



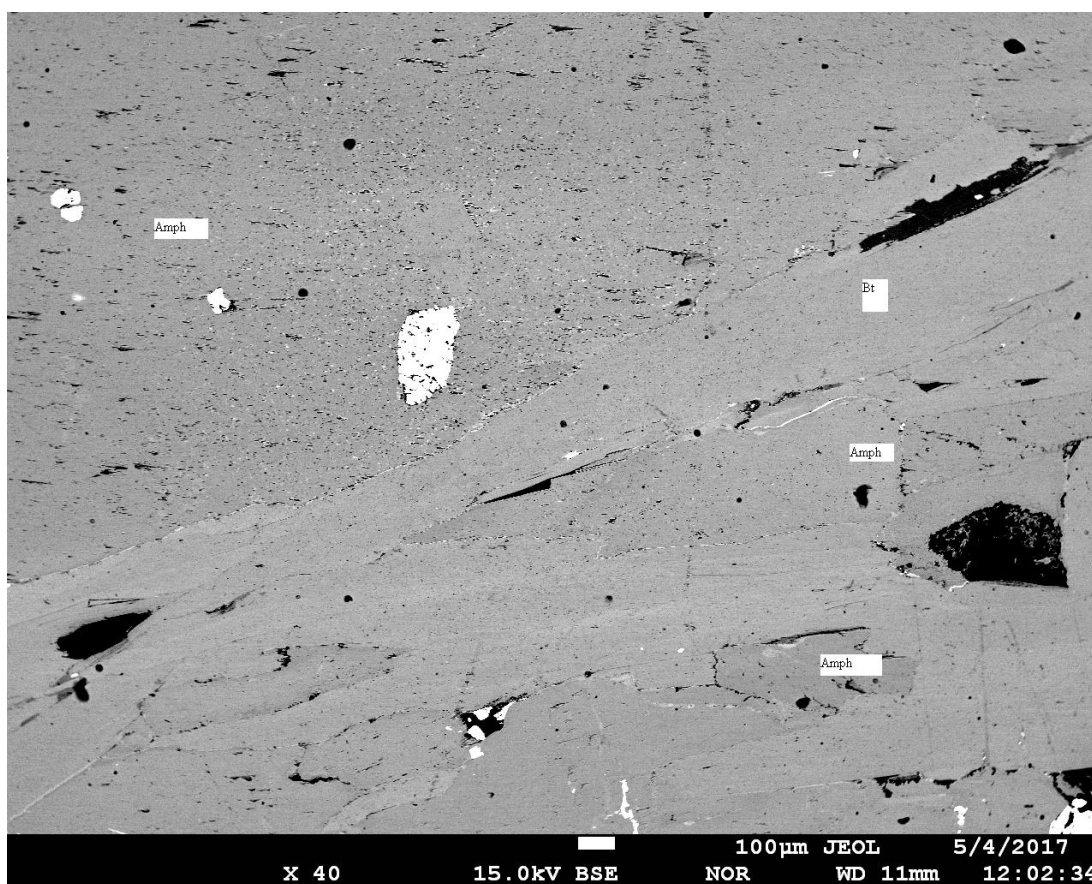
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A petrological and petrogenetic study of fluid-rock interaction associated with apatite–iron ore formation at Malmberget, northern Sweden

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Abstract

Tectonic forces and metamorphism have caused deformation and alteration in rocks associated to apatite iron ores in the LKAB mining field in Malmberget, northern Sweden. From a mining perspective, some rocks cause stability problems in the underground mine. Especially troublesome rocks are biotite rich rocks with low rigid competence, locally termed biotite schist. Biotite schist is often mapped in close relation to ores and intermediate-mafic metavolcanic rocks. This study aims to establish physical and chemical properties of the biotite schist and their relation to adjoining metavolcanic rocks in the Alliansen ore body. Three main subdivisions have been established before analysis of the rocks: first a slightly altered intermediate-mafic metavolcanic rock; secondly, a biotite altered mafic metavolcanic rock and finally a biotite schist. Results from this study indicate that phlogopite and magnesium-rich amphiboles dominates in both metabasites and biotite schist rocks. From geothermobarometry, the results indicate that different regimes have led to biotite formation in the metavolcanic rocks and biotite schist. Potassium enrichment in altered metavolcanic rocks might have contributed to formation of the biotite schist. Potassium enrichment and sericite findings suggest metasomatism.

Key words: *Malmberget, Alliansen, alteration, biotite schist, geochemical analysis, geothermobarometry, core logging.*

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1. Introduction

Biotite altered rocks are found associated with apatite iron ores at one of *Luossavaara-Kiirunavaara Aktiebolag* (LKAB) mines, situated in Malmberget northern Sweden. The biotite rich zones are considered unstable from a mining perspective, since they provide low rigid competence.

1.1 Aim

The aim of this study is to characterize biotite rich alteration zones; which have a spatial association to apatite iron ore deposits at Malmberget, northern Sweden. Another associated goal is to see if it is possible to determine how the biotite-rich zones have formed, based on physical and chemical examinations of drill cores; i.e. to propose a petrogenetic model for biotite formation.

A second aim is to find out if there is any evidence that mafic metavolcanic rocks are precursors to biotite schist rock.

1.2 Geological setting

This section starts with an overview over northern Norrbotten, followed by more detailed descriptions of Malmberget's stratigraphy.

1.2.1 Norrbotten – general information

Northern Norrbotten is underlain by Archaean to Proterozoic rocks that are predominantly crystalline – a narrow belt of sedimentary cover is found at the eastern rim of the Caledonian orogen. The oldest Archaean bedrock (c. > 2.68 Ga) dominates northernmost Sweden (fig. 1) – stretching approximately to the Kiruna region (Bergman, Kübler & Martinsson 2001).

Svecofennian Proterozoic rocks comprise a great variety of supracrustal and intrusive rocks that encompass several rock units formed between c. 1.96-1.78 Ga. The general groups are *Porphyrite group* and the overlying *Porphyry group* – collectively known as the *Kiruna Porphyries*. The older metasediments in Norrbotten includes calc-silicate rocks, calc-alkaline sedimentary rocks and minor amounts of carbonate rocks (Bergman, Kübler & Martinsson 2001).

The Kiruna Porphyries are associated to a shift from extensional magmatism (Porphyrite group) to a compressional setting (Porphyry group). Additionally, the shift is correlated to a change from low titanium-bearing to high titanium-bearing volcanic rocks – which also separate the Porphyrite- from the Porphyry group. The Porphyry group, hosts apatite iron ore (Perdahl & Martinsson 1995). Various intrusive events with diverse composition – from felsic granites to mafic gabbros and diabases – are observed frequently across northern Norrbotten. Commonly the structural grain in N Norrbotten trends NNE to NNW (Bergman, Kübler & Martinsson 2001).

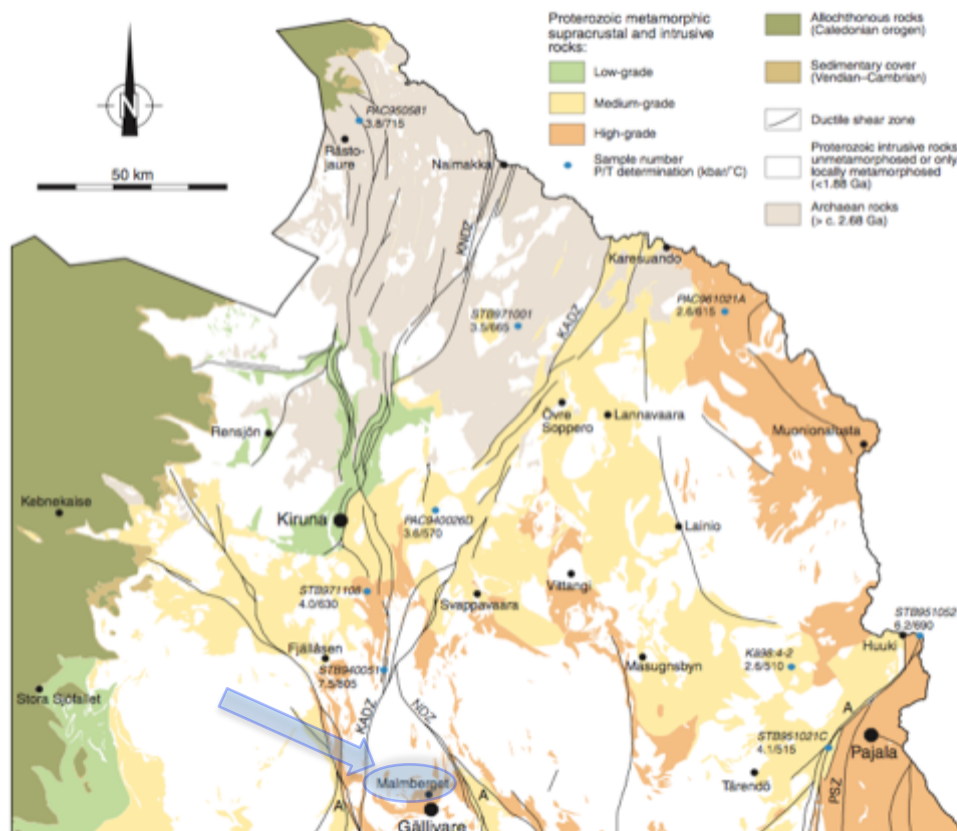


Fig. 1. Metamorphic map of the northern part of Norrbotten county. (Modified from Bergman Kübler & Martinsson 2001). Malmberget marked in yellow and orange = medium to high metamorphic grade. KADZ = Karesuando–Arjeplog deformation zone, NDZ = Nautanen deformation zone.

1.2.2 Malmberget

Malmberget is a mining town in Gällivare municipality in Norrbotten, NNE Sweden (fig. 1). Malmberget belongs to the northern Norrbotten ore province that contains Copper and iron ore deposits. *Apatite iron ore* from *Luossavaara-Kirunavaara AB* mines (LKAB), in Malmberget and Kiruna, is of significant size and considered as the most important iron ore producer in Europe (Lund, 2013). Malmberget have been mined since the 18th century. Iron ore deposits show greater deformation and higher metamorphic grade compared to Kiruna (Bergman, Kübler & Martinsson 2001).

Malmberget is bordering a region with Archaean and Proterozoic rocks NNE and an entirely Proterozoic terrain WSW, east of the Caledonian orogen (fig. 1). The mining town belongs to the northwest part of the Fennoscandian shield. The rocks in Malmberget formed during the Svecokarelian orogeny around 1.96-1.75 Ga (Bergman, Kübler & Martinsson 2001).

Malmberget is purely crystalline and dominated by metavolcanic rocks that record high-grade metamorphism (fig. 1). Extrusive and intrusive rocks, besides apatite iron ores, form the stratigraphy of the area (fig. 2). Intrusive rocks in Malmberget derive from Granite-pegmatite association – also known as *Lina granite suite* – the Perthite monzonite suite and gabbro, dolerite and metagabbro suite (Bergman, Kübler & Martinsson 2001). According to Witschard (1984) there are similarities between the Perthite monzonite suite and the Porphyry group; both units show compositional resemblance for both trace- and major elements such as alkali/silica relationship. Furthermore, density and magnetic susceptibility is similar.

1.2.3 Tectonics, metamorphism and alterations

The early stages of the Svecokarelian orogen encompassed a tectonic shift leading to increased deformation around 1.88 Ga – initiation of the Porphyry group. The shift around 1.88 influenced a change in magma composition, from calc-alkaline to alkali calcic. The change is believed related to a shift from a subduction setting to an extension regime (Perdahl & Martinsson 1995). Another rock-re-working period is linked to the final phase of the Svecokarelian orogeny around 1.86-1.76 Ga – related to Granite-pegmatite association (Bergman, Kübler & Martinsson 2001, Witschard 1984, Geijer 1930). Since there are deformation patterns in Malmberget that includes both Lina granites and older metavolcanic rocks, deformation is interpreted younger than 1.8 Ga (Bergman, Kübler & Martinsson 2001).

The structural grain in Malmberget differs from overall pattern in northern Norrbotten. Evidence for at least two phases of folding is seen at Malmberget. *The Karesuando-Arjeplog deformation zone* in west and the *Nautanen deformation zone* in east (see fig. 1) have influenced deformation in the study area. In northern Malmberget the foliations bend towards Karesuando-Arjeplog deformation zone. Nautanen deformation zone has influenced to strong ductile deformation. The deformation zones in the area have influenced an E-W trending compression. Major fold structures trends NW-SE–NNW-SSE. Deformation and metamorphism during late Svecokarelian orogeny is suggested related to shear zones, and Granite-pegmatite association intrusions (Bergman, Kübler & Martinsson 2001).

Proterozoic high-grade metamorphism has influenced to migmatitisation and recrystallization. The greatest metamorphic temperature and pressure recorded in Norrbotten is to 805 °C and 7.5 kbar respectively. Principal alterations in Norrbotten are albite- and scapolite alteration. Other alterations are K-feldspar, chlorite, skarn, epidote and sericite among others. Svecofennian scapolitisation is commonly observed in intrusive and supracrustal rocks related to shear zones. Sodium metasomatism has affected many metavolcanic rocks. Widespread albitisation has affected apatite iron ore footwall rocks, and K-feldspar alteration is common (Bergman, Kübler & Martinsson 2001).

1.2.4 Rock units in Malmberget

Porphyry group

The metavolcanic Porphyry group basement is in general strongly metamorphosed. The group hosts apatite iron ores – magnetite and to a lesser extent also hematite in its upper parts. Locally preserved porphyritic texture or amygdalites suggest the rocks were derived from an extrusive source. The rocks are generally felsic to intermediate and alkali-calcic, from basalt–rhyolite (Bergman, Kübler & Martinsson 2001). The main phase of the Svecokarelian orogeny is considered associated to emplacement of the Porphyry group (Witschard 1984).

Apatite iron ores

The E and W-N located apatite iron ores in Malmberget differ. Deposits located W and N are nearly continuous while the E deposits are documented as relatively isolated bodies (fig. 3.). Moreover, there are differences in composition. The W (and N) part includes both magnetite and hematite and apatite banding is frequent, whereas the E part constitutes of

magnetite with less apatite. Sillimanite-, muscovite- and quartz-bearing gneiss is located in the footwall to W ores – andalusite, corundum and barite are occasionally also discovered. In places granite and pegmatite dykes crosscut the apatite iron ores. Additionally, dykes and sills of more mafic origin have intruded the ore bodies (Geijer 1930).

The ore-host-rocks are mainly K-feldspar and albite rich; felsic rocks are encountered in remote areas. Biotite- and scapolite alteration is associated to mafic host rocks. Apatite, amphibole, pyroxene and biotite are leading gangue minerals. Accessory minerals are pyrite, chalcopyrite, bornite and molybdenite (Bergman, Kübler & Martinsson 2001).

The mode of formation of the apatite iron ore is not known; although, in modern times the most widely accepted theory concerns hydrothermal ore formation related to the Svecokarelian orogeny 1.88-1.89 Ga. Furthermore, magmatic-hydrothermal intrusion-related high-temperature processes induced by volatiles has probably contributed to the ore formation (Bergman, Kübler & Martinsson 2001).

Perthite monzonite suite

Perthite monzonite suite is believed emplaced subvolcanically. The composition is dominated by monzonite/quartz monzonite. This suite shows signs of magma mingling and mixing. Perthite monzonite suite plot in syn-collision and volcanic arc field in a Rb vs. Y+Nb diagram (Bergman, Kübler & Martinsson 2001).

Granite-pegmatite association (*Lina granite*)

Rocks in this suite comprise granites, pegmatites and aplites that have been observed as massifs or as intrusions. Some pegmatites incorporate parts of country rocks. Emplacement of the Granite-pegmatite association relates to metamorphism and deformation during late stage of the Svecokarelian orogeny. Rocks bordering Granite-pegmatite association show high-grade metamorphic alteration and deformation. An extensive granite body from to this group is situated in NW Malmberget – see fig. 3. Additionally, recrystallization of ore host rocks

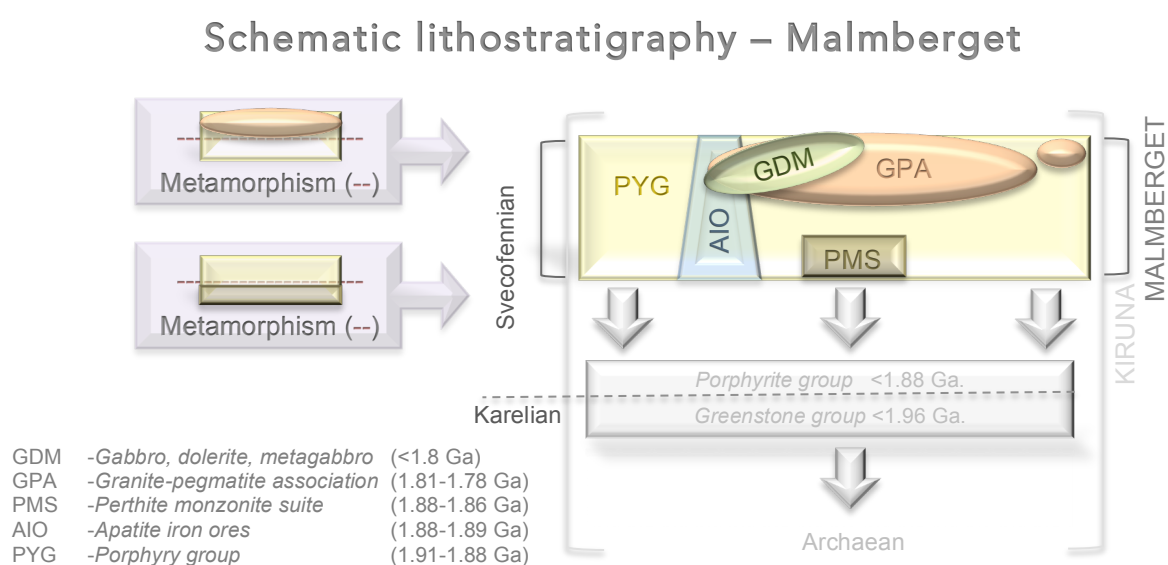


Fig. 2. Schematic illustration showing approximate rock unit relationships. Malmberget's stratigraphy compared with a more extensive lithostratigraphy in Kiruna. Metamorphic peaks related to PMS and GPA are emphasized.

progressively increases towards NW. Weak foliation pattern is commonly observed in the Granite-pegmatite association rocks (Bergman, Kübler & Martinsson 2001).

Gabbro, metagabbro and diabase

Rocks belonging to GDM are the youngest rocks in Malmberget since crosscutting relationship with GPA and other rocks are recognized. GDM is high in iron, vanadium and titanium and low in silica.

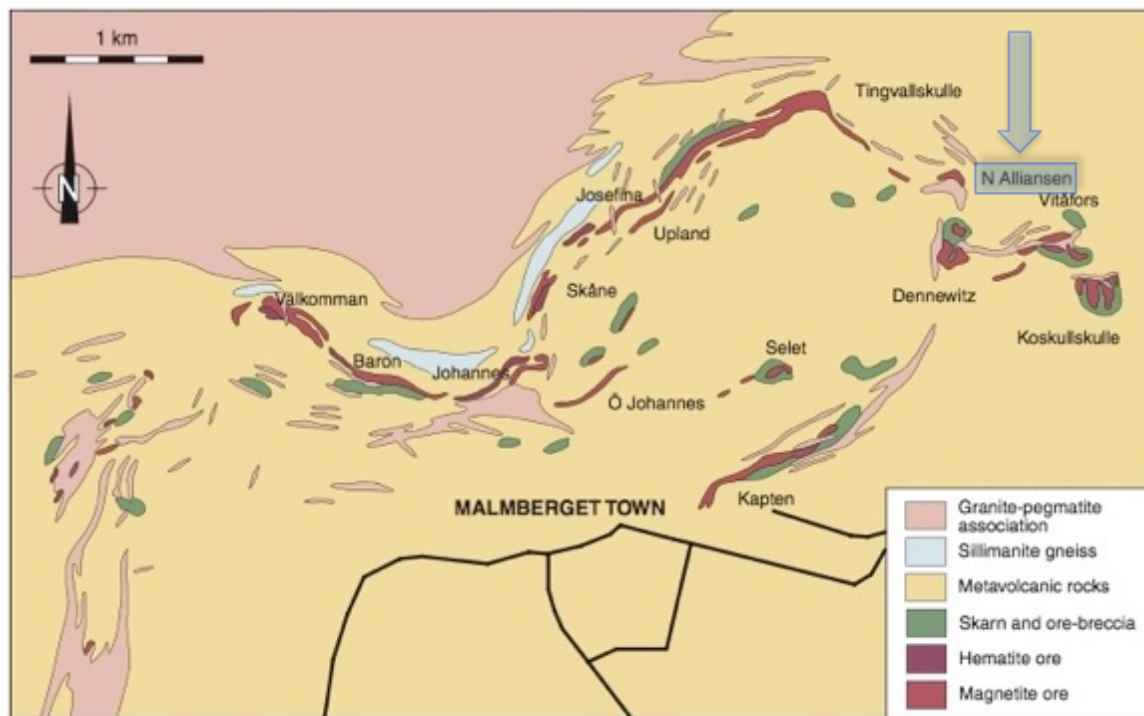


Fig. 3. Geological map of the Malmberget area (modified from Geijer 1930a). Names refer to major ore bodies. Samples relating to this study were taken from *Alliansen* ore body – marked in blue at image top right.

2. Methods

2.1 Drill core logging and sampling

Initially, drill cores were logged (appendix A) in LKAB's logging facility in Gällivare, followed by selection of samples. Samples were selected from three diamond boreholes from the Alliansen ore body (fig. 3 and 4) – drilled from 1250 m depth and downward. Each borehole has been given a unique identity number: 34/15, 37/15 and 76/15. The core samples were marked with permanent marker annotating borehole number, depth and downward direction of borehole. Following marking samples were hammered out from 1 m drill cores. Samples were selected based on visible alteration grade – from the least altered mafic rock to the most altered rock named biotite schist. Studied rocks are assumed to belong to the Porphyry group and perhaps also gabbro, dolerite and metagabbro suite (fig. 2).

In this study the biotite alteration has been subdivided into three separate phases; two within a metamorphic volcanic rock type termed *Grey leptite* (GLE) and another one termed *Biotite schist* (BSF). Leptite is a term used in LKAB to describe metavolcanic rocks from the porphyry group. BSF is the term used when biotite is visibly dominating the rock. The three subdivisions are as follows:

- GLE
- Biotite altered GLE (abbreviated GLE+Bt)
- BSF

When logging, drill cores representative sample pieces between 0.1-0.3 m was selected for rock descriptions and further analysis.

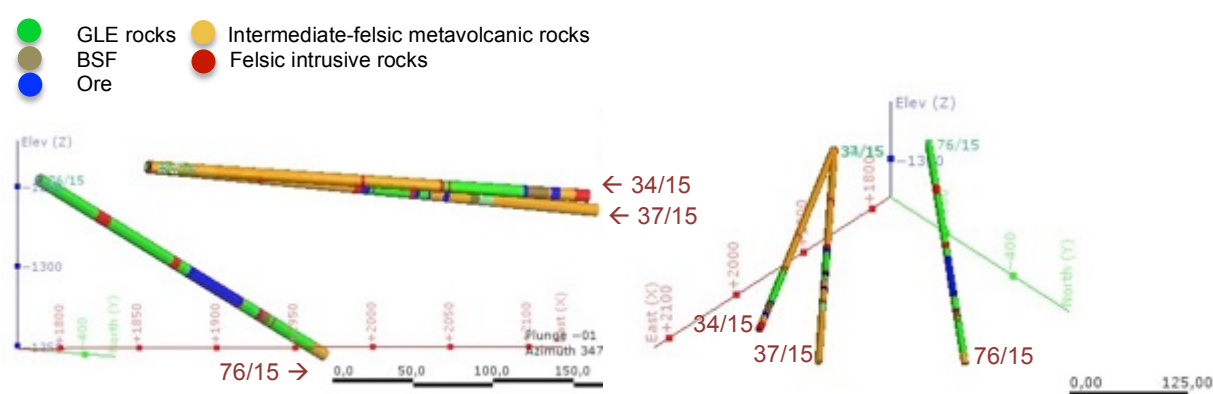


Fig. 4. Screenshots from Leapfrog© – showing spatial relationships between boreholes from different angles. Red text marks individual borehole-Id. Colours indicate logged lithology.

2.2 Sample preparation and analysis

2.2.1 Analysis methods

Besides core logging, following methods were used:

Analysis method	Product name	Results	EC
Handheld XRF analysis	<i>Olympus innov-X: Delta Premium</i>	Semi quantitative	^{12}Mg and up
XRF spectrometry	<i>Rigaku ZSX Primus II</i>	Quantitative	^4Be - ^{92}U
XRF core scanner	<i>Itrax XRF core scanner</i>	Qualitative	$^{12}\text{Mg}/^{13}\text{Al}$ - ^{92}U
Electron microprobe analysis	<i>Jeol JXA-8530F HyperProbe</i>	Quantitative and qualitative	^5B - ^{92}U
Activity composition calculations	<i>AX2 software</i>		
Geothermobarometry	<i>THERMOCALC</i>		

EC = Element coverage

Furthermore, the following methods were conducted from the three divisions established when logging. Separation was made in order to compare rocks with diverse biotite content. Since the samples varied in length, more data was collected from longer pieces when running the core scanner and handheld XRF analysis. Skarn is an abbreviation used for dark, black or dark green, minerals interpreted as amphiboles or pyroxenes.

2.2.2 Thin section preparation

Samples were shipped to Stockholm University. In the University laboratory work started with preparation of 16 thin sections, in the size of 28×48×0,003 mm. Preparation started with cutting the Ø 40 mm drill cores into halves, followed by marking 28×48 mm areas for sawing. The markings were placed onto cores depending on textural appearance of individual samples so that as much as information as possible could be found in future microscopic studies. In the next step blocks were cut out, and a little hatch mark on the right short side were placed to mark downward direction of borehole. After cutting, base of blocks were ground with silicon carbide – i.e. parts intended to be glued to glass slides of thin sections. Lastly samples were given identity numbers and shipped to Warsaw for thin section completion.

The thin sections (appendix B) are named from borehole and depth. All sample names initiate with an ‘A’ for the Alliansen ore body, followed by the two first digits of the diamond borehole and lastly the depth is included. The depth is a four-digit number where the first digit is hundreds of metres and the last is tens of centimetres. For an example, A341663 means Alliansen borehole 34/15 at 166.3 m depth.

2.2.3 Handheld XRF preparation

For the handheld study, see appendix C organised data, each sample was prepared by marking every third centimetre with a permanent marker, for planned measuring points. The handheld device was firstly calibrated, and measurements started with a measurement on a rock not related to this study (first measurement in appendix C – raw data) to see that it worked.

2.2.4 XRF spectrometry on glass beads - preparation

Preparation for the XRF spectrometry analysis involved pulverising 20-40 g of samples to clay size fractions to achieve a whole rock analysis. Samples were weighed to make it possible to calculate loss of ignition afterwards. Malin Söderman at Stockholm University was later responsible for adding flux and melting, making of glass beads, and analysing. Three glass beads were prepared, one from each diamond bore hole (appendix D), corresponding to the three rock subdivisions. Analysis was conducted on the following sample pieces:

A-XRF341980 – GLE rock

A-XRF372559 – BSF rock

A-XRF762304 – GLE+Bt

2.2.5 Loss on Ignition

Before using data from XRF spectrometry, the Loss on ignition (LOI) was used to normalise raw data, since heating of samples (<1000 °C) caused loss of volatiles from internal structures within minerals, such as water and carbon dioxide (Winter 2014). Following calculation is from Mu, Saffarzadeh & Shimaoka (2017):

$$LOI (\%) = \left(\frac{\text{mass loss of sample}}{\text{mass of original sample}} \right) \times 100 = \left(\frac{W_1 - W_2}{W_1 - W_0} \right) \times 100$$

W_0 = Blank crucible mass; W_1 = Crucible + sample pre-ignition mass; W_2 = Crucible + sample post-ignition mass

2.2.6 XRF Core scanner preparation

Preparation for the core scanner involved adjustment so that core surfaces were in the approximate same level. This was fixed with foam rubber material to level up lower cores. Cores were placed on a plank. Since the machine could only analyse a limited length for each run, four runs were done. Malin Kylander was responsible for running the analysis and calibration of the core scanner (appendix E).

2.2.7 Preparation for electron microprobe analysis

From microscopy studies, three thin sections were chosen for electron microprobe analysis. Samples were selected from one borehole to get as closely related alteration grades as possible. The samples were carbon coated since carbon coating is essential for conduction to the electron microprobe instrument (appendix F).

2.3 Information about the XRF and electron microprobe method

General principles are written with support from Winter (2014).

2.3.1 Information about the XRF method

X-ray fluorescence spectroscopy (XRF) involves irradiation onto a solid sample, which influence electron-transitions in the inner electron shells of the various elements within the sample. When excited electrons return to ground state, fluorescence x-rays with individual spectra in the higher-energy x-ray range are released. In order for the radiated x-ray spectrum to diffract, organized crystal lattices are required. The dispersion of the spectrum can later be measured with an x-ray detector. The detector scans the unique frequency corresponding to individual elements. XRF methods are able to detect concentration down to a few ppm and are considered to be relatively accurate and exact.

2.3.2 Information about the Electron microprobe analysis method

The electron microprobe analysis method (EMPA) probes a small mineral area of 10 µm. The analysis is done from a polished thin section that is bombarded with a Ø 2-µm electron-beam that excites atoms in sample and in return releases fluorescence x-rays. X-rays can either be scattered by wavelength (WDS) or energy (EDS). WDS requires an isolated crystal and an individual channel for each element that are to be analysed. Furthermore, WDS have better resolution of elements and most WDS-probes have four or more channels. In the channels the elements from the excited sample are passing two-four times, and then counted by a computer. Two to four passes per channel makes the computer analyse between 8-14 principal elements in sample mineral. WDS have been used in this study.

EDS is in comparison with WDS less accurate but is a more compact system and only requires a small detector port. An EDS can be attached to a scanning electron microscope and adds data to the image that makes chemical analysis possible. EMPA gives a relatively quick and correct mineral analysis and can be used for analysing zoning compositions from core to rim. Beneficial with EMPA is that it is a none non-destructive method – besides possible <20 µm caves created if the beam intensity is rather high – but it is not suitable for mineral analysis since only small areas are analysed. The detection limits are too high to identify trace elements; hence, major elements are analysed.

2.4 Core scanner and handheld XRF data

After sorting data from the core scanner and the handheld XRF, *K* and *Fe* concentrations are schemed in order to see if there is any variation. Another use of the data is to see if there are any indicators of depletion or enrichment of elements within the rocks.

Mean values associated to rock classification were given by an initial organisation of data. Subsequently, mean values for individual elements in each separate rock group were calculated. Lastly, results from each classification group (for individual elements) were then divided by number of measurements. Also, standard deviation is calculated from mean values given by the handheld XRF to express variation within each rock group. *Mg* values were only given from the handheld XRF. *Fe*, *Mg* and *K* were of particular interest for biotite composition.

The core scanner was calibrated to move at a velocity of 0.1 mm/s. Measurements exceeding detector capacity above 250 000 kcps have not been used.

2.5 THERMOCALC and AX

Thermodynamic calculations have been performed by THERMOCALC. THERMOCALC is a program that uses a dataset from Holland & Powell (1998) to estimate pressure and temperature (P and T). AX is a program that searches activities for rock forming minerals. AX is used for creating input data to THERMOCALC. Input to AX are oxides analysed in the electron microprobe (appendix F). Mineral abbreviations used in THERMOCALC:

<i>ab</i> =albite	<i>an</i> =anorthite	<i>ann</i> =annite	<i>clin</i> =clinochlore	<i>daph</i> =daphnite
<i>ep</i> =epidote	<i>fact</i> =ferroactinolite	<i>fctd</i> =Fe-chloritoid	<i>mctd</i> =Mg-chloritoid	<i>mic</i> =microcline
<i>mt</i> =magnetite	<i>mu</i> =muscovite	<i>parg</i> =pargasite	<i>phl</i> =phlogopite	<i>san</i> =sanidine
<i>tr</i> =tremolite	<i>ts</i> =tschermakite	<i>q</i> =quartz		

THERMOCALC and AX software is used to calculate P and T of metamorphism from EMPA data. AX calculates activity compositions for rock-forming minerals. First an input file was

made for each mineral analysed with EMPA within each rock subdivision. Individual Wt. % of 11 individual oxides is taken into account in AX calculation; mineral compositions have been calculated for those with the highest total percentage when several crystals of the same mineral were analysed.

In order for THERMOCALC to succeed in performing calculations, additional phases that were not analysed but assumed as present were added: in all rocks quartz, H₂O were added. TC uses an equation (eq. 2) to find correlation between P and T within natural systems. The equation is a result from Gibbs free energy equation (eq.1) combined with the gas law and other thermodynamic equations for volume entropy, enthalpy and the equilibrium constant:

$$\Delta G_{reaction} = \sum (n_{products} G_{products} - n_{reactants} G_{reactants}) \quad [\text{Eq. 1}]$$

On a univariant line $\Delta G=0$ – products and reactants are in equilibrium.

$$\Delta G = 0 = a + bT + cP + RT \ln K \quad [\text{Eq. 2}]$$

ΔG = difference in Gibbs free energy, a =difference in enthalpy, b =difference in entropy, c =difference in volume, R = gas constant and K =the equilibrium constant. (Winter, 2014)

THERMOCALC diagnostics reveal uncertainties from end-member activities and influential elements, correspondingly e^* and HAT value. To achieve a 95 % reliability of PT estimates, there is a maximum sigfit value given for each individual calculation. Sigfit value gives an overall indication of reliability for all calculated data.

2.6 Limitations

The study is concentrated only to host rocks within one ore body, Alliansen, and there is a possibility that alteration grades of the rocks vary more than what is found within this study.

2.7 Sources of error

The handheld XRF could not measure light elements (LE) – i.e. elements lighter than Mg. When pulverising samples for preparation of the glass beads; alloy might have detached from the steel of the grinding set. The grinding set alloy might, according to the manufacturer (Retsch 2017), cause abrasion-related contamination of iron and chromium.

Some core scanner data exceeded the detector capacity and thus have greater error; error values have not been included in calculations. When performing the handheld XRF there is a risk of human factor related errors, i.e. not having fixed contact with samples or wobbling when measuring. ACF diagrams are plotted with conversion of Fe₂O₃ to FeO*, thereby ignoring Fe³⁺. Conversions are made from molecular mass of 0.5Fe₂O₃/FeO that gives a factor of 0.8887 [(0.5(127.689)) / 71.44], which was multiplied with Fe₂O₃ values.

Various results from the electron microprobe analysis were low in total, but calculated anyway. A possible problem could be too thin carbon coating on the thin sections. Phases not analysed but assumed present were used in geothermobarometry calculations. Added phases have an influence on the result since activity is calculated as 1 by THERMOCALC (i.e. as a pure end-member).

3. Results

Results are given from each method of analysis separately. Rock subdivisions have been colour-coded to facilitate analysis of results:

GLE	GLE + Bt	BSF
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3.1 Drill core logging and rock descriptions

3.1.1 GLE

The least altered GLE shows equigranular, interlocking texture with crystal grains about <1 mm in diameter (fig.5) – the observed grains are interpreted as biotite and feldspars, although most grains are too small to scratch. When mineral alignment is observed it seems associated to very thin (<1 mm) biotite crystals visible at joint surfaces or drill core ends. The dominating colour is moderately grey.

3.1.2 Biotite altered GLE

The biotite altered GLE correspond to a gradual increase of biotite compared to the GLE. The rock is observed as partly equigranular and partly patchy or schistose and banded (fig. 5). Occasionally porphyroblasts, anhedral biotite or feldspars, are seen. The patchy parts often shows mineral crystals that are larger, >1 mm. A supplemental and common mineral is magnetite. Hematite, skarn, apatite and chlorite minerals are included in the less frequently observed components. Chlorite is inferred from soapy, smooth brown-black portions within in biotite rich zones. Bands in this subgroup can range from mm up to several tens of centimetres in width. Bands are mostly composed of biotite, but iron ore-, apatite or skarn bands are also seen. Biotite altered GLE is medium to dark grey colour and sometimes with a tint of light red, green or white. There is sometimes a big difference in the appearance of GLE when comparing wet and dry example. Dry hand specimens might look much darker in contact with water. This subgroup is observed most closely related to BSF. Commonly, gradual transition is seen between GLE and BSF.

3.1.3 BSF

There are some variation discovered when examining different BSF cores; one thing that all have in common is the biotite foliation which influence to generally one joint set of the rock (fig. 5). The BSF is dominantly composed of biotite. Biotite crystals range from mm to centimetre scale. BSF's with larger grain size sometimes displays flaky surfaces.

Alterations or disseminations seen in the BSF vary between iron ore, apatite, feldspar, skarn and scapolite. Chlorite minerals are inferred in intersections that feel soapy. The BSF can vary in colour from rusty or gold-like brown or grey, to black matte or lustrous.

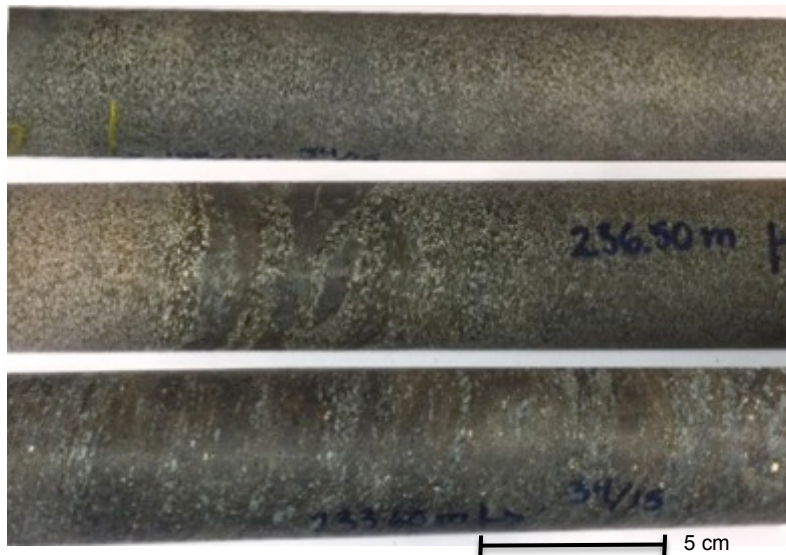


Fig. 5. Image representing rock subdivisions studied. From top to bottom: GLE; biotite altered GLE and BSF. All from diamond bore hole 34/15.

3.2 XRF spectrometry data

For raw data, see Appendix D. All XRF spectrometry is given in weight per cent (Wt. %).

3.2.1 LOI processed – normalised – data:

Data was processed from LOI that correlates to dry weight before ignition. Analysed bulk rock compositions for sample: A-XRF341980 (GLE), A-XRF372559 (BSF), and A-XRF762304 (GLE+Bt).

	GLE	GLE + bt	BSF
(wt. %)	A-XRF34	A-XRF76	A-XRF37
SiO₂	46,98	53,74	43,02
Al₂O₃	15,74	12,07	10,75
CaO	5,90	5,32	1,01
MgO	5,94	9,75	21,37
MnO	0,08	0,03	0,02
P₂O₅	0,11	0,09	0,07
Fe₂O₃	12,54	7,45	11,54
Na₂O	5,16	2,40	0,31
K₂O	2,72	7,28	9,46
TiO₂	1,12	0,79	0,90
Total:	96,30	98,92	98,46

Fig. 6. Processed XRF spectrometry data. Rock division abbreviations are included for clarity. Fe₂O₃ not corrected.

3.3 Core scanner and handheld XRF

Diagrams display maximum mean values (mean_{max}) for K, Fe and Mg cations. Data is from core scanner and handheld XRF data. Measurements are from all samples, within separate rock subdivision. Semi- quantitative core scanner results are used as a comparison with handheld results. Abbreviation *kcps* = *thousand counts per second*.

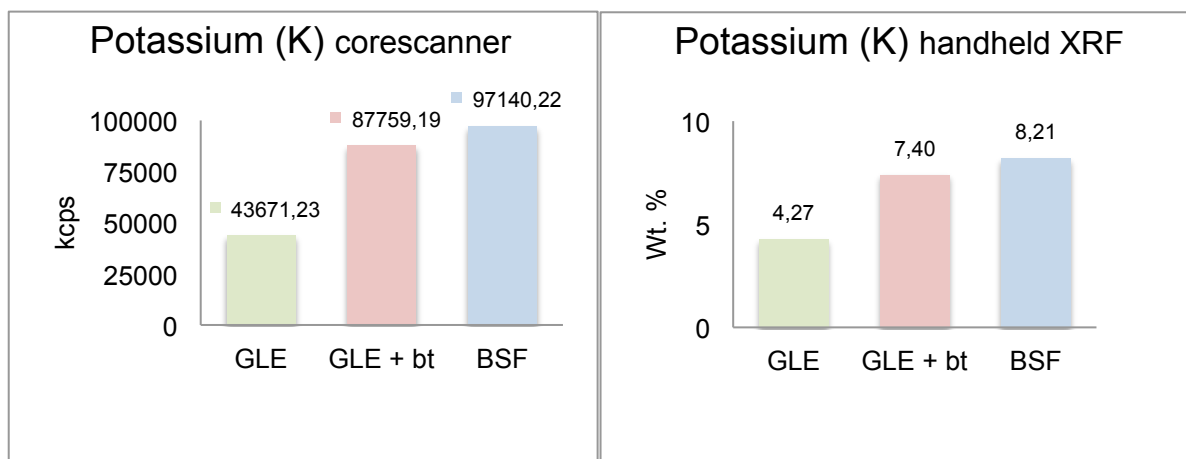


Fig. 7. Mean_{max} K-value calculated from all samples, based on group of classification. To the left: core scanner values. To the right: handheld XRF values.

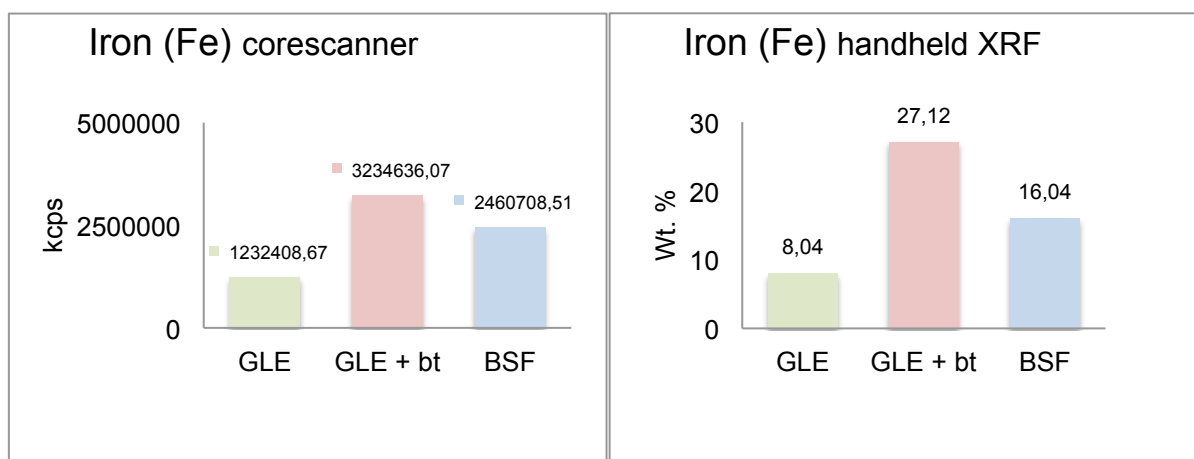


Fig. 8. Mean_{max} Fe-value calculated from all samples, based on group of classification. To the left: core scanner values. To the right: handheld XRF values.

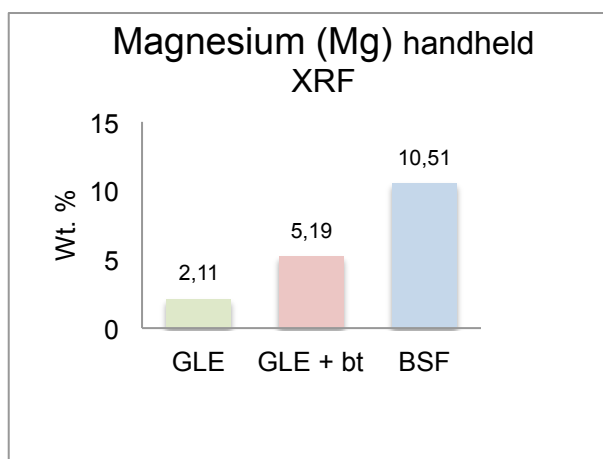


Fig. 9. Mean_{max} Mg-value calculated from all samples, based on group of classification. Handheld XRF values only since Mg was not measured in core scanner analysis.

3.3.1 Standard deviation table from handheld XRF data

Standard deviation is calculated from mean_{ma} to see variation – dispersion – within each classified rock type:

(Wt. %)	GLE	GLE + Bt	BSF
K	1.08	2.17	2.77
Fe	1.87	9.42	4.65
Mg	2.17	3.15	4.13

Fig. 10. Standard deviation from mean values associated to rock classification.

3.4 Microscopy

16 thin sections were first divided according to the core logging into three groups – GLE; biotite altered GLE and BSF – and then studied. Mineral abbreviations used:

Amp – Amphibole *Mu* – Muscovite *Bt* – Biotite *Mgt* – Magnetite
Chl – Chlorite *Ep* – Epidote *Sc* – Sericite *Pl* – plagioclase feldspar

Thin section descriptions are done with support from Raith et al., 2012. Microscopy images are collected in appendix B. XPL refers to cross polarized light and PPL is used for plane polarised light.

3.4.1 GLE

In general GLE rock showed a rather equigranular fine to medium grained groundmass consisting of opaque minerals interpreted as magnetite, maybe also sulphides, amphiboles, feldspars and epidotes with intermixes of tabular biotite grains varying between mm and cm in length (fig. 5). Metamorphic imprint can be deduced from preferred orientation of grains and mineralogy – creating bands; biotite crystals show alignment (fig. 11-12) and the crystal long axis reveal a preferred orientation. The groundmass shows sericitization affecting both plagioclase in groundmass and rims of biotite crystals. Lamellar plagioclase crystals are observed partly replaced by sericite.

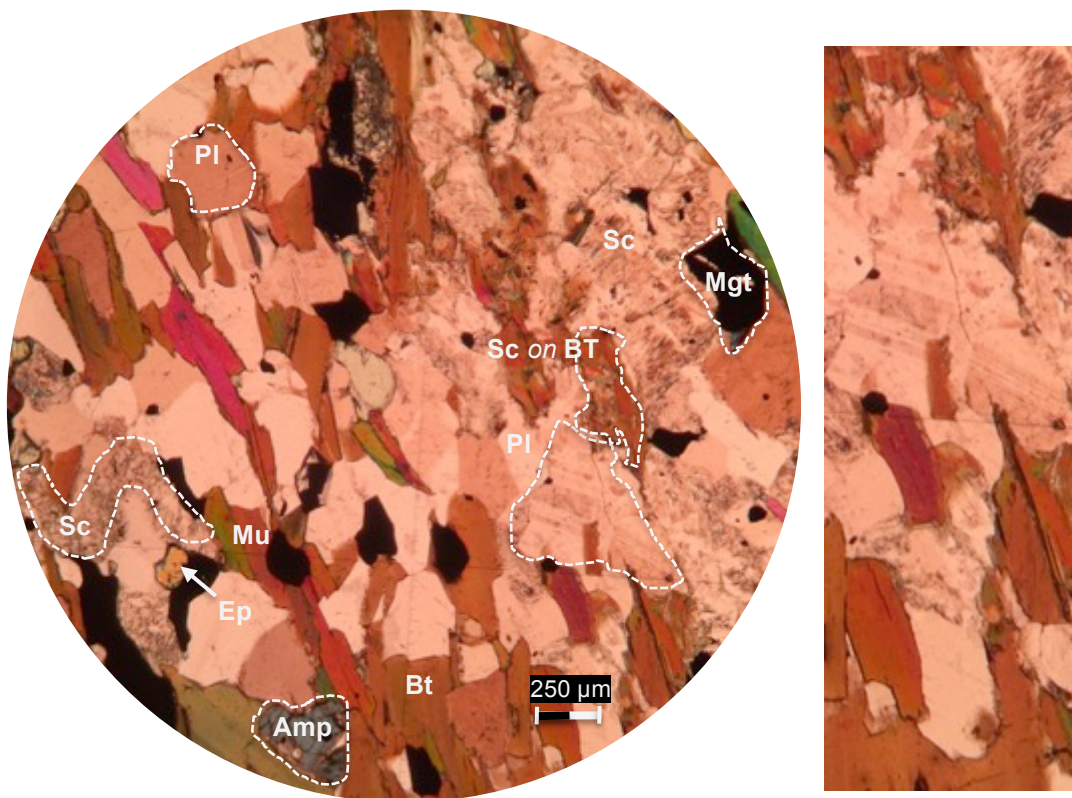


Fig. 12. A341663 XPL – grey leptite rock. Left: A representative image showing mineralogy. Right: close up view showing sericite replacing plagioclase.

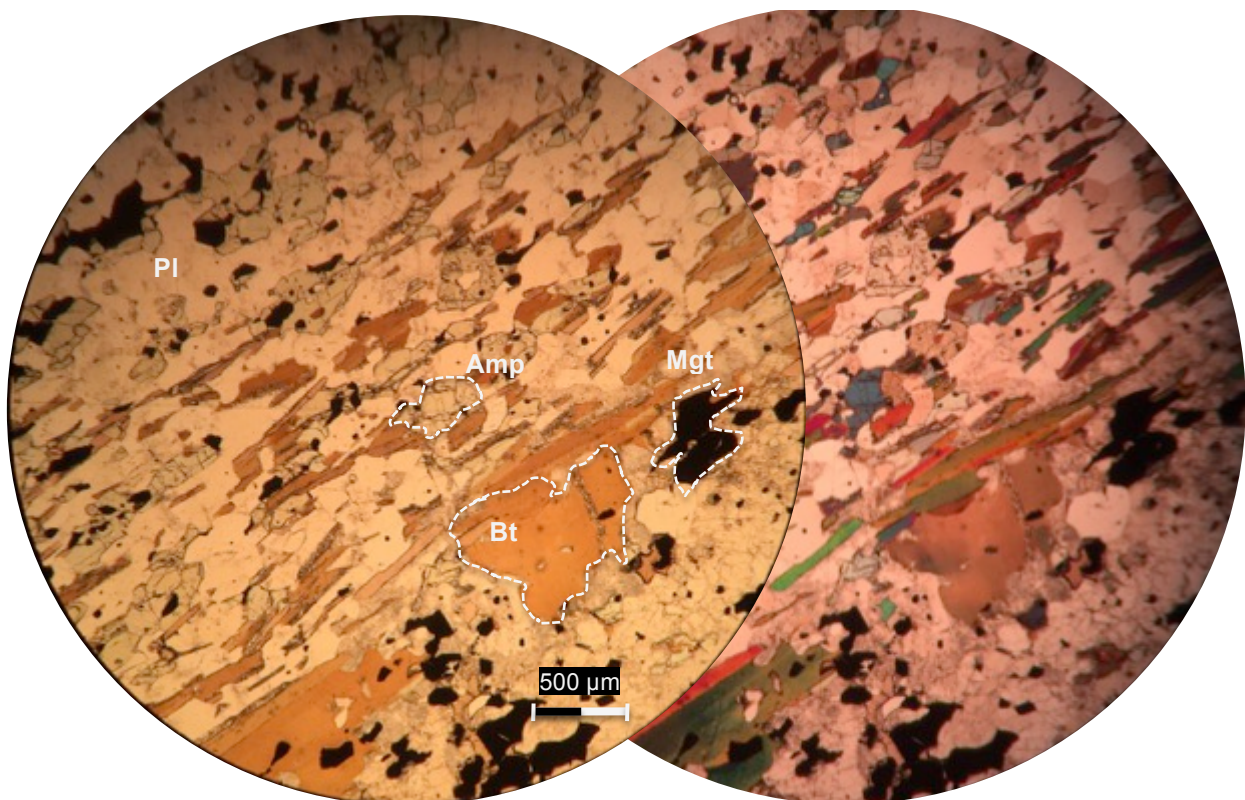


Fig. 11. A341980 – GLE rock with aligned biotite crystals. Left: PPL. Right: XPL.

3.4.2 Biotite altered GLE

The biotite altered GLE shows varying degree of biotite-sericite dominating extents in an otherwise granoblastic, equigranular groundmass (fig 13). The groundmass is constituted of feldspars, amphiboles and opaque minerals. Stretched and aligned minerals show metamorphic imprint on the fabric. Biotite and opaque minerals are generally more developed, larger grains. Biotite and sericitization is more abundant compare to GLE. Banded mica-rich zones are commonly observed. Microscopic structures that were recognised in some of the rocks were fluid inclusions, folds, and kinkbands. Fig. 13 shows a biotite crystal overgrowing a fold, also liquid bubbles are revealed analogue to the fold.

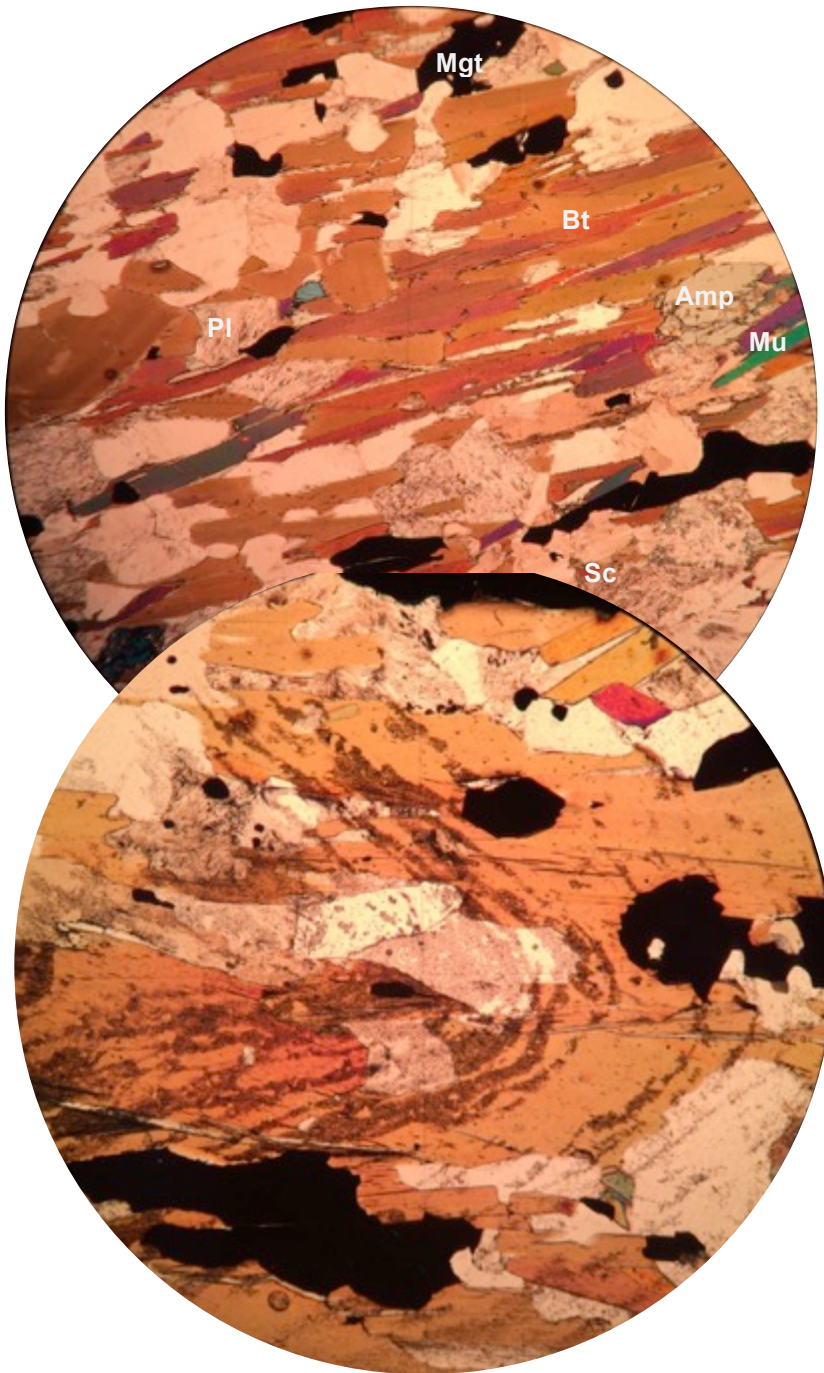


Fig. 13. Above: XPL - A342363. Biotite is more abundant and sericitization is inferred as more extensive. The felsic components are reduced compared to fig. 11-12. Below: XPL - A371958. A micro-scale fold is observed.

3.4.3 BSF

The BSF showed a rather limited mineralogical variation, dominated by biotite. Partly the textural pattern was crenulated and folded (fig. 14). Biotite replacing amphibole is observed (fig. 15). In comparison to GLE rocks, feldspar was not detected. Sericitization was frequently observed. BSF rocks showed plastic deformation; kinkbands, folds and fluid inclusions. Muscovite replacing biotite was observed (fig. 14).

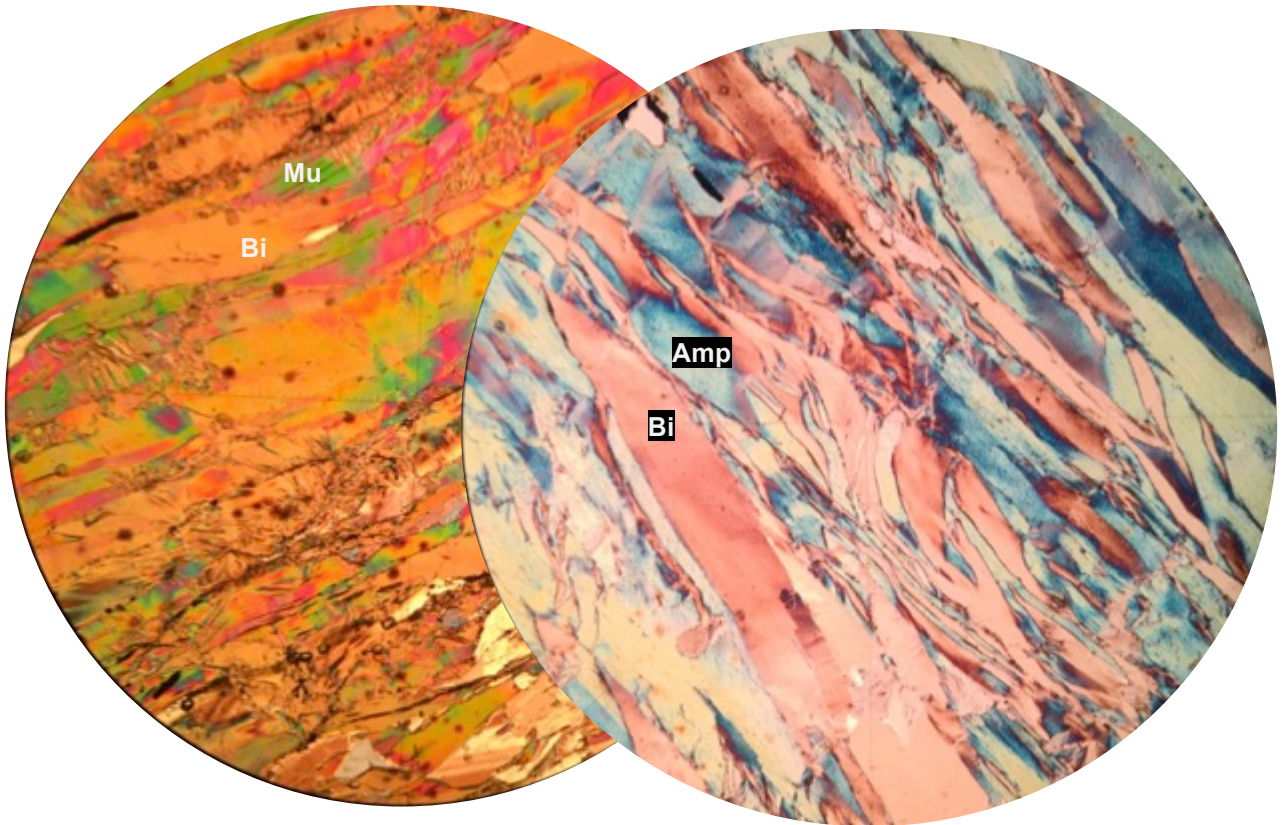


Fig. 14. Left: A372498 – XPL. Plastic deformation; kinkbands, crenulation and folds are visible. Right: Mica rich XPL view of A342336. Biotite schist rock.

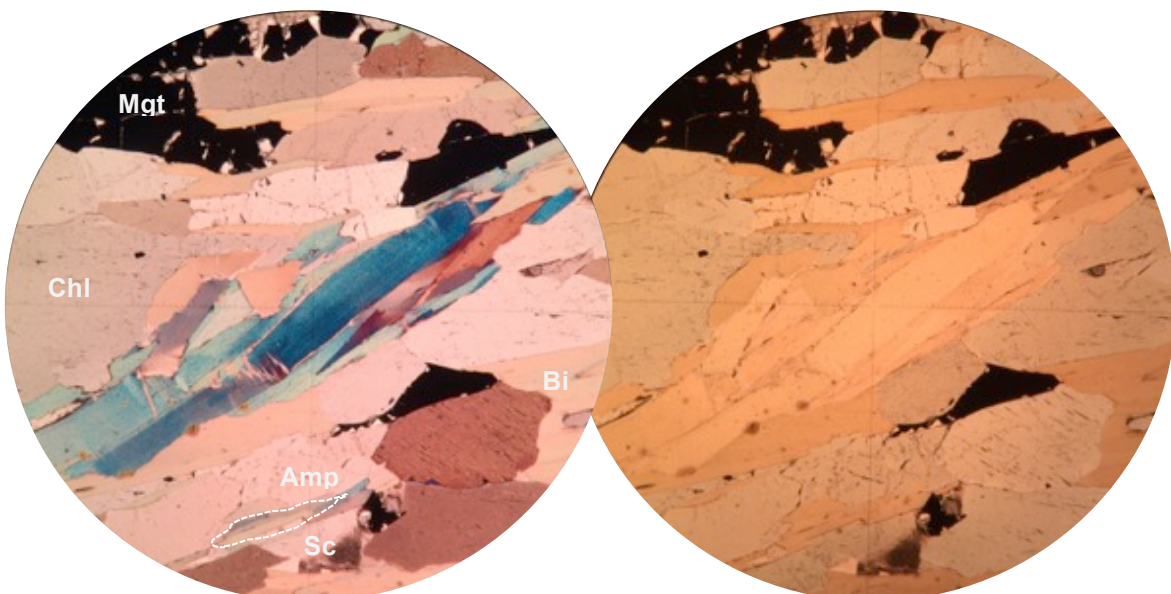


Fig. 15. Biotite schist – A342336. Left: XPL. Right: PPL. Dashed line where biotite is replacing amphibole.

3.4.4 Summarized chart – identified minerals

	GLE	GLE + Bt	BSF
Amphibole	X	X	X
Biotite	X	X	X
Chlorite			X
Epidote	X	X	
Muscovite	X	X	X
Magnetite	X	X	X
Plagioclase	X	X	
Sericite	X	X	X

Fig. 16. Summarized table of identified minerals correlated to rock type classification.

3.4.5 Microscopic comparison of alteration grades from borehole 34/15

Difference between the most primary GLE and the fully altered BSF can be deduced when comparing on the same scale. Increment of grain size combined with a decrease of feldspars is shown in fig. 17:



Fig. 17. XPL and PPL images. From top to bottom: GLE, GLE+Bt and BSF rock. A gradual decrease of felsic mineral content and crystal size increase is visible in the more altered rocks. Width of view 2 mm.

3.5 Electron microprobe analysis

Electron microprobe analysis was made based on the three rock subdivisions from borehole 34/15. Rocks analysed are shown in fig. 17. Results (appendix F) were given in oxides and

recalculated in excel to find end-members by balancing cations related to oxygen's per formula unit. Minor element cations are ignored (F, Ba, Ti, Ni, Cr, V and Sr).

Analysis number	Stoichiometry	Calculated oxygen per formula unit	Reliability (%)	Interpreted mineral
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A341980 GLE rock

1	$K_{1.02}Mg_{2.06}Fe_{0.84}Al_{1.16}Si_{3.18}$	12	92.42	Biotite
2	$K_{1.01}Mg_{2.14}Fe_{0.78}Al_{1.17}Si_{3.17}$	12	92.62	Biotite
3	$Na_{0.44}Ca_{3.45}Mg_{2.98}Fe_{1.05}Si_{8.03}$	24	96.35	Amphibole
4	$Na_{0.47}Ca_{3.38}Mg_{2.96}Fe_{1.09}Si_{8.05}$	24	96.71	Amphibole
5	$Na_{0.91}Al_{1.03}Si_{2.97}$	8	97.85	Plagioclase feldspar
6	$Na_{0.89}Al_{1.05}Si_{2.96}$	8	97.19	Plagioclase feldspar
7	$Na_{0.92}Al_{1.03}Si_{2.97}$	8	97.14	Plagioclase feldspar
8	$K_{0.94}Al_{0.97}Si_3$	8	96.77	K-feldspar
9	Ca_1CO_2	3	97.71	Calcite
10	$Na_{0.45}Ca_{3.36}Mg_{2.93}Fe_{1.19}Si_{8.02}$	24	98.64	Amphibole

A342365 GLE+Bt rock

11	$K_1Mg_{2.22}Fe_{0.79}Al_{1.21}Si_{3.17}$	12	94.74	Biotite
12	$K_{1.04}Mg_{2.26}Fe_{0.75}Al_{1.21}Si_{3.18}$	12	95.71	Biotite
13	$Na_{0.40}Ca_{3.54}Mg_{2.76}Fe_{1.25}Si_{7.89}$	24	98.01	Amphibole
14	$Na_{0.35}Ca_{3.56}Mg_{2.81}Fe_{1.13}Si_{7.97}$	24	97.50	Amphibole
15	$Na_{0.86}Al_{1.23}Si_{2.67}$	8	96.71	Plagioclase feldspar
16	$Na_{0.83}Al_{1.27}Si_{2.72}$	8	94.04	Plagioclase feldspar
17	$K_{0.92}Al_{0.99}Si_3$	8	97.43	K-feldspar
18	$Na_{0.96}Al_1Si_{2.99}$	8	96.77	Plagioclase feldspar
19	$Na_{0.98}Al_{0.99}Si_3$	8	97.84	Plagioclase feldspar

A342336 BSF rock

20	$K_{1.02}Mg_{2.61}Fe_{0.64}Al_{1.04}Si_{3.29}$	12	95.55	Biotite
21	$K_{1.01}Mg_{2.57}Fe_{0.63}Al_{1.05}Si_{3.30}$	12	95.36	Biotite
22	$Mg_{3.29}Fe_{0.68}Al_{1.11}Si_{3.99}$	14	91.88	Chloritoid
23	$K_{1.02}Mg_{2.55}Fe_{0.66}Al_{1.05}Si_{3.29}$	12	94.84	Biotite
24	$K_{1.04}Mg_{2.55}Fe_{0.66}Al_{1.06}Si_{3.28}$	12	95.79	Biotite
25	$K_1Mg_{2.58}Fe_{0.61}Al_{1.06}Si_{3.29}$	12	97.11	Biotite
26	$Na_{0.82}Ca_{1.55}Mg_{4.15}Fe_{1.11}Si_{8.05}$	24	96.52	Amphibole
27	$Na_{0.78}Ca_{1.54}Mg_{4.29}Fe_{1.03}Si_{8.15}$	24	97.06	Amphibole
28	$Na_{0.95}Al_{0.97}Si_{3.03}$	8	98.98	Plagioclase feldspar
29	$Mg_{4.66}Fe_{1.65}Al_{2.35}Si_{4.03}$	18	86.43	Chlorite

Fig. 15. Table separated by rock classification and re-calculated EMPA-data; inferred minerals.

4. Calculations from results

Calculations are based on handheld XRF, EMPA and XRF spectrometry analysis results.

4.1 Ternary diagram

ACF chemographic diagrams are created From XRF-spectrometry data. Sample A-XRF34 is classified as GLE, A-XRF37 BSF and A-XRF76 as GLE + Bt.

The concept for making a ternary chemographic diagram is to focus on major variable phases and ignore conventional phases. Major components are balanced by withdrawal of minor components. Ternary diagrams are used when bulk composition is known. Gibbs phase rule states $F = C - P + 2$ where F = degree of freedom; C = number of components; P = number of phases and +2 states that the minimum number of freedom is correlated to a limited change of pressure and temperature (P and T). A sufficient change of P or T will lead to a new assemblage within a system – equilibrium shift. Ternary graphs are used for describing 4-5 components within a system in equilibrium.

4.1.1 ACF ternary diagram from XRF spectrometry data

ACF diagrams are plotted to illustrate mineral assemblage related to a metabasaltic protolith. Calculations are from molar percentages where $A = \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 - \text{Na}_2\text{O} - \text{K}_2\text{O}$, $C = \text{CaO} - 3.3 \text{ P}_2\text{O}_5$ and $F = \text{FeO} + \text{MgO} + \text{MnO}$. Albite, quartz and water are conventional within ACF-diagrams. Fe is given as FeO^* by conversion from Fe_2O_3 . (Fe^{3+} is ignored). Common ACF-related minerals and average basalt are drawn in fig. 20 (reference: Winter 2014) for reference.

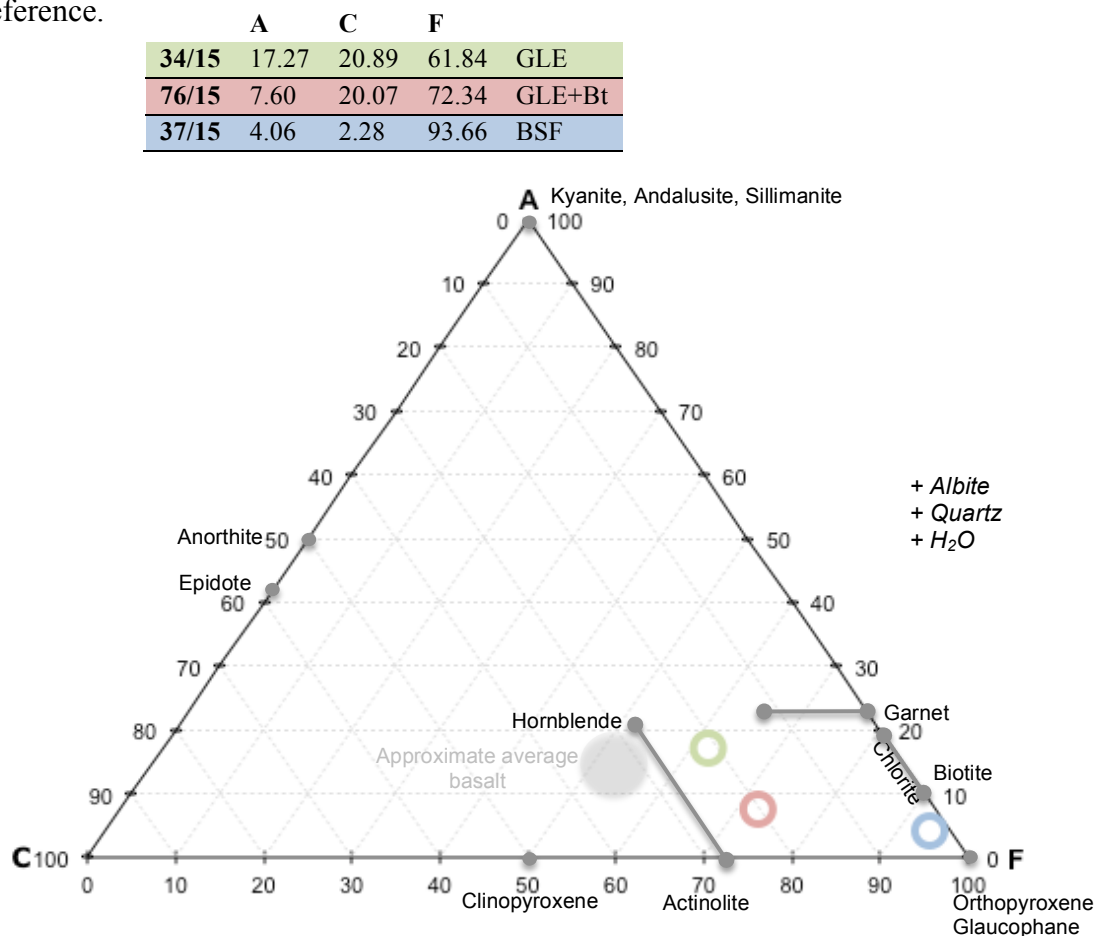


Fig. 19. ACF diagram. Coloured circles represent bulk compositions from XRF-spectrometry analysis. Green = GLE; red = GLE+Bt and blue = BSF. An average basalt composition is plotted for reference.

4.2 Metamorphic reaction interpretation from Ti/Zr ratio and Wt.% K

Ti/Zr ratios were compared to see if GLE-rocks are potential precursors to BSF. Zr and Ti are considered as rather inert and immobile elements during metamorphic reactions (Philpotts & Ague 2009). Thereafter, K was compared to see if there is an indication of potassium added to GLE+Bt and BSF compared to GLE – i.e. contributing to biotite formation. All values are calculated from mean. Samples are from 34/15 (fig. 17):

34/15	GLE	GLE + Bt	BSF
	198 m	236.5 m	233.6 m

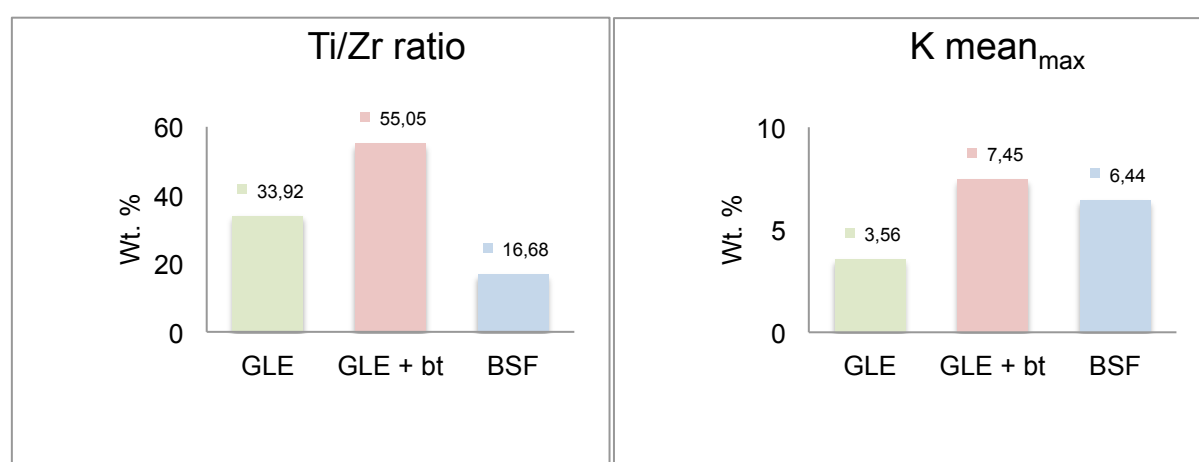


Fig. 20. Ti/Zr ratio (left) and K variation (right) related to rock subdivisions. Wt. % K is greater in both GLE+Bt and BSF compared to GLE. Ti/Zr is greater in GLE+Bt although lesser in BSF when comparing with GLE.

4.3 Geothermobarometry

For THERMOCALC and AX related in- and output data – see appendix G.

4.3.1 Pressure-temperature estimates from THERMOCALC

Rock subdivisions were calculated separately in THERMOCALC based on EMPA, logged and microscopic identified mineralogy (appendix A, B, F and G). From Bergman, Kübler & Martinsson (2001) the majority of northern Norrbotten are metamorphosed at various T and P between 2-4 kbar.

Magnetite, chlorite, muscovite and epidote were not analysed in GLE and GLE+Bt. Consequently, adding not analysed phases might influence to calculation errors. The added minerals were consistent with inferred bulk composition for mafic protolith rocks (Klein & Philpotts 2013) together with minerals observed in microscope and when logging. AX output was 0 in activity for sanidine in the biotite altered GLE so microcline was added from calculations in fig. 18 analysis 17. Analysis 26-27 in Fig. 18 indicated pargasite, which was added together with magnetite and muscovite in PT estimates for BSF.

THERMOCALC was run with a search for average T (avT). Sensible P-window was set between 1-7 kbar and T-window 100-700 °C. Sigfit values exceeded the 95 % confidence according to the diagnostics. Hence, T output is interpreted as suspect. The following chart is limited from temperatures related to pressure interval 2-4 kbar:

P (kbar)	GLE			GLE+Bt			BSF		
	avT	sd	Sigfit <1.61	avT	sd	Sigfit <1.61	avT	sd	Sigfit <1.73
2	312	40	3.3	326	44	3.8	632	217	4.9
3	328	45	3.7	321	43	3.6	639	308	5.7
4	342	53	4.2	315	44	3.7	603	396	6.2

Fig. 21. avT for GLE; GLE+Bt and BSF between 2-4 kbar. Calculation errors exceeding sigfit values marked in red.

THERMOCALC stated that the results for GLE was unlikely to be useful since incomplete set of reactions have been used. Attempts to find more likely results failed.

5. Discussion of results

5.1 Handheld XRF and core scanner data

Handheld XRF-data have been used prior to core scanner data since magnesium is crucial when studying biotite. K, Fe and Mg are increased in the more altered rocks compared to GLE. Highest standard deviation regarding K and Fe is related to the biotite altered GLE. This might imply dissemination of magnetite from surrounding rocks, but also formation of biotite resulting from potassium enrichment. BSF showed the largest standard deviation for Mg that can relate to various concentrations in individual minerals – i.e. biotite, chlorite and amphibole. Overall, high standard deviation implies a great variety in composition in the GLE + Bt rock.

5.2 Microscopy

Alteration grades are verified in thin sections. A progressive increase of mafic components prior to felsic components was observed. Biotite crystals were observed gradually larger in the more altered rocks (i.e. GLE+Bt and BSF). Biotite overgrowing folds suggest biotite crystallised later. Crenulated pattern in BSF is interpreted as fluidal. Also, where biotite is replacing amphibole reaction is inferred in a setting where biotite is favoured. Sericite implies hydrothermal alteration of feldspars and other potassium-aluminium bearing minerals (Klein & Philpotts 2013).

5.3 ACF diagram

From rock subdivisions and geochemical analysis combined, the following 3-phase triangles are inferred for each rock subdivision. GLE and GLE + Bt bulk composition plot well into three-phase stability fields (fig. 28-29) specifying the following assemblages: Ep–Act–Bt; An–Act–Bt or Hbl–Act–Bt (*Hbl* = *hornblende*). GLE + Bt plots closer to F indicating a more mafic rock compared to GLE.

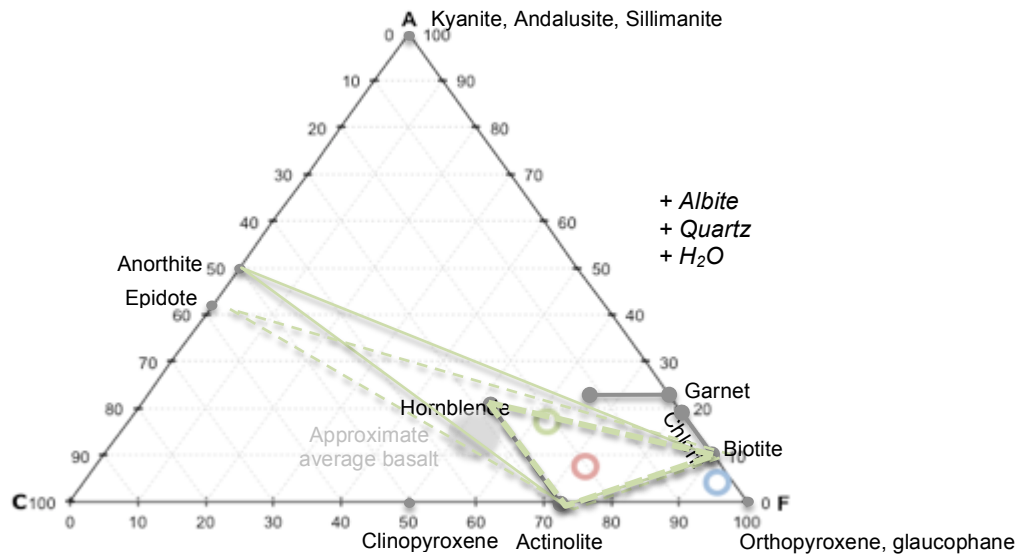


Fig. 22. Green triangles shows possible three phase assemblages for GLE (+ albite, quartz and water).

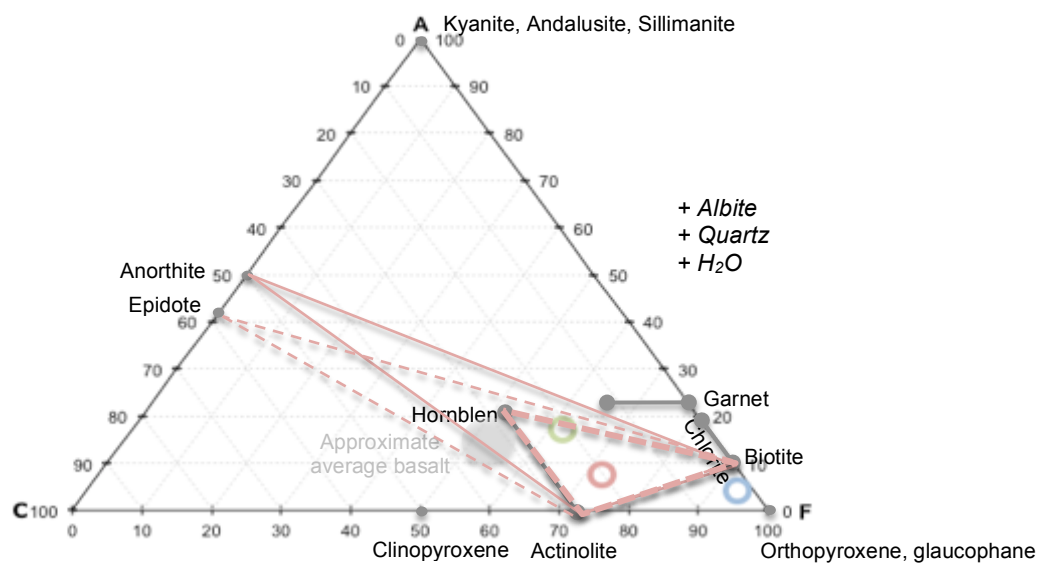


Fig. 23. Red triangles shows possible three phase assemblages for GLE + Bt (+ albite, quartz and water).

The BSF bulk composition is close to the 'F' apex in the diagram. Hence, the BSF shows a ferromagnesian composition that corresponds with observations and analyses. Compositions enclosing BSF are Bt–Chl–Act or Bt–Chl–Hbl. Also pyroxene would be assumed within stable three-phase fields for BSF bulk, together with amphibole and biotite/chlorite. However, no pyroxene was analysed.

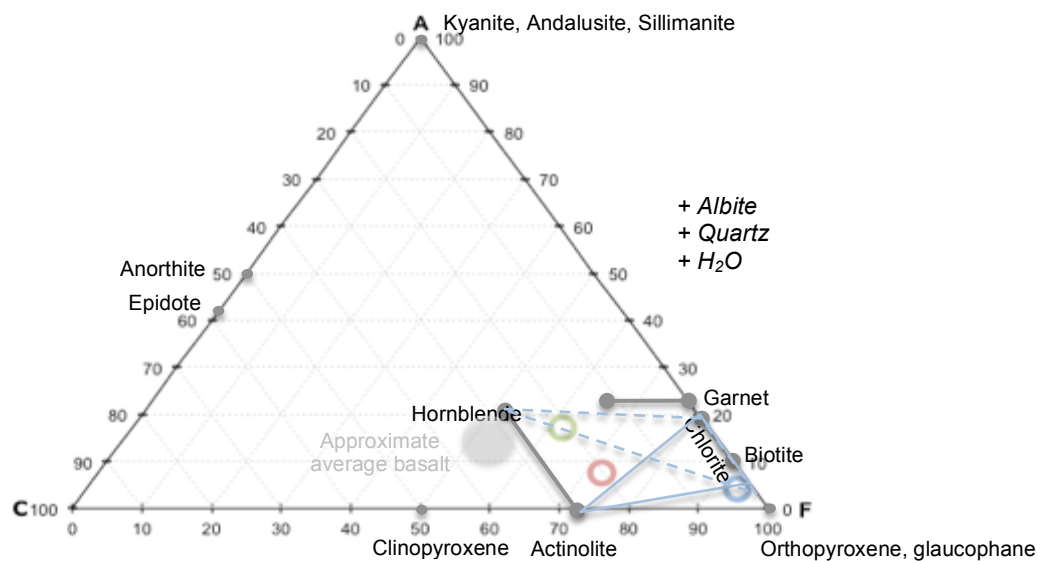


Fig.24. Blue triangles shows possible three phase assemblages for GLE + Bt (+ albite, quartz and water).

5.4 Geothermobarometry

THERMOCALC derived P-T relationship for each rock subdivision indicated suspect diagnostics. Hence, there is a possibility that the rocks are not in equilibrium, or that additional phases were needed to validate more exact P-T points for individual assemblages. However, some roughly estimated theories for relationship between rock subdivisions were deduced:

1. GLE and GLE + Bt probably formed at Greenschist facies.
2. There is a possible retrograde relationship between GLE and GLE+Bt.
3. BSF formed in response to a thermal input, most likely related to amphibolite facies.

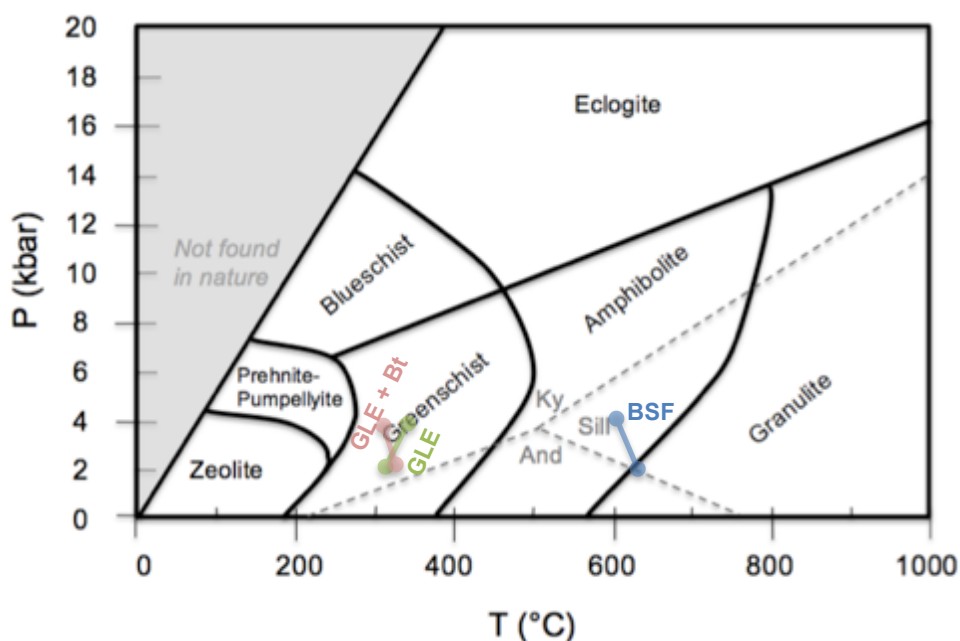


Fig. 25. Metamorphic facies chart. avT for GLE; GLE+Bt and BSF is roughly drawn between 2-4 kbar, referring to THERMOCALC output.

6. Conclusion

The conclusions from this study, irrespectively of errors, are as follows:

- GLE and biotite altered GLE are deduced to be related from geothermobarometry calculations – metamorphosed under greenschist facies.
- Local variations regarding hydrothermal imprints and possible retrograde metamorphism may have caused compositional differences between GLE and GLE+Bt.
- GLE +Bt and BSF have likely experienced potassium enrichment.
- Both BSF and GLE+Bt might reflect hydrothermal biotite formation. Studied rocks disclose metasomatism, which is inferred from progressive sericitization and potassium increase in the more altered rocks.
- BSF probably formed at amphibolite facies conditions as a result from a temperature increase.
- The biotite is perhaps a product of potassium supply to an open, or partly open, system where the magnesium end-member was preferred prior to iron end-member.

6.1 Suggestions for future studies

First of all, more detailed and extensive EMPA analysis might enable more suitable and precise data input to AX and THERMOCALC; hence, to receive a more reliable thermodynamic verification regarding PT conditions. A wider frame of reference, as including surrounding rocks might contribute for a better understanding of biotite genesis. It would be interesting to perform radiometric dating of the biotite rich rocks to see if there is a correlation between the Granite-pegmatite association or the gabbro dolerite intrusions and the biotite formation.

7. Acknowledgements

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Appendix A; core logging data

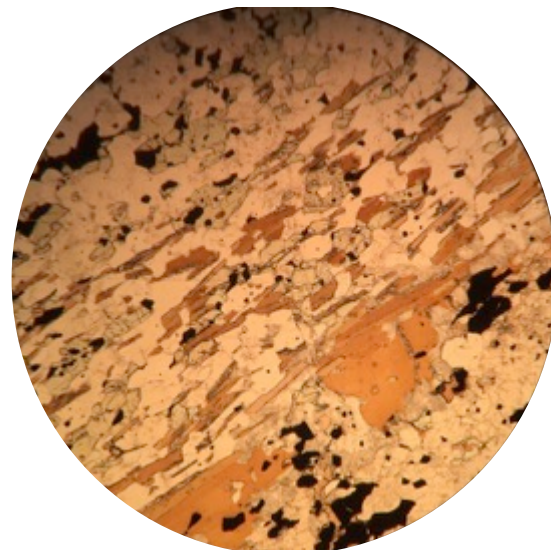
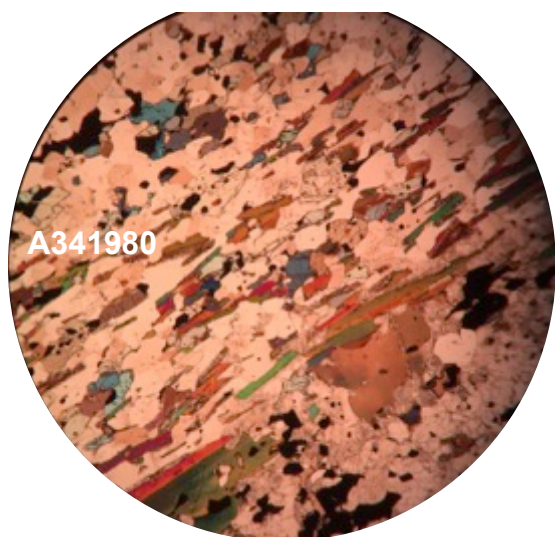
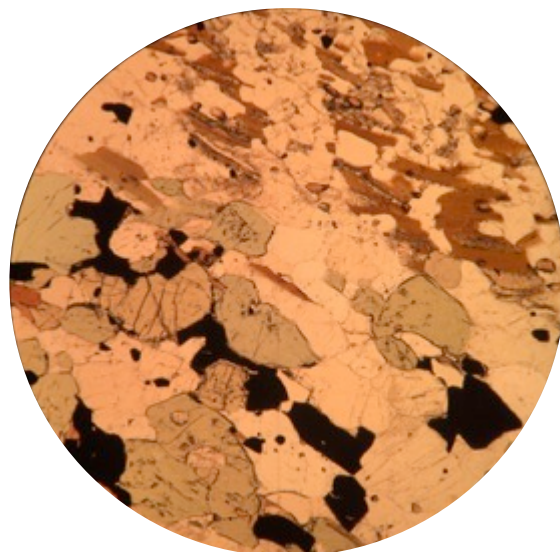
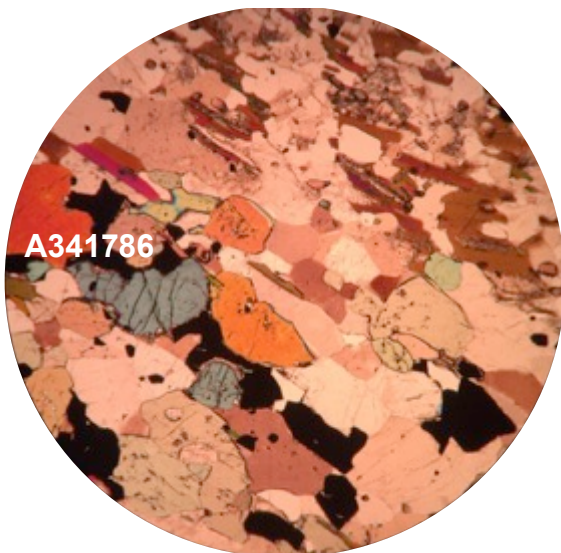
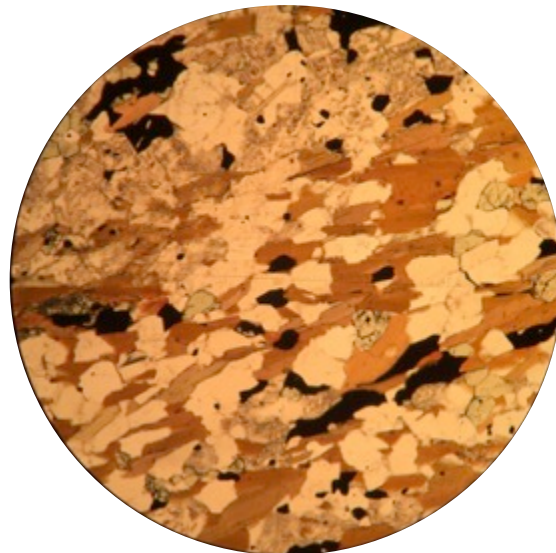
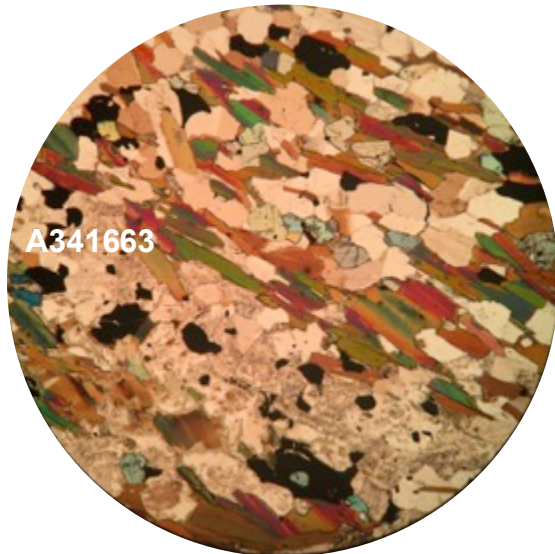
DBH 34/15									
0	Meter från (m)	Meter till (m)	Bergart	Strainintensitet	Omvandling 1	Omvandling 2	Omvandling 3	DBH 37/15	DBH 76/15
1,35	47,15	1,35	GRA	Medel	SK0	SK0	SK0	0,05	0,07
47,15	69,8	31,03	RGL	Medel	RO2	SK0	SK0	31,03	50,58
69,8	76,91	60,15	RGL	Medel	RO1	GR0	SK0	60,15	61,84
76,91	80,6	78	GRA	Medel	SK2	V11	BI0	78	77,92
80,6	145,77	136,45	RGL	Låg	SK0	SK0	BI0	136,45	86,1
145,77	150,94	138,58	GRA	Medel	SK1	GR1	RO0	138,58	118,58
150,94	157,04	180,1	MGN	Medel	SK2	GR1	RO0	180,1	125,06
157,04	159,09	187,65	GLE	Medel	HE0	GR0	SK0	187,65	133,8
159,09	160,12	190,1	MGN	Medel	BI0	GR0	SK0	190,1	180,95
160,12	168,87	193,15	GLE	Låg	SK0	HE0	SK0	193,15	182,08
168,87	171,9	194,7	GLE	Låg	BI1	MGO	SK0	194,7	196,22
171,9	176,51	201,85	GLE	Hög	BI1	RO1	MGO	201,85	197,53
176,51	185,44	221,55	GRA	Låg	SK0	BI1	MGO	221,55	200,63
185,44	189,04	236,55	MGN	Hög	BI0	RO0	SK0	236,55	206,19
189,04	192,48	242,15	GLE	Hög	SK0	SK0	MGO	242,15	208,79
192,48	198,83	244,7	MGN	Medel	SK0	GR0	SK0	244,7	211
198,83	200,43	258,45	RGL	Hög	SK0	GR0	SK0	258,45	247,03
200,43	209,37	259,7	RGL	Hög	BI1	MGO	SK0	259,7	253,52
209,37	213,65	265,9	MGN	Medel	BI0	SK0	V10	265,9	254,87
213,65	228,64	275,5	RGL	Hög	SK1	MGO	SK0	275,5	259,57
228,64	234,95	285,1	BSF	Hög	SK0	SK0	SK0	285,1	EOH
234,95	245		GLEG	Medel	BI0				
245	266,41		RGL	Hög	BI1				
266,41	290,9		RGL	Medel	SK1				
290,9	296,27		RGL	Låg	SK2				
296,27	320,34		RGL	Medel	SK1				
320,34	EOH								
DBH 37/15									
0	Meter från (m)	Meter till (m)	Bergart	Strainintensitet	Omvandling 1	Omvandling 2	Omvandling 3	DBH 76/15	DBH 76/15
0,05	31,03	0,05	RGL	Medel	RO2	SK0	SK0	0,07	0,07
31,03	60,15	31,03	RGL	Medel	RO1	GR0	SK0	50,58	50,58
60,15	78	60,15	RGL	Medel	BI1	RO0	GR0	61,84	61,84
78	136,45	78	RGL	Medel	SK2	V11	BI0	77,92	77,92
136,45	138,58	136,45	GRA	Låg	SK0	SK0	BI0	86,1	86,1
138,58	180,1	138,58	RGL	Medel	SK1	GR1	RO0	118,58	118,58
180,1	187,65	180,1	RGL	Medel	SK2	GR1	RO0	125,06	125,06
187,65	190,1	187,65	PEG	Medel	HE0	GR0	SK0	133,8	133,8
190,1	193,15	190,1	GLE	Medel	BI0	GR0	SK0	180,95	180,95
193,15	194,7	193,15	GRA	Medel	SK0	HE0	SK0	182,08	182,08
194,7	201,85	194,7	GLE	Medel	BI1	MGO	SK0	196,22	196,22
201,85	221,55	201,85	GLE	Medel	BI1	RO1	MGO	197,53	197,53
221,55	227,55	221,55	GLE	Medel	SK1	BI1	MGO	200,63	200,63
227,55	236,55	227,55	GLE	Medel	BI0	RO0	SK0	206,19	206,19
236,55	242,15	236,55	GLE	Medel	BI1	SK0	MGO	208,79	208,79
242,15	244,7	242,15	MGN	Medel	SK0	GR0	SK0	211	211
244,7	258,45	244,7	BSF	Medel	SK0	GR0	SK0	247,03	247,03
258,45	259,7	258,45	RGL	Medel	SK1	MGO	SK0	253,52	253,52
259,7	265,9	259,7	MGN	Medel	BI0	SK0	V10	254,87	254,87
265,9	275,5	265,9	RGL	Medel	SK1	MGO	SK0	259,57	259,57
275,5	285,1	275,5	GRA	Medel	SK0	SK0	SK0	EOH	EOH
285,1	EOH	285,1							
DBH 76/15									
0	Meter från (m)	Meter till (m)	Bergart	Strainintensitet	Omvandling 1	Omvandling 2	Omvandling 3	DBH 76/15	DBH 76/15
0,07	50,58	0,07	GLE	Medel	RO2	SK0	SK0	0,07	0,07
50,58	61,84	50,58	GRA	Låg	RO1	GR0	SK0	50,58	50,58
61,84	77,92	61,84	GLE	Medel	BI1	RO0	GR0	61,84	61,84
77,92	86,1	77,92	GLE	Medel	SK2	V11	BI0	77,92	77,92
86,1	118,58	86,1	GLE	Medel	SK0	SK0	BI0	86,1	86,1
118,58	125,06	118,58	GRA	Låg	SK1	GR1	RO0	118,58	118,58
125,06	133,8	125,06	GLE	Medel	SK2	GR1	RO0	125,06	125,06
133,8	180,95	133,8	MGN	Medel	HE0	GR0	SK0	133,8	133,8
180,95	182,08	180,95	GRA	Låg	BI0	GR0	SK0	180,95	180,95
182,08	196,22	182,08	GLE	Medel	SK0	HE0	SK0	182,08	182,08
196,22	197,53	196,22	MGN	Medel	BI1	MGO	SK0	196,22	196,22
197,53	200,63	197,53	GRA	Låg	BI1	RO1	MGO	197,53	197,53
200,63	206,19	200,63	BSF	Hög	SK1	BI1	MGO	200,63	200,63
206,19	208,79	206,19	GLE	Medel	BI0	RO0	SK0	206,19	206,19
208,79	211	208,79	GLE	Hög	BI1	SK0	MGO	208,79	208,79
211	247,03	211	GLE	Medel	SK0	GR0	SK0	211	211
247,03	253,52	247,03	RGL	Medel	SK0	GR0	SK0	247,03	247,03
253,52	254,87	253,52	GLEG	Medel	SK1	MGO	SK0	253,52	253,52
254,87	259,57	254,87	RGL	Låg	BI0	SK0	V10	254,87	254,87
259,57	EOH	259,57			SK1	MGO	SK0	EOH	EOH
EOH		EOH							

Appendix B; Thin section images

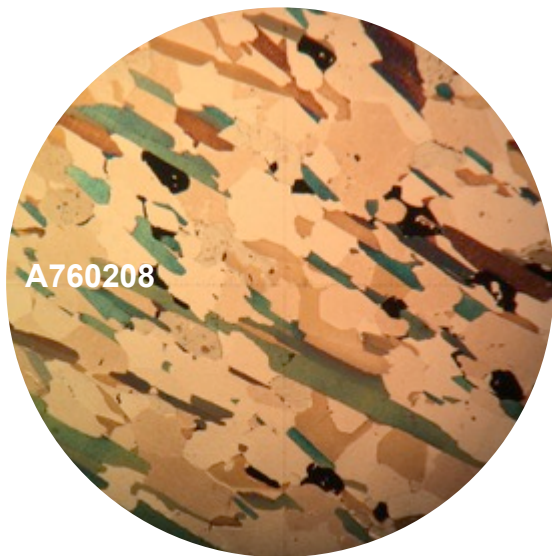
GLE

Crossed polarised light

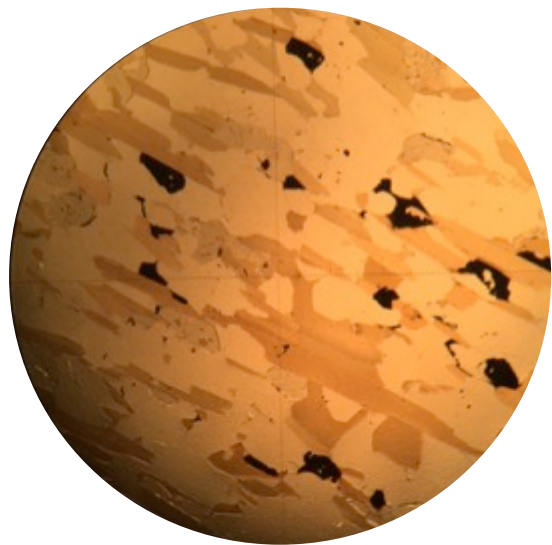
Plane polarised light



Crossed polarised light



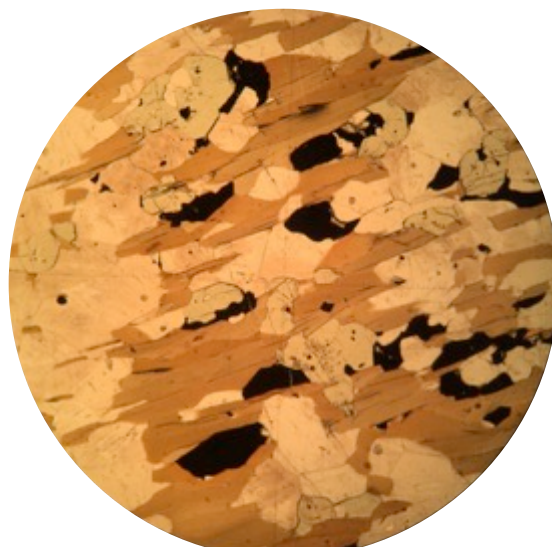
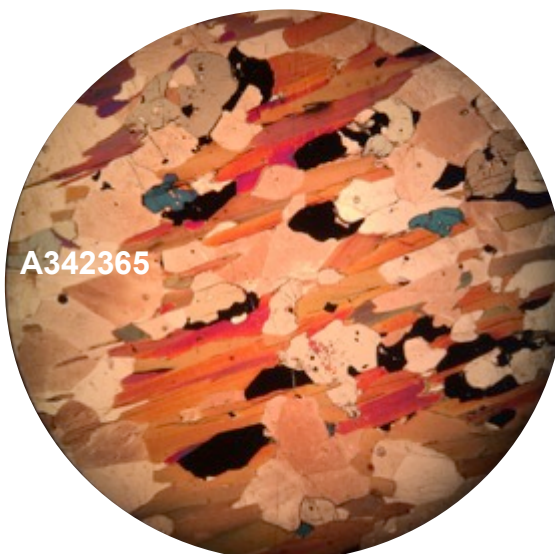
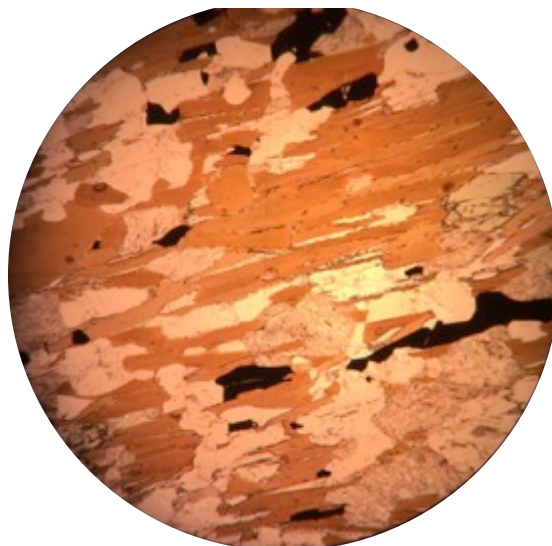
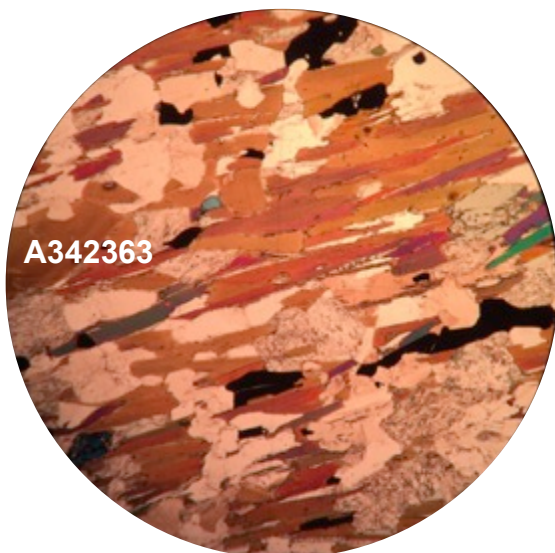
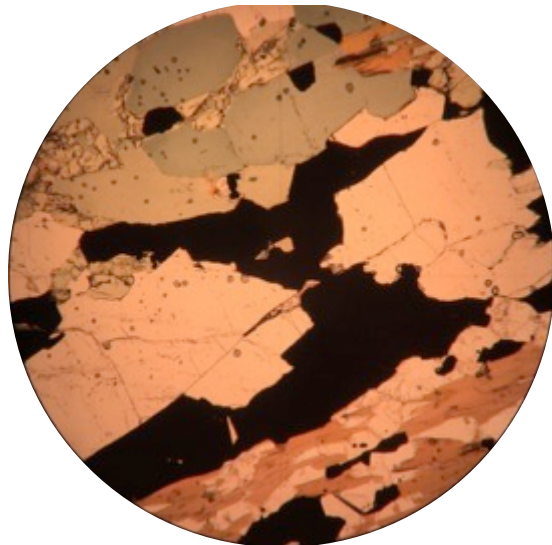
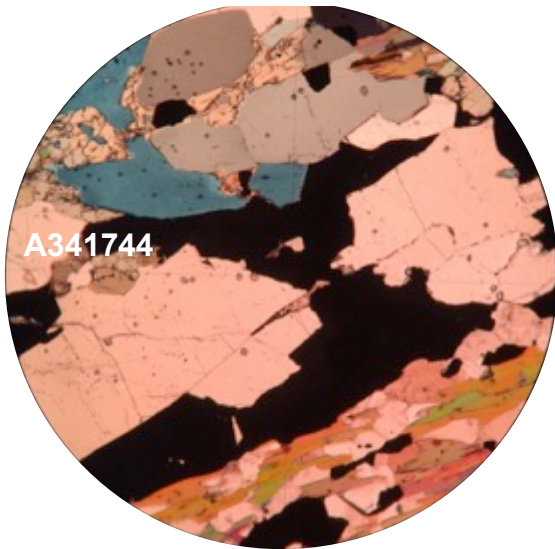
Plane polarised light



Biotite altered GLE

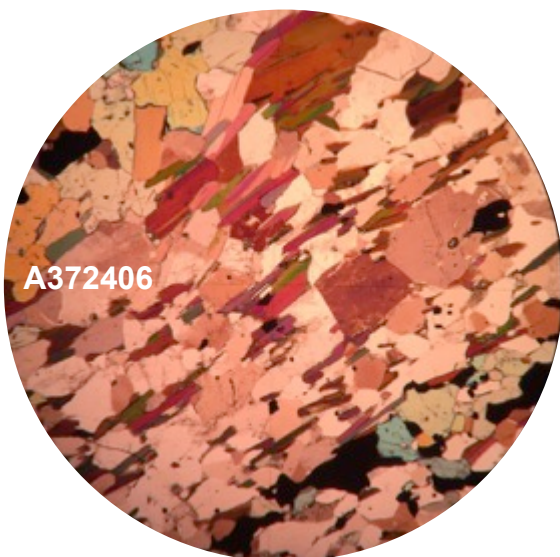
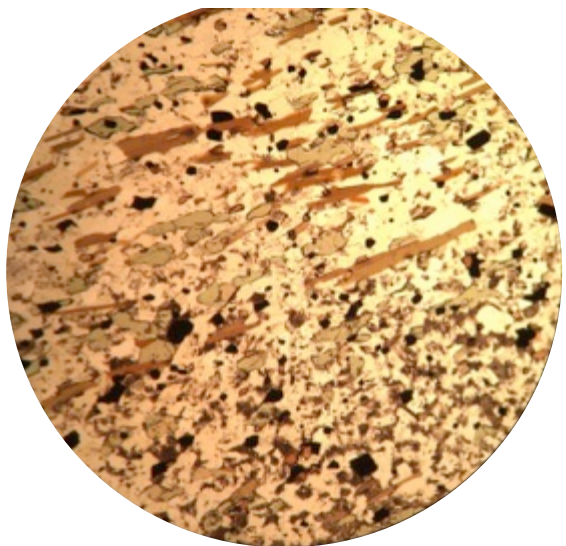
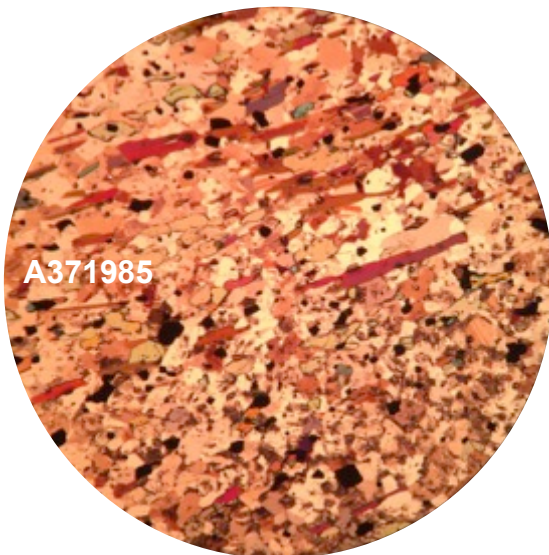
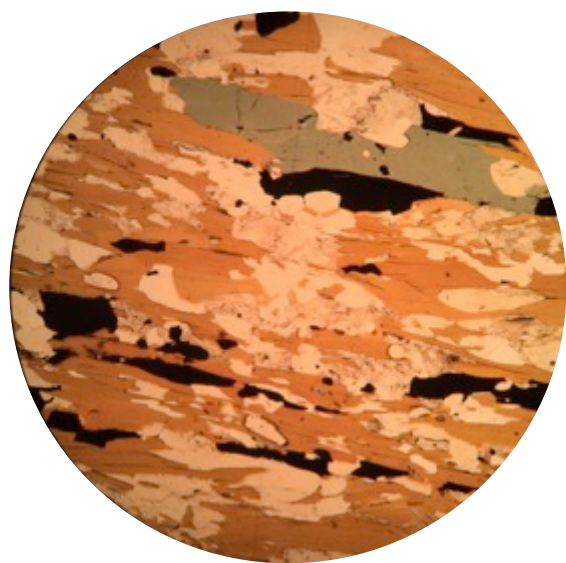
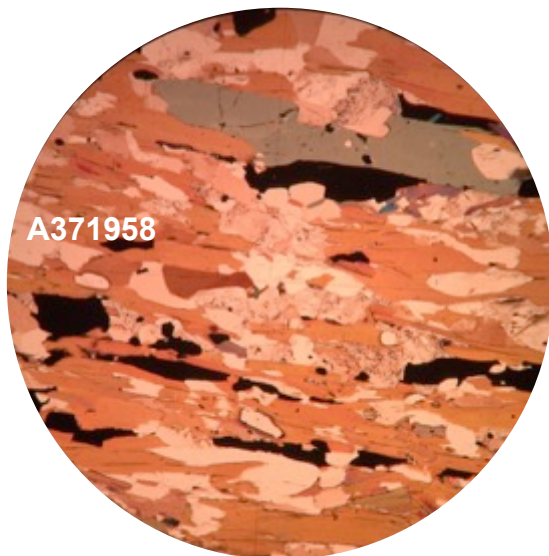
Crossed polarised light

Plane polarised light



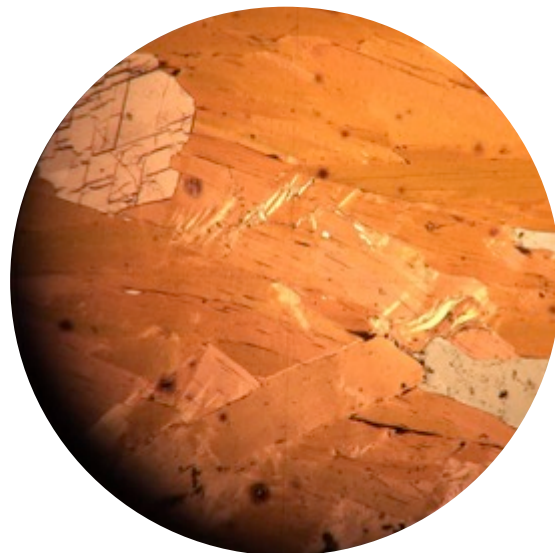
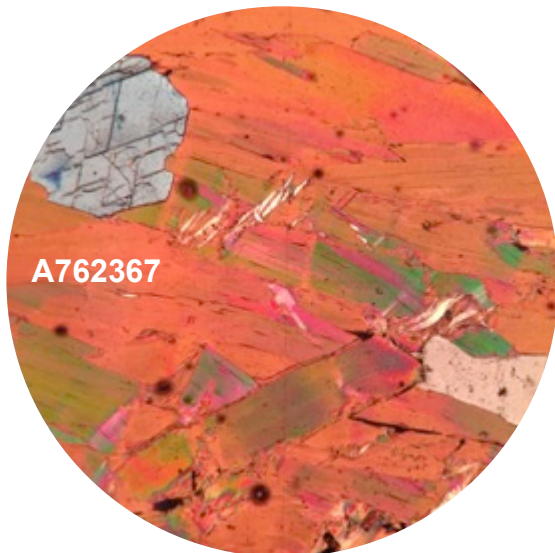
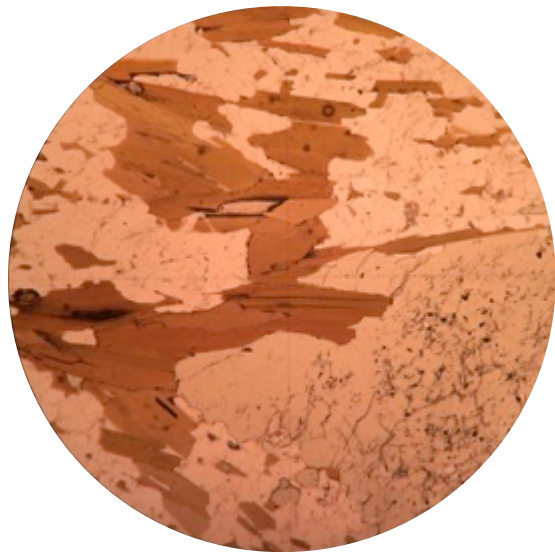
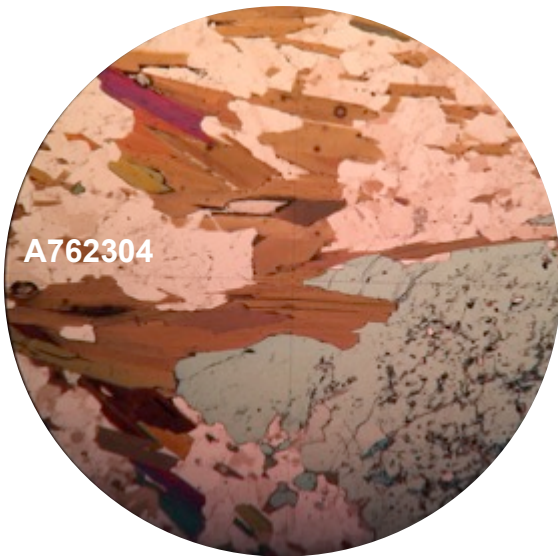
Crossed polarised light

Plane polarised light



Crossed polarised light

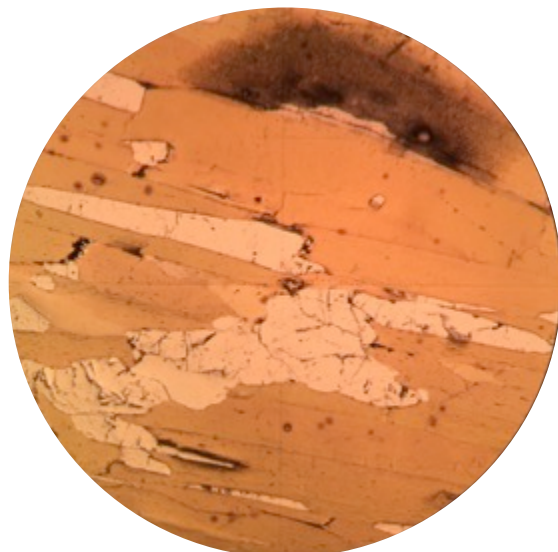
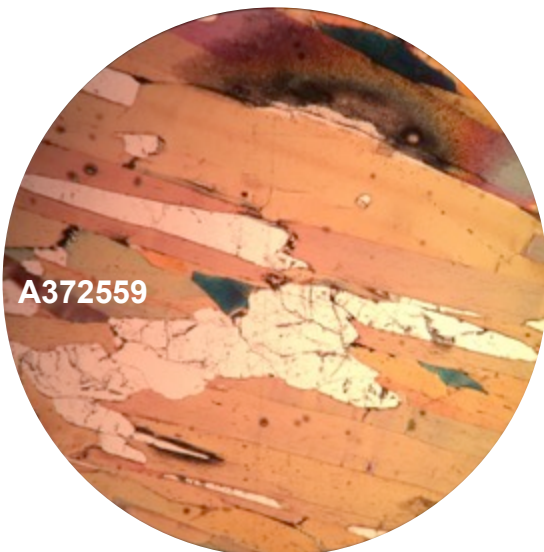
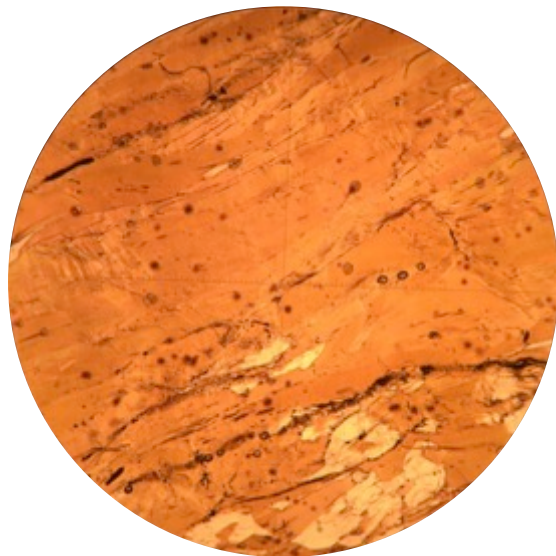
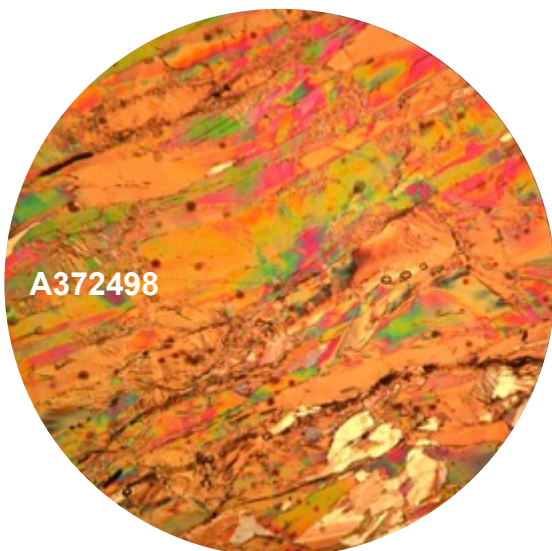
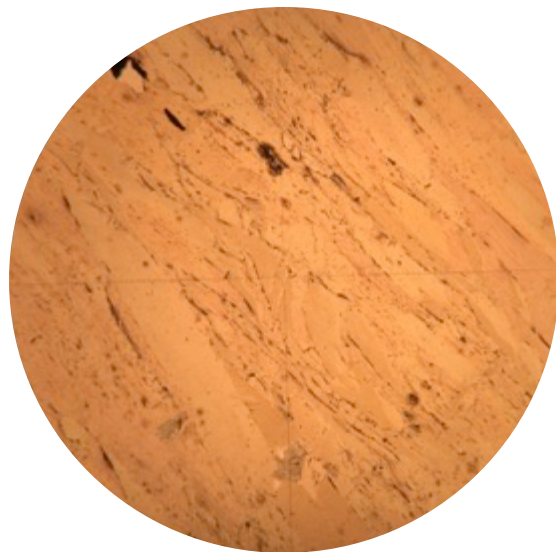
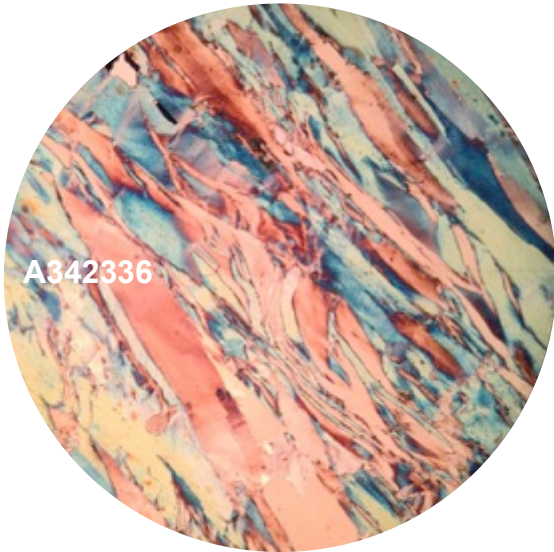
Plane polarised light



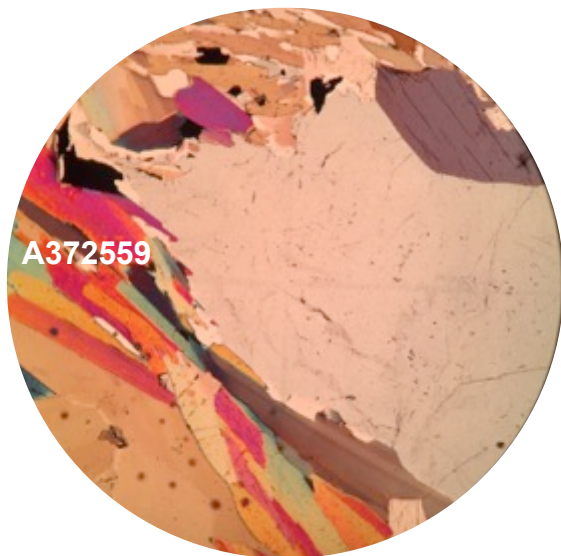
BSF

Crossed polarised light

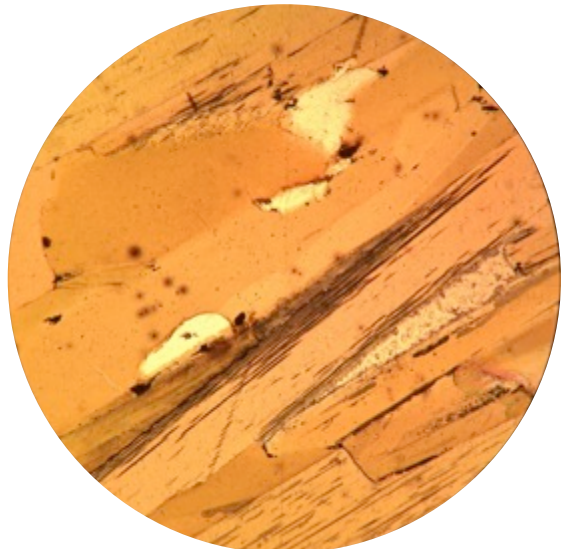
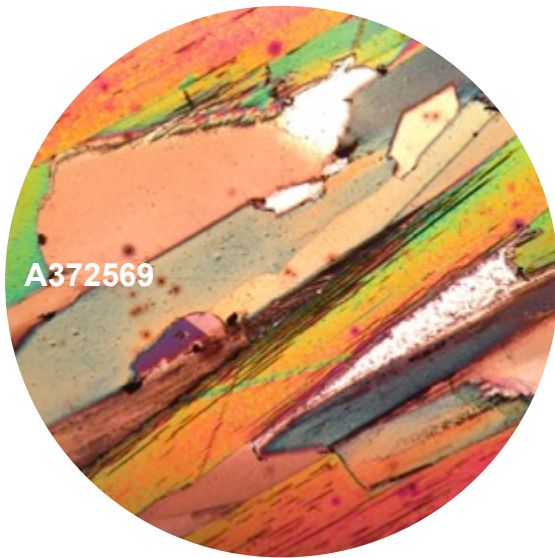
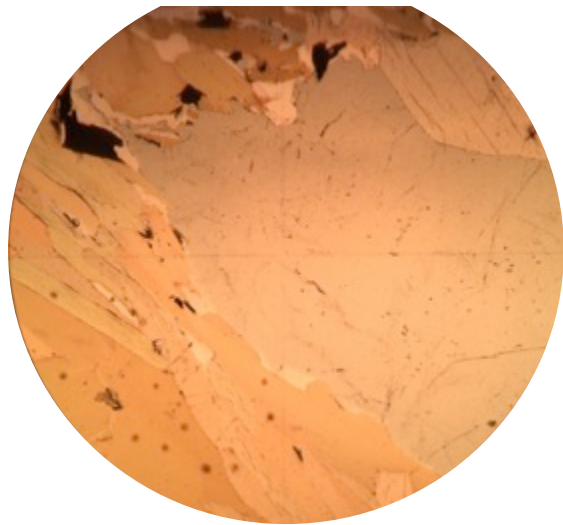
Plane polarised light



Crossed polarised light



Plane polarised light



Appendix C; Handheld XRF data

Raw data

Date	Time	Reading	Mode	Mg	Mg +/-	Al	Al +/-	Si	Si +/-	P	P +/-	S
17-01-16	06:20:39	#4	Mining Plus	5	0,63	5,62	0,11	21,17	0,18	0,0639	0,0099	ND
17-01-16	06:21:57	#5	Mining Plus	3,38	0,63	5,44	0,11	19,68	0,17	ND		ND
17-01-16	06:23:27	#6	Mining Plus: ND			5,84	0,11	20,55	0,18	0,0483	0,0122	0,0762
17-01-16	06:24:54	#7	Mining Plus	2,18	0,63	5,61	0,11	19,84	0,17	0,1323	0,0122	0,0547
17-01-16	06:26:30	#8	Mining Plus: ND			5,84	0,11	20,63	0,18	0,1145	0,0128	0,0741
17-01-16	06:30:54	#9	Cal Check									
17-01-16	06:38:48	#10	Mining Plus	2,41	0,56	4,51	0,09	15,14	0,13	1,0689	0,0183	ND
17-01-16	06:40:34	#11	Mining Plus	4,19	0,63	2,73	0,09	8,97	0,09	0,2858	0,0096	ND
17-01-16	06:41:49	#12	Mining Plus	5,18	0,66	3,5	0,1	11,9	0,12	0,7915	0,0163	ND
17-01-16	06:43:15	#13	Mining Plus: ND			1,43	0,07	7,1	0,06	8,23	0,05	ND
17-01-16	06:44:39	#14	Mining Plus	5,42	0,63	3,58	0,1	12,42	0,12	1,1119	0,0188	ND
17-01-16	06:46:04	#15	Mining Plus	5,58	0,68	3,93	0,11	13,74	0,14	0,5561	0,0143	ND
17-01-16	06:47:26	#16	Mining Plus	6,04	0,69	3,62	0,1	11,6	0,12	0,06	0,0076	ND
17-01-16	06:48:47	#17	Mining Plus	5,18	0,58	3,18	0,08	11,16	0,1	0,0519	0,0064	ND
17-01-16	06:59:05	#18	Mining Plus: ND			6,11	0,11	23,38	0,19	0,0792	0,0107	ND
17-01-16	07:00:45	#19	Mining Plus: ND			5,62	0,11	23,07	0,18	0,0674	0,011	ND
17-01-16	07:02:23	#20	Mining Plus: ND			5,82	0,11	22,58	0,18	0,0899	0,0116	ND
17-01-16	07:03:46	#21	Mining Plus: ND			5,92	0,11	22,82	0,18	0,1205	0,012	ND
17-01-16	07:05:11	#22	Mining Plus: ND			5,61	0,1	22,93	0,12	0,0473	0,0105	ND
17-01-16	07:06:41	#23	Mining Plus: ND			5,56	0,1	21,31	0,12	0,1006	0,0113	ND
17-01-16	07:08:01	#24	Mining Plus	2,05	0,58	5,56	0,11	20,92	0,17	0,0609	0,01	ND
17-01-16	07:16:58	#25	Mining Plus: ND			5,87	0,1	26,15	0,13	0,1762	0,0117	ND
17-01-16	07:18:21	#26	Mining Plus: ND			5,9	0,1	25,25	0,13	0,2476	0,0125	ND
17-01-16	07:19:54	#27	Mining Plus: ND			5,89	0,1	24,34	0,19	0,2103	0,0119	ND
17-01-16	07:21:27	#28	Mining Plus: ND			5,78	0,1	24,53	0,19	0,1281	0,011	ND
17-01-16	07:22:53	#29	Mining Plus: ND			5,65	0,1	24,09	0,13	0,2489	0,0123	ND
17-01-16	07:24:17	#30	Mining Plus: ND			5,74	0,1	24,34	0,13	0,1982	0,0118	ND
17-01-16	07:28:46	#31	Cal Check									
17-01-16	07:37:08	#32	Mining Plus: ND			5,58	0,09	24,36	0,13	0,4427	0,0143	ND
17-01-16	07:38:27	#33	Mining Plus: ND			5,44	0,1	23,42	0,13	0,6909	0,0166	ND
17-01-16	07:39:45	#34	Mining Plus	1,82	0,6	5,46	0,1	18,9	0,16	0,2016	0,012	ND
17-01-16	07:41:06	#35	Mining Plus: ND			6,27	0,11	20,75	0,18	0,0859	0,0113	ND
17-01-16	07:42:39	#36	Mining Plus	1,86	0,61	6,11	0,11	20,72	0,17	ND		0,0293
17-01-16	07:44:13	#37	Mining Plus: ND			6,33	0,11	21,18	0,18	0,0787	0,0119	0,0319
17-01-16	07:45:37	#38	Mining Plus	4,3	0,62	5,85	0,11	19,82	0,17	0,1056	0,0115	ND
17-01-16	07:47:01	#39	Mining Plus: ND			5,77	0,11	19,61	0,17	0,0585	0,0112	0,0342
17-01-16	07:48:26	#40	Mining Plus	2,2	0,6	5,98	0,11	19,77	0,17	0,1006	0,0117	0,04
17-01-16	07:50:01	#41	Mining Plus	2,78	0,61	5,74	0,11	19,95	0,17	0,0908	0,0116	0,031
17-01-16	07:51:35	#42	Mining Plus	1,8	0,6	5,9	0,11	20,51	0,17	ND		0,0399
17-01-16	07:56:04	#43	Cal Check									
17-01-16	07:58:30	#44	Mining Plus	9,13	0,66	3,2	0,1	14,02	0,14	0,0628	0,0078	ND
17-01-16	07:59:49	#45	Mining Plus	8,75	0,64	3,2	0,1	16,35	0,15	0,0254	0,0079	ND
17-01-16	08:05:44	#46	Cal Check									
17-01-16	08:08:56	#47	Mining Plus	10,33	0,64	2,71	0,09	15,35	0,14	0,32	0,0117	ND
17-01-16	08:10:12	#48	Mining Plus	10,39	0,65	3,15	0,1	14,15	0,14	0,2077	0,0099	ND
17-01-16	08:11:33	#49	Mining Plus	9,31	0,64	2,82	0,1	14,75	0,14	0,0914	0,0086	ND
17-01-16	08:12:55	#50	Mining Plus	8,56	0,61	2,89	0,09	13,65	0,13	0,3829	0,0113	ND
17-01-16	08:14:16	#51	Mining Plus	7,88	0,62	2,62	0,09	10,87	0,1	0,9336	0,0163	ND
17-01-16	08:15:44	#52	Mining Plus	10,67	0,65	2,9	0,1	16,28	0,15	1,5625	0,0244	ND
17-01-16	08:20:13	#53	Cal Check									
17-01-16	08:24:35	#54	Mining Plus	2,29	0,58	5,45	0,11	20,81	0,17	0,04	0,0084	ND
17-01-16	08:25:54	#55	Mining Plus	3,22	0,59	5,61	0,11	21,9	0,18	0,0634	0,0093	ND
17-01-16	08:27:14	#56	Mining Plus	3,62	0,59	5,21	0,11	19,73	0,16	0,1108	0,0102	ND
17-01-16	08:31:38	#57	Cal Check									
17-01-16	08:37:18	#58	Mining Plus	2,45	0,58	5,3	0,11	20,39	0,16	0,1439	0,0103	ND
17-01-16	08:38:41	#59	Mining Plus	6,7	0,69	2,32	0,08	11,34	0,12	ND		ND
17-01-16	08:39:59	#60	Mining Plus	4,85	0,62	5,05	0,11	16,31	0,15	ND		ND
17-01-16	08:41:25	#61	Mining Plus	2,53	0,59	5,75	0,11	21,53	0,18	ND		ND
17-01-16	08:42:53	#62	Mining Plus	3,08	0,6	5,66	0,11	21,15	0,17	0,087	0,0108	ND
17-01-16	08:44:15	#63	Mining Plus	2,35	0,6	5,82	0,11	20,76	0,17	0,0876	0,0104	ND
17-01-16	08:45:38	#64	Mining Plus	3,02	0,6	5,58	0,11	20,62	0,17	0,0987	0,0108	ND
17-01-16	08:50:02	#65	Cal Check									
17-01-16	08:54:36	#66	Mining Plus	3,8	0,6	3,38	0,09	11,85	0,11	2,7371	0,0318	ND
17-01-16	08:55:58	#67	Mining Plus	6,52	0,63	4,17	0,1	16,02	0,15	0,4041	0,0129	ND
17-01-16	08:57:19	#68	Mining Plus	6,59	0,62	5,16	0,11	18,55	0,16	0,2669	0,0118	ND
17-01-16	08:58:47	#69	Mining Plus	3,84	0,6	5,45	0,11	20,17	0,17	0,0541	0,0097	ND
17-01-16	09:03:19	#70	Cal Check									

17-01-16	09:10:54	#71	Mining Plus	5,98	0,63	4,4	0,11	17,32	0,15	0,7387	0,0167	ND
17-01-16	09:12:09	#72	Mining Plus	6,12	0,61	2,16	0,08	8,82	0,09	1,9454	0,0249	ND
17-01-16	09:13:30	#73	Mining Plus	4,39	0,6	5,4	0,11	19,85	0,17	0,0976	0,0098	ND
17-01-16	09:14:49	#74	Mining Plus	4,16	0,59	5,17	0,11	18,7	0,16	ND		ND
17-01-16	09:20:27	#75	Mining Plus	3,45	0,59	5,55	0,11	19,78	0,16	0,0566	0,0095	ND
17-01-16	09:21:50	#76	Mining Plus	2,64	0,59	5,56	0,11	19,34	0,16	0,5894	0,0159	ND
17-01-16	09:23:15	#77	Mining Plus ND			5,65	0,1	21,17	0,17	0,0654	0,0109	ND
17-01-16	09:27:44	#78	Cal Check									
17-01-16	09:32:16	#79	Mining Plus	2,28	0,59	5,71	0,11	21,06	0,17	0,0639	0,0098	ND
17-01-16	09:33:40	#80	Mining Plus ND			5,68	0,1	24,88	0,13	0,1953	0,0122	ND
17-01-16	09:35:02	#81	Mining Plus ND			5,06	0,1	22,21	0,13	0,1216	0,0126	ND
17-01-16	09:36:23	#82	Mining Plus ND			5,6	0,09	24,22	0,13	0,2278	0,0126	ND
17-01-16	09:40:46	#83	Cal Check									
17-01-16	09:48:00	#84	Mining Plus ND			6,34	0,11	22,97	0,18	0,0839	0,0122	ND
17-01-16	09:49:18	#85	Mining Plus ND			5,68	0,1	20,76	0,12	0,0718	0,0115	0,0389
17-01-16	09:50:40	#86	Mining Plus ND			5,55	0,1	20,74	0,12	0,1358	0,0125	0,0958
17-01-16	09:52:11	#87	Mining Plus ND			5,67	0,1	20,81	0,17	0,1466	0,0133	0,1051
17-01-16	09:53:39	#88	Mining Plus ND			5,52	0,1	20,56	0,12	ND		0,0638
17-01-16	09:55:36	#89	Mining Plus ND			5,78	0,1	22	0,12	0,0734	0,0124	ND
17-01-16	09:56:54	#90	Mining Plus ND			5,99	0,1	22,39	0,12	0,0958	0,0125	ND
17-01-16	09:58:16	#91	Mining Plus ND			5,77	0,1	21,62	0,17	ND		0,0462
17-01-16	10:02:44	#92	Cal Check									
17-01-16	10:30:26	#93	Mining Plus	10,22	0,65	2,54	0,09	14,69	0,14	ND		ND
17-01-16	10:31:48	#94	Mining Plus	7,79	0,64	2,17	0,08	19,22	0,17	ND		ND
17-01-16	10:33:08	#95	Mining Plus	11,27	0,65	3,72	0,11	17,41	0,16	0,1468	0,0103	ND
17-01-16	10:34:27	#96	Mining Plus	2,74	0,56	4,34	0,09	16,22	0,14	0,7317	0,0153	ND
17-01-16	10:35:44	#97	Mining Plus	10,68	0,66	2,83	0,1	15,48	0,15	0,0708	0,0089	ND
17-01-16	10:37:01	#98	Mining Plus	7,71	0,64	1,71	0,08	17,37	0,16	0,0439	0,0104	ND
17-01-16	10:38:17	#99	Mining Plus	7,77	0,63	1,93	0,08	16,81	0,15	0,2249	0,0119	ND
17-01-16	10:39:36	#100	Mining Plus	9,3	0,65	1,82	0,08	16,34	0,15	ND		ND
17-01-16	10:42:07	#101	Mining Plus	11,05	0,65	3,5	0,11	17,82	0,16	0,1426	0,0101	ND
17-01-16	10:43:35	#102	Mining Plus	10,48	0,65	3,56	0,11	16,83	0,16	0,5603	0,0147	ND
17-01-16	10:44:54	#103	Mining Plus	10,57	0,66	3,54	0,11	17,43	0,16	ND		ND
17-01-16	10:46:13	#104	Mining Plus	10,82	0,66	3,77	0,11	17,53	0,16	0,0546	0,0084	ND
17-01-16	10:47:28	#105	Mining Plus	9,63	0,64	3,19	0,1	15,48	0,14	2,3177	0,0305	ND
17-01-16	10:49:17	#106	Mining Plus	11,34	0,66	3,44	0,11	16,47	0,16	0,1072	0,0091	ND
17-01-16	10:50:43	#107	Mining Plus	8,55	0,64	4,19	0,11	18,01	0,16	0,1787	0,0101	ND
17-01-16	10:51:57	#108	Mining Plus	10,26	0,65	3,59	0,11	15,95	0,15	0,082	0,0084	ND
17-01-16	10:53:17	#109	Mining Plus	8,5	0,63	3,93	0,11	17,97	0,16	0,1493	0,0096	ND
17-01-16	10:55:04	#110	Mining Plus	5,81	0,6	3,08	0,09	21,31	0,18	ND		ND
17-01-16	10:56:20	#111	Mining Plus	9,99	0,64	3,9	0,11	18,41	0,17	ND		ND
17-01-16	10:57:46	#112	Mining Plus	5,18	0,56	5,14	0,1	21,6	0,17	ND		ND
17-01-16	10:59:06	#113	Mining Plus	10,28	0,66	3,76	0,11	17,34	0,16	ND		ND
17-01-16	11:00:40	#114	Mining Plus	7,68	0,61	4,74	0,11	20,46	0,17	ND		ND
17-01-16	11:01:54	#115	Mining Plus	11,17	0,66	3,92	0,11	17,46	0,16	ND		ND
17-01-16	11:03:10	#116	Mining Plus	10,6	0,66	3,75	0,11	17,79	0,17	ND		ND
17-01-16	11:04:27	#117	Mining Plus	10,2	0,66	3,65	0,11	17,57	0,16	ND		ND
17-01-16	11:05:47	#118	Mining Plus	1,93	0,54	5,26	0,1	22,61	0,17	0,1892	0,0107	ND
17-01-16	11:07:12	#119	Mining Plus	10,68	0,66	3,96	0,11	17,33	0,16	0,0384	0,0082	ND
17-01-16	11:11:41	#120	Cal Check									
17-01-16	11:23:07	#121	Mining Plus	2,81	0,61	5,75	0,11	18,62	0,16	0,1349	0,0111	ND
17-01-16	11:24:29	#122	Mining Plus	3,87	0,61	6,13	0,11	19,48	0,17	ND		0,0374
17-01-16	11:25:44	#123	Mining Plus	3,06	0,62	5,86	0,11	18,66	0,16	0,0554	0,0103	0,063
17-01-16	11:27:01	#124	Mining Plus	3,87	0,62	6,08	0,11	19,31	0,17	0,0413	0,0109	0,1356
17-01-16	11:28:25	#125	Mining Plus	3,11	0,61	5,68	0,11	18,78	0,16	0,1119	0,0116	0,0412
17-01-16	11:29:51	#126	Mining Plus	2,62	0,6	6,13	0,11	18,98	0,16	0,0963	0,0112	0,0463
17-01-16	11:31:10	#127	Mining Plus	2,21	0,6	6,09	0,11	19,21	0,16	ND		0,0358
17-01-16	11:32:29	#128	Mining Plus	3,15	0,61	6,25	0,11	19	0,16	ND		0,0798
17-01-16	11:33:51	#129	Mining Plus	4,33	0,62	6,24	0,11	19,88	0,17	ND		0,1562
17-01-16	11:35:22	#130	Mining Plus	3,2	0,61	4,67	0,11	20,66	0,17	ND		0,0323
17-01-16	11:36:44	#131	Mining Plus	3,73	0,61	4,71	0,11	21,16	0,18	ND		0,0345
17-01-16	11:38:05	#132	Mining Plus	4,89	0,62	4,83	0,11	20,94	0,18	ND		ND
17-01-16	11:39:22	#133	Mining Plus	4,88	0,61	3,97	0,1	20,76	0,17	ND		ND
17-01-16	11:40:39	#134	Mining Plus	4,02	0,58	4,88	0,1	22,09	0,18	ND		ND
17-01-16	11:42:12	#135	Mining Plus	6,81	0,63	3,99	0,11	16,63	0,15	2,4067	0,0311	ND
17-01-16	11:43:27	#136	Mining Plus	10,22	0,66	3,64	0,11	18,94	0,17	0,0755	0,0098	ND
17-01-16	11:44:44	#137	Mining Plus	2,55	0,58	4,36	0,1	21,37	0,17	0,3264	0,013	0,0397
17-01-16	11:46:14	#138	Mining Plus	6,08	0,67	1,95	0,08	17,16	0,16	0,5081	0,0159	0,0632
17-01-16	11:48:00	#139	Mining Plus	3,06	0,57	5,35	0,11	22,8	0,18	0,1458	0,0105	0,0411
17-01-16	11:49:20	#140	Mining Plus	2,11	0,54	4,59	0,1	21,16	0,16	0,1444	0,01	ND

S +/-	Cl	Cl +/-	K	K +/-	Ca	Ca +/-	Ti	Ti +/-	V	V +/-	Cr	Cr +/-
	ND			4,3716	0,0377	1,7411	0,0178	0,4172	0,0134	0,0518	0,0066	ND
	ND			2,3394	0,0215	5,1811	0,0434	0,4845	0,0143	0,0624	0,007	ND
0,0046	ND			1,8221	0,0179	6,79	0,06	0,4648	0,0149	0,0397	0,007	0,0154 0,0032
0,0042	ND			2,036	0,0192	5,5625	0,0463	0,4084	0,0135	0,0393	0,0064	ND
0,0046	ND			1,8333	0,0179	6,76	0,06	0,4715	0,015	0,0633	0,0075	ND
	ND			0,895	0,0098	1,9801	0,0172	0,1015	0,0071	0,0611	0,0046	ND
	9,03	0,18		2,8155	0,0248	0,6667	0,009	0,2266	0,0099	0,105	0,006	ND
	ND			2,2415	0,0215	1,5026	0,0153	0,2023	0,0088	0,0778	0,0052	ND
	ND			0,7339	0,0074	16,41	0,08	0,1494	0,0102	0,0987	0,0069	ND
	ND			3,1938	0,0283	1,7234	0,0166	0,228	0,0093	0,0629	0,0051	ND
	ND			3,2709	0,0306	1,0379	0,0122	0,2116	0,0095	0,077	0,0055	ND
	ND			2,6952	0,0256	0,3001	0,0067	0,2144	0,0092	0,0849	0,0054	ND
	7,79	0,18		2,9443	0,0255	0,3445	0,007	0,2499	0,0097	0,0592	0,0052	ND
	ND			6,2045	0,0486	2,3289	0,0217	0,4652	0,0149	0,0683	0,0076	ND
	ND			4,473	0,0363	3,6917	0,0309	0,4592	0,0146	0,0565	0,0072	ND
	ND			3,9976	0,0329	4,3719	0,0358	0,4764	0,0149	0,0541	0,0073	0,0113 0,0031
	ND			3,7193	0,0305	4,5593	0,0366	0,4368	0,0143	0,0523	0,0071	0,0101 0,003
	ND			4,0445	0,0228	3,6619	0,0214	0,3991	0,0133	0,0524	0,0068	0,0109 0,003
	ND			4,0538	0,023	4,3447	0,0245	0,4366	0,0139	0,0642	0,0073	0,0151 0,0032
	ND			3,428	0,0286	2,6839	0,0233	0,409	0,0131	0,0594	0,0067	ND
	ND			2,5162	0,0164	1,3584	0,0119	0,4504	0,0136	0,036	0,0064	0,0089 0,0027
	ND			2,9432	0,0183	1,4392	0,0124	0,4617	0,0138	0,045	0,0067	ND
	ND			2,5215	0,0216	1,3619	0,014	0,4742	0,014	0,0455	0,0066	ND
	ND			2,3638	0,0206	1,4984	0,0148	0,5004	0,0143	0,0452	0,0067	ND
	ND			2,5669	0,0166	1,7127	0,0131	0,4806	0,0138	0,0291	0,0063	ND
	ND			2,6953	0,0171	1,6969	0,0131	0,4448	0,0135	0,0472	0,0066	ND
	ND			0,7162	0,0087	2,4128	0,0154	0,4698	0,0132	0,0206	0,0058	ND
	ND			2,3185	0,0158	2,3796	0,016	0,4816	0,014	0,0337	0,0064	ND
	ND			2,1009	0,0194	4,3133	0,036	0,4166	0,013	0,0463	0,0062	ND
	ND			3,5551	0,0307	3,8653	0,0331	0,5941	0,0163	0,0536	0,0076	ND
0,0042	ND			2,7425	0,0243	4,7792	0,0394	0,513	0,0151	0,0462	0,0071	ND
0,0043	ND			2,9601	0,0261	4,9699	0,0412	0,5664	0,0162	0,0419	0,0074	0,0095 0,003
	ND			3,05	0,0268	4,7301	0,0395	0,5447	0,0154	0,067	0,0075	ND
0,0042	ND			2,7739	0,0249	4,9193	0,0413	0,5334	0,0154	0,0523	0,0073	ND
0,0041	ND			2,3789	0,0214	5,2956	0,0431	0,4805	0,0145	0,0497	0,0069	0,0117 0,003
0,0041	ND			2,8312	0,0251	5,192	0,0429	0,49	0,0148	0,0488	0,007	0,0107 0,0031
0,0041	ND			2,4446	0,0218	4,5866	0,0375	0,4453	0,0139	0,0367	0,0064	ND
	ND			5,2342	0,0475	0,111	0,0071	0,26	0,0102	0,0481	0,0053	ND
	ND			5,0065	0,0436	1,3245	0,0145	0,2369	0,0101	0,0568	0,0056	ND
	ND			4,8606	0,0426	2,4187	0,0229	0,1717	0,0092	0,0489	0,0052	ND
	ND			6,06	0,05	0,6372	0,0101	0,1942	0,0094	0,0464	0,0052	ND
	ND			5,1395	0,0449	1,5881	0,0164	0,1817	0,0092	0,0537	0,0052	ND
	3,66	0,2		6,23	0,05	1,4191	0,0152	0,2351	0,0102	0,0557	0,0056	ND
	3,87	0,18		5,2279	0,0446	1,5845	0,016	0,1809	0,0092	0,0774	0,0056	ND
	ND			6,44	0,06	4,0491	0,0366	0,2753	0,0118	0,0348	0,0059	ND
	ND			7,03	0,05	0,1697	0,0094	0,4079	0,0131	0,0693	0,0069	0,0099 0,003
	ND			7,67	0,06	0,6937	0,0121	0,5145	0,0151	0,0683	0,0075	0,0104 0,0031
	ND			5,9238	0,0472	2,9485	0,0257	0,4513	0,0138	0,0658	0,007	0,0172 0,0033
	ND			6,53	0,05	1,9322	0,0186	0,4905	0,0143	0,0715	0,0072	0,0097 0,0031
	ND			1,0826	0,0121	5,2304	0,0474	0,2312	0,0098	0,075	0,0056	ND
	ND			3,5243	0,0306	3,1262	0,0276	0,2631	0,0106	0,06	0,0058	ND
	ND			7,45	0,06	0,8322	0,0127	0,4869	0,0146	0,084	0,0076	0,0113 0,0032
	ND			5,3882	0,0438	3,5295	0,0303	0,4814	0,0148	0,0608	0,0073	0,0102 0,0031
	ND			5,8279	0,0469	2,657	0,0241	0,4894	0,0148	0,0625	0,0073	ND
	ND			5,8131	0,0472	3,3192	0,029	0,4858	0,0149	0,0544	0,0072	0,0107 0,0031
	ND			1,9365	0,0175	6,0627	0,0488	0,2619	0,0103	0,0852	0,006	ND
	ND			4,7238	0,0409	2,3018	0,0218	0,3509	0,0119	0,0547	0,006	0,0101 0,003
	ND			4,3932	0,0376	2,0538	0,0198	0,3973	0,0128	0,0451	0,0061	ND
	ND			3,5947	0,0303	2,4638	0,0221	0,3273	0,0118	0,0355	0,0058	ND

	ND		5,1501	0,0439	2,876	0,0263	0,465	0,0139	0,0409	0,0064	0,0111	0,0031
	6,54	0,17	3,7887	0,0325	4,4628	0,0377	0,405	0,0124	0,11	0,0069	ND	
	ND		3,6943	0,0315	1,6326	0,0163	0,3971	0,0126	0,0463	0,0061	ND	
	ND		3,7087	0,0312	1,5043	0,0151	0,3921	0,0122	0,0459	0,0059	ND	
	ND		3,3713	0,0283	2,4698	0,0218	0,4594	0,0134	0,0362	0,0061	0,0131	0,0029
	ND		2,5553	0,0225	4,218	0,0348	0,3846	0,0128	0,037	0,0061	0,0086	0,0029
	ND		2,3384	0,0206	4,1918	0,0338	0,4906	0,0145	0,0316	0,0065	0,011	0,0029
	ND		2,9275	0,0253	1,8562	0,0176	0,468	0,0137	0,0592	0,0067	ND	
	ND		1,988	0,014	2,8779	0,0175	0,3658	0,0125	0,0462	0,0064	ND	
	ND		0,7777	0,0093	4,6674	0,0261	0,3889	0,0135	0,0472	0,0069	ND	
	ND		1,2782	0,011	3,5355	0,02	0,3906	0,0128	0,0424	0,0064	ND	
	ND		1,5358	0,0152	5,6015	0,0437	0,4202	0,0141	0,0405	0,0068	ND	
0,0042	ND		1,7268	0,0131	4,8371	0,0267	0,4535	0,0141	0,0416	0,0068	ND	
0,0046	ND		1,8948	0,0136	6,2612	0,0325	0,5105	0,015	0,04	0,0071	0,0132	0,003
0,0047	ND		1,431	0,0144	7,87	0,06	0,4465	0,0146	0,048	0,0071	ND	
0,0044	ND		1,2877	0,011	7,902	0,0398	0,3794	0,0133	0,0345	0,0065	ND	
	ND		1,6798	0,0126	7,297	0,0361	0,4462	0,0143	0,0403	0,007	ND	
	ND		0,9936	0,0099	6,4619	0,0327	0,4211	0,0138	0,031	0,0066	0,0104	0,0028
0,0042	ND		2,5638	0,0221	4,756	0,0377	0,3724	0,013	0,0446	0,0065	0,0117	0,0029
	ND		4,1669	0,0376	2,1502	0,0209	0,2935	0,0108	0,0831	0,0061	ND	
	ND		2,9612	0,0269	6,27	0,05	0,1873	0,0102	0,0262	0,0053	ND	
	ND		7,51	0,07	1,294	0,0157	0,4446	0,0141	0,0351	0,0065	ND	
	ND		2,4874	0,0213	1,138	0,0117	0,1502	0,0081	0,0886	0,0055	ND	
	ND		5,1064	0,0458	2,027	0,0203	0,3299	0,0116	0,0725	0,0063	ND	
	ND		1,8648	0,0181	6,16	0,05	0,1799	0,0097	0,0546	0,0055	ND	
	ND		2,6476	0,0242	5,4155	0,0464	0,2079	0,01	0,0493	0,0055	ND	
	ND		2,7137	0,0252	4,4262	0,0393	0,1934	0,0097	0,0588	0,0055	ND	
	ND		8,27	0,07	1,004	0,0139	0,3488	0,0129	0,0282	0,006	ND	
	ND		8,51	0,07	0,8549	0,013	0,3603	0,013	0,031	0,0061	ND	
	ND		8,08	0,07	0,6546	0,0117	0,346	0,0127	0,033	0,0061	ND	
	ND		8,74	0,08	ND		0,4402	0,014	0,0382	0,0065	ND	
	ND		7,46	0,06	3,8483	0,0348	0,4575	0,0145	0,0485	0,007	ND	
	ND		7,79	0,07	0,219	0,0092	0,437	0,0136	0,046	0,0064	ND	
	ND		7,13	0,06	0,0666	0,0087	0,3836	0,0128	0,0278	0,0059	ND	
	ND		7,53	0,07	ND		0,4431	0,0134	0,043	0,0062	ND	
	ND		7,07	0,06	0,0994	0,0086	0,4399	0,0134	0,0435	0,0063	ND	
	ND		2,4325	0,0217	4,7526	0,0389	0,1681	0,0095	0,0215	0,0049	0,0086	0,0027
	ND		7,64	0,07	0,4719	0,0106	0,3795	0,0131	0,0359	0,0062	ND	
	ND		4,6092	0,036	ND		0,1982	0,0094	ND		0,0077	0,0023
	ND		8,42	0,07	0,4786	0,011	0,5296	0,0153	0,0272	0,0066	ND	
	ND		5,8546	0,048	0,0894	0,0084	0,2916	0,0114	0,0356	0,0057	ND	
	ND		8,72	0,08	0,1422	0,0098	0,4317	0,014	0,028	0,0063	ND	
	ND		8,16	0,07	0,9348	0,0136	0,5134	0,0151	0,0396	0,0068	ND	
	ND		8,25	0,07	0,788	0,0128	0,4054	0,0137	0,0389	0,0065	ND	
	ND		2,9818	0,0242	0,2221	0,0077	0,1649	0,0088	0,0238	0,0048	ND	
	ND		9,1	0,08	ND		0,4375	0,0141	0,0296	0,0063	ND	
	ND		4,1213	0,0349	3,3562	0,0293	0,5271	0,015	0,0617	0,0072	ND	
0,0041	ND		4,1137	0,0349	3,7209	0,0321	0,5835	0,016	0,0332	0,007	0,0112	0,003
0,0042	ND		3,9807	0,0341	3,6209	0,0314	0,5469	0,0153	0,0597	0,0073	0,0113	0,0031
0,0049	ND		3,7901	0,0325	4,7868	0,0402	0,5883	0,0163	0,0578	0,0077	ND	
0,0041	ND		3,2022	0,0277	5,5073	0,0452	0,5845	0,016	0,0564	0,0075	ND	
0,0041	ND		3,3041	0,0281	4,68	0,0384	0,5313	0,0151	0,0598	0,0073	ND	
0,0041	ND		3,4119	0,0289	5,2122	0,0423	0,5404	0,0155	0,0414	0,0071	ND	
0,0044	ND		3,8283	0,0325	4,7804	0,0398	0,5718	0,016	0,0661	0,0077	ND	
0,0051	ND		3,4779	0,03	5,7476	0,0472	0,512	0,0155	0,056	0,0075	ND	
0,004	ND		8,04	0,06	0,8944	0,0133	0,6401	0,017	0,0346	0,0074	ND	
0,004	ND		7,96	0,06	1,4166	0,0165	0,6075	0,0167	0,0518	0,0077	ND	
	ND		8,17	0,07	1,3486	0,0161	0,6901	0,0177	0,0454	0,0078	ND	
	ND		6,22	0,05	5,391	0,0442	0,5033	0,0155	0,0322	0,007	ND	
	ND		6,61	0,05	2,884	0,0252	0,3924	0,0136	0,037	0,0066	ND	
	ND		8,12	0,07	4,4092	0,0386	0,513	0,0157	0,0481	0,0074	ND	
	ND		7,41	0,06	1,9674	0,0207	0,5498	0,0157	0,039	0,007	ND	
0,004	ND		8	0,06	3,3089	0,0284	0,32	0,0128	0,0481	0,0067	ND	
0,0041	ND		2,9163	0,0275	6,71	0,06	0,2941	0,0123	0,0266	0,0059	ND	
0,0041	ND		9,01	0,07	0,9243	0,0138	0,2798	0,0119	0,0764	0,0072	ND	
	ND		6,3378	0,0472	1,9626	0,018	0,18	0,0096	0,0571	0,0058	ND	

Mn	Mn +/-	Fe	Fe +/-	Co	Co +/-	Ni	Ni +/-	Cu	Cu +/-	Zn	Zn +/-	As
0,0311	0,0031	9,34	0,08	0,097	0,0071	ND		ND		ND		ND
0,0435	0,0034	9,38	0,08	0,0633	0,0069	0,0043	0,0014	ND		ND		ND
0,0364	0,0033	6,04	0,05	0,0595	0,0059	0,0044	0,0013	ND		ND		ND
0,0348	0,0032	8,94	0,08	0,0753	0,0069	ND		ND		ND		ND
0,0438	0,0035	6,49	0,06	0,0747	0,0062	ND		ND		ND		ND
0,0206	0,0027	15,43	0,12	0,0983	0,0076	ND		0,0036	0,0006	ND		0,002
0,0335	0,0042	40,5	0,32	0,2387	0,0138	ND		ND		ND		ND
0,0394	0,0036	26,48	0,23	0,1586	0,0106	ND		ND		ND		ND
0,047	0,0041	20,06	0,1	0,1204	0,0105	ND		0,0042	0,0008	ND		0,0152
0,029	0,0032	21,51	0,18	0,1297	0,0094	ND		ND		ND		ND
0,0481	0,004	29,22	0,25	0,1936	0,0118	ND		ND		ND		ND
0,0439	0,0043	41,19	0,35	0,2317	0,0139	ND		ND		ND		ND
0,0283	0,0033	22,55	0,18	0,1246	0,0097	ND		ND		ND		ND
0,0482	0,0035	5,5667	0,0467	0,0468	0,0057	ND		ND		ND		ND
0,0418	0,0034	5,9653	0,0498	0,0595	0,0058	0,0038	0,0012	ND		ND		ND
0,0403	0,0033	5,3928	0,0458	0,0515	0,0056	0,0051	0,0012	ND		ND		ND
0,0406	0,0033	4,6203	0,0396	0,0389	0,0051	0,0043	0,0011	ND		ND		ND
0,0444	0,0034	6,125	0,0358	0,0587	0,0058	ND		ND		ND		ND
0,041	0,0033	5,3924	0,0327	0,0513	0,0055	0,0037	0,0012	ND		ND		ND
0,0454	0,0033	6,71	0,05	0,0649	0,0059	0,0046	0,0013	ND		ND		ND
0,0268	0,0028	5,0903	0,0301	0,0645	0,0052	ND		0,0032	0,0006	ND		ND
0,02	0,0026	5,8645	0,0341	0,0611	0,0056	0,0042	0,0012	ND		ND		ND
0,0214	0,0026	5,0545	0,0414	0,057	0,0051	0,0057	0,0012	ND		ND		ND
0,0179	0,0025	5,366	0,0438	0,0617	0,0053	0,0062	0,0012	ND		ND		ND
0,0134	0,0024	5,3011	0,0314	0,0592	0,0052	0,0041	0,0012	0,0029	0,0006	ND		ND
0,0179	0,0025	4,6399	0,0283	0,0523	0,0049	0,0053	0,0012	ND		ND		ND
0,0494	0,0033	7,852	0,043	0,0785	0,0062	ND		ND		ND		ND
0,0454	0,0034	7,9015	0,0444	0,0889	0,0065	ND		ND		ND		ND
0,0615	0,0039	12,33	0,1	0,1127	0,008	ND		ND		ND		ND
0,0536	0,0036	6,1	0,05	0,0685	0,0059	0,0101	0,0014	ND		ND		ND
0,0553	0,0037	6,57	0,06	0,0689	0,0061	0,0091	0,0014	ND		ND		ND
0,0577	0,0038	5,5051	0,048	0,0594	0,0057	0,0096	0,0014	ND		ND		ND
0,0709	0,004	6,81	0,06	0,0682	0,0061	0,0073	0,0014	ND		ND		ND
0,0729	0,0041	6,81	0,06	0,0731	0,0062	0,0103	0,0014	ND		ND		ND
0,0664	0,0039	7,32	0,06	0,0578	0,0063	0,0096	0,0014	ND		ND		ND
0,073	0,0041	7,37	0,06	0,0673	0,0064	0,0079	0,0014	0,0034	0,0006	ND		ND
0,0666	0,0039	7,53	0,06	0,0704	0,0064	0,0063	0,0014	ND		ND		ND
0,0265	0,0031	16,06	0,14	0,103	0,0085	ND		ND		ND		ND
0,0319	0,0032	14,48	0,12	0,0978	0,0081	ND		ND		ND		ND
0,0459	0,0035	16,36	0,14	0,116	0,0087	ND		ND		ND		ND
0,0362	0,0032	13,74	0,12	0,1073	0,0079	ND		ND		ND		ND
0,0317	0,0032	16,4	0,14	0,1254	0,0086	ND		ND		ND		ND
0,04	0,0034	15,56	0,13	0,1228	0,0085	ND		ND		ND		ND
0,0379	0,0036	24,17	0,2	0,1578	0,0104	ND		ND		ND		ND
0,064	0,004	10,03	0,09	0,073	0,0074	0,0114	0,0016	0,0152	0,001	ND		ND
0,0404	0,0033	8,97	0,07	0,0775	0,0068	ND		ND		ND		ND
0,0625	0,0039	8,16	0,07	0,0823	0,0068	ND		ND		ND		ND
0,0692	0,0041	10,72	0,09	0,096	0,0075	ND		ND		ND		ND
0,0598	0,0038	9,36	0,07	0,0769	0,007	ND		ND		ND		ND
0,0925	0,0047	28,82	0,25	0,1507	0,0116	ND		ND		ND		ND
0,0655	0,0039	14,04	0,12	0,1002	0,0082	ND		ND		ND		ND
0,0463	0,0036	9,58	0,08	0,0932	0,0073	ND		ND		ND		ND
0,0549	0,0038	7,77	0,06	0,0711	0,0066	ND		ND		ND		ND
0,0559	0,0037	7,6	0,06	0,0639	0,0065	0,0056	0,0014	0,0034	0,0006	ND		ND
0,0591	0,0038	7,46	0,06	0,0702	0,0065	ND		0,0041	0,0007	ND		ND
0,0494	0,0039	23,38	0,18	0,1458	0,0103	ND		ND		ND		0,0037
0,0459	0,0036	14,98	0,13	0,122	0,0086	ND		ND		ND		ND
0,0391	0,0034	12,01	0,1	0,0952	0,0077	ND		ND		ND		ND
0,0369	0,0032	8,72	0,07	0,0755	0,0066	ND		ND		ND		ND

0,0495	0,0037	11,44	0,1	0,0927	0,0077	ND		ND		ND		0,0022
0,0593	0,0042	25,26	0,2	0,1588	0,0109	ND		0,004	0,0008	ND		0,0062
0,0286	0,003	10,1	0,08	0,1082	0,0071	ND		ND		ND		ND
0,0396	0,0033	12,01	0,1	0,0927	0,0075	ND		ND		ND		ND
0,0405	0,0033	9,83	0,08	0,072	0,0069	ND		ND		ND		ND
0,0425	0,0033	8,59	0,07	0,0959	0,0068	ND		ND		ND		ND
0,0406	0,0032	6,43	0,05	0,0703	0,0059	ND		ND		ND		ND
0,0365	0,0032	9,07	0,07	0,0802	0,0067	ND		ND		ND		ND
0,0238	0,0027	4,7149	0,0285	0,0478	0,005	0,0048	0,0011	0,0029	0,0006	ND		ND
0,0196	0,0026	3,3757	0,0238	0,0384	0,0044	0,0056	0,0011	ND		ND		ND
0,0211	0,0026	4,3948	0,0271	0,0383	0,0047	0,0068	0,0011	ND		ND		ND
0,0497	0,0035	4,6897	0,0399	0,0519	0,0052	0,0045	0,0012	ND		ND		ND
0,0457	0,0033	4,5219	0,029	0,0518	0,005	0,0037	0,0012	0,003	0,0006	ND		ND
0,0683	0,0039	4,1226	0,027	0,0433	0,0049	0,0061	0,0012	ND		ND		ND
0,0741	0,0041	4,254	0,0374	0,0467	0,005	0,0036	0,0011	ND		ND		ND
0,0773	0,0041	4,0814	0,0269	0,0443	0,0049	0,0056	0,0012	ND		ND		ND
0,0592	0,0036	2,8911	0,0209	0,0245	0,0041	0,0066	0,0011	ND		ND		ND
0,0549	0,0036	3,6799	0,0246	0,0442	0,0046	0,0064	0,0012	ND		ND		ND
0,045	0,0034	5,545	0,046	0,0463	0,0055	ND		0,0037	0,0006	ND		ND
0,0364	0,0034	18,71	0,16	0,1153	0,0092	ND		ND		ND		ND
0,0565	0,0037	8,81	0,08	0,0882	0,007	0,0058	0,0015	0,0036	0,0007	ND		ND
0,0354	0,0032	8,49	0,08	0,0772	0,0068	0,009	0,0015	ND		ND		ND
0,014	0,0025	12,68	0,1	0,0921	0,0072	ND		ND		ND		0,0021
0,0312	0,0033	15,42	0,13	0,1047	0,0086	ND		ND		ND		ND
0,0597	0,0039	15,94	0,13	0,1258	0,0089	ND		0,0037	0,0007	ND		ND
0,0472	0,0036	13,61	0,12	0,1146	0,0082	ND		ND		ND		ND
0,0485	0,0037	17,45	0,15	0,1129	0,0091	ND		ND		ND		ND
0,0294	0,0031	7,84	0,07	0,0874	0,0066	0,0067	0,0014	ND		ND		ND
0,0255	0,0029	8,03	0,07	0,08	0,0066	0,0081	0,0015	ND		ND		ND
0,0258	0,003	8,81	0,08	0,0915	0,007	ND		ND		ND		ND
0,0219	0,0029	8,57	0,08	0,0864	0,0068	0,0065	0,0015	ND		ND		ND
0,0272	0,0031	8,96	0,08	0,0905	0,0071	0,0075	0,0015	ND		ND		ND
0,0197	0,003	12	0,11	0,0932	0,0079	ND		ND		ND		ND
0,0234	0,0028	8,15	0,07	0,0657	0,0064	0,0059	0,0014	ND		ND		ND
0,0239	0,003	12,06	0,11	0,1009	0,0078	ND		ND		ND		ND
0,0199	0,0028	9,43	0,08	0,0945	0,0069	0,005	0,0015	ND		ND		ND
0,029	0,0029	6,08	0,05	0,0595	0,0056	0,0056	0,0012	ND		ND		ND
0,0249	0,0029	8,18	0,07	0,0783	0,0066	0,0053	0,0014	ND		ND		ND
0,0101	0,002	3,4662	0,0297	0,037	0,004	0,0075	0,0011	ND		ND		ND
0,0148	0,0027	8,84	0,08	0,1001	0,007	0,0051	0,0015	ND		ND		ND
0,0188	0,0025	4,8849	0,0426	0,0465	0,0049	0,0044	0,0011	ND		ND		ND
0,0159	0,0027	8,72	0,08	0,0894	0,0069	0,0061	0,0015	ND		ND		ND
0,0254	0,003	9,01	0,08	0,0871	0,0071	0,0077	0,0015	ND		ND		ND
0,0197	0,0029	8,88	0,08	0,085	0,007	0,0053	0,0015	ND		ND		ND
0,013	0,0021	2,8085	0,0246	0,0267	0,0036	0,0076	0,001	ND		ND		ND
0,026	0,003	8,97	0,08	0,1035	0,0071	0,0077	0,0016	ND		ND		ND
0,0275	0,0029	7,42	0,06	0,072	0,0063	0,012	0,0015	ND		ND		ND
0,0345	0,0032	6,6	0,06	0,0752	0,0061	0,0105	0,0014	ND		ND		ND
0,0331	0,0032	8,09	0,07	0,0802	0,0066	0,0102	0,0015	ND		ND		ND
0,0323	0,0031	6,36	0,05	0,0643	0,006	0,0109	0,0014	ND		ND		ND
0,0369	0,0032	7,21	0,06	0,0718	0,0064	0,0093	0,0014	ND		ND		ND
0,0314	0,0031	6,76	0,06	0,0697	0,0061	0,0076	0,0014	0,0039	0,0006	ND		ND
0,0348	0,0031	5,4077	0,0463	0,0573	0,0055	0,0103	0,0013	0,0031	0,0006	ND		ND
0,037	0,0032	5,93	0,05	0,0601	0,0058	0,0083	0,0013	0,0034	0,0006	ND		ND
0,0314	0,0031	5,5454	0,0484	0,0621	0,0057	0,0101	0,0014	0,0083	0,0008	ND		ND
0,0236	0,0029	5,78	0,05	0,0645	0,0058	0,0064	0,0013	ND		ND		ND
0,0275	0,003	6,36	0,05	0,0697	0,0061	0,005	0,0013	ND		ND		ND
0,0303	0,0032	7,21	0,06	0,0671	0,0064	0,0063	0,0014	ND		ND		ND
0,0349	0,0033	6,78	0,06	0,0669	0,0063	0,0059	0,0014	ND		ND		ND
0,0205	0,0027	4,6022	0,0393	0,0421	0,0051	0,0056	0,0012	ND		ND		ND
0,0427	0,0036	8,19	0,07	0,0725	0,0069	0,0045	0,0014	0,0044	0,0007	ND		0,0021
0,0377	0,0034	8,81	0,08	0,087	0,0071	0,0047	0,0015	ND		ND		ND
0,0361	0,0032	5,4374	0,0456	0,0548	0,0057	0,006	0,0013	ND		ND		ND
0,0661	0,0041	8,6	0,08	0,099	0,0072	ND		ND		ND		ND
0,0266	0,0028	4,056	0,0349	0,0421	0,0048	0,0066	0,0012	ND		ND		ND
0,0241	0,0028	8,27	0,06	0,0684	0,0064	ND		ND		ND		ND

As +/-	Zr	Zr +/-	Mo	Mo +/-	Ag	Ag +/-	Cd	Cd +/-	Sn	Sn +/-	Sb	Sb +/-
	0,0143	0,0003	ND		0,0183	0,0009	0,0238	0,0011	0,0242	0,0013	0,031	0,0016
	0,0146	0,0003	ND		0,0194	0,0009	0,0259	0,0011	0,0268	0,0013	0,0297	0,0016
	0,0158	0,0003	ND		0,0221	0,0009	0,028	0,0011	0,0282	0,0013	0,0367	0,0016
	0,0149	0,0003	ND		0,0202	0,0009	0,028	0,0011	0,0266	0,0013	0,0349	0,0016
	0,0148	0,0003	ND		0,0213	0,0009	0,0262	0,0011	0,0274	0,0013	0,0342	0,0016
0,0003	0,0058	0,0003	ND		ND		0,0143	0,001	0,0148	0,0012	0,0163	0,0015
	0,004	0,0003	ND		ND		ND		ND		ND	
	0,0044	0,0003	ND		ND		0,011	0,0013	ND		0,0148	0,0018
0,0006	0,0046	0,0003	ND		ND		0,0195	0,0012	0,0208	0,0014	0,0238	0,0017
	0,0119	0,0004	ND		ND		0,0184	0,0012	0,0177	0,0014	0,0245	0,0017
	0,0082	0,0004	ND		ND		0,0138	0,0014	0,0114	0,0016	0,0135	0,0019
	0,0149	0,0005	ND		ND		ND		ND		ND	
	0,0088	0,0003	ND		ND		0,0174	0,0011	0,0151	0,0013	0,0226	0,0016
	0,0194	0,0004	ND		0,0219	0,0009	0,0265	0,001	0,0276	0,0013	0,0364	0,0016
	0,02	0,0004	ND		0,0213	0,0009	0,0262	0,001	0,0259	0,0013	0,0325	0,0015
	0,0208	0,0004	ND		0,0223	0,0009	0,0277	0,001	0,0287	0,0013	0,0405	0,0016
	0,0201	0,0004	ND		0,0207	0,0009	0,0268	0,001	0,0262	0,0012	0,0375	0,0015
	0,0208	0,0004	ND		0,0227	0,0009	0,0272	0,001	0,0275	0,0012	0,0389	0,0016
	0,0206	0,0004	ND		0,0226	0,0009	0,0261	0,001	0,0266	0,0012	0,0386	0,0015
	0,0204	0,0004	ND		0,0209	0,0009	0,0287	0,001	0,0261	0,0012	0,035	0,0015
	0,0259	0,0004	ND		0,0225	0,0009	0,028	0,001	0,0281	0,0012	0,0377	0,0015
	0,0269	0,0004	ND		0,0209	0,0009	0,0266	0,001	0,0302	0,0013	0,0385	0,0015
	0,028	0,0004	ND		0,0206	0,0008	0,0252	0,001	0,026	0,0012	0,0336	0,0014
	0,0282	0,0004	ND		0,0206	0,0009	0,0254	0,001	0,0267	0,0012	0,0376	0,0015
	0,0279	0,0004	ND		0,0222	0,0009	0,0274	0,001	0,0286	0,0012	0,0401	0,0015
	0,027	0,0004	ND		0,0201	0,0008	0,0253	0,001	0,0253	0,0012	0,0356	0,0014
	0,0474	0,0005	ND		0,0187	0,0009	0,0208	0,001	0,0248	0,0012	0,0309	0,0015
	0,0471	0,0006	ND		0,0197	0,0009	0,0253	0,0011	0,0234	0,0013	0,033	0,0016
	0,0262	0,0005	ND		ND		0,0232	0,0011	0,0216	0,0013	0,0287	0,0016
	0,0171	0,0004	ND		0,0226	0,0009	0,027	0,001	0,0308	0,0013	0,0376	0,0016
	0,0156	0,0003	ND		0,0204	0,0009	0,0281	0,0011	0,028	0,0013	0,0359	0,0016
	0,0167	0,0003	ND		0,0223	0,0009	0,0262	0,001	0,0259	0,0013	0,0357	0,0016
	0,0162	0,0003	ND		0,0197	0,0009	0,0264	0,001	0,0278	0,0013	0,0388	0,0016
	0,0165	0,0004	ND		0,0207	0,0009	0,0262	0,0011	0,0268	0,0013	0,0348	0,0016
	0,0156	0,0003	ND		0,0217	0,0009	0,0268	0,0011	0,0258	0,0013	0,0338	0,0016
	0,0164	0,0004	ND		0,0218	0,0009	0,0252	0,0011	0,0247	0,0013	0,037	0,0016
	0,0163	0,0003	ND		0,0212	0,0009	0,027	0,0011	0,0265	0,0013	0,0331	0,0016
	0,0244	0,0005	ND		ND		0,0222	0,0012	0,0215	0,0014	0,0308	0,0017
	0,0288	0,0005	ND		ND		0,0234	0,0011	0,0235	0,0014	0,028	0,0016
	0,018	0,0004	0,0016	0,0003	ND		0,0215	0,0011	0,0185	0,0013	0,0287	0,0017
	0,0347	0,0006	ND		ND		0,0226	0,0011	0,0249	0,0013	0,0347	0,0017
	0,0274	0,0005	ND		ND		0,0223	0,0011	0,0222	0,0014	0,0315	0,0017
	0,0239	0,0005	0,0014	0,0003	ND		0,0197	0,0011	0,0163	0,0013	0,0237	0,0015
	0,0191	0,0004	ND		ND		0,0197	0,0012	0,0186	0,0014	0,0228	0,0017
	0,0165	0,0004	ND		0,022	0,001	0,0261	0,0011	0,0266	0,0013	0,0358	0,0016
	0,0145	0,0003	ND		0,0185	0,0009	0,0229	0,0011	0,0224	0,0013	0,0282	0,0015
	0,0131	0,0003	ND		0,018	0,0009	0,0242	0,0011	0,025	0,0013	0,0316	0,0016
	0,0132	0,0003	ND		0,019	0,001	0,0243	0,0011	0,0249	0,0013	0,0332	0,0016
	0,0142	0,0003	ND		0,0186	0,0009	0,0254	0,0011	0,0246	0,0013	0,0288	0,0015
	0,0042	0,0003	ND		ND		0,0147	0,0013	0,0182	0,0016	0,0189	0,0019
	0,0107	0,0003	ND		ND		0,0223	0,0011	0,0181	0,0013	0,0253	0,0016
	0,0127	0,0003	ND		0,0186	0,0009	0,0244	0,0011	0,025	0,0013	0,0289	0,0016
	0,0119	0,0003	ND		0,0205	0,0009	0,0259	0,0011	0,0249	0,0013	0,0336	0,0016
	0,0118	0,0003	ND		0,0199	0,0009	0,0227	0,001	0,0232	0,0013	0,0328	0,0016
	0,0112	0,0003	ND		0,0208	0,0009	0,0251	0,0011	0,0255	0,0013	0,0321	0,0016
0,0004	0,0095	0,0003	ND		ND		0,0177	0,0012	0,0166	0,0014	0,0208	0,0017
	0,0101	0,0003	ND		ND		0,0239	0,0012	0,0231	0,0014	0,0294	0,0017
	0,0107	0,0003	ND		0,0208	0,001	0,0247	0,0011	0,0234	0,0013	0,0273	0,0016
	0,0112	0,0003	ND		0,017	0,0009	0,0216	0,001	0,0238	0,0013	0,0291	0,0015

0,0003	0,0088	0,0003	ND		0,019	0,001	0,0246	0,0011	0,0224	0,0013	0,0307	0,0016
0,0005	0,0032	0,0003	ND	ND			0,0189	0,0012	0,0183	0,0014	0,0245	0,0017
	0,0112	0,0003	ND		0,0173	0,0009	0,023	0,0011	0,0218	0,0013	0,0309	0,0016
	0,0127	0,0003	ND	ND			0,0237	0,0011	0,0247	0,0013	0,0299	0,0016
	0,0162	0,0004	ND		0,0185	0,0009	0,0259	0,0011	0,025	0,0013	0,0335	0,0016
	0,0157	0,0003	ND		0,0199	0,0009	0,0239	0,0011	0,0248	0,0013	0,0302	0,0015
	0,0155	0,0003	ND		0,0199	0,0009	0,0257	0,001	0,0253	0,0012	0,0324	0,0015
	0,0156	0,0003	ND		0,0181	0,0009	0,0259	0,0011	0,0244	0,0013	0,0307	0,0016
	0,0292	0,0004	ND		0,0206	0,0008	0,0246	0,001	0,0268	0,0012	0,0355	0,0014
	0,0315	0,0004	ND		0,0231	0,0009	0,0262	0,001	0,0255	0,0012	0,0364	0,0015
	0,0287	0,0004	ND		0,0222	0,0008	0,0256	0,001	0,0262	0,0012	0,036	0,0014
	0,0224	0,0004	ND		0,021	0,0009	0,0262	0,001	0,0277	0,0012	0,0405	0,0015
	0,0228	0,0004	ND		0,0206	0,0009	0,0273	0,001	0,027	0,0012	0,036	0,0015
	0,0207	0,0003	ND		0,0223	0,0009	0,0268	0,001	0,0292	0,0012	0,0387	0,0015
	0,0203	0,0004	ND		0,0213	0,0009	0,029	0,001	0,0286	0,0012	0,0382	0,0015
	0,0185	0,0003	ND		0,0224	0,0009	0,0264	0,001	0,0291	0,0012	0,0387	0,0015
	0,0207	0,0003	ND		0,0224	0,0008	0,0288	0,001	0,0292	0,0012	0,0387	0,0015
	0,0236	0,0004	ND		0,0223	0,0009	0,0288	0,001	0,0303	0,0012	0,0386	0,0015
	0,0181	0,0003	ND		0,0222	0,0009	0,0283	0,001	0,0258	0,0012	0,0397	0,0015
	0,0282	0,0005	ND	ND			0,0239	0,0012	0,0241	0,0015	0,0294	0,0017
	0,0254	0,0004	ND		0,0212	0,0009	0,0278	0,0011	0,0275	0,0013	0,0373	0,0016
	0,0133	0,0003	ND		0,0215	0,0009	0,0292	0,0011	0,0273	0,0013	0,035	0,0016
0,0003	0,0323	0,0005	ND	ND			0,0199	0,001	0,0187	0,0012	0,0254	0,0015
	0,0299	0,0005	ND	ND			0,0235	0,0012	0,0232	0,0014	0,03	0,0017
	0,0167	0,0004	ND	ND			0,0232	0,0012	0,0229	0,0014	0,0275	0,0017
	0,0237	0,0004	ND	ND			0,025	0,0011	0,0255	0,0014	0,0341	0,0017
	0,0194	0,0004	ND	ND			0,0244	0,0012	0,0209	0,0014	0,0279	0,0017
	0,0168	0,0004	0,0013	0,0002	0,0251	0,001	0,0305	0,0011	0,0307	0,0013	0,041	0,0016
	0,0414	0,0006	ND		0,0231	0,0009	0,0286	0,0011	0,0295	0,0013	0,0402	0,0016
	0,0444	0,0006	0,0016	0,0003	0,0231	0,001	0,028	0,0011	0,0308	0,0014	0,0406	0,0017
	0,0274	0,0005	ND		0,0216	0,0009	0,0285	0,0011	0,031	0,0013	0,0397	0,0016
	0,0493	0,0007	ND		0,0217	0,0009	0,0265	0,0011	0,0287	0,0013	0,038	0,0016
	0,0274	0,0005	ND		0,0204	0,001	0,0277	0,0011	0,0273	0,0014	0,0335	0,0017
	0,0321	0,0005	0,0014	0,0003	0,023	0,0009	0,0271	0,0011	0,0316	0,0013	0,0378	0,0016
	0,0337	0,0005	ND		0,021	0,001	0,0249	0,0011	0,0259	0,0014	0,0356	0,0017
	0,0201	0,0004	ND		0,0213	0,0009	0,0259	0,0011	0,0252	0,0013	0,0377	0,0016
	0,0548	0,0007	ND		0,0212	0,0009	0,0277	0,001	0,0265	0,0012	0,0374	0,0015
	0,026	0,0004	ND		0,0225	0,0009	0,0289	0,0011	0,0312	0,0013	0,0419	0,0016
	0,024	0,0004	ND		0,0235	0,0008	0,0262	0,0009	0,0279	0,0011	0,038	0,0014
	0,0306	0,0005	ND		0,0226	0,001	0,0289	0,0011	0,0303	0,0014	0,0407	0,0017
	0,0303	0,0004	ND		0,0206	0,0008	0,0254	0,001	0,0258	0,0012	0,0339	0,0014
	0,0239	0,0004	ND		0,0219	0,001	0,0297	0,0011	0,0311	0,0014	0,037	0,0016
	0,025	0,0004	0,0014	0,0003	0,0229	0,001	0,0305	0,0011	0,0305	0,0014	0,0382	0,0017
	0,0241	0,0004	ND		0,0212	0,001	0,0298	0,0011	0,0309	0,0014	0,0379	0,0017
	0,0352	0,0004	0,0013	0,0002	0,0226	0,0008	0,0258	0,0009	0,0302	0,0011	0,0428	0,0014
	0,0212	0,0004	ND		0,0223	0,001	0,0313	0,0011	0,028	0,0013	0,0388	0,0017
	0,0126	0,0003	ND		0,0221	0,0009	0,0262	0,0011	0,0274	0,0013	0,0381	0,0016
	0,0132	0,0003	ND		0,0243	0,0009	0,0296	0,0011	0,0272	0,0013	0,0408	0,0016
	0,0135	0,0003	ND		0,0213	0,0009	0,0271	0,0011	0,0264	0,0013	0,0358	0,0016
	0,0124	0,0003	ND		0,0227	0,0009	0,0281	0,0011	0,0289	0,0013	0,0383	0,0016
	0,013	0,0003	ND		0,0218	0,0009	0,0261	0,0011	0,0263	0,0013	0,0379	0,0016
	0,0129	0,0003	ND		0,0213	0,0009	0,0264	0,001	0,0252	0,0012	0,0354	0,0015
	0,0122	0,0003	ND		0,0188	0,0009	0,0267	0,001	0,0261	0,0012	0,035	0,0015
	0,0127	0,0003	ND		0,0211	0,0009	0,0267	0,001	0,0294	0,0013	0,037	0,0016
	0,0141	0,0003	ND		0,0209	0,0009	0,0281	0,001	0,0283	0,0013	0,0397	0,0016
	0,0408	0,0006	0,0016	0,0003	0,023	0,0009	0,0288	0,0011	0,027	0,0013	0,0388	0,0016
	0,0481	0,0006	0,002	0,0003	0,0226	0,0009	0,0285	0,0011	0,0289	0,0013	0,0385	0,0016
	0,0475	0,0006	ND		0,024	0,001	0,0294	0,0011	0,029	0,0013	0,0393	0,0016
	0,0298	0,0005	0,0013	0,0003	0,0236	0,0009	0,0282	0,0011	0,0294	0,0013	0,0396	0,0016
	0,0469	0,0006	ND		0,0221	0,0009	0,0282	0,001	0,0286	0,0012	0,0388	0,0015
0,0003	0,0279	0,0005	ND		0,0236	0,001	0,0287	0,0011	0,0308	0,0013	0,0408	0,0017
	0,0338	0,0005	ND		0,0221	0,001	0,0288	0,0011	0,03	0,0014	0,039	0,0017
	0,0231	0,0004	ND		0,0234	0,0009	0,0301	0,001	0,0311	0,0013	0,0399	0,0016
	0,0376	0,0006	0,0016	0,0003	0,0235	0,001	0,0293	0,0011	0,0318	0,0014	0,0373	0,0017
	0,037	0,0005	ND		0,0198	0,0008	0,0266	0,001	0,0265	0,0012	0,0354	0,0015
	0,0316	0,0005	0,0013	0,0002	0,0209	0,0009	0,0267	0,001	0,0242	0,0012	0,0346	0,0015

W	W +/-	Pb	Pb +/-	Bi	Bi +/-	LE	LE +/-	Unit
ND		ND		0,0037	0,0003	51,99	0,41	%
ND		ND		0,0031	0,0003	53,83	0,41	%
ND		ND		0,0029	0,0003	56,26	0,42	%
ND		ND		0,0026	0,0003	54,97	0,41	%
	0,0035	0,0007	0,001	0,0003	0,0025	0,0003	55,61	0,41 %
ND		ND		0,0033	0,0003	58,23	0,39	%
ND		ND		0,0094	0,0008	30,19	0,33	%
ND		ND		0,022	0,0009	47,87	0,42	%
ND		ND		0,0063	0,0004	45,51	0,25	%
ND		ND		0,0056	0,0004	50,51	0,41	%
ND		ND		0,0071	0,0006	42,07	0,4	%
ND		ND		0,0084	0,0008	33,9	0,37	%
ND		ND		0,0052	0,0004	46,28	0,38	%
ND		ND		0,003	0,0003	54,35	0,38	%
ND		ND		0,0031	0,0003	54,71	0,39	%
ND		ND		0,0026	0,0003	55,75	0,39	%
ND		ND		0,0026	0,0003	56,06	0,39	%
ND		ND		0,0029	0,0003	56,87	0,2	%
ND		ND		0,0026	0,0003	58,5	0,2	%
ND		ND		0,0024	0,0003	57,86	0,4	%
ND		ND		0,0022	0,0003	58,11	0,19	%
ND		ND		0,0023	0,0003	57,62	0,2	%
ND		ND		0,0026	0,0003	58,24	0,38	%
ND		ND		0,0031	0,0003	57,91	0,38	%
ND		ND		0,0019	0,0003	59,7	0,19	%
ND		ND		0,0026	0,0003	59,99	0,19	%
ND		ND		0,0034	0,0003	57,87	0,2	%
ND		ND		0,0042	0,0003	57,05	0,21	%
ND		ND		0,0031	0,0003	54,13	0,4	%
ND		ND		0,0028	0,0003	56,62	0,41	%
ND		ND		0,0025	0,0003	56,37	0,4	%
ND		ND		0,0025	0,0003	56,47	0,41	%
ND		ND		0,0021	0,0003	54,45	0,41	%
ND		ND		0,0024	0,0003	57,45	0,42	%
	0,0037	0,0007	ND	0,0023	0,0003	56,11	0,4	%
ND		ND		0,0022	0,0003	55,18	0,4	%
ND		ND		0,0025	0,0003	56,44	0,4	%
ND		ND		0,0078	0,0005	51,63	0,44	%
ND		ND		0,0048	0,0004	50,33	0,41	%
ND		ND		0,0113	0,0005	47,16	0,4	%
ND		ND		0,0053	0,0004	51,16	0,43	%
ND		ND		0,0066	0,0004	49,39	0,41	%
ND		ND		0,0578	0,0012	47,05	0,39	%
ND		ND		0,0067	0,0005	42,3	0,38	%
ND		ND		0,005	0,0004	47,46	0,4	%
ND		ND		0,0031	0,0003	54,52	0,39	%
ND		ND		0,004	0,0003	51,83	0,38	%
ND		ND		0,0043	0,0004	50,93	0,38	%
ND		ND		0,0038	0,0003	53,07	0,38	%
ND		ND		0,0072	0,0006	43,9	0,41	%
ND		ND		0,0052	0,0004	52,53	0,41	%
ND		ND		0,0032	0,0003	51,49	0,38	%
ND		ND		0,0033	0,0003	52,54	0,39	%
ND		ND		0,0037	0,0003	54,1	0,39	%
ND		ND		0,0034	0,0003	53,3	0,39	%
ND		ND		0,0052	0,0004	46,24	0,38	%
ND		ND		0,0051	0,0004	50,21	0,41	%
ND		ND		0,0037	0,0003	50,28	0,4	%
ND		ND		0,0028	0,0003	55,12	0,4	%

ND	ND	0,0048	0,0004	51,32	0,41 %	
ND	ND	0,0068	0,0005	40,09	0,36 %	
ND	ND	0,003	0,0003	54,14	0,4 %	
ND	ND	0,0044	0,0004	54,07	0,4 %	
ND	ND	0,0032	0,0003	54,74	0,39 %	
ND	ND	0,0025	0,0003	55,82	0,4 %	
ND	ND	0,0025	0,0003	58,08	0,39 %	
					%	
ND	ND	0,0029	0,0003	56,27	0,4 %	
ND	ND	0,0026	0,0003	59,03	0,19 %	
ND	ND	0,0024	0,0003	63,14	0,19 %	
ND	ND	0,0019	0,0003	60,11	0,19 %	
					%	
ND	ND	0,0024	0,0003	56,76	0,39 %	
ND	ND	0,002	0,0003	61,63	0,19 %	
ND	ND	0,0018	0,0003	60,38	0,19 %	
ND	ND	ND		57,34	0,4 %	
ND	ND	ND		59,91	0,19 %	
ND	ND	ND		59,56	0,19 %	
ND	ND	0,0021	0,0003	59,67	0,19 %	
ND	ND	0,002	0,0003	57,58	0,39 %	
					%	
ND	ND	0,0049	0,0004	46,89	0,41 %	
ND	ND	0,0033	0,0003	52,28	0,42 %	
ND	ND	0,0047	0,0004	49,42	0,42 %	
ND	ND	0,0034	0,0003	59,23	0,4 %	
ND	ND	0,0052	0,0004	47,74	0,42 %	
ND	ND	0,004	0,0004	48,67	0,41 %	
ND	ND	0,0042	0,0004	51,05	0,41 %	
ND	ND	0,0033	0,0003	47,45	0,41 %	
ND	ND	0,0058	0,0004	49,71	0,42 %	
ND	ND	0,0056	0,0004	50,5	0,42 %	
ND	ND	0,0047	0,0004	50,24	0,43 %	
ND	ND	0,0051	0,0004	49,78	0,42 %	
ND	ND	0,0117	0,0005	48,31	0,4 %	
ND	ND	0,0059	0,0004	47,9	0,42 %	
ND	ND	0,0051	0,0004	53,06	0,42 %	
ND	ND	0,0057	0,0004	49,76	0,42 %	
ND	ND	0,0065	0,0004	52,11	0,41 %	
ND	ND	0,0026	0,0003	56,06	0,4 %	
ND	ND	0,0053	0,0004	50,72	0,42 %	
ND	ND	0,0018	0,0002	59,59	0,39 %	
ND	ND	0,0053	0,0004	50,04	0,42 %	
ND	ND	0,0029	0,0003	55,75	0,41 %	
ND	ND	0,0048	0,0004	49,15	0,42 %	
ND	ND	0,0055	0,0004	48,93	0,42 %	
0,0037	0,0007	ND	0,0052	0,0004	49,95	0,42 %
ND	ND		0,0019	0,0002	63,6	0,39 %
ND	ND		0,0058	0,0004	49,18	0,42 %
					%	
ND	ND	0,0025	0,0003	56,96	0,41 %	
ND	ND	0,0028	0,0003	55,15	0,41 %	
ND	ND	0,0022	0,0003	55,74	0,41 %	
ND	ND	0,0023	0,0003	54,74	0,41 %	
ND	ND	0,0028	0,0003	55,47	0,4 %	
ND	ND	0,0024	0,0003	56,55	0,4 %	
ND	ND	0,0021	0,0003	57,61	0,4 %	
ND	ND	0,0025	0,0003	56,11	0,41 %	
ND	ND	0,0025	0,0003	53,81	0,4 %	
ND	ND	0,0033	0,0003	55,79	0,41 %	
ND	ND	0,0039	0,0003	53,7	0,4 %	
ND	ND	0,0048	0,0004	51,59	0,39 %	
ND	ND	0,0026	0,0003	51,21	0,39 %	
ND	ND	0,0025	0,0003	54,24	0,38 %	
ND	ND	0,0036	0,0003	48,61	0,39 %	
ND	ND	0,0053	0,0004	48,06	0,41 %	
ND	ND	0,0074	0,0004	53,99	0,38 %	
ND	ND	0,003	0,0003	55,37	0,45 %	
ND	ND	0,0026	0,0003	54,04	0,37 %	
ND	ND	0,0026	0,0003	54,95	0,36 %	

Appendix D; XRF spectrometry data

Analysis	Andreas_Marie-Louise_1feb_1	A-XRF34	StdCalib0313	17-02-01 13:47	A-XRF37	StdCalib0313	17-02-01 13:58	A-XRF76	StdCalib0313	17-02-01 14:10
	SiO2	mass%	48,787		43,697		54,326			
	Al2O3	mass%	16,34		10,922		12,201			
	CaO	mass%	6,125		1,028		5,381			
	MgO	mass%	6,17		21,703		9,853			
	MnO	mass%	0,088		0,02		0,027			
	P2O5	mass%	0,115		0,073		0,094			
	Fe2O3	mass%	13,025		11,717		7,529			
	Na2O	mass%	5,359		0,318		2,424			
	K2O	mass%	2,828		9,604		7,363			
	TiO2	mass%	1,163		0,918		0,8			
Standards										
	Andreas_Marie-Louise_1feb_1	AGV-2	StdCalib0313	17-02-01 09:37	AGV-2	StdCalib0313	17-02-01 11:08	AGV-2	StdCalib0313	17-02-01 12:39
				0			0			0
				0			0			0
	SiO2	mass%	60,264		60,261		60,261		60,252	60,252
	Al2O3	mass%	17,129		17,131		17,135		17,138	17,138
	CaO	mass%	5,226		5,218		5,225		5,224	5,224
	MgO	mass%	1,773		1,779		1,779		1,779	1,779
	MnO	mass%	0,1		0,099		0,1		0,1	0,1
	P2O5	mass%	0,511		0,512		0,512		0,512	0,512
	Fe2O3	mass%	6,799		6,797		6,797		6,799	6,799
	Na2O	mass%	4,234		4,244		4,227		4,235	4,235
	K2O	mass%	2,912		2,909		2,912		2,909	2,909
	TiO2	mass%	1,052		1,05		1,05		1,052	1,052
Average										
			60,26		60,26		60,26		60,15	60,15
			17,13		17,13		17,13		17,15	17,15
			5,22		5,22		5,22		5,27	5,27
			1,78		1,78		1,78		1,82	1,82
			0,10		0,10		0,10		0,10	0,10
			0,51		0,51		0,51		0,49	0,49
			6,80		6,80		6,80		6,79	6,79
			4,24		4,24		4,24		4,25	4,25
			2,91		2,91		2,91		2,92	2,92
			1,05		1,05		1,05		1,07	1,07
									Expected	Residual
									60,15	0,11
									17,15	-0,02
									5,27	-0,05
									1,82	-0,04
									0,10	0,00
									0,49	0,02
									6,79	0,01
									4,25	-0,01
									2,92	-0,01
									1,07	-0,02
LOIs										
Marie-Louise_17jan17										
Sample ID	Crucible weight (g)	Crucible + sample weight (g)	Sample weight (g)	105 °C	Crucible + sample weight (g)	1000 °C	Crucible + sample weight (g)	Sample 105 °C	Sample 1000 °C	LOI
A-XRF3419	24,556	29,5433	4,9873		29,5324		29,3586	4,9764	4,8026	3,48
A-XRF3725	25,3656	30,3686	5,003		30,3607		30,2918	4,9951	4,9262	1,38
A-XRF7623	30,0635	35,1013	5,0378		35,0968		35,0471	5,0333	4,9836	0,99
										1,08

Appendix E; Core scanner data

Measurement Settings

Base path:	Sample name:	Section name	User ID
C:\Data\ML and Alasdair	Alliansen	Run 4	Malin
Year	Month	Day	
	2017	1 17-18	
Voltage		15 kV	
Current		5 mA	
Exposure time		0 ms	
Step size		2500 microns	
XRF exp. time		25 seconds	
XRF voltage		30 kV	
XRF current		50 mA	
Tube		Mo	

Notes on Results

The data are given in peak area.

There are some samples that exceed the detectors capacity (250,000 kps) and there is thus a greater error on these samples, it is likely some signal is lost. These are highlighted using conditional formatting.

You can change elements in the graph by clicking on the data and sliding the highlighted box. As you do this the position of the graph/photo changes so you need to adjust this.

I have left all elements that were reasonable in the datasheet. There is no "minimum" peak area that is required but I like to have ca 400. Some elements are low except for in certain layers (e.g. P) so I have left these.

I have trimmed the edges of the samples based on the analytical quality which means that the length of the scan may not completely fill the sample length (but only for a couple of mm max).

34795	618.55	146874.966	5.56	676	6142	181	209	623	103270	4584	38350	70700	1546737	1481	35	893	1920	3216	0	26668	35703	4644	3142	419	590	138	0	138507	52943
230.30	621.05	143129.026	6.67	764	6700	112	146	564	86743	25373	34718	5342	1351399	852	372	460	2437	488	308	22755	22659	3645	2013	393	509	0	0	150747	56260

621.55	141185.32	5.27	733	5843	611	133	648	3832.6	33300	40300	6236	138016.0	3008	1020	317	1767	3360	113	26274	20089	3247	3385	366	319	935	0	142763	5622			
626.05	146322.93	5.37	820	6543	169	495	97982	13027	35655	4836	106422.5	1204	20	318	2267	1238	0	24249	20089	5208	3185	562	605	20	127	136055	5281	20	127	136055	5281
628.55	146890.531	5.65	833	6507	182	174	534	10363.5	8313	40000	7145	145500.0	1410	0	3016	1608	1303	0	26888	37714	5594	4284	531	488	208	0	133483	54818	0	133483	54818
631.65	137946.239	5.03	809	6515	182	153	546	102443	9362	36962	6480	134121.4	1962	0	426	1295	681	0	26370	38514	5595	5612	388	431	432	415	136465	57293	0	136465	57293
633.55	151604.078	5.57	764	6094	139	168	434	98136	11116	38004	7995	122722.8	3664	534	567	1795	766	0	25432	37169	5517	5694	408	541	289	0	128028	53522	0	128028	53522
638.05	142686.636	5.75	736	6396	182	143	475	93276	13279	37613	7388	1422194	1045	240	3969	1698	734	0	23418	38654	4650	4902	568	706	0	0	133042	54178	0	133042	54178
636.55	141407.5	5.26	866	6065	194	161	486	97057	16236	38688	8270	1462698	1504	453	611	1508	1209	0	26887	37613	4252	5656	448	510	306	407	130379	53428	0	130379	53428
641.05	150922.449	5.73	796	5766	247	362	638	100630	28366	53125	8271	1356394	1391	214	802	1604	652	0	23817	11041	4636	3968	476	780	289	0	125156	53134	0	125156	53134
641.55	149032.449	5.38	773	6080	320	214	538	94783	13761	44172	7327	1380698	1045	342	521	1565	1404	0	27945	15042	4488	3524	584	2031	445	476	125434	53134	0	125434	53134
646.05	152094.543	4.84	727	6452	323	181	426	883179	44032	32157	6095	1369658	844	0	669	1334	3444	59	23492	14364	4308	3613	247	475	335	477	127209	53845	0	127209	53845
648.55	143905.536	5.48	748	6593	138	118	436	95732	26380	36391	9031	1369658	1078	380	490	1465	621	0	25368	12664	5078	4024	349	427	33	0	138484	55937	0	138484	55937
651.05	141567	5.69	849	6500	134	260	481	97594	14436	36983	6790	1369647	956	324	580	2057	1383	159	25329	20658	4600	4626	383	489	397	292	138464	54889	0	138464	54889
652.55	139462.828	5.55	842	6489	339	168	452	97821	14722	36701	5518	1270596	1486	735	186	2253	486	0	24905	22433	5491	3444	304	304	304	304	140262	55204	0	140262	55204
656.05	136763.932	4.69	817	6595	140	189	508	102976	27923	37762	6002	1309718	1376	45	554	1839	447	0	25864	22278	4895	4196	448	321	95	30	138136	55013	0</		

34715	716.05	147913.422	8.69	781	4126	210	199	570	91542	19785	36925	5794	14384221	852	60	240	1613	937	0	23990	19810	2565	3388	185	441	676	0	123956	53743
296.50	718.55	138642.484	9.09	811	4183	385	217	621	89244	20449	33175	5747	1515380	1014	186	338	1782	972	220	25217	23178	2799	3637	343	397	125	277	130638	54747
	721.05	138446.281	7.77	815	6496	90	227	603	91364	17499	32658	5818	1336125	855	247	118	1668	437	707	25219	24188	2956	3452	309	473	125	337	136192	54747
	721.55	140113.375	7.25	793	6148	188	207	727	92392	24755	38962	6563	1571248	1019	0	96	1902	909	125	26061	22467	25463	3869	349	425	333	372	130212	55212
	726.05	139213.766	7.93	802	6359	209	225	723	92921	19314	36738	5378	1378569	1109	0	915	1935	840	111	26790	23810	2659	3655	212	425	333	372	137446	57622
	728.55	139966.75	8.14	781	6028	341	200	760	93544	22770	38868	5818	1391573	1024	168	603	1755	783	82	25321	23770	3543	224	588	226	202	137652	57185	
	731.05	139006.234	8	777	6345	347	232	726	93760	29631	38530	5818	1250912	1024	633	290	2493	3232	0	20993	24972	3371	3556	437	770	164	0	143552	59087
	733.55	127216.852	7.58	784	6777	190	211	651	97768	19510	33117	5746	1146077	8746	738	2030	1891	259	262	25981	25546	2788	4536	282	410	77	115	144969	57931
	736.05	140453.734	7.14	836	6020	331	263	2352	72545	59711	32587	6742	1260938	945	229	172	2332	121	367	25094	22080	3407	3051	437	422	435	338	142492	58196
	739.55	134054.554	7.67	812	6269	189	217	789	91546	18977	32604	4785	1260789	904	269	1637	625	537	34555	21889	3675	4440	150	306	99	482	139919	56438	
	741.05	139535.288	8.62	745	6217	320	196	473	92084	26995	34133	4760	1401609	905	249	409	1876	939	57	25434	29618	3268	4645	409	511	289	125262	54341	
	743.55	141180.672	7.99	805	6302	178	218	505	99607	17606	35081	4793	1447931	901	346	633	1580	700	0	26284	22037	3370	4376	343	553	438	0	133517	56244
	746.05	142080.938	8.79	816	5703	156	270	1422	77959	37797	34425	6713	1339883	970	170	1442	1379	465	420	24561	18605	2674	3454	342	442	56	324	130680	54711
	748.55	154800.554	7.36	743	5148	482	335	3697	40539	82747	27564	6801	1374475	1495	186	1001	1450	216	1342	18719	2502	1125	498	661	123	347	124573	54646	
	751.05	152616.438	9.35	768	5284	92	253	253	92037	89506	24746	7488	1314745	1335	188	500	670	413	744	17451	32214	3528	668	206	300	500	132719	53163	

73

37.75	256.70	807.09	154402.1234	6.34	583	4602	278	161	999	1208.76	11320	34402	1499	1629306	2337	782	2304	1220	934	0	40376	561	112309	268	269	456	238	133953	5625
		805.59	140004.469	6.37	369	3110	0	58	2773	1579470	2281	0	0	0	2889	0	899	0	0	0	2889	1349	3575	601	351	137	24	137614	3697
		812.09	151050.531	6.87	446	5712	23	177	564	38508	83598	13095	2773	1579470	2281	52	0	1122	472	151	17859	2588	34066	54	618	32	1239	0	145147
		814.59	138232.047	5.7	437	5893	61	115	567	40761	72546	35334	1211	187100	1211	542	33	1429	1594	403	10352	3638	8970	351	364	256	740	228	132593
		817.09	138254.594	7.86	341	6425	0	118	486	36662	71745	7180	3604	1334672	1206	0	0	1555	0	0	8910	1079	8396	330	65	727	125232	19547	0
		815.59	131982.141	5.04	371	6232	26	132	474	24001	100647	30509	3450	1311188	2033	535	0	1279	1372	0	13915	4398	13802	0	355	252	602	489	134594
		822.09	142112.031	6.82	503	5857	32	152	705	52443	50669	39040	3707	1331784	1737	713	713	382	0	0	27558	3386	18802	715	161	29	712	440	155663
		824.59	142940.453	6.42	400	5512	48	115	628	24008	789917	15944	2920	1361345	1324	219	691	626	0	0	13796	2371	2319	285	178	380	360	417	147771
		827.09	153851.423	7.56	480	6233	28	133	628	24008	1377936	11418	1499	1594313	1541	1009	914	1304	140	0	23455	2564	12488	399	259	324	440	276	148270
		825.59	143683.958	5.9	450	5467	65	130	634	54003	66559	38951	2526	1395301	1542	1009	914	1304	140	0	13006	2564	12488	399	259	324	440	276	148270
		832.09	138636.189	6.11	343	6032	0	170	429	28053	103836	11149	3229	1353933	794	0	1346	1421	509	0	13006	2564	12488	399	259	324	440	276	148270
		834.59	144488.734	5.75	440	5707	32	72	738	53891	66895	17790	2228	15426607	1332	796	795	1775	0	6	23151	2777	7992	741	906	132	848	469	150003
		837.09	150774.125	4.74	432	4903	98	151	774	71869	50382	23664	2439	15547716	1251	407	2407	2407	1448	333	25897	515	5669	786	438	129	29	0	142404
		839.59	150918.313	5.68	499	4645	240	166	918	806	96540	12998	30534	1499	1586842	1400	537	395	1883	1187	489	42791	0	6976	866	47	381	275	0
		842.09	147008.25	5.14	448	4755	158	118	651	69980	2601	22914	27032	1499	1470977	1287	0	439	868	2581	433	42659	1111	12225	832	210	364	802	222
		844.59	130821.172	5.08	377	5305	147	113	651	69980	2601	22914	27032	1499	147097														

Appendix F; Electron microprobe analysis

Group : Sample : Page																				1	
Weight percent																					
No.	F	Na2O	SiO2	Al2O3	MgO	K2O	Cl	CaO	BaO	TiO2	NiO	FeO	MnO	Cr2O3	V2O3	SrO	CO2	Total	Comment		
1	0.0784	0.1337	37.96	11.71	16.55	9.57	0.3879	0.0085	0.2009	3.77	0	11.94	0.0494	0	0.0586	0	0	92.4174	MarieA341980-bt1		
2	0.3114	0.0884	38.08	11.9	17.23	9.54	0.3969	0.0085	0.1428	3.59	0	11.25	0.0475	0	0.0306	0	0	92.6161	MarieA341980-bt2		
3	0	1.46	51.98	0.7013	12.94	0	0.0071	20.85	0	0.1235	0	8.13	0.161	0	0	0	0	96.353	MarieA341980-amph1		
4	0	1.57	52.28	0.711	12.9	0.0042	0.0141	20.51	0	0.0855	0	8.47	0.1588	0.0096	0	0	0	96.7133	MarieA341980-amph2		
5	0	10.51	66.46	19.56	0.0099	0.1068	0	1.0825	0.0607	0.0286	0	0.0316	0	0	0	0	0	97.8502	MarieA341980-pl1		
6	0	10.21	65.78	19.73	0.0076	0.1498	0	1.1216	0.0129	0.0373	0	0.1364	0.0085	0	0	0	0	97.1942	MarieA341980-pl2		
8	0	10.54	65.74	19.29	0	0.1884	0	1.1221	0	0.0159	0	0.2428	0	0	0	0	0	97.1393	MarieA341980-pl3		
9	0	0.2496	62.73	17.21	0	15.4	0	0.8358	0.2905	0.0025	0	0.0502	0	0	0	0	0	96.7687	MarieA341980-Kfs1		
10	0	0	0	0	0.007	0	0	54.718	0	0	0	0	0.021	0	0	0	42.961	97.7071	MarieA341980-calc1		
11	0	1.54	52.94	0.7279	12.98	0	0.0041	20.72	0	0.0702	0	9.37	0.2604	0.0121	0.0183	0	0	98.6431	MarieA341980-amph3		
12	1.11	0.1144	38.71	12.52	18.21	9.54	0.1814	0.0531	0.1513	2.43	0	11.56	0.1258	0.0189	0.0153	0	0	94.7402	MarieA342365-bt1		
13	1.11	0.094	39.21	12.68	18.7	10.02	0.2213	0.0076	0.1589	2.2	0.0041	11.12	0.1093	0.0141	0.0614	0	0	95.7107	MarieA342365-bt2		
14	0	1.35	51.48	1.5592	12.03	0.0201	0.0171	21.52	0	0.1214	0.0103	9.74	0.1289	0	0.0338	0	0	98.0108	MarieA342365-amph1		
15	0	1.1799	51.97	1.2631	12.3	0	0.0022	21.66	0	0.0741	0	8.82	0.1955	0	0.0339	0	0	97.4987	MarieA342365-amph2		
17	0.1482	9.22	55.39	21.68	0	0.7878	2.63	6.68	0	0	0.0249	0.104	0.0084	0.0049	0.0317	0	0	96.71	MarieA342365-plagCl1		
18	0	8.89	56.46	22.38	0	0.4599	1.56	4.25	0	0	0.0145	0.0229	0.0021	0	0	0	0	94.0395	MarieA342365-plagCl2		
19	0	0.5816	63.02	17.69	0	15.09	0	0.0195	0.9137	0.01	0	0.1014	0.0084	0	0	0	0	97.4347	MarieA342365-Kfs1		
20	0	10.91	66.3	18.79	0.0134	0.0842	0	0.5633	0.0231	0	0	0.0882	0.0021	0	0	0	0	96.7744	MarieA342365-Pil		
21	0	11.28	67.21	18.84	0	0.1379	0	0.261	0	0.0046	0	0.0904	0.0149	0	0	0	0	97.8389	MarieA342365-Pt2		
22	2.46	0.0525	40.35	10.84	21.49	9.85	0.2115	0.0399	0.0111	0.7247	0.002	9.41	0.0516	0.0426	0.0128	0	0	95.5488	MarieA342336-bt1		
23	2.46	0.0913	40.56	10.95	21.19	9.78	0.183	0.013	0.0588	0.7209	0.0514	9.24	0.0392	0.019	0	0	0	95.3567	MarieA342336-bt2		
24	1.66	0.0941	42.19	10	23.3	5.77	0.0125	0.1489	0.0086	0.0051	0.0226	8.58	0.0434	0.0237	0.0257	0	0	91.8846	MarieA342336-ms1		
25	2.33	0.129	40.11	10.86	20.87	9.78	0.1858	0.0313	0.1407	0.7936	0	9.55	0.0557	0	0.0077	0	0	94.8439	MarieA342336-Bt3		
26	2.27	0.1169	40.36	11.09	21	10.05	0.219	0.0121	0.1532	0.7746	0	9.68	0.0598	0.0047	0	0	0	95.7904	MarieA342336-Bt4		
27	2.66	0.1508	41.2	11.2	21.68	9.83	0.192	0.03	0	0.9019	0.0287	9.13	0.0598	0.0166	0.0334	0	0	97.1133	MarieA342336-amph1		
29	1.36	2.79	52.81	2.17	18.25	0.6686	0.0359	9.48	0	0.0674	0.0433	8.72	0.0995	0	0.0258	0	0	96.5206	MarieA342336-amph1		
30	1.44	2.67	54.03	1.2131	19.08	0.5578	0.0156	9.51	0	0.0919	0.0868	8.19	0.1121	0.0167	0.044	0	0	97.0581	MarieA342336-amph2		
31	0	11.11	68.78	18.8	0.0182	0.0516	0	0.0624	0.0167	0.0285	0	0.1119	0	0	0	0	0	98.9794	MarieA342336-pl1		
32	0	0.0266	31.01	15.36	24.06	0.2399	0.0015	0.2754	0	0	0.0164	15.16	0.2375	0	0.0449	0	0	86.4323	MarieA342336-Chl-in-B		
Minimum	0	0	0	0	0	0	0	0.0076	0	0	0	0	0	0	0	0	0	86.4322			
Maximum	2.66	11.28	68.78	22.38	24.06	15.4	2.63	54.718	0.9137	3.77	0.0868	15.16	0.2604	0.0426	0.0614	0	42.961	98.9793			
Average	0.6689	3.3501	49.4862	11.4285	11.2006	4.4027	0.2234	6.7446	0.0808	0.5749	0.0105	6.1738	0.0711	0.0063	0.0165	0	1.4814	95.9202			
Sigma	0.9646	4.4709	14.6725	7.4293	9.4275	5.3377	0.5507	12.1592	0.1783	1.0592	0.0202	5.0293	0.0746	0.0103	0.0196	0	7.9777	2.5474			
No. of data 29																					

Appendix G; THERMOCALC in- and output files

GLE A341980

AX-file

phl	0.24	0.0181	ann	0.0072	0.00210
tr	0.33	0.096	ts	0.009	0.0097
an	0.093	0.0115	ab	0.94	0.0235
san	0.94	0.0235	ab	0.165	0.0173

q H2O clin mt ep mu cc Co2

*

THERMOCALC output – average pressure-temperature calculations

Excluded: cc, Co2

calcs use:

an INCOMPLETE independent set of reactions has been calculated

Activities and their uncertainties

	phl	ann	tr	ts	an	ab	san
a	0.240	0.00720	0.330	0.00900	0.0930	0.940	0.940
sd(a)/a	0.15612	0.58598	0.29091	1.07778	0.24679	0.05000	0.05000

	ab	q	H2O	clin	mt	ep	mu
a	0.165	1.00	1.00	1.00	1.00	1.00	1.00
sd(a)/a	0.20917	0		0	0	0	0

•INCOMPLETE• independent set of reactions

- 1) $\text{phl} + 2\text{tr} + 6\text{mu} = \text{ts} + 2\text{an} + 7\text{san} + 2\text{clin}$
- 2) $\text{tr} + 4\text{san} + 2\text{clin} = 4\text{phl} + \text{ts} + 8\text{q} + 4\text{H}_2\text{O}$
- 3) $\text{tr} + 3\text{mu} = 2\text{an} + 3\text{san} + \text{q} + \text{clin}$
- 4) $15\text{tr} + 6\text{san} + 6\text{mt} + 18\text{mu} = 22\text{phl} + 2\text{ann} + 3\text{ts} + 66\text{q} + 12\text{ep}$

Calculations for the independent set of reactions

at P = 4.0 kbar (for $x(\text{H}_2\text{O}) = 1.0$)

	T(P)	sd(T)	a	sd(a)	b	c	ln_K	sd(ln_K)
1	480	43	135.69	2.67	-0.18738	11.074	-6.250	1.375
2	330	35	178.35	2.61	-0.21873	0.047	-9.063	1.295
3	371	30	68.43	1.00	-0.11491	6.521	-3.827	0.592
4	220	96	333.96	14.63	-0.41051	3.840	-38.394	6.539

Average temperatures (for $x(\text{H}_2\text{O}) = 1.0$)

corresponding average T

	avT	sd	fit
lsq	342	53	4.24

diagnostics on this average T

for 95% confidence, fit (= $\text{sd}(\text{fit}) = \sqrt{\text{MSWD}}$) < 1.61 (but larger may be OK)

column:

- 1-3: result of doubling the uncertainty on ln a.
- 4: $e^* = \ln a$ residuals normalised to $\text{sd}(\ln a)$: $|e^*| > 2.5$ suspect?
- 5: hat = diagonal elements of the hat matrix: hat > 0.33 influential.
- 6-7: observed and calculated activities of endmembers.
- 8-9: regression-through-origin x,y values

	T	sd	fit	e*	hat	a(obs)	a(calc)	x	y
phl	373	41	2.93	4.9	0.18	0.240	0.513	0.03	15.61
ann	335	54	4.12	1.1	0.04	0.00720	0.0138	-0.02	-10.49
tr	341	52	4.16	-1.5	0.00	0.330	0.214	0.00	3.83
ts	332	50	3.86	-3.3	0.07	0.00900	0.000265	0.02	16.19
an	318	71	4.08	-1.6	0.59	0.0930	0.0623	0.06	39.11
san	349	49	3.83	-2.3	0.02	0.940	0.838	-0.01	-4.16
q	342	53	4.24	0	0	1.00	1.00	0	0
H2O	342	53	4.24	0	0	1.00	1.00	0	0
clin	342	53	4.24	0	0	1.00	1.00	0	0
mt	342	53	4.24	0	0	1.00	1.00	0	0
ep	342	53	4.24	0	0	1.00	1.00	0	0
mu	342	53	4.24	0	0	1.00	1.00	0	0

(Because an incomplete set of independent reactions has been used, the following results are unlikely to be useful. Vary the run conditions to try and get a complete set...)

P	1.0	2.0	3.0	4.0	5.0	6.0	7.0
av T	297	312	328	342	356	369	382
sd	37	40	45	53	63	75	87
sigfit	3.2	3.3	3.7	4.2	4.9	5.7	6.6

=====

GLE+Bt A342365

AX-file

phl	0.30	0.022	ann	0.0043	0.00136
tr	0.35	0.096	ts	0.011	0.010
an	0.022	0.0115	ab	0.98	0.0245
san	0				

q H2O mic clin mt ep mu

*

THERMOCALC output – average pressure-temperature calculations

calcs use:

an independent set of reactions has been calculated

Activities and their uncertainties

	phl	ann	tr	ts	an	q	H2O
a	0.300	0.00430	0.350	0.0110	0.0220	1.00	1.00
sd(a)/a	0.12273	0.63109	0.27143	0.90909	0.45455	0	

	mic	clin	mt	ep	mu
a	1.00	1.00	1.00	1.00	1.00
sd(a)/a	0	0	0	0	0

Independent set of reactions

- 1) $\text{phl} + 2\text{tr} + 6\text{mu} = \text{ts} + 2\text{an} + 7\text{mic} + 2\text{clin}$
- 2) $\text{tr} + 4\text{mic} + 2\text{clin} = 4\text{phl} + \text{ts} + 8\text{q} + 4\text{H}_2\text{O}$
- 3) $15\text{tr} + 6\text{mic} + 6\text{mt} + 18\text{mu} = 22\text{phl} + 2\text{ann} + 3\text{ts} + 66\text{q} + 12\text{ep}$
- 4) $15\text{tr} + 9\text{mic} + 6\text{mt} + 18\text{mu} = 25\text{phl} + 2\text{ann} + 6\text{an} + 72\text{q} + 12\text{ep}$

Calculations for the independent set of reactions

at P = 4.0 kbar(for x(H2O) = 1.0)

	T(P)	sd(T)	a	sd(a)	b	c	ln_K	sd(ln_K)
1	394	105	61.62	2.77	-0.08459	10.938	-8.840	1.401
2	362	24	227.29	2.64	-0.28893	0.446	-8.276	1.068
3	257	81	371.07	14.64	-0.46101	3.992	-35.168	5.736

4 181 61 405.45 14.79 -0.63092 9.909 -48.151 5.918
Average temperatures (for x(H₂O) = 1.0)

corresponding average T
avT sd fit
lsq 315 44 3.66

diagnostics on this average T
for 95% confidence, fit (= sd(fit) = sqrt(MSWD)) < 1.61 (but larger may be OK)

column:
1-3: result of doubling the uncertainty on ln a.
4: e* = ln a residuals normalised to sd(ln a) : |e*| >2.5 suspect?
5: hat = diagonal elements of the hat matrix : hat >0.33 influential.
6-7: observed and calculated activities of endmembers.
8-9: regression-through-origin x,y values

	T	sd	fit	e*	hat	a(obs)	a(calc)	x	y
phl	343	53	3.31	2.1	0.45	0.300	0.386	0.06	30.76
ann	309	43	3.46	1.3	0.02	0.0043	0.0100	-0.01	-8.37
tr	309	41	3.34	-2.5	0.03	0.350	0.176	0.01	11.15
ts	303	34	2.78	-4.4	0.06	0.0110	0.000206	0.02	16.44
an	320	47	3.60	1.2	0.17	0.0220	0.0384	0.03	18.58
q	315	44	3.66	0	0	1.00	1.00	0	0
H2O	315	44	3.66	0	0	1.00	1.00	0	0
mic	315	44	3.66	0	0	1.00	1.00	0	0
clin	315	44	3.66	0	0	1.00	1.00	0	0
mt	315	44	3.66	0	0	1.00	1.00	0	0
ep	315	44	3.66	0	0	1.00	1.00	0	0
mu	315	44	3.66	0	0	1.00	1.00	0	0

P	1.0	2.0	3.0	4.0	5.0	6.0	7.0
av T	329	326	321	315	308	300	292
sd	46	44	43	44	47	52	57
sigfit	4.1	3.8	3.6	3.7	3.9	4.2	4.6

=====

BSF A342336

AX-file

phl	0.44	0.033	ann	0.00167	0.00059
tr	0.093	0.0116	fact	0.000007	0.0000072
ab	0.99	0.0249			
clin	0.19	0.0189	daph	0.0012	0.000493

q H2O clin mt mu parg
*

THERMOCALC output – average pressure-temperature calculations

calcs use:
an independent set of reactions has been calculated

Activities and their uncertainties

	phl	ann	tr	fact	ab	clin	daph
a	0.440	0.00167	0.0930	7.00e-6	0.990	0.190	0.00120
sd(a)/a	0.10000	0.69911	0.28985	1.23366	0.05000	0.19093	0.71888

	q	H2O	mu	parg
a	1.00	1.00	1.00	1.00
sd(a)/a	0		0	0

Independent set of reactions

- 1) $tr + daph = fact + clin$
- 2) $11phl + 12fact + 12ab + 3clin + 9mu = 20ann + 69q + 12H_2O + 12parg$
- 3) $16phl + 12fact + 12ab + 3daph + 9mu = 25ann + 69q + 12H_2O + 12parg$

Calculations for the independent set of reactions
at $P = 4.0$ kbar (for $x(H_2O) = 1.0$)

	T(P)	sd(T)	a	sd(a)	b	c	ln_K	sd(ln_K)
1	156	419	21.53	2.38	-0.02043	0.764	-4.430	1.469
2	391	122	471.97	29.45	-0.96331	2.615	28.670	20.410
3	285	132	476.71	32.61	-1.00980	4.211	15.995	23.069

Average temperatures (for $x(H_2O) = 1.0$)

corresponding average T

	avT	sd	fit
lsq	603	396	6.23

diagnostics on this average T
for 95% confidence, $fit (= sd(fit) = \sqrt{MSWD}) < 1.73$ (but larger may be OK)

column:

- 1-3: result of doubling the uncertainty on $\ln a$.
- 4: $e^* = \ln a$ residuals normalised to $sd(\ln a)$: $|e^*| > 2.5$ suspect?
- 5: $\hat{a}$ = diagonal elements of the hat matrix : $\hat{a} > 0.27$ influential.
- 6-7: observed and calculated activities of endmembers.
- 8-9: regression-through-origin x,y values

	T	sd	fit	e^*	$\hat{a}$	a(obs)	a(calc)	x	y
phl	580	373	5.84	-1.9	0.01	0.440	0.363	0.00	2.90
ann	786	393	5.28	4.1	0.29	0.00167	0.0291	0.01	3.31
tr	323	368	4.64	4.7	0.36	0.0930	0.363	-0.01	-12.94
fact	615	389	6.09	1.9	0.01	7.00e-6	7.61e-5	0.00	-0.44
ab	587	395	6.14	0.9	0.01	0.990	1.04	-0.00	-2.25
clin	606	373	5.87	1.8	0.00	0.190	0.269	0.00	-1.67
daph	771	371	5.16	-3.6	0.16	0.00120	8.71e-5	-0.01	-1.79
q	603	396	6.23	0	0	1.00	1.00	0	0
H2O	603	396	6.23	0	0	1.00	1.00	0	0
mu	603	396	6.23	0	0	1.00	1.00	0	0
parg	603	396	6.23	0	0	1.00	1.00	0	0

P	1.0	2.0	3.0	4.0	5.0	6.0	7.0
av T	590	632	639	603	538	471	423
sd	143	217	308	396	463	505	528
sigfit	4.2	4.9	5.7	6.2	6.6	6.8	6.9

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