboit E-23	2800	Middle Missisauga	44	Min 30-705	tourmaline	35.71	0.55	31.15	0.00	7.35	0.00	7.86	0.50	2.41	0.04	0.00	0.00	0.19	0.00	85.75
Musquodoboit E-23	2800	Middle Missisauga	49	Min 30-710	tourmaline	34.23	0.83	28.49	0.00	15.20	0.02	4.49	2.69	1.33	0.09	0.02	0.01	0.18	0.00	87.56
Musquodoboit E-23	2800	Middle Missisauga	50	Min 30-711	tourmaline	34.51	0.96	27.31	0.01	15.96	0.02	4.90	2.49	1.41	0.08	0.01	0.02	0.22	0.00	87.88
Musquodoboit E-23	2800	Middle Missisauga	53	Min 30-714	tourmaline	35.79	0.57	32.31	0.02	7.55	0.00	7.22	0.47	2.38	0.02	0.00	0.00	0.15	0.00	86.49
Musquodoboit E-23	2800	Middle Missisauga	54	Min 30-715	tourmaline	35.51	0.56	33.71	0.02	8.20	0.00	6.05	0.63	1.91	0.02	0.00	0.00	0.19	0.00	86.80
Musquodoboit E-23	2800	Middle Missisauga	55	Min 30-716	tourmaline	35.26	0.65	33.11	0.13	6.25	0.00	7.10	1.05	1.76	0.02	0.01	0.00	0.18	0.00	85.51
Musquodoboit E-23	2800	Middle Missisauga	56	Min 30-717	tourmaline	35.31	0.60	33.92	0.09	6.29	0.00	7.00	1.08	1.75	0.00	0.02	0.00	0.16	0.00	86.23
Musquodoboit E-23	2800	Middle Missisauga	57	Min 30-718	tourmaline	36.42	0.74	35.66	0.00	4.99	0.02	6.81	0.47	1.90	0.03	0.03	0.00	0.17	0.00	87.23
Musquodoboit E-23	2800	Middle Missisauga	58	Min 30-719	tourmaline	36.16	0.67	35.55	0.00	5.00	0.03	6.69	0.39	1.91	0.01	0.01	0.00	0.19	0.00	86.63
Musquodoboit E-23	2800	Middle Missisauga	67	Min 30-728	tourmaline	35.23	1.07	34.81	0.00	8.07	0.04	5.10	0.74	1.70	0.05	0.03	0.00	0.19	0.00	87.03
Musquodoboit E-23	2800	Middle Missisauga	68	Min 30-729	tourmaline	35.37	1.06	35.02	0.00	7.92	0.04	4.99	0.76	1.70	0.05	0.03	0.00	0.16	0.00	87.09
Musquodoboit E-23	2800	Middle Missisauga	69	Min 30-730	tourmaline	36.03	0.98	34.21	0.15	7.51	0.03	5.89	0.96	1.63	0.02	0.01	0.00	0.23	0.00	87.65
Musquodoboit E-23	2800	Middle Missisauga	70	Min 30-731	tourmaline	35.67	1.04	34.71	0.11	7.32	0.03	5.76	0.87	1.60	0.03	0.00	0.00	0.22	0.00	87.36
Musquodoboit E-23	2800	Middle Missisauga	71	Min 30-732	tourmaline	35.87	0.26	33.23	0.00	7.06	0.06	7.14	0.53	2.10	0.03	0.00	0.00	0.20	0.00	86.48
Musquodoboit E-23	2800	Middle Missisauga	72	Min 30-733	tourmaline	35.49	0.32	33.42	0.01	7.27	0.05	6.86	0.53	2.09	0.03	0.01	0.00	0.17	0.00	86.27
Musquodoboit E-23	2800	Middle Missisauga	79	Min 30-740	tourmaline	34.98	0.22	33.56	0.00	11.45	0.33	3.48	0.14	2.11	0.05	0.02	0.00	0.19	0.00	86.53
Musquodoboit E-23	2800	Middle Missisauga	80	Min 30-741	tourmaline	35.52	0.21	33.63	0.00	11.59	0.33	3.49	0.14	2.12	0.04	0.00	0.00	0.18	0.00	87.26
Musquodoboit E-23	2800	Middle Missisauga	83	Min 30-744	tourmaline	36.00	0.72	35.39	0.02	6.44	0.01	5.63	0.23	1.95	0.02	0.01	0.00	0.17	0.00	86.58
Musquodoboit E-23	2800	Middle Missisauga	84	Min 30-745	tourmaline	35.91	0.74	35.27	0.01	6.82	0.00	5.75	0.29	1.89	0.02	0.03	0.00	0.18	0.00	86.91
Musquodoboit E-23	2800	Middle Missisauga	85	Min 30-746	tourmaline	35.46	1.50	33.34	0.00	8.02	0.06	5.79	0.68	1.85	0.03	0.02	0.00	0.17	0.00	86.91
Musquodoboit E-23	2800	Middle Missisauga	86	Min 30-747	tourmaline	35.26	1.35	33.29	0.01	8.36	0.04	5.26	0.81	1.76	0.02	0.01	0.00	0.22	0.00	86.38
Musquodoboit E-23	2800	Middle Missisauga	87	Min 30-748	tourmaline	36.13	0.67	33.21	0.00	7.42	0.05	6.50	0.78	2.01	0.03	0.02	0.00	0.21	0.00	87.01
Musquodoboit E-23	2800	Middle Missisauga	88	Min 30-749	tourmaline	35.61	1.90	31.35	0.03	7.87	0.05	6.63	0.94	1.83	0.03	0.00	0.01	0.18	0.00	86.43
Musquodoboit E-23	2800	Middle Missisauga	96	Min 30-757	tourmaline	35.95	0.35	33.22	0.00	7.12	0.05	7.23	0.92	1.96	0.02	0.00	0.00	0.16	0.00	86.98
Musquodoboit E-23	2800	Middle Missisauga	97	Min 30-758	tourmaline	35.87	0.26	33.81	0.00	7.00	0.04	6.97	0.66	1.91	0.01	0.00	0.00	0.19	0.00	86.72
Musquodoboit E-23	1375	Top Logan Canyon	1	Min 30-759	tremolite (amph)	57.21	0.00	0.15	0.00	1.12	0.01	23.01	13.81	0.04	0.02	0.00	0.36	0.00	95.73	
Musquodoboit E-23	1375	Top Logan Canyon	2	Min 30-760	tremolite (amph)	57.11	0.00	0.17	0.00	1.19	0.00	22.75	13.86	0.02	0.02	0.00	0.34	0.00	95.47	
Musquodoboit E-23	1375	Top Logan Canyon	5	Min 30-763	tremolite (amph)	57.03	0.00	0.33	0.00	0.61	0.00	23.23	13.95	0.05	0.04	0.01	0.00	0.30	0.00	95.55
Musquodoboit E-23	1375	Top Logan Canyon	6	Min 30-764	tremolite (amph)	56.96	0.00	0.24	0.00	0.61	0.00	23.18	14.01	0.02	0.02	0.01	0.00	0.36	0.00	95.40
Musquodoboit E-23	1375	Top Logan Canyon	7	Min 30-765	tremolite (amph)	56.68	0.00	0.28	0.00	0.68	0.00	23.16	13.89	0.05	0.02	0.00	0.00	0.35	0.00	95.11
Musquodoboit E-23	1375	Top Logan Canyon	8	Min 30-766	tremolite (amph)	56.55	0.00	0.36	0.00	0.66	0.00	23.05	13.83	0.05	0.05	0.02	0.00	0.34	0.00	94.92
Musquodoboit E-23	2600	Middle Missisauga	8	Min 30-780	tremolite (amph)	56.89	0.00	0.32	0.00	1.34	0.00	22.93	13.71	0.08	0.05	0.01	0.00	0.31	0.00	95.64
Musquodoboit E-23	2600	Middle Missisauga	9	Min 30-781	tremolite (amph)	56.22	0.00	0.71	0.00	1.20	0.00	22.99	13.62	0.19	0.13	0.00	0.00	0.33	0.00	95.40
Musquodoboit E-23	2600	Middle Missisauga	13	Min 30-785	tremolite (amph)	56.56	0.00	0.32	0.00	0.96	0.01	23.26	13.07	0.43	0.16	0.00	0.00	0.31	0.00	95.10
Musquodoboit E-23	2600	Middle Missisauga	14	Min 30-786	tremolite (amph)	56.03	0.04	0.77	0.00	0.90	0.00	23.26	12.96	0.65	0.29	0.00	0.00	0.33	0.00	95.22
Musquodoboit E-23	2600	Middle Missisauga	15	Min 30-787	tremolite (amph)	56.81	0.00	0.27	0.00	0.56	0.00	23.29	13.92	0.11	0.05	0.00	0.00	0.31	0.00	95.33
Musquodoboit E-23	2600	Middle Missisauga	16	Min 30-788	tremolite (amph)	56.48	0.00	0.39	0.00	0.56	0.00	23.47	13.69	0.24	0.10	0.00	0.00	0.31	0.00	95.24
Musquodoboit E-23	2600	Middle Missisauga	17	Min 30-789	tremolite (amph)	56.32	0.00	0.46	0.00	1.08	0.01	22.86	13.72	0.12	0.04	0.00	0.00	0.35	0.00	94.96
Musquodoboit E-23	2600	Middle Missisauga	18	Min 30-790	tremolite (amph)	56.19	0.00	0.86	0.00	1.05	0.01	23.02	13.89	0.17	0.07	0.02	0.00	0.36	0.00	95.63
Musquodoboit E-23	2600	Middle Missisauga	21	Min 30-793	tremolite (amph)	56.65	0.00	0.25	0.00	0.46	0.00	23.85	13.72	0.07	0.04	0.00	0.00	0.35	0.00	95.40
Musquodoboit E-23	2600	Middle Missisauga	22	Min 30-794	tremolite (amph)	56.90	0.00	0.40	0.00	0.42	0.00	23.43	13.73	0.08	0.04	0.00	0.00	0.32	0.00	95.30
Musquodoboit E-23	2600	Middle Missisauga	25	Min 30-797	tremolite (amph)	56.16	0.00	0.30	0.00	0.86	0.01	23.39	13.67	0.25	0.15	0.03	0.00	0.32	0.00	95.16
Musquodoboit E-23	2600	Middle Missisauga	26	Min 30-798	tremolite (amph)	56.27	0.00	0.18	0.00	0.86	0.01	23.48	13.73	0.17	0.06	0.03	0.00	0.33	0.00	95.11
Musquodoboit E-23	2600	Middle Missisauga	27	Min 30-799	tremolite (amph)	55.86	0.00	0.77	0.00	1.28	0.00	22.99	13.75	0.24	0.14	0.00	0.00	0.30	0.00	95.32
Musquodoboit E-23	2600	Middle Missisauga	28	Min 30-800	tremolite (amph)	55.43	0.00	1.05	0.00	1.32	0.00	22.83	13.53	0.24	0.19	0.01	0.00	0.32	0.00	94.93
Musquodoboit E-23	2600	Middle Missisauga	33	Min 30-805	tremolite (amph)	57.18	0.00	0.25	0.00	0.91	0.01	23.55	14.00	0.06	0.03	0.00	0.00	0.31	0.00	96.31
Musquodoboit E-23	2600	Middle Missisauga	35	Min 30-807	tremolite (amph)	57.12	0.00	0.28	0.00	0.92	0.02	23.57	13.91	0.10	0.05	0.00	0.00	0.29	0.00	96.26
Musquodoboit E-23	2600	Middle Missisauga	37	Min 30-809	tremolite (amph)	56.97	0.01	0.41	0.00	0.50	0.03	23.88	13.86	0.12	0.11	0.00	0.00	0.29	0.00	96.18
Musquodoboit E-23	2600	Middle Missisauga	46	Min 30-818	tremolite (amph)	57.33	0.01	0.48												

Table 7. Whole rock geochemical analyses of specific lithologies from cuttings

Formation	Banquereau	Logan Canyon				Mississauga			Abenaki	
Depth (m)	960	1800	2190 (1)	2190 (2)	2190 (3)	2500 (1)	2500 (2)	2500 (3)	3415A	3415B
Lithology ¹	sst	mds	mds	mds	mds	mds	mds	mds	cmds	cmds
CIA	44.17	81.05	77.30	72.26	52.78	78.13	67.00	67.13	n.d.	n.d.
File	14-433	14-434	14-435	14-436	14-437	14-440	14-441	14-442	14-438	14-39
Major elements (wt%)										
SiO ₂	68.99	57.73	53.83	59.50	43.81	50.81	55.63	55.67	18.64	11.45
TiO ₂	0.73	1.12	1.22	1.06	0.54	1.17	0.98	0.91	0.34	0.18
Al ₂ O ₃	7.90	19.34	19.32	17.04	7.32	21.30	17.82	16.49	5.74	2.94
Fe ₂ O _{3t}	3.77	6.97	8.15	5.65	23.42	8.57	6.00	8.00	3.83	3.28
MnO	0.02	0.04	0.05	0.03	0.27	0.05	0.03	0.03	0.08	0.09
MgO	1.13	1.32	1.61	1.19	2.00	1.83	1.20	1.05	2.04	2.63
CaO	4.00	0.49	0.98	1.62	2.47	0.68	2.82	2.63	30.18	40.42
Na ₂ O	0.36	0.45	0.49	0.41	0.37	0.46	0.35	0.35	0.22	0.10
K ₂ O	1.96	2.67	2.85	2.70	1.34	3.67	2.84	2.51	0.96	0.60
P ₂ O ₅	0.09	0.08	0.13	0.11	0.31	0.20	0.10	0.12	0.08	0.07
L.O.I	9.72	9.15	10.96	10.22	16.95	10.20	11.18	10.78	37.13	36.77
Total	98.67	99.36	99.59	99.53	98.80	98.94	98.95	98.54	99.23	98.53
Trace elements (ppm)										
Ba	209	346	341	317	216	337	291	278	133.00	88.00
Rb	74	120	114	101	45	144	105	97	34.00	21.00
Sr	290	91	98	119	115	112	165	145	307.00	365.00
Y	25	35	35	33	32	34	31	33	12.00	8.00
Zr	516	255	243	263	260	234	231	287	48.00	32.00
Nb	12	19	24	19	10	22	16	16	7.00	5.00
Pb	15	30	33	24	14	35	34	27	11.00	13.00
Ga	12	28	28	24	11	29	24	23	8.00	4.00
Zn	65	95	103	92	56	118	100	106	202.00	77.00
Cu	16	32	33	25	17	48	28	30	28.00	46.00
Ni	26	64	76	69	24	84	68	61	57.00	36.00
V	79	146	156	129	88	142	121	127	54.00	41.00
Cr	104	157	173	157	75	153	135	133	86.00	62.00
La	28.2	49	52.3	44	26	48	42.2	42.9	17.70	12.40
Ce	66.1	104	110	95.1	57	96.6	90.2	92.2	37.50	26.60
Pr	7.01	11.9	12.7	11.1	6.66	11.3	10.4	10.9	4.24	2.97
Nd	25	42.2	45.2	39.4	24.9	39.9	37.2	39.3	15.80	10.80
Sm	4.6	8	8.5	7.6	5.1	7.3	7.1	7.5	3.00	2.10
Eu	0.92	1.76	1.88	1.67	1.16	1.68	1.54	1.68	0.68	0.50
Gd	4	6.9	7.2	6.6	4.9	6.4	6	6.5	2.70	1.90
Tb	0.7	1.1	1.2	1.1	0.9	1.1	1	1.1	0.40	0.30
Dy	4	6.3	6.5	6.2	5.1	6.1	5.7	6	2.30	1.50
Ho	0.9	1.3	1.3	1.2	1.1	1.3	1.2	1.2	0.50	0.30
Er	2.6	3.7	3.8	3.5	3.4	3.8	3.5	3.5	1.30	0.80
Tm	0.41	0.57	0.58	0.55	0.54	0.58	0.53	0.53	0.19	0.12
Yb	2.6	3.6	3.5	3.3	3.3	3.6	3.3	3.4	1.20	0.70
Lu	0.41	0.52	0.52	0.5	0.52	0.53	0.49	0.49	0.17	0.10
Co	9	24	25	18	6	25	19	17	6.00	4.00
Cs	2.8	7.1	6.4	5.8	2	8	6.6	6.2	1.90	1.10
Hf	13.2	6.9	6.7	7.1	6.2	6.4	6.4	7.8	1.20	0.70
Sb	b.d. ²	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	1.10	0.50
Sc	9	19	19	17	13	21	17	17	7.00	5.00
Ta	0.9	1.7	1.9	1.5	0.7	1.9	1.4	1.3	0.40	0.30
Th	7.7	13	13	11.7	6.7	12.8	11.8	11.8	4.00	2.20
U	3.1	2.9	3.1	2.8	1.6	3	2.8	3.3	1.10	0.90

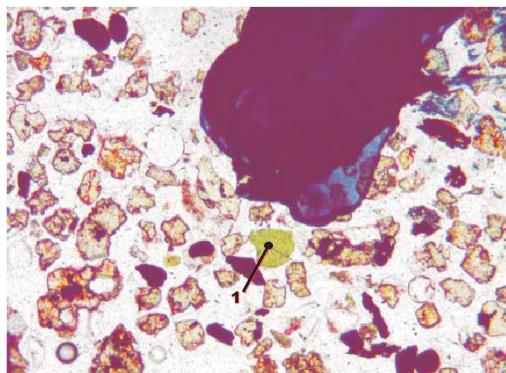
¹ sst = sandstone; mds = mudstone; cmds = calcareous mudstone; ² b.d. = below detection limit; n.d. = not determined

Table 8: Interpreted tectonic environments and provenance lithologies

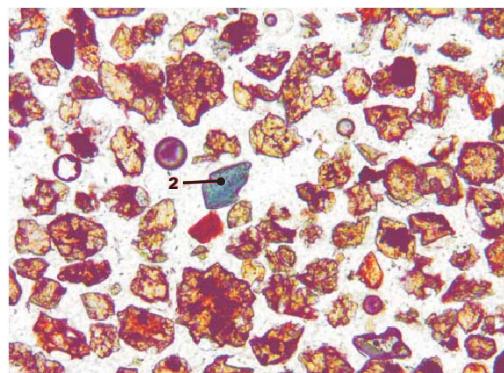
Stratigraphic Unit	Th vs Sc	TiO ₂ vs Ni	K ₂ O vs Rb	Co/Th vs La/Sc	La/Sc vs Th/Sc	Th-Hf-Co	La/Th vs Hf	Ti/Zr vs La/Sc	La-Th-Sc	Th-Co-Zr/10	K ₂ O/Na ₂ O vs SiO ₂	Al ₂ O ₃ /SiO ₂ vs K ₂ O/Na ₂ O
Banquereau Fm	INT - F	F	INT - F	INT	INT	UC	PM	CIA	CIA	PM	PM	PM
Logan Canyon Fm	INT	INT - F	INT - F	INT	INT	UC	F	ACM	CIA	CIA - PM	OIA - ACM - PM	PM - ACM
Missisauga Fm	INT	INT	INT - F	INT	INT	UC	F	ACM - CIA	CIA	CIA	PM - ACM	PM - ACM
Abenaki Carbonates	INT - M	N.D.	INT - M	INT	INT	UC	N.D.	ACM	CIA	CIA - ACM	N.D.	PM - ACM

Appendix 1:
Microphotographs of Representative
Detrital Minerals

960 metres



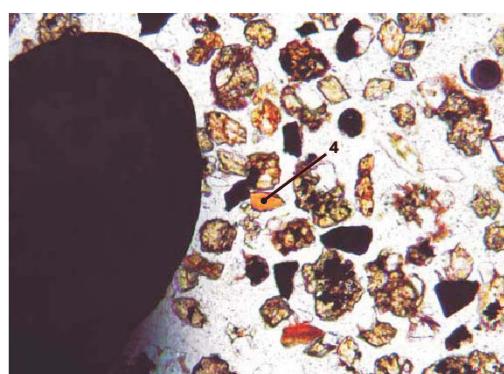
960 m, 10x Mag, Glauconite (pos. 1)



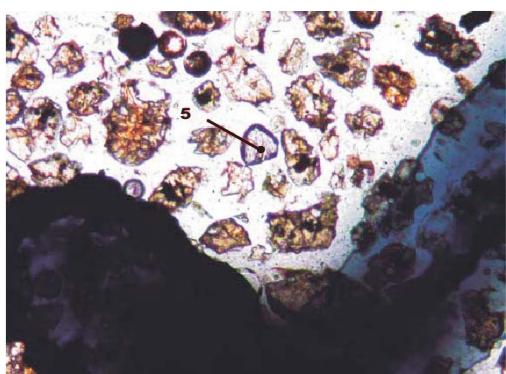
960 m, 10x Mag, Blue tourmaline (pos. 2)



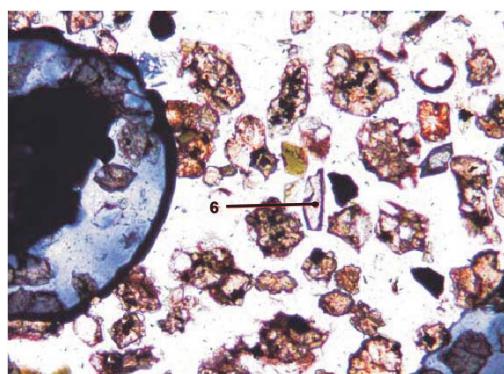
960 m, 20x Mag, Plagioclase (Albite)
(pos. 3)



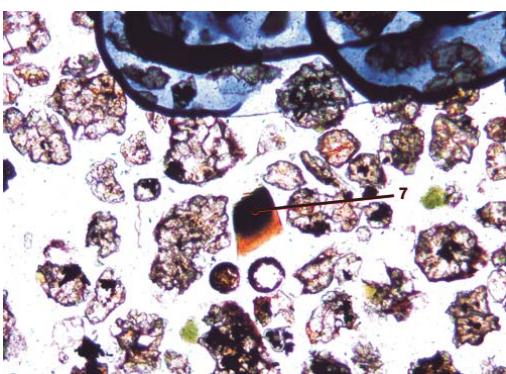
960 m, 10x Mag, Brown tourmaline (pos. 4)



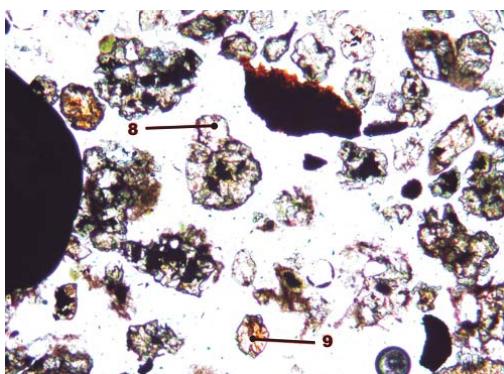
960 m, 10x Mag, Zircon (pos. 5)



960 m, 10x Mag, Garnet (pos. 6)

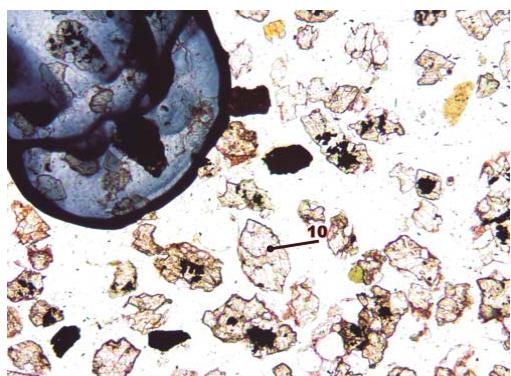


960 m, 20x Mag, Apatite (pos. 7)

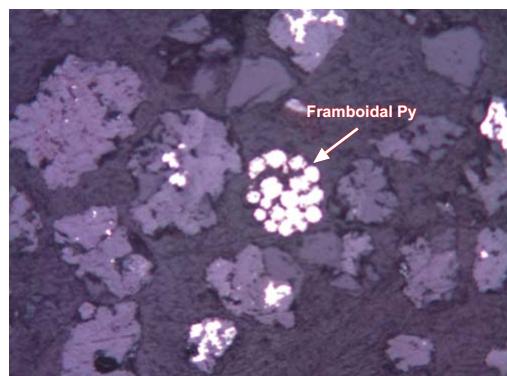


960 m, 20x Mag, Individual carbonate
(pos. 9) and carbonate within cutting (pos. 8)

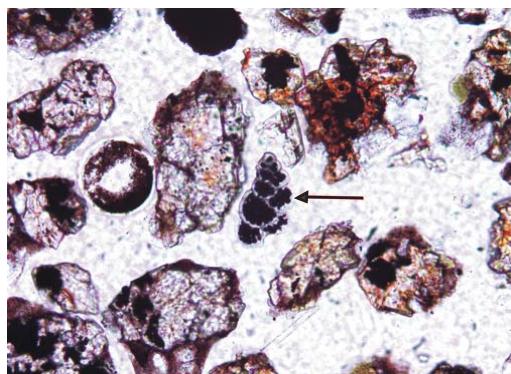
960 metres



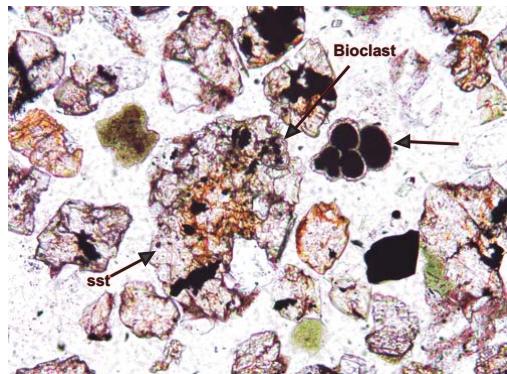
960 m, 20x Mag, Carbonate (pos. 10)



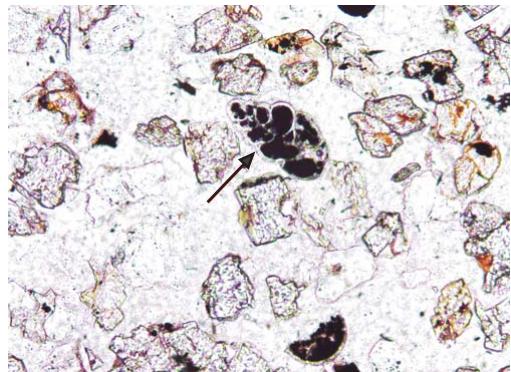
960 m, 5x Mag, Framboidal pyrite (pos. 11)



960 m, 20x Mag, Foram (pos. 12)



960 m, 20x Mag, Foram and bioclast in sandstone (pos. 13)

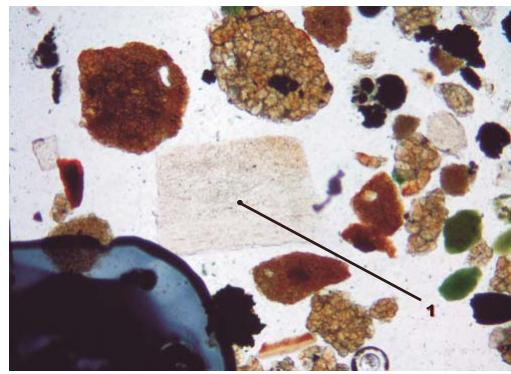


960 m, 20x Mag, Foram (pos. 14)

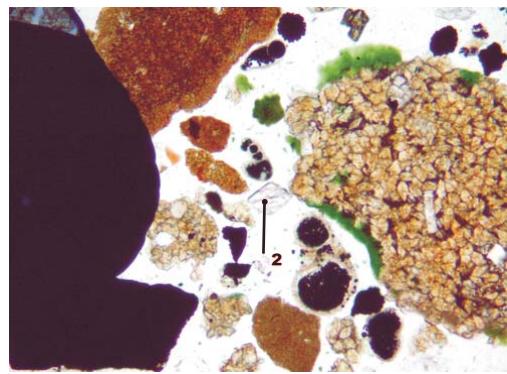


960 m, 5x Mag, Pyrite (pos. 15)

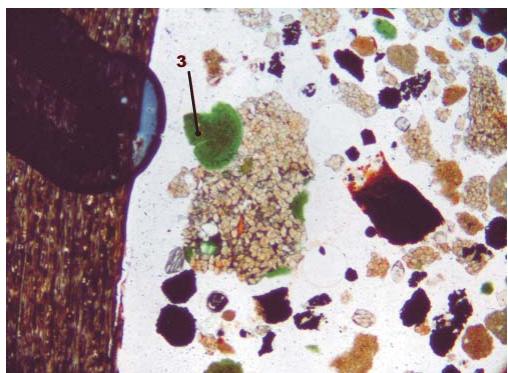
1270 metres



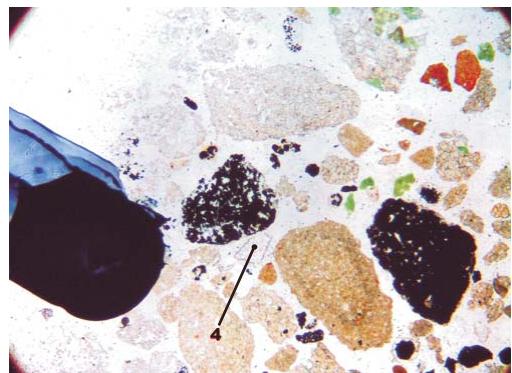
1270 m, 10x Mag, K-Feldspar (pos. 1)



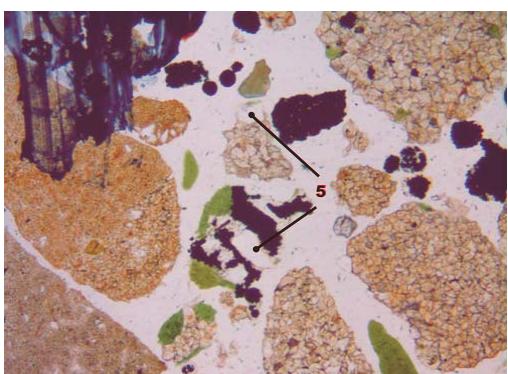
1270 m, 20x Mag, Calcite (pos. 2)



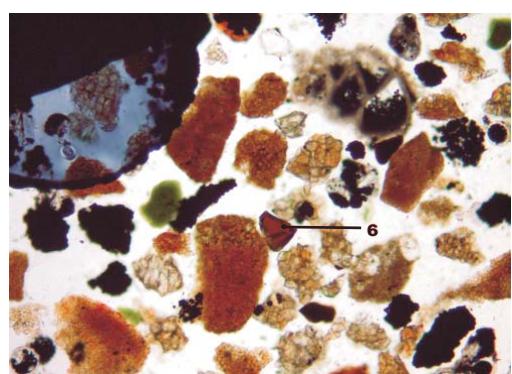
1270 m, 5x Mag, Glauconite within sandstone cutting (pos. 3)



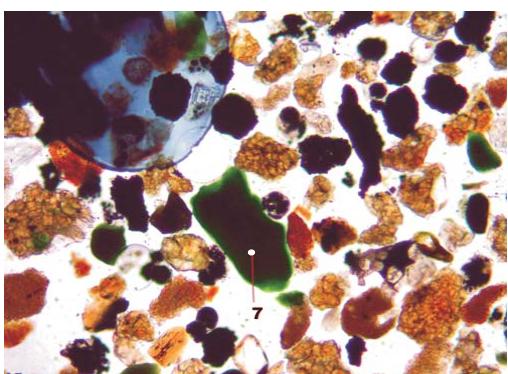
1270 m, 5x Mag, Garnet (pos. 4)



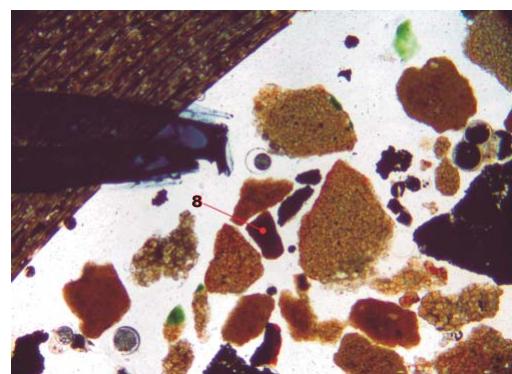
1270 m, 10x Mag, Quartz within cuttings (pos. 5)



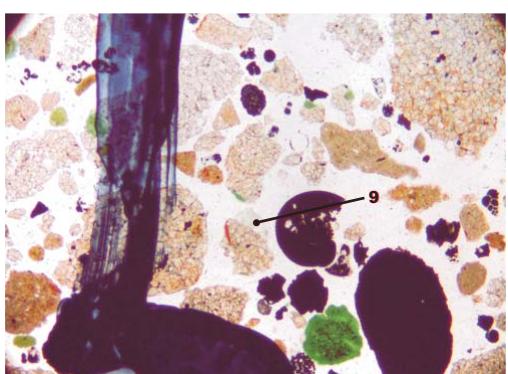
1270 m, 10x Mag, ?Chromite or brown garnet (pos. 6)



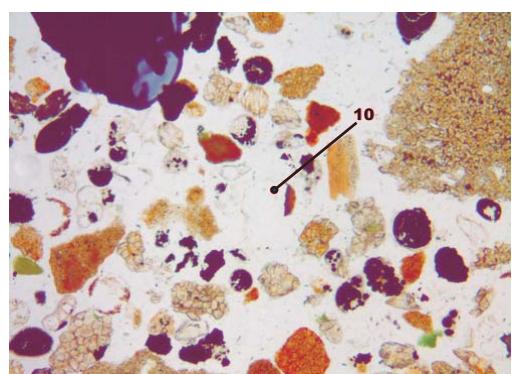
1270 m, 10x Mag, Glauconite (pos. 7)



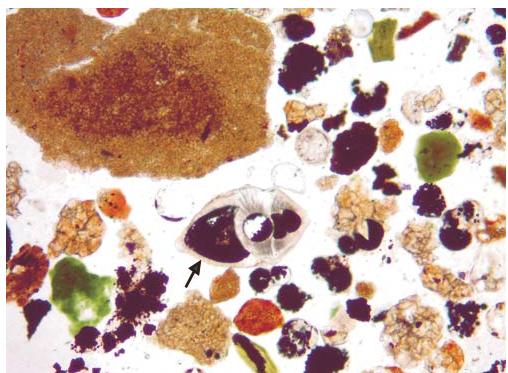
1270 m, 5x Mag, Glauconite (pos. 8)



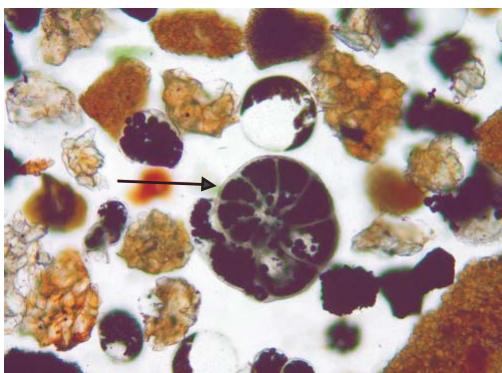
1270 m, 10x Mag, Calcite within cutting (pos. 9)



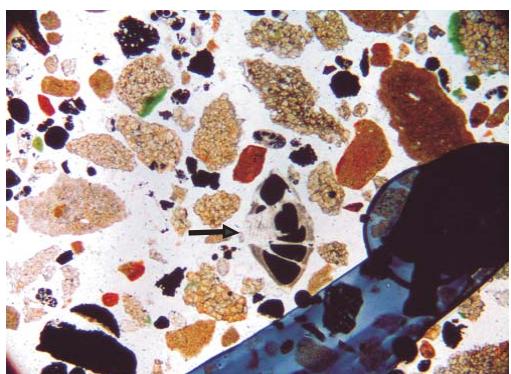
1270 m, 10x Mag, Brown carbonate (pos. 10)



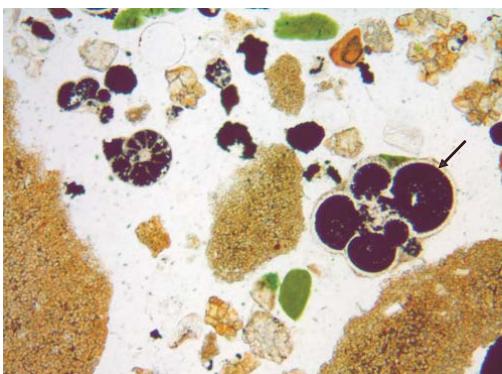
1270 m, 20x Mag, Foram (pos. 11)



1270 m, 20x Mag, Foram (pos. 12)

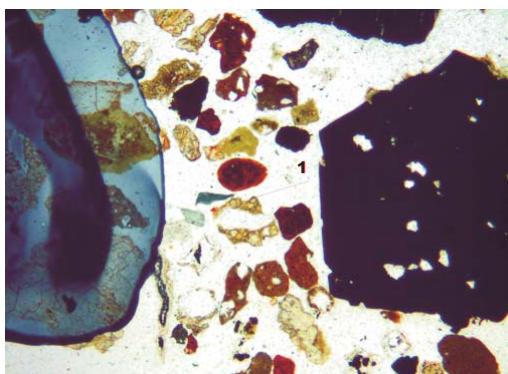


1270 m, 5x Mag, Foram (pos. 13)

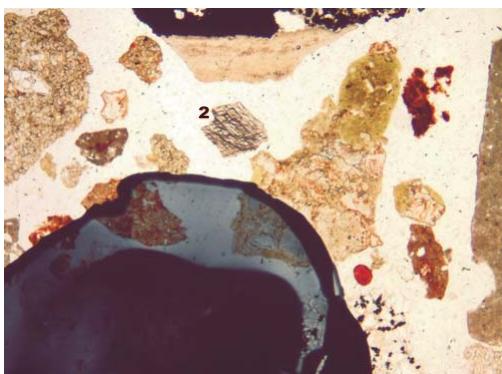


1270 m, 10x Mag, Forams (pos. 14)

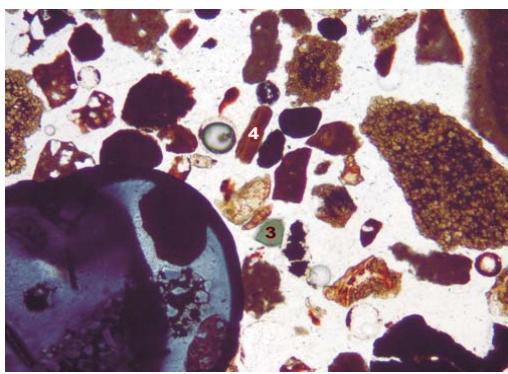
1375 metres



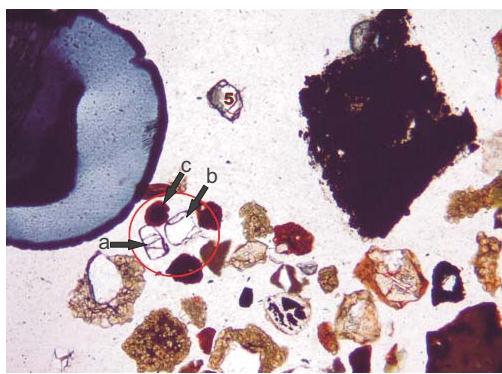
1375 m, 10x Mag, Blue tourmaline (pos. 1)



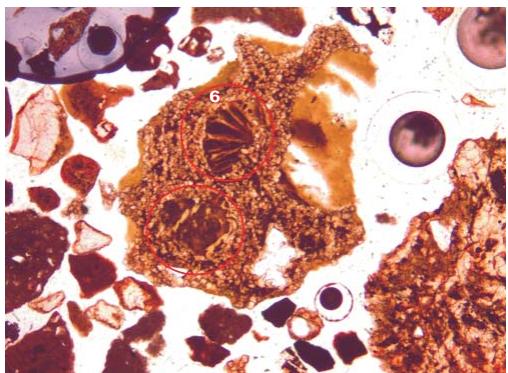
1375 m, 10x Mag, Calcite (pos. 2)



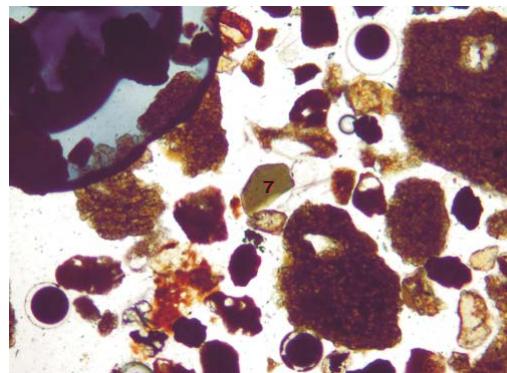
1375 m, 10x Mag, Greenish-blue tourmaline (pos. 3) and brown ?biotite (pos. 4)



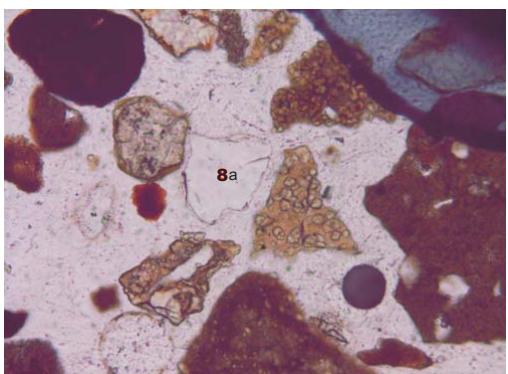
1375 m, 10x Mag, Apatite (a), quartz (b), magnetite (c) and quartz (pos. 5)



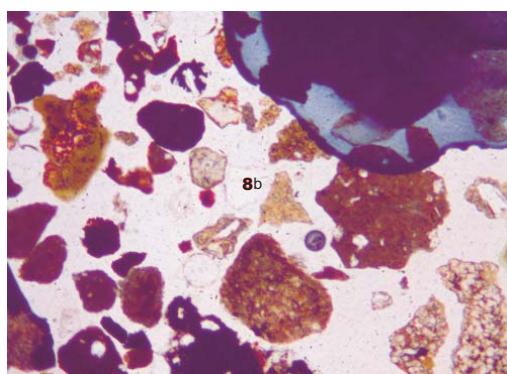
1375 m, 10x Mag, Bioclasts (pos. 6)



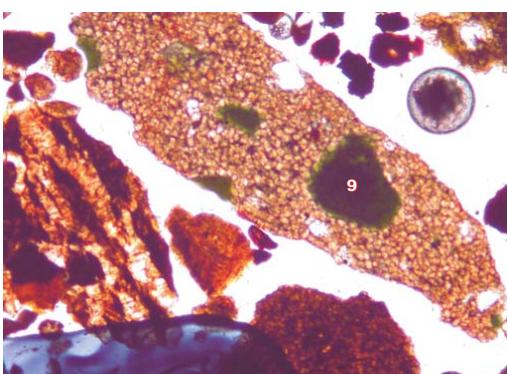
1375 m, 10x Mag, Glauconite (pos. 7)



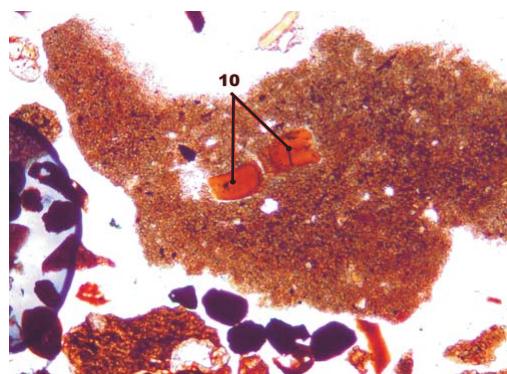
1375 m, 20x Mag, Quartz (pos. 8a)



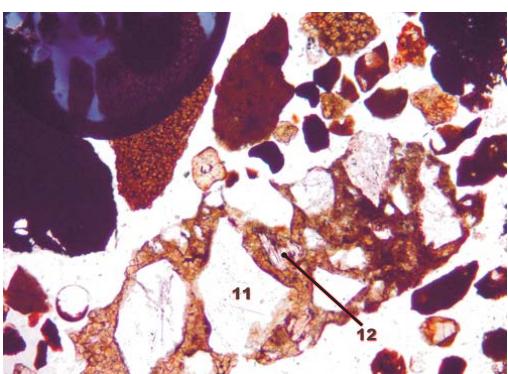
1375 m, 10x Mag, Quartz (pos. 8b)



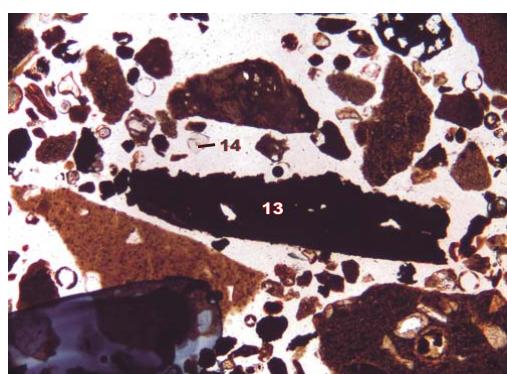
1375 m, 10x Mag, Glauconite within cutting (pos. 9)



1375 m, 10x Mag, Chlorite altering from biotite within cutting (pos. 10)

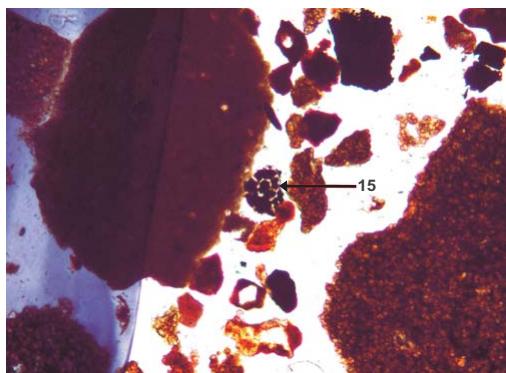


1375 m, 10x Mag, Quartz (pos. 11) and carbonate (pos. 12) within cutting



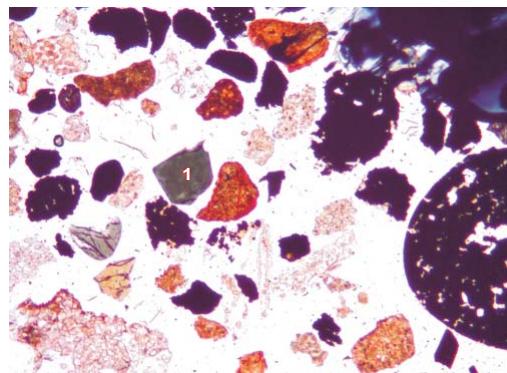
1375 m, 10x Mag, Magnetite (pos. 13) and zircon (pos. 14)

1375 metres



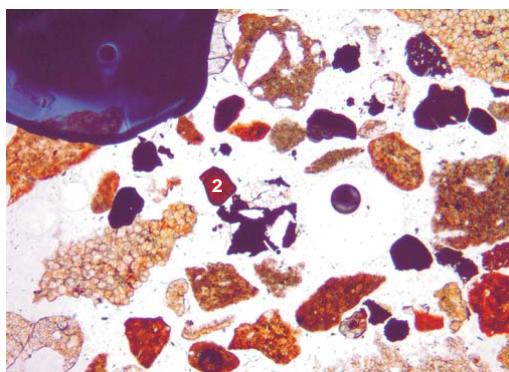
1375 m, 10x Mag, Foram (pos. 15)

1800 metres

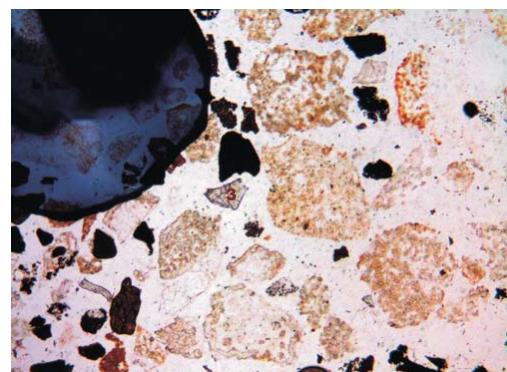


1800 m, 10x Mag, Blue tourmaline (pos. 1)

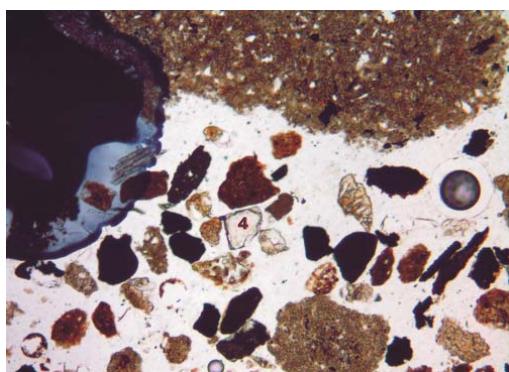
1800 metres



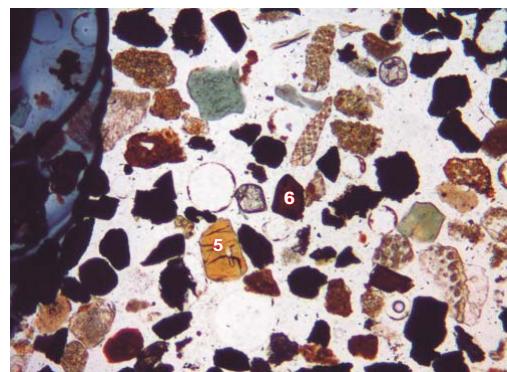
1800 m, 10x Mag, ?Chromite (pos. 2)



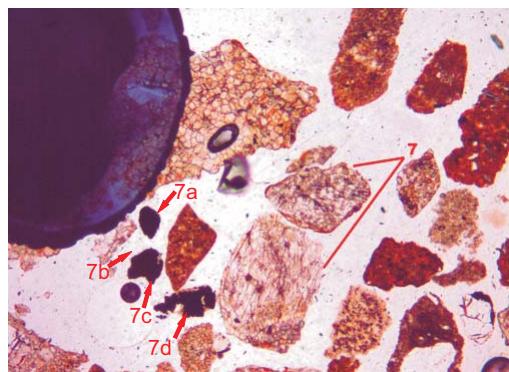
1800 m, 10x Mag, Zircon (pos. 3)



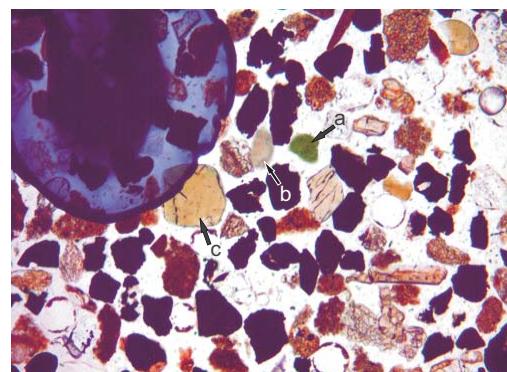
1800 m, 10x Mag, Garnet (pos. 4)



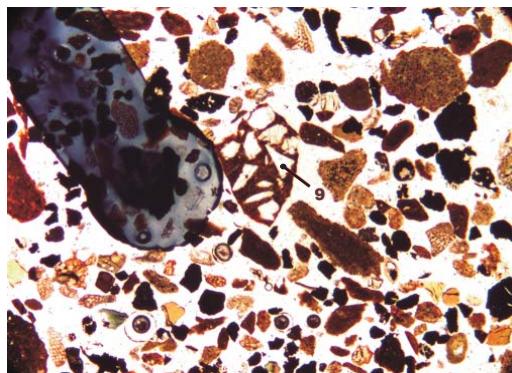
1800 m, 10x Mag, Brown tourmaline (pos. 5) and chromite (pos. 6)



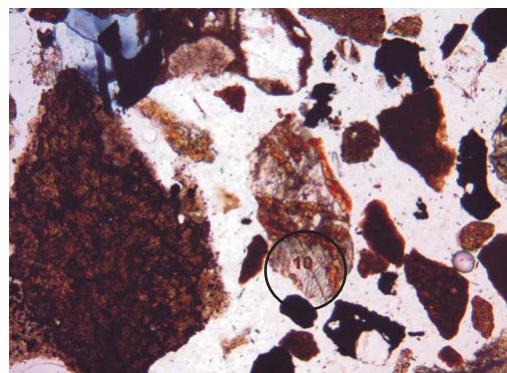
1800 m, 10x Mag, Ilmenite (pos. 7a), calcite (pos. 7b), altered ilmenite (pos. 7c), pyrite (pos. 7d)



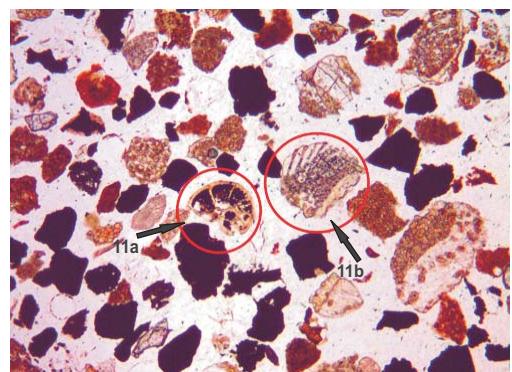
1800 m, 10x Mag, Glauconite (a), tourmaline (b, c)



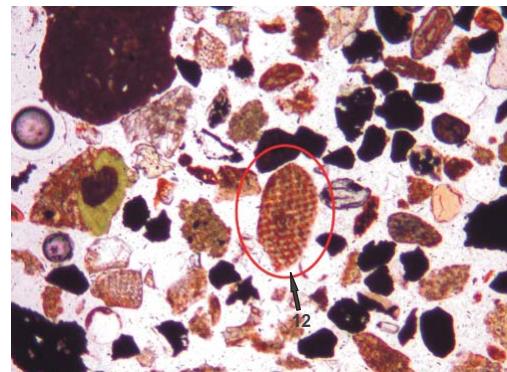
1800 m, 10x Mag, Quartz within cutting
(pos. 9)



1800 m, 10x Mag, Carbonate within cutting
(pos. 10)

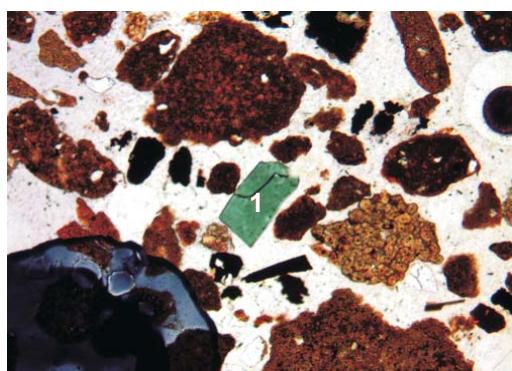


1800 m, 10x Mag, Fossils, Foram
(pos. 11a) and possible shell fragment
(pos. 11b)

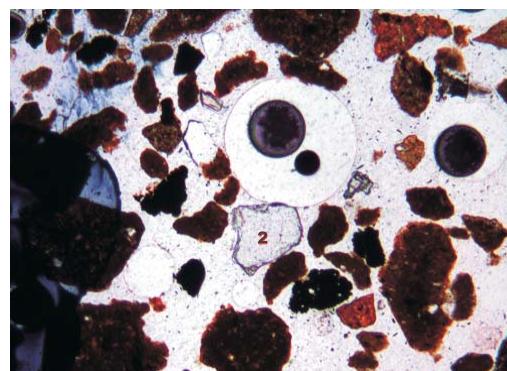


1800 m, 10x Mag, ?Echinoderm fossil
(pos. 12)

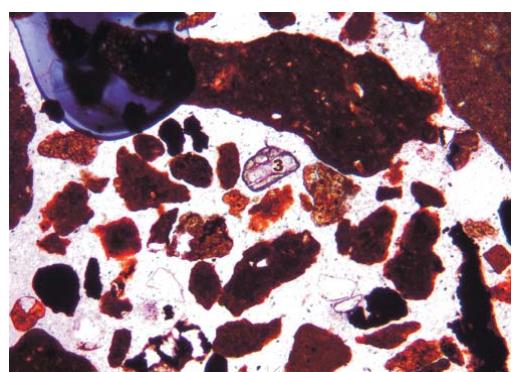
2190 metres



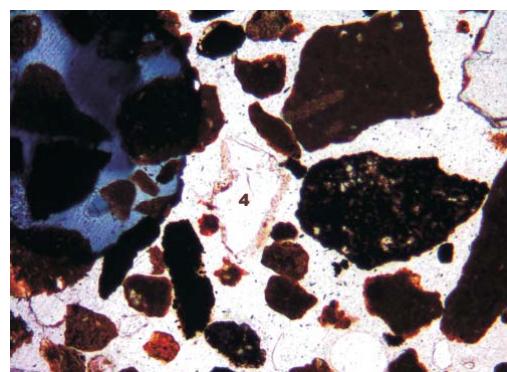
2190 m, 10x Mag, Blue tourmaline (pos. 1)



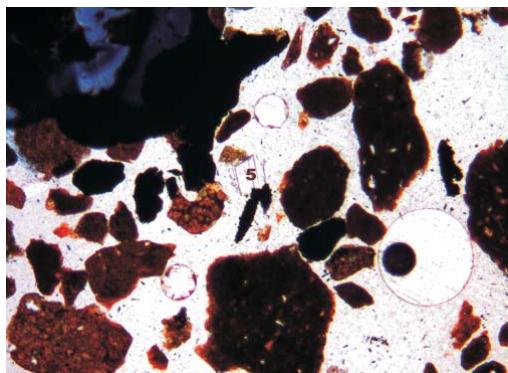
2190 m, 10x Mag, Garnet (pos. 2)



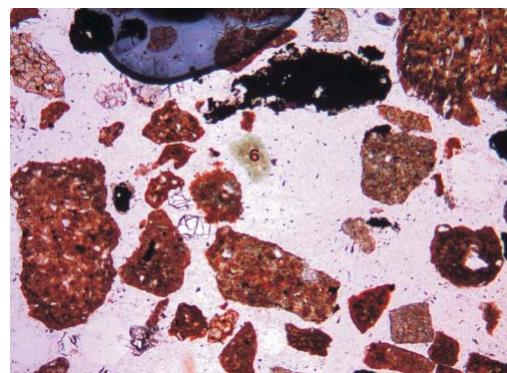
2190 m, 10x Mag, Zircon (pos. 3)



2190 m, 10x Mag, Quartz (pos. 4)

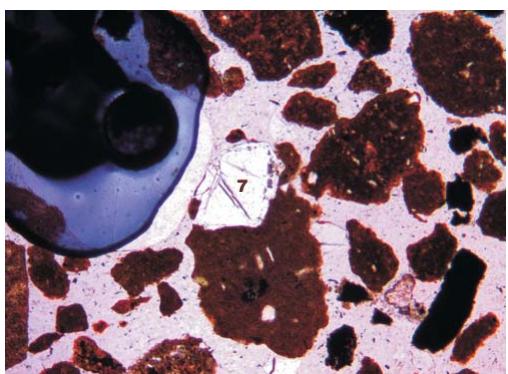


2190 m, 10x Mag, K-Feldspar (pos. 5)



2190 m, 10x mag, Glauconite (pos. 6)

2500A metres

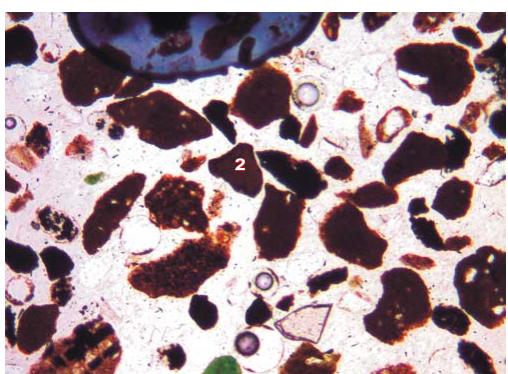


2190 m, 10x Mag, K-Feldspar within cutting (pos. 7)

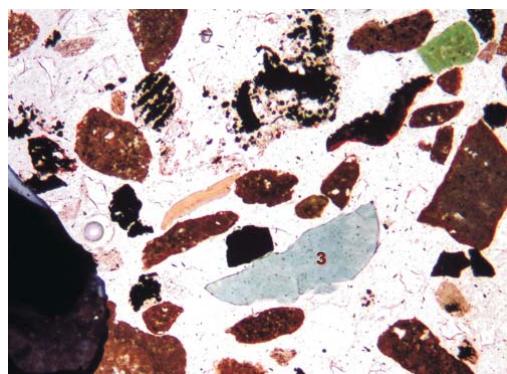


2500A m, 10x Mag, K-Feldspar (pos. 1)

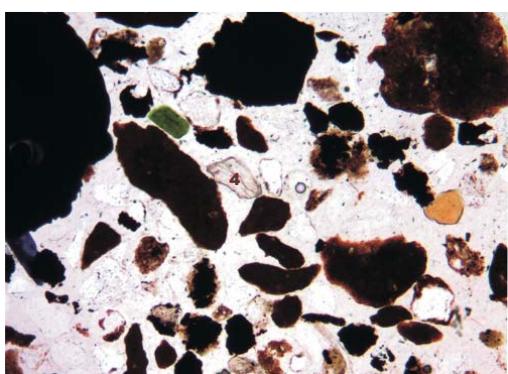
2500A metres



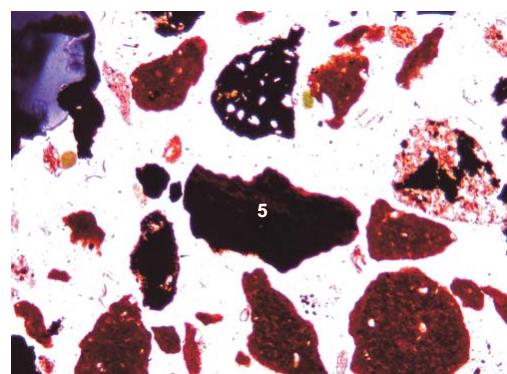
2500A m, 10x Mag, Chromite (pos. 2)



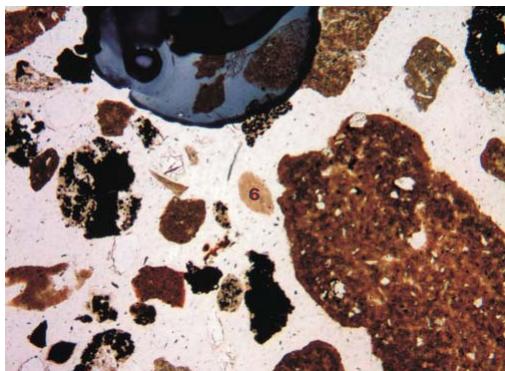
2500A m, 10x Mag, Blue tourmaline (pos. 3)



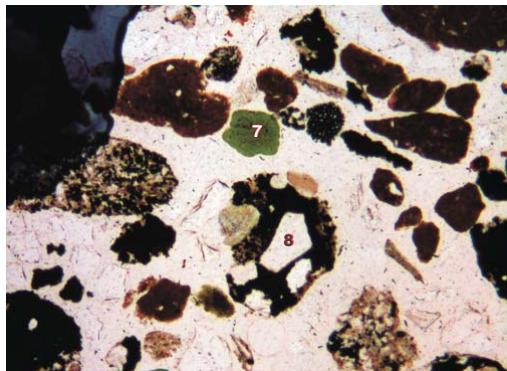
2500A m, 10x Mag, Carbonate (pos. 4)



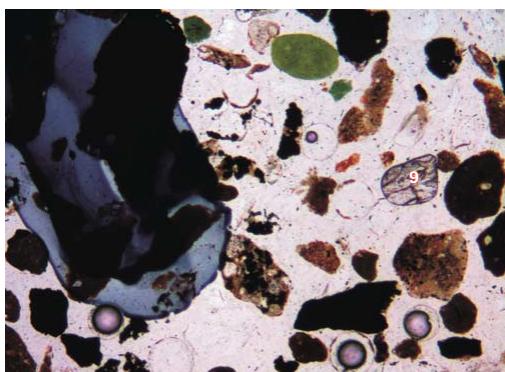
2500A m, 10x Mag, Magnetite (pos. 5)



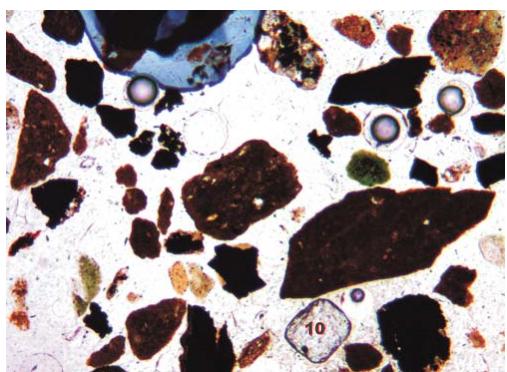
2500A m, 10x Mag, Pale brown zircon
(pos. 6)



2500A m, 10x Mag, Glauconite (pos. 7)
and quartz within cutting (pos. 8)

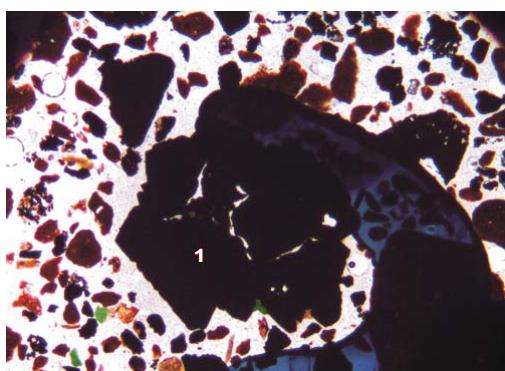


2500A m, 10x Mag, Zircon (pos. 9)

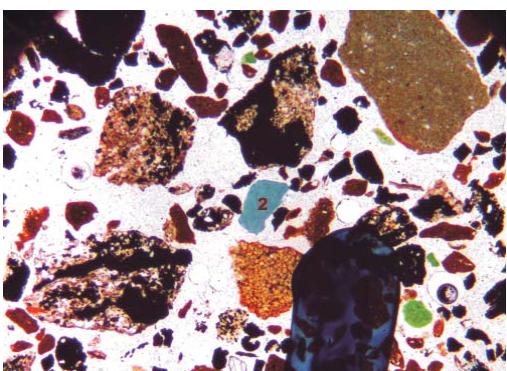


2500A m, 10x Mag, zircon (pos. 10)

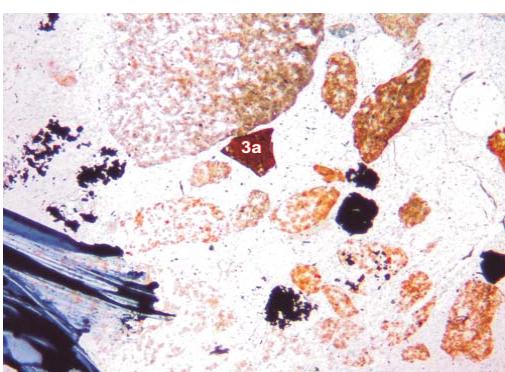
2500B metres



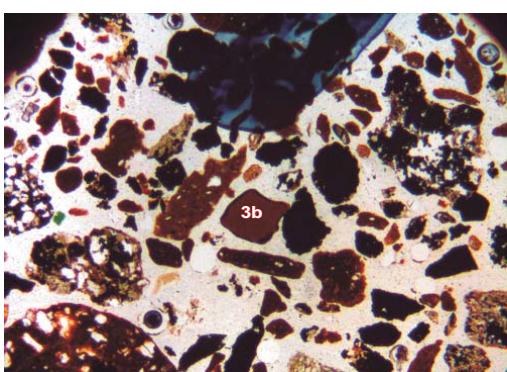
2500B m, 5x Mag, Pyrite (pos. 1)



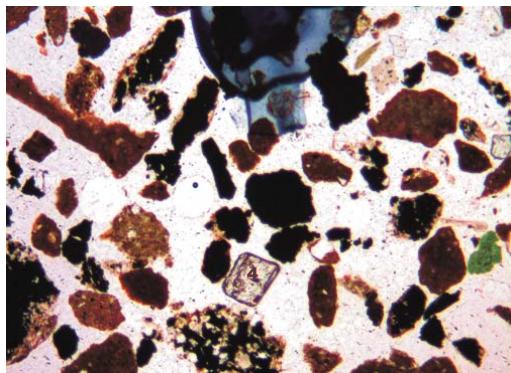
2500B m, 5x Mag, Blue tourmaline (pos. 2)



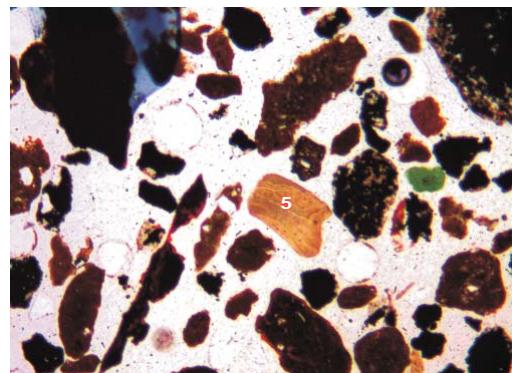
2500B m, 10x Mag, Chromian spinel
(pos. 3a)



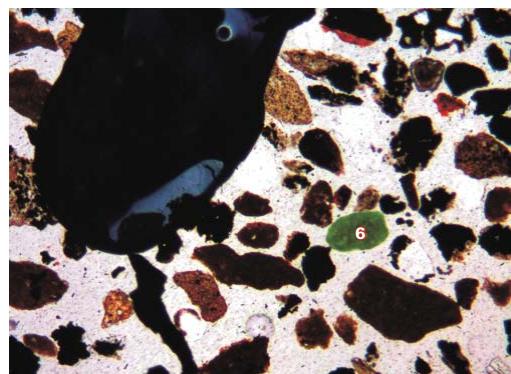
2500B m, 5x Mag, Chromian spinel
(pos. 3b)



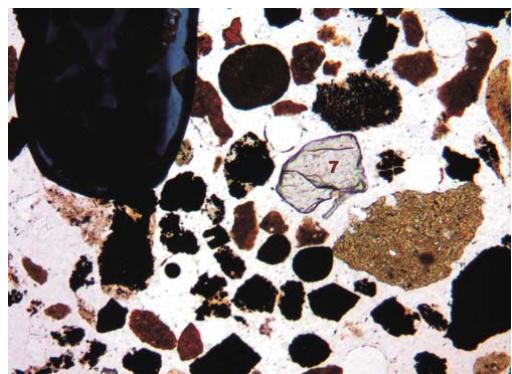
2500B m, 10x Mag, Very high relief, colorless zircon (pos. 4)



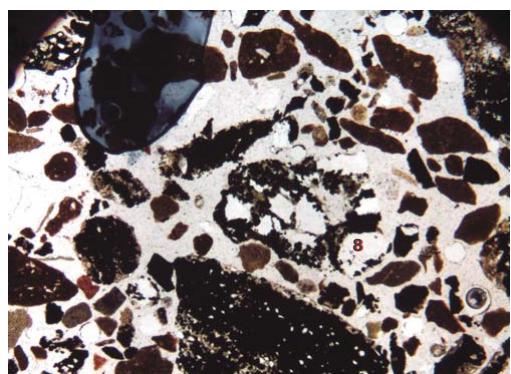
2500B m, 10x Mag, Brown carbonate (pos. 5)



2500B m, 10x Mag, Glauconite (pos. 6)

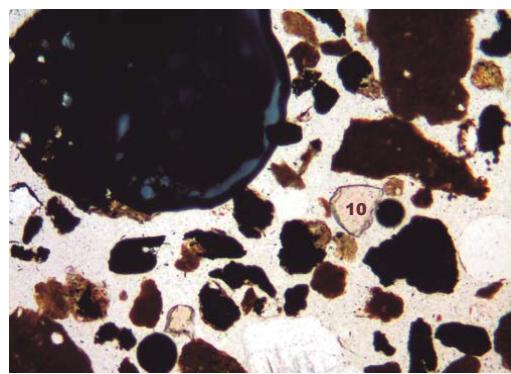


2500B m, 10x Mag, Zircon (pos. 7)

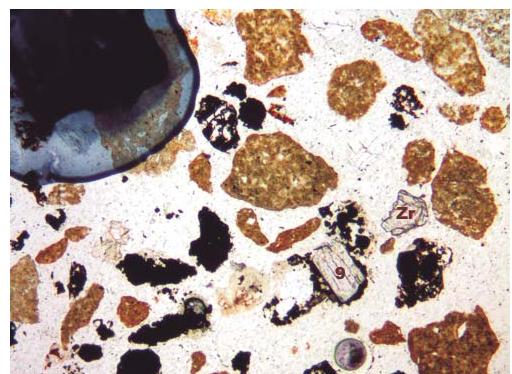


2500B m, 5x mag, Quartz within cutting (pos. 8)

2500B metres

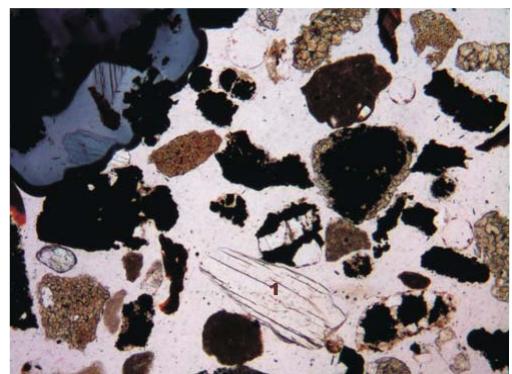


2500B m, 10x Mag, Garnet (pos. 10)



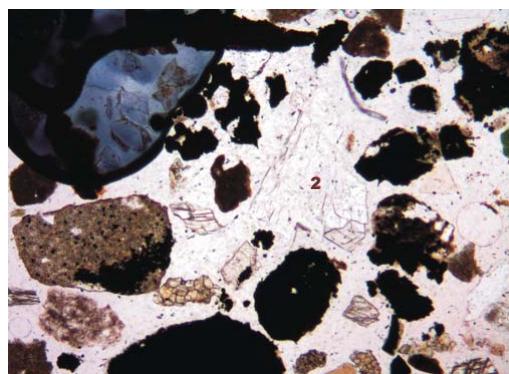
2500B m, 10x Mag, Zircon within cutting (pos. 9)

2600 metres

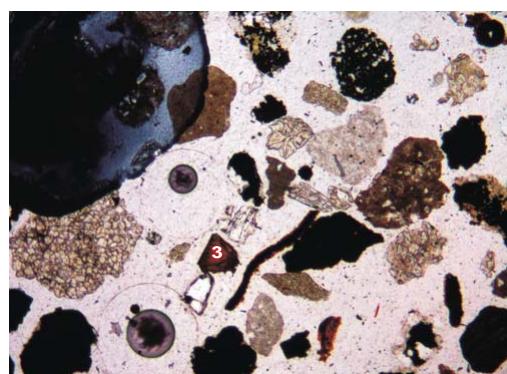


2600 m, 10x Mag, Feldspar (pos. 1)

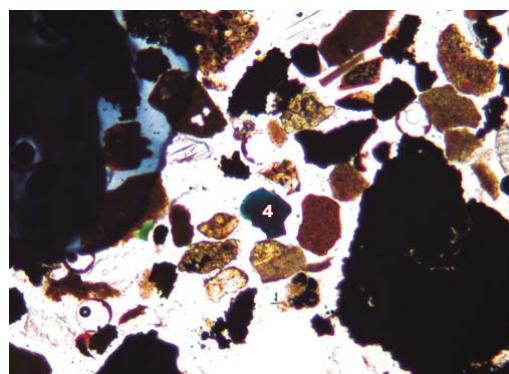
2600 metres



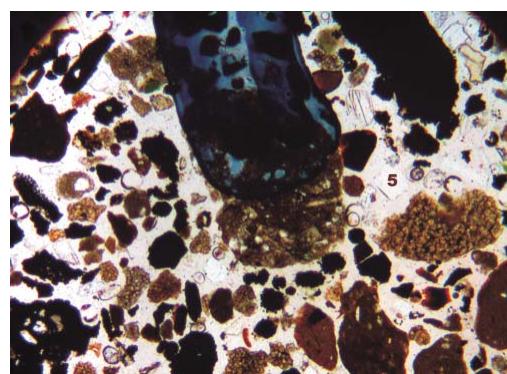
2600 m, 10x Mag, Carbonate (pos. 2)



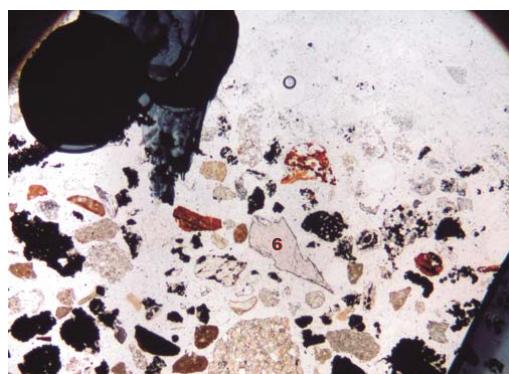
2600 m, 5x Mag, Chromian spinel (pos. 3)



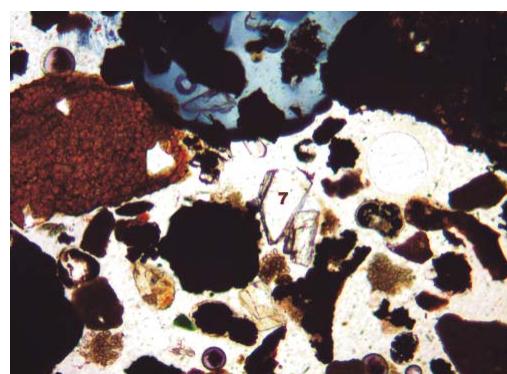
2600 m, 10x Mag, Blue tourmaline (pos. 4)



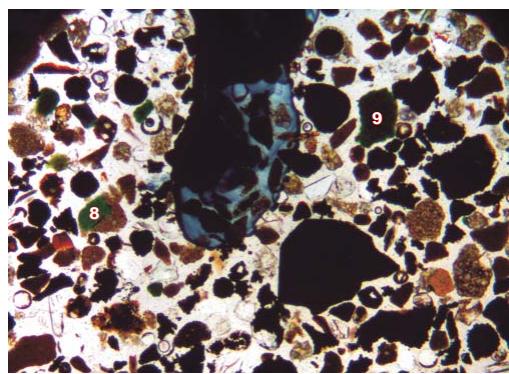
2600 m, 5x Mag, Tremolite (pos. 5)



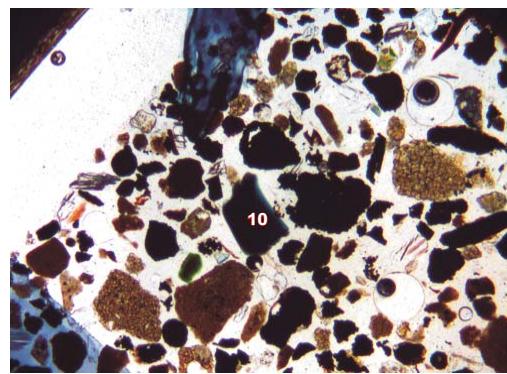
2600 m, 5x Mag, Garnet (pos. 6)



2600 m, 10x Mag, Zircon (pos. 7)

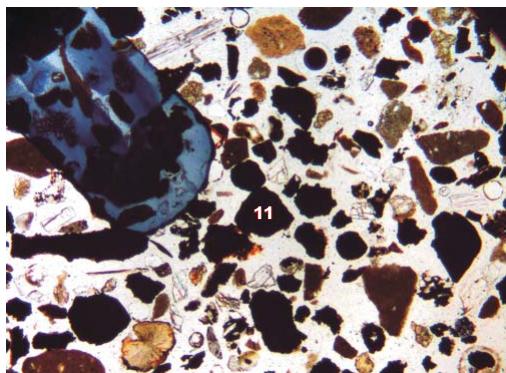


2600 m, 5x Mag, Glauconite (pos. 8, 9)



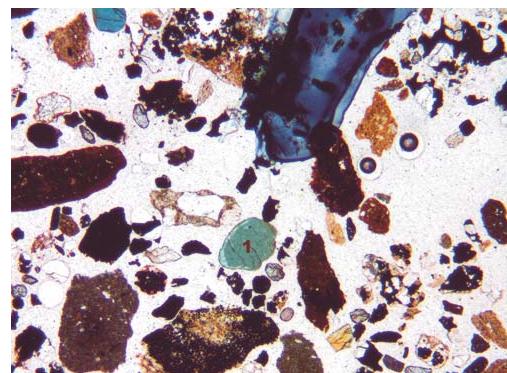
2600 m, 5x Mag, Blue tourmaline (pos. 10)

2600 metres



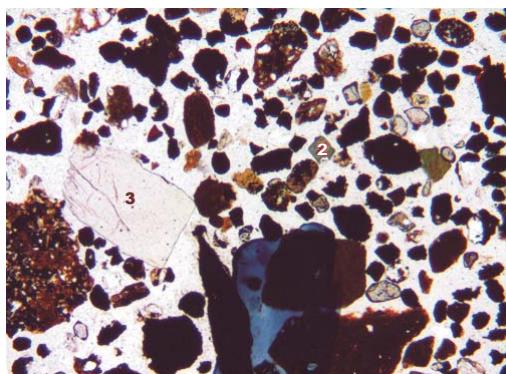
2600 m, 5x Mag, Magnetite (pos. 11)

2800 metres

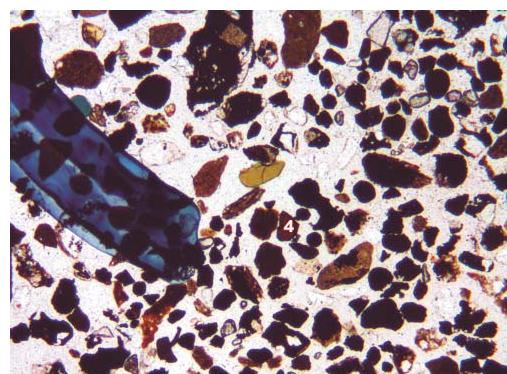


2800 m, 5x Mag, Blue tourmaline (pos. 1)

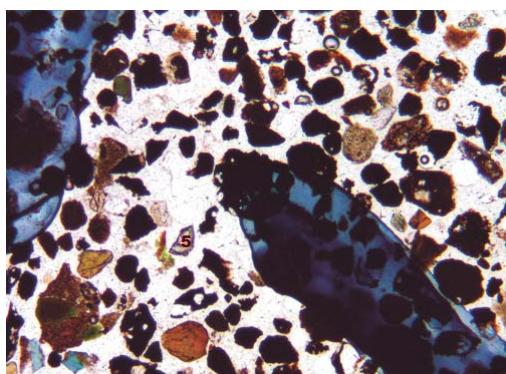
2800 metres



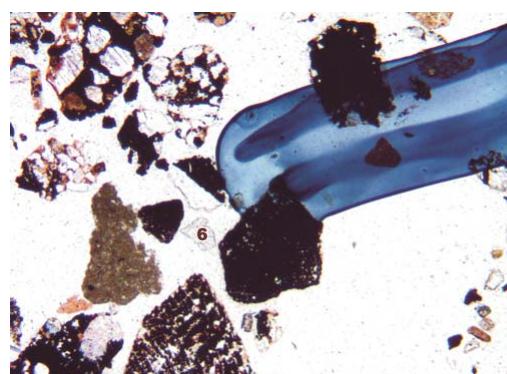
2800 m, 5x Mag, Green tourmaline (pos. 2)
and K-feldspar (pos. 3)



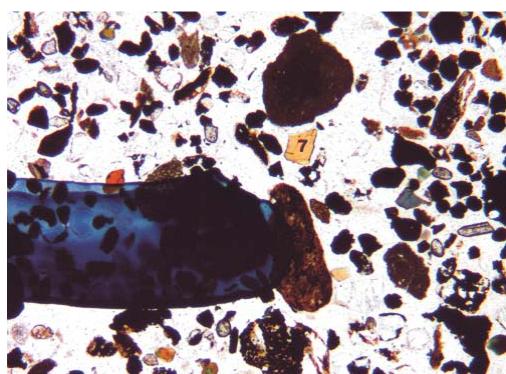
2800 m, 5x Mag, Chromian spinel (pos. 4)



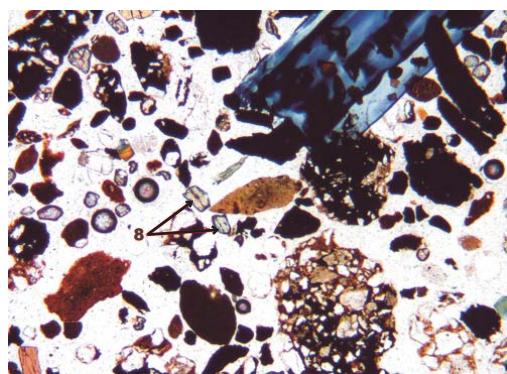
2800 m, 5x Mag, Garnet (pos. 5)



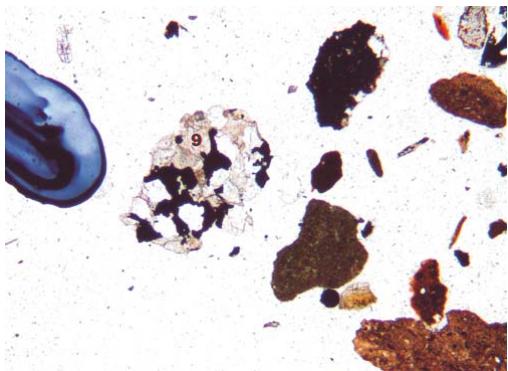
2800 m, 5x Mag, ?Calcite (pos. 6)



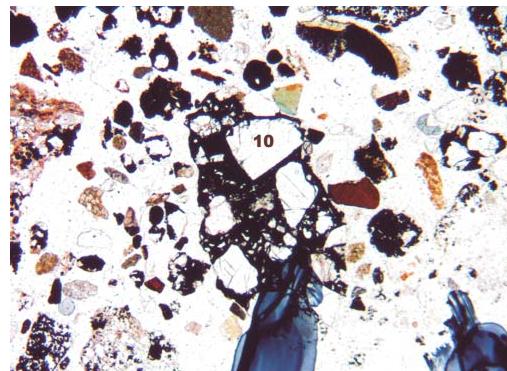
2800 m, 5x Mag, Brown tourmaline (pos. 7)



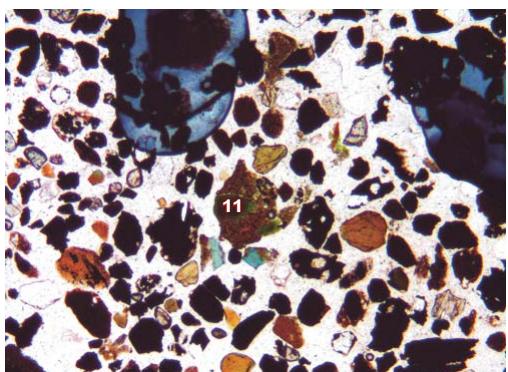
2800 m, 5x Mag, Zircon (pos. 8)



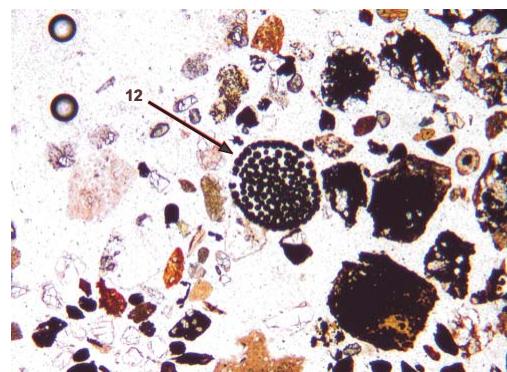
2800 m, 5x Mag, Carbonate within cutting
(pos. 9)



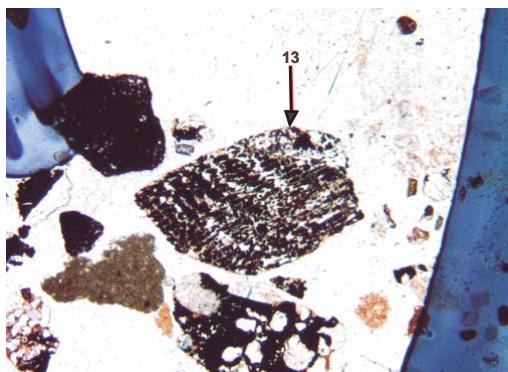
2800 m, 5x Mag, Quartz within cutting (pos. 10)



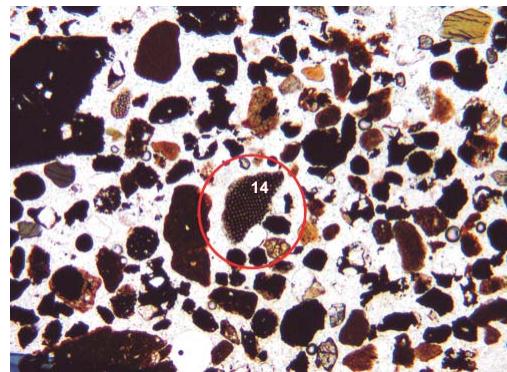
2800 m, 5x Mag, Glauconite within cutting
(pos. 11)



2800 m, 5x Mag, ?Pyrite-replaced fossil or
framboidal pyrite (pos. 12)



2800 m, 5x Mag, Fossilized wood (pyrite
replaced) (pos. 13)



2800 m, 5x Mag, ?Bryozoan or ?coral
(pos. 14)

Appendix 2:
Back Scattered Electron (BSE) Images
of Representative Detrital Minerals

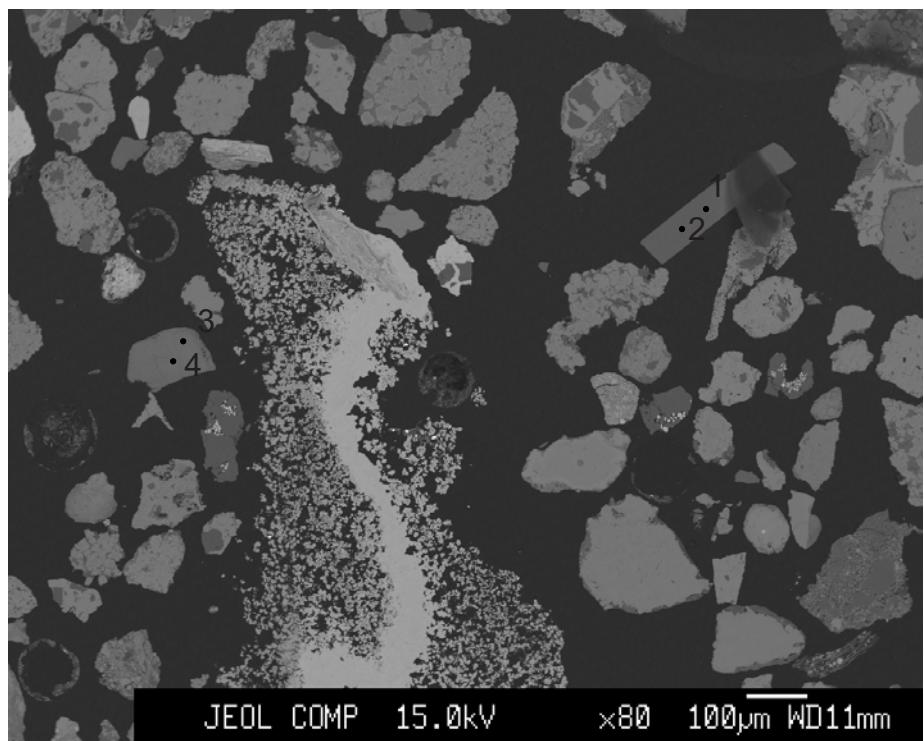


Figure 1 E-23 1375 m

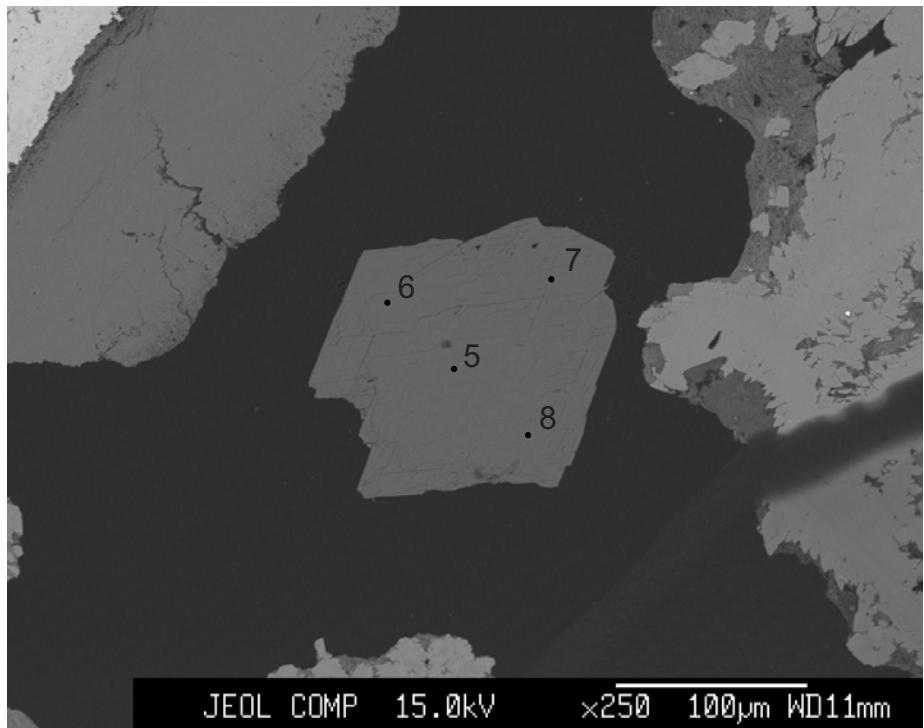


Figure 2 E-23 1375 m

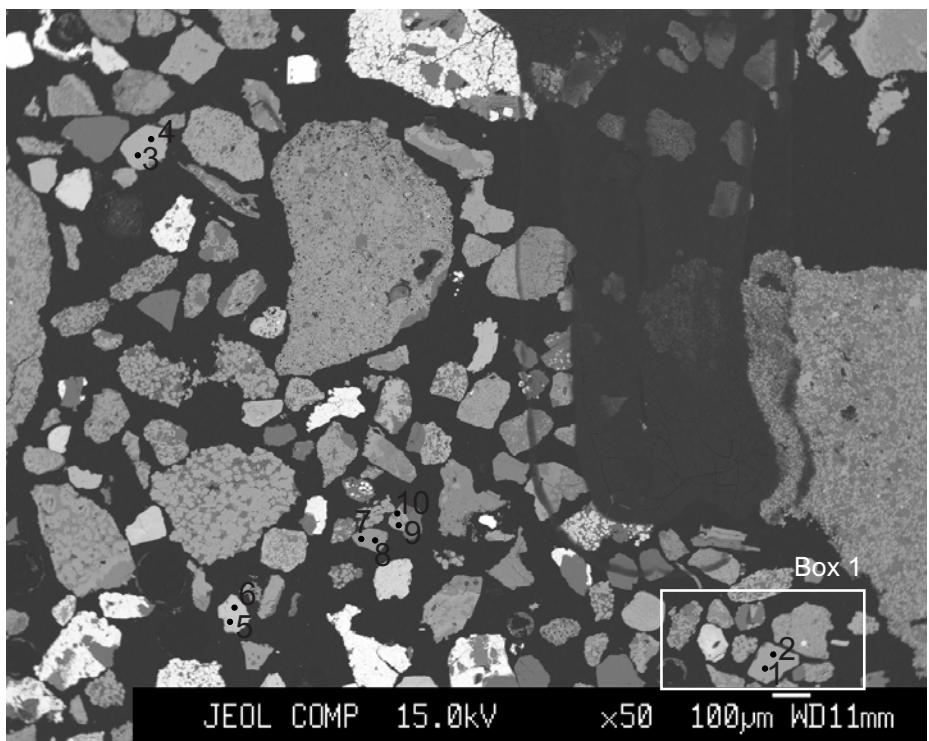


Figure 3 E-23 1800 m

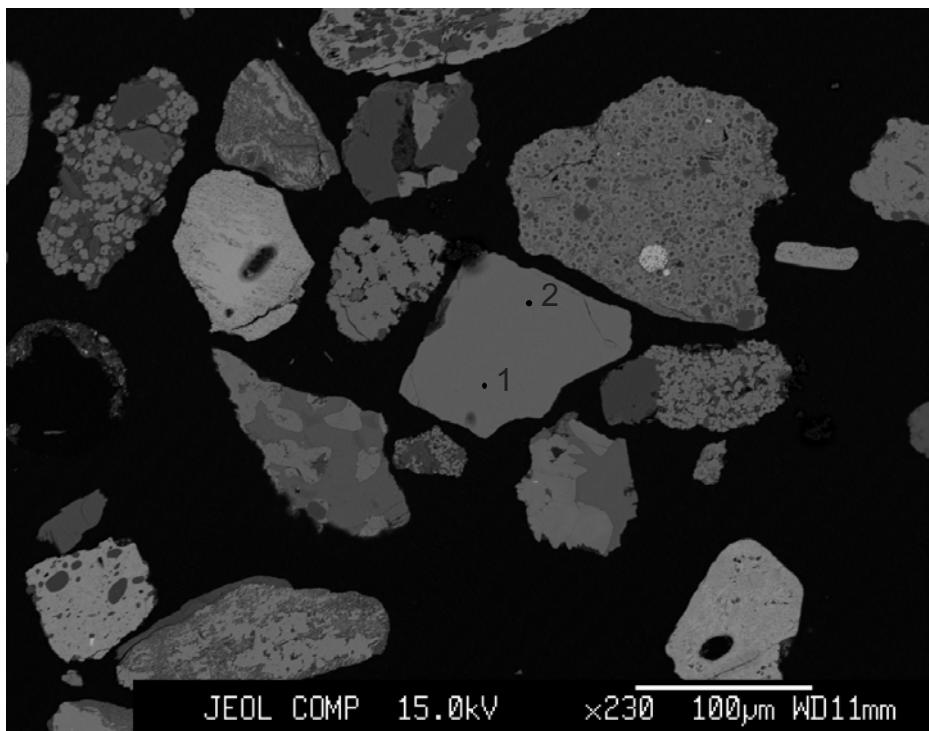


Figure 4 E-23 1800 m
(in reference to box 1 in figure 3)

1. Garnet (Almandine)
2. Garnet (Almandine) (lt)
3. Chromian Spinel
4. Chromian Spinel
5. Chromite
6. Chromite
7. Chromian Spinel
8. Chromian Spinel
9. Chromian Spinel (lt)
10. Chromian Spinel

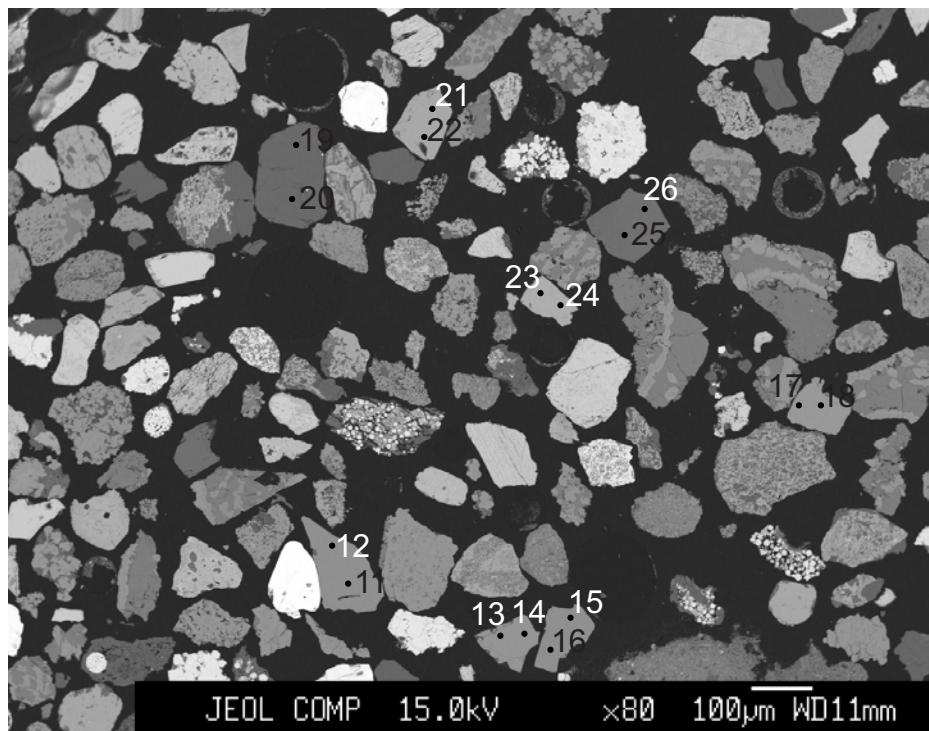


Figure 5 E-23 1800 m

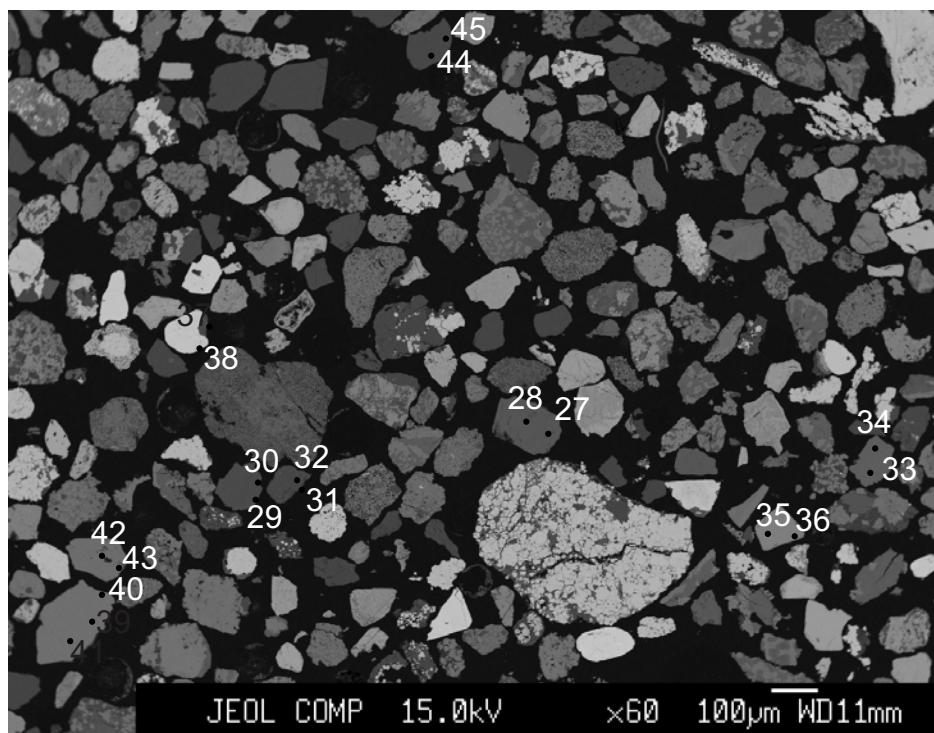


Figure 6 E-23 1800 m

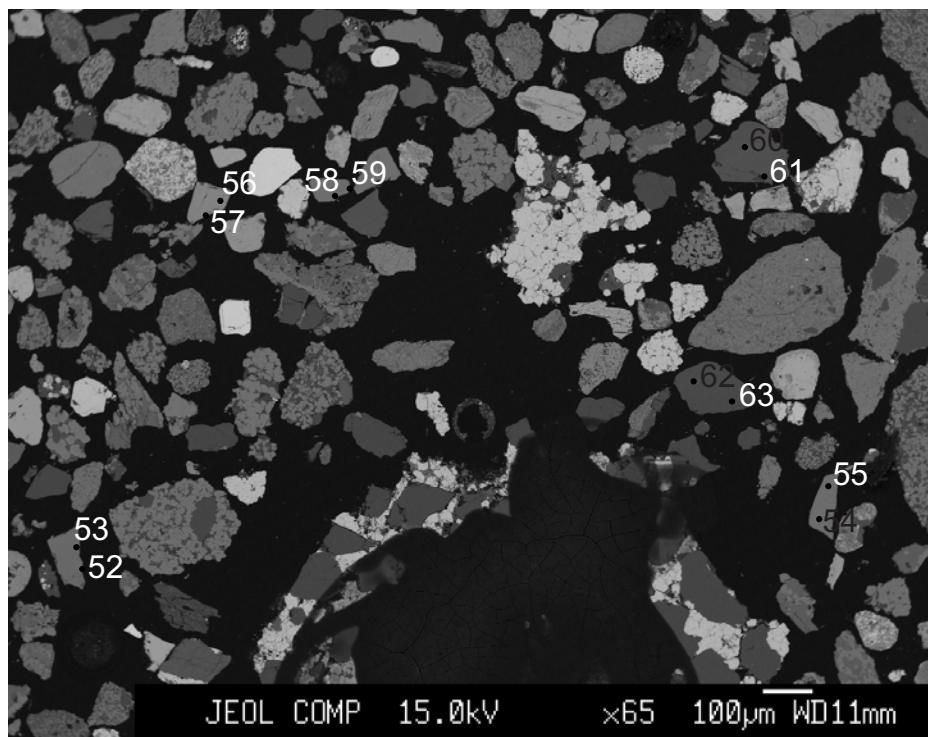


Figure 7 E-23 1800 m

- 52. Garnet (Almandine)
- 53. Garnet (Almandine) (It)
- 54. Garnet (Almandine) (It)
- 55. Garnet (Almandine) (It)
- 56. Chromite
- 57. Chromite
- 58. Chromian Spinel
- 59. Chromian Spinel
- 60. Tourmaline
- 61. Tourmaline
- 62. Tourmaline
- 63. Tourmaline

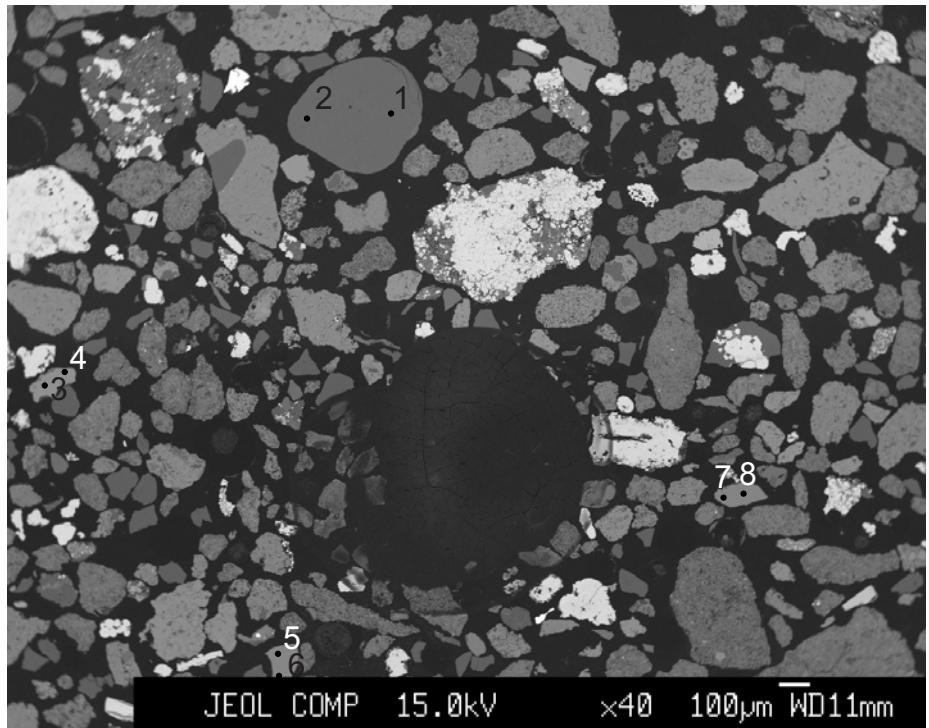


Figure 8 E-23 2190 m

- 1. Tourmaline
- 2. Tourmaline
- 3. Garnet (Almandine)
- 4. Garnet (Almandine)
- 5. Garnet (Almandine)
- 6. Garnet (Almandine)
- 7. Garnet (Almandine)
- 8. Garnet (Almandine)

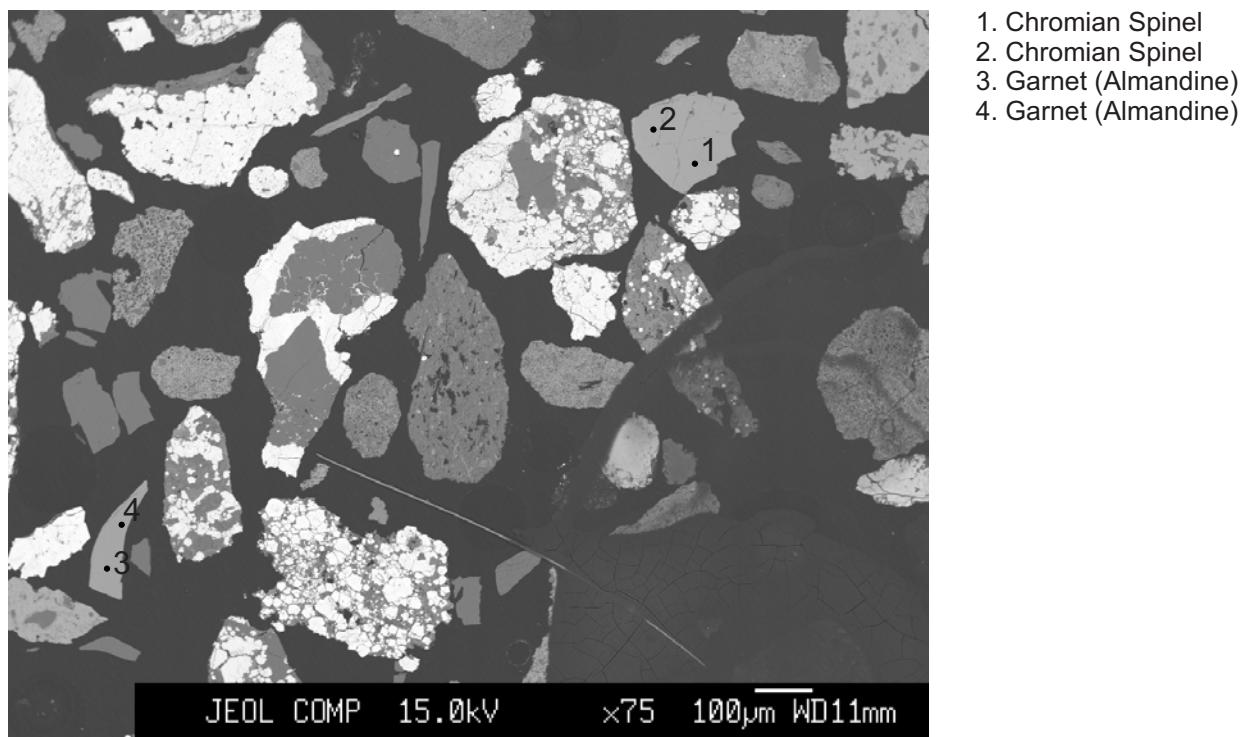


Figure 9 E-23 2500A m

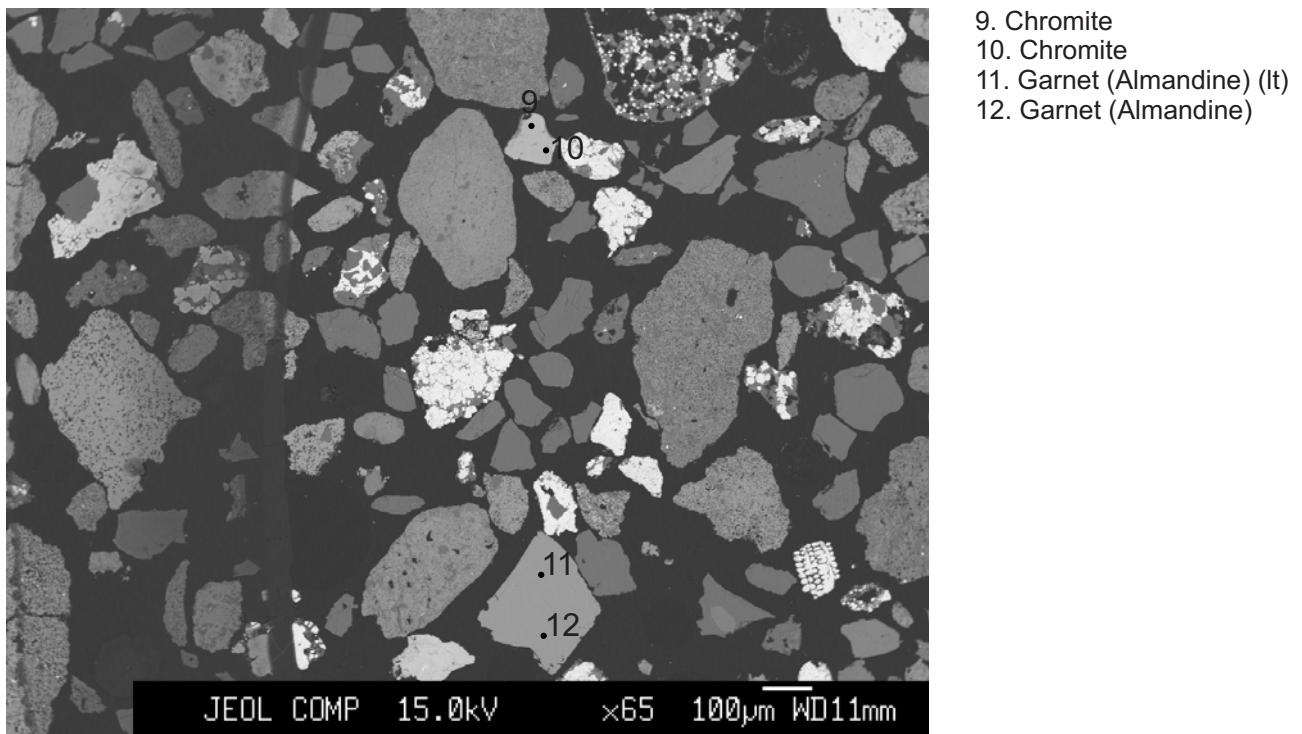


Figure 10 E-23 2500A m

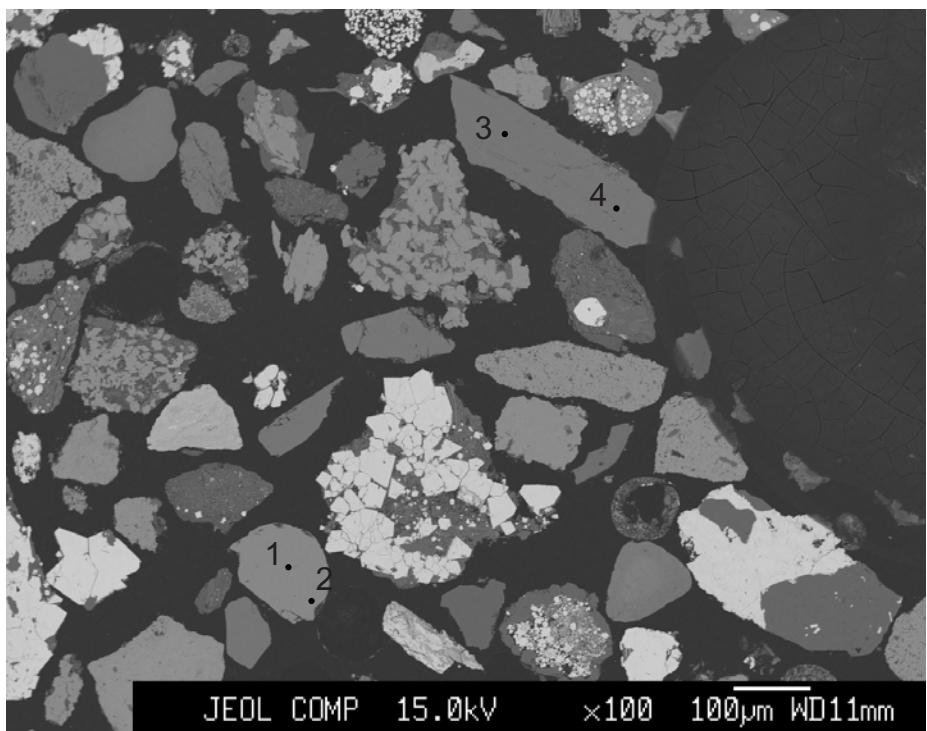


Figure 11 E-23 2600 m

1. Garnet (Almandine)
2. Garnet (Almandine)
3. Diopside (Cpx)
4. Diopside (Cpx)

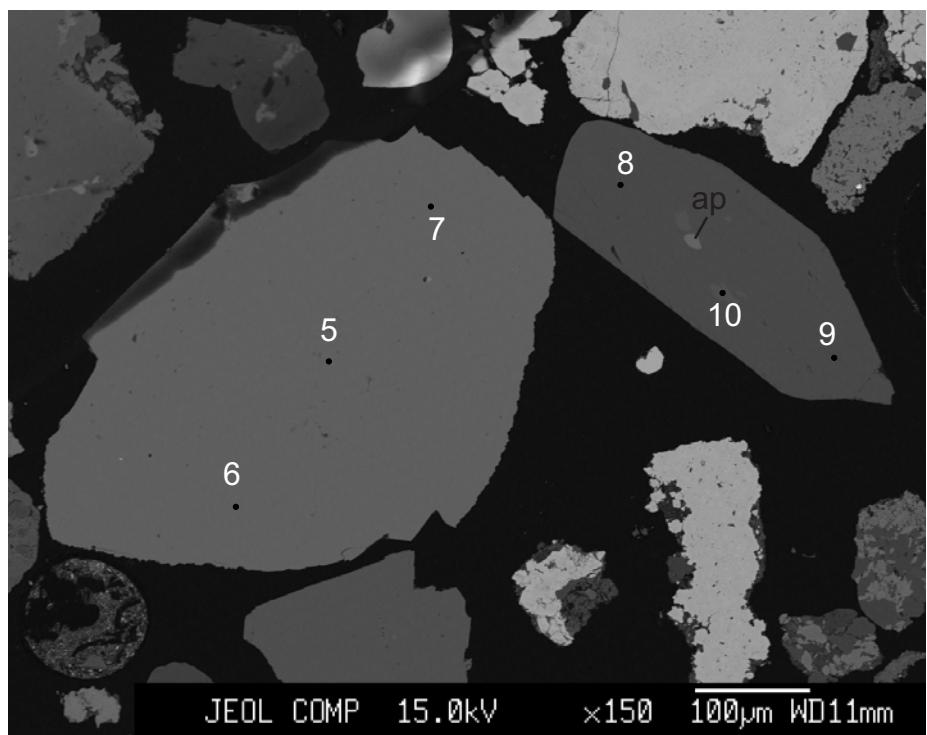


Figure 12 E-23 2600 m

5. Almandine
6. Almandine
7. Almandine
8. Tremolite (Amph)
9. Tremolite (Amph)
10. Diopside (Cpx) (lt)

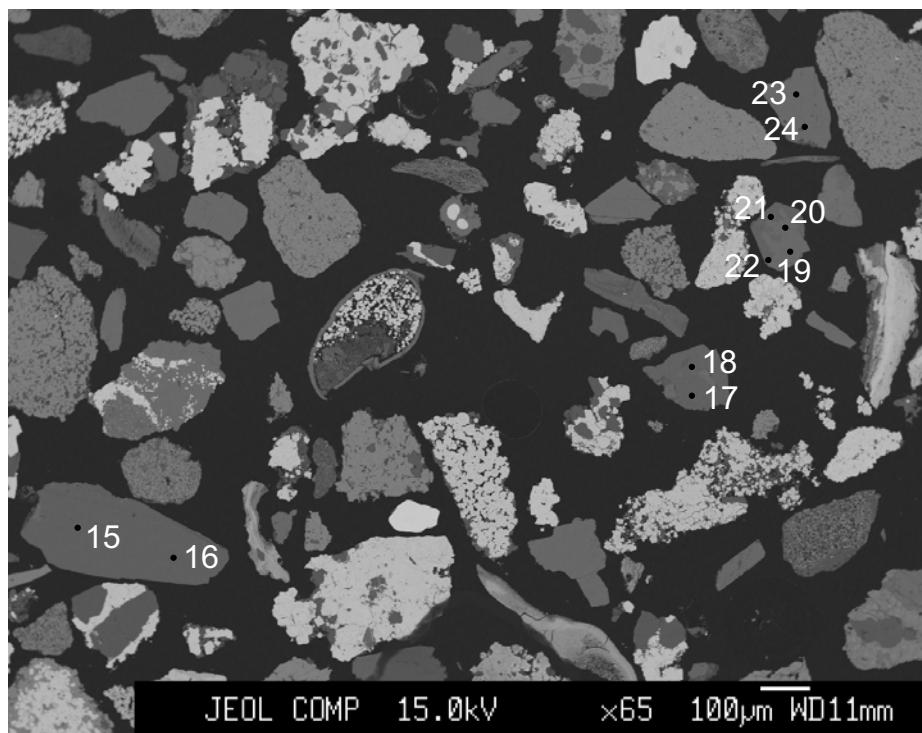


Figure 13 E-23 2600 m

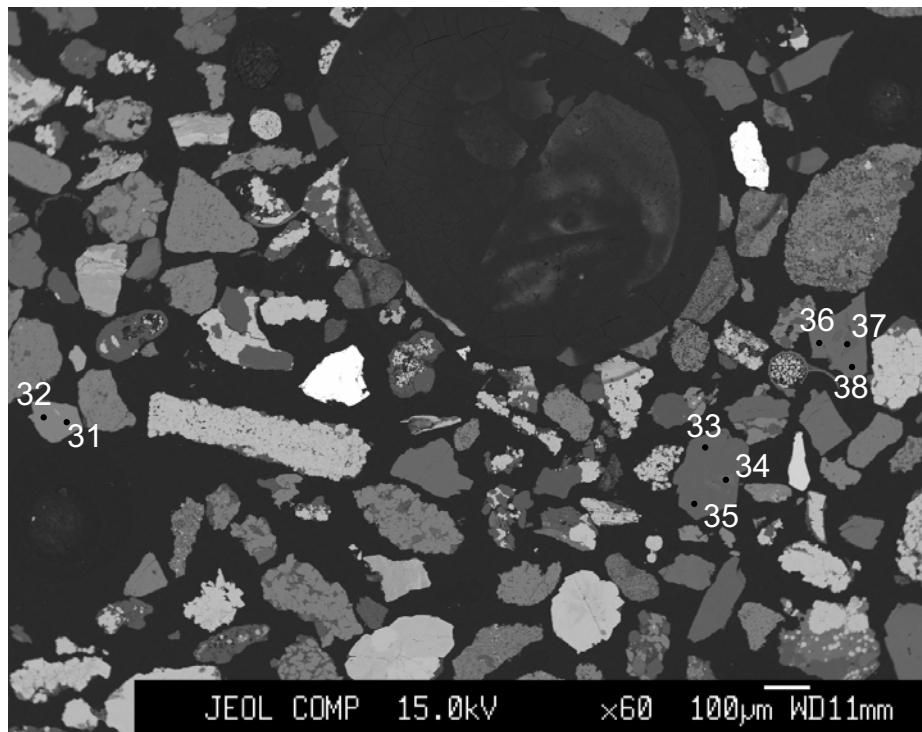


Figure 14 E-23 2600 m

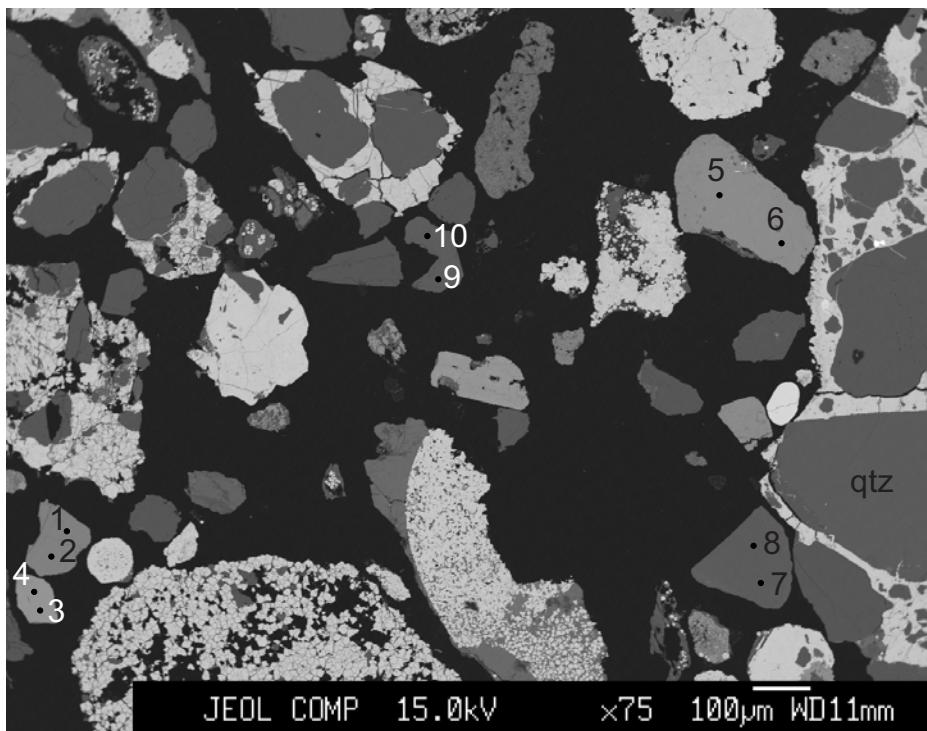
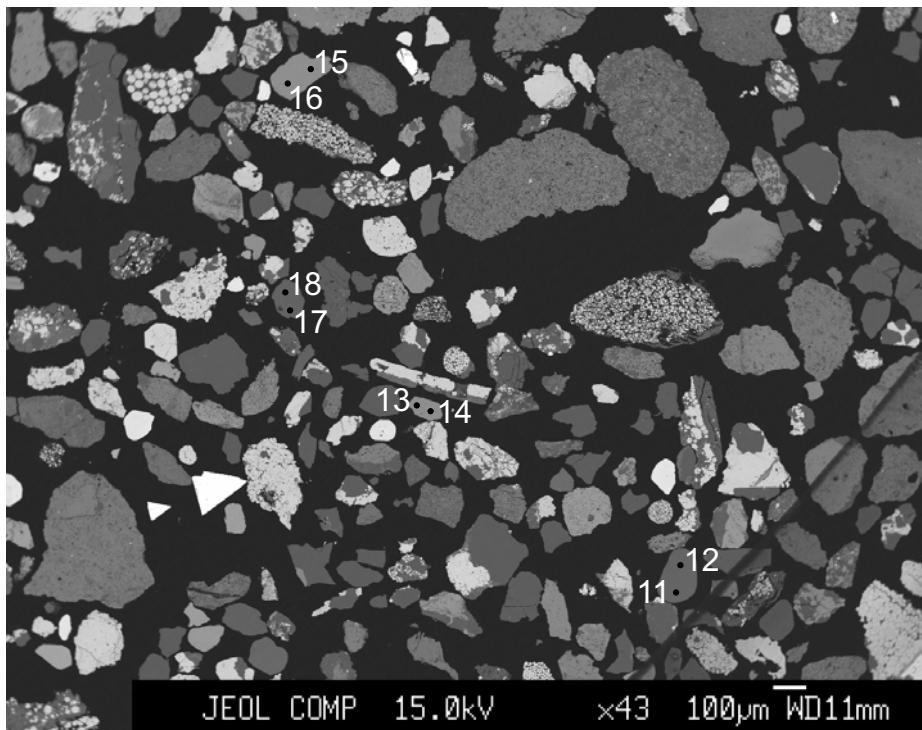


Figure 15 E-23 2800 m

1. Garnet (Almandine)
2. Garnet (Almandine)
3. Chromite
4. Chromite
5. Chromian Spinel (ht)
6. Chromian Spinel (ht)
7. Tourmaline
8. Tourmaline
9. Tourmaline
10. Tourmaline



11. Tourmaline
12. Tourmaline
13. Garnet (Spessartine)
14. Garnet (Spessartine)
15. Garnet (Almandine)
16. Garnet (Almandine)
17. Tourmaline
18. Tourmaline

Figure 16 E-23 2800 m

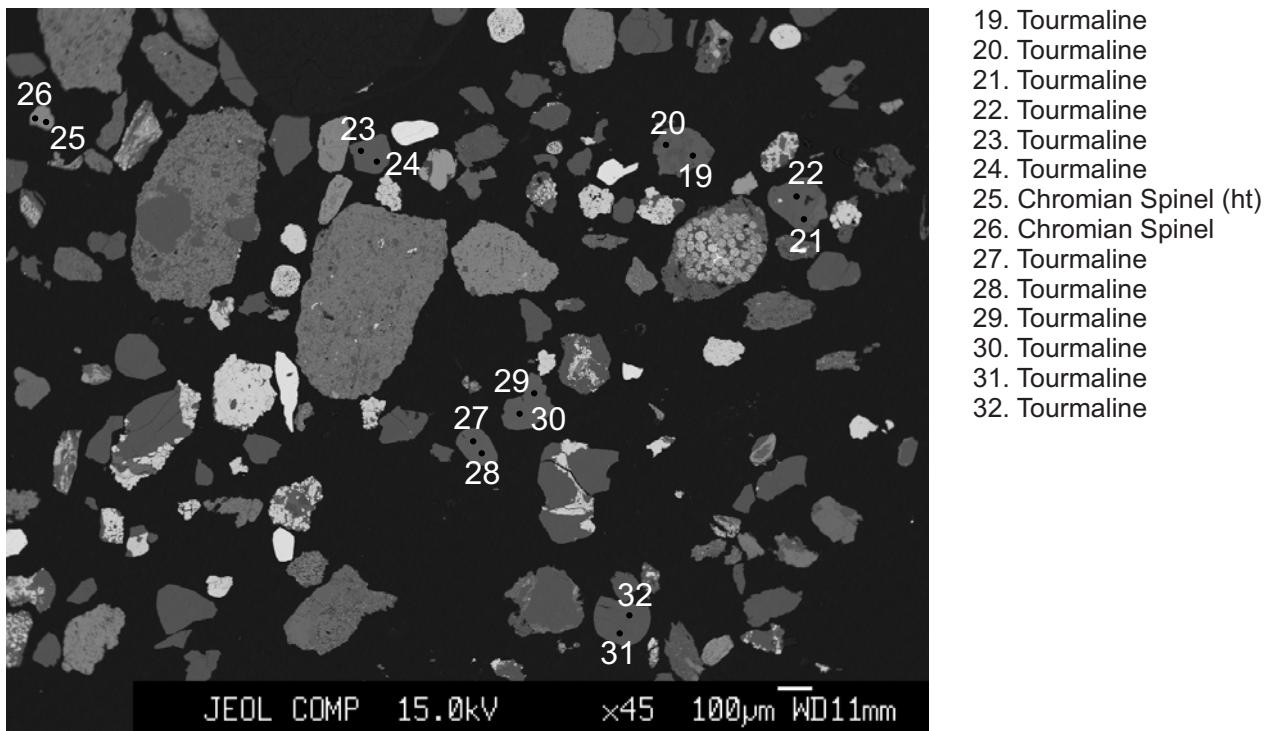


Figure 17 E-23 2800 m

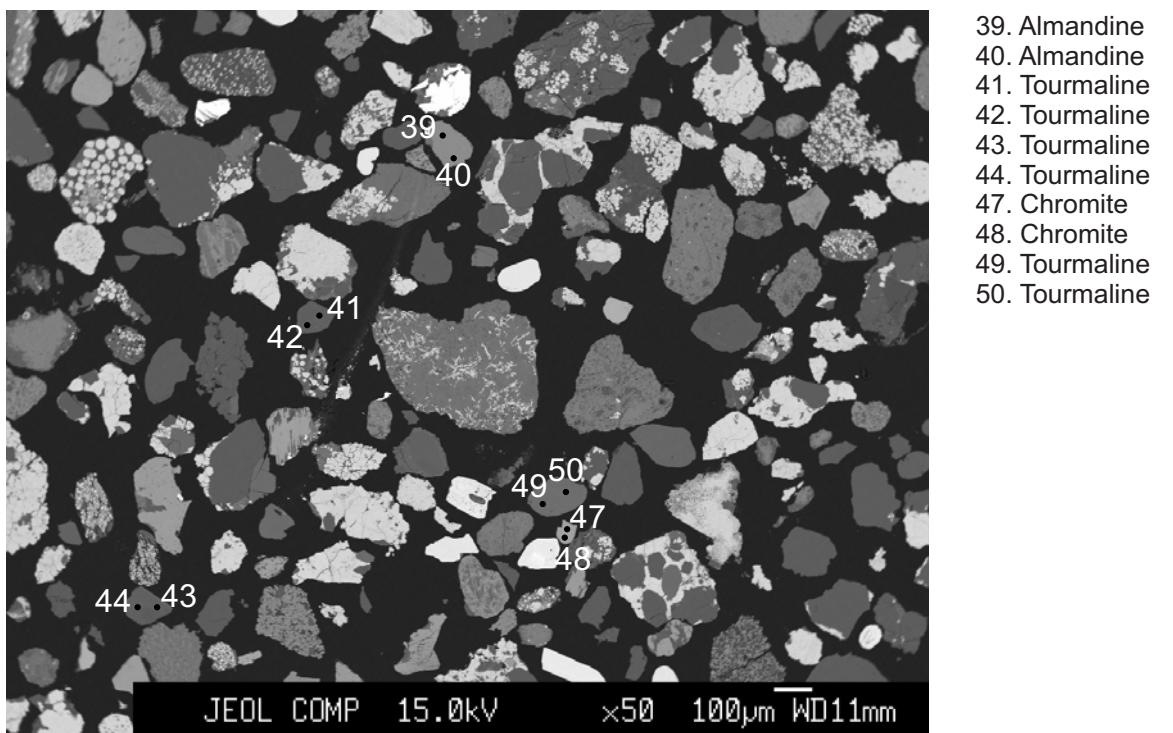


Figure 18 E-23 2800 m

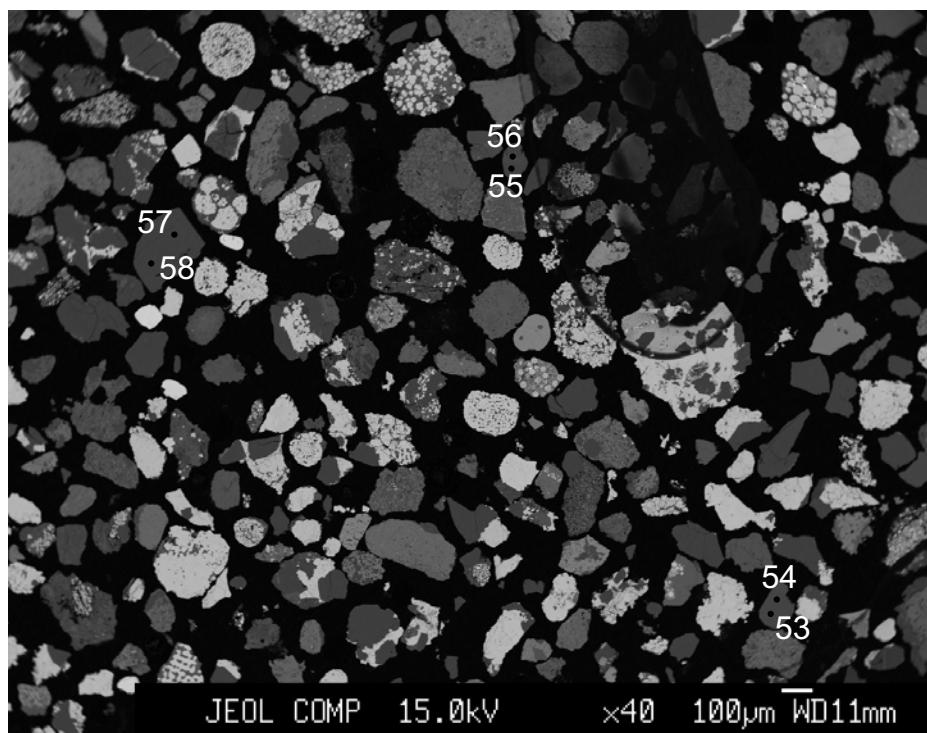


Figure 19 E-23 2800 m

53. Tourmaline
54. Tourmaline
55. Tourmaline
56. Tourmaline
57. Tourmaline
58. Tourmaline

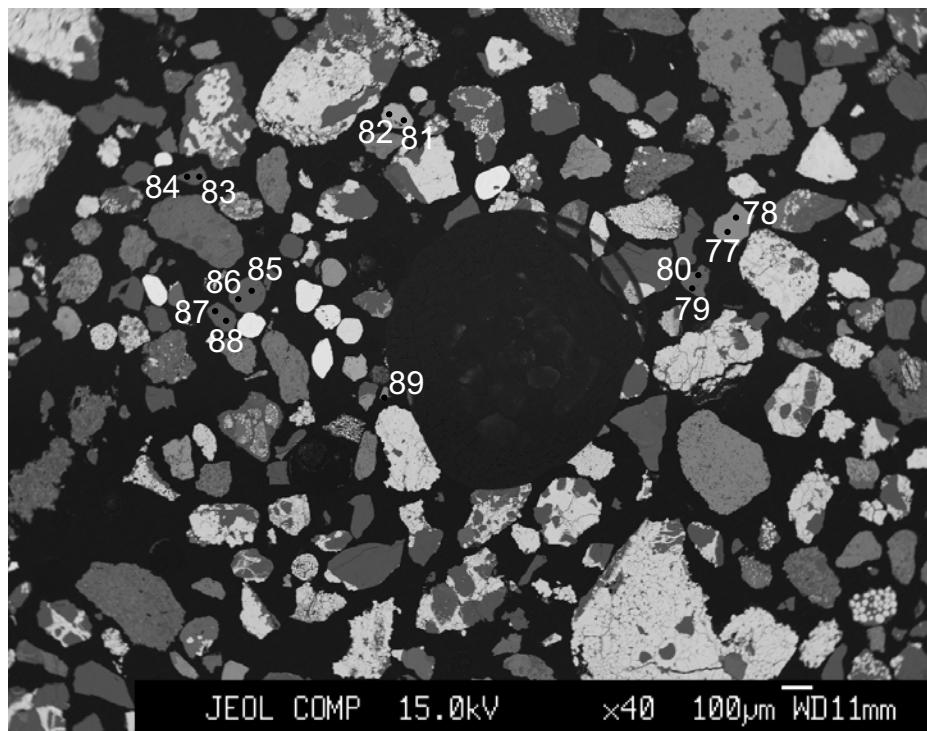


Figure 20 E-23 2800 m

77. Chromian Spinel (ht)
78. Chromian Spinel (ht)
79. Tourmaline
80. Tourmaline
81. Chromite
82. Chromite
83. Tourmaline
84. Tourmaline
85. Tourmaline
86. Tourmaline
87. Tourmaline
88. Tourmaline
89. Chromian Spinel

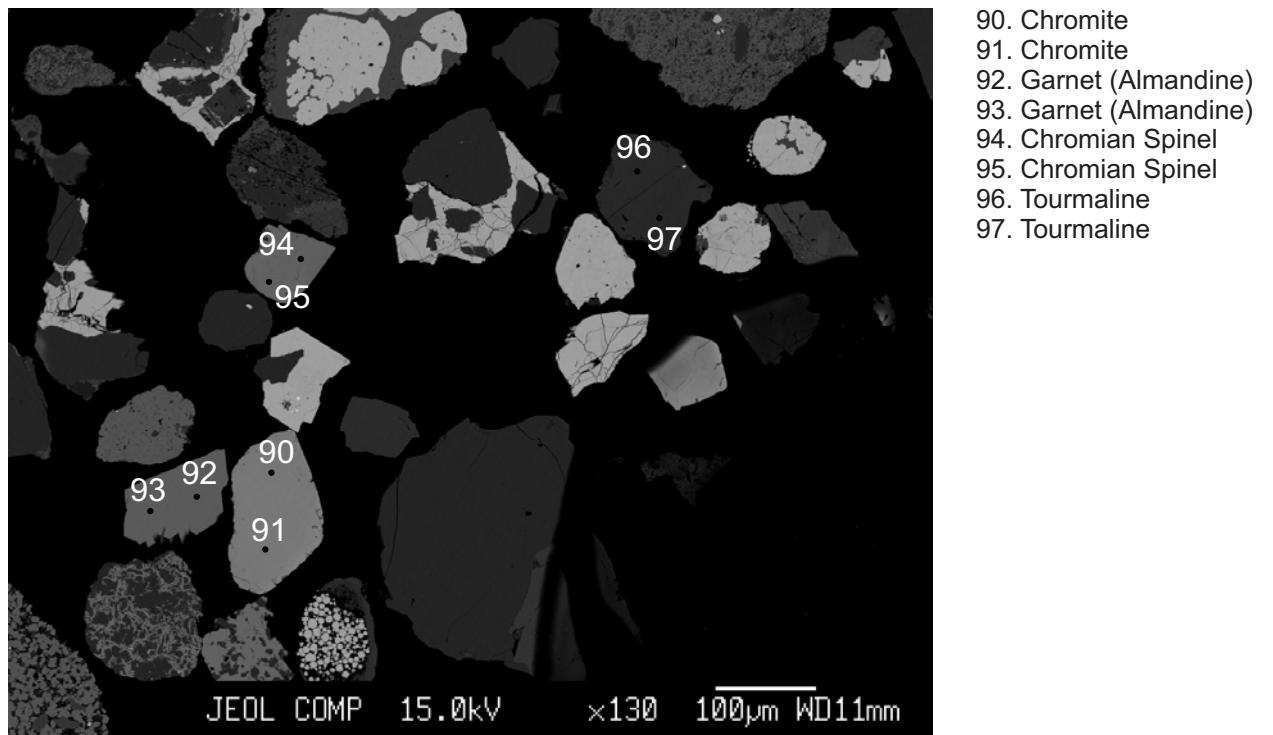


Figure 21 E-23 2800 m