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Archaeometallurgical residues from Ned’s Garden & Cindermill, Shropshire

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Abstract

Twenty-one samples of residues from bloomery iron-making at Ned's Garden and Cindermill, Shropshire, have been investigated by microanalytical and bulk chemical techniques.

The two sites showed slags with a rather similar range of compositions, morphologies and textures, despite the earlier, 13th century, Ned's Garden site, being interpreted as having been manually-blown, in comparison to the water-power employed at the later 15th century (?) Cindermill site. Both sites produced residues which were relatively iron-poor (46-62 wt% FeO) and the slags from each of the two sites formed a coherent suite across this range. The two suites of slags differed, however, in their ratio of silica to alumina and in various features of their trace element contents. Although only a very small number of pieces of furnace ceramic were analysed, these did not support the possibility that the silica to alumina ratio was controlled by the furnace materials; rather it would appear this was due to the use of slightly different iron ores.

Analysis of iron ore samples showed more variability in ore composition than anticipated, but the dataset was too small to identify the same compositional differences as observed in the slags. Further work on the ores is desirable. Tentative modelling of the ore-slag relationship suggests that between 40 and 60% of the iron was extracted from the ore.

The relatively low iron content of the slag is emphasised by the observation that very little of the slag, from either site, contains wustite. This would have been likely to have decreased the potential of the slag to keep the bloom decarburised and would have lead to the production of a 'steely' bloom.

Low-iron slags of the general type described here form an important part of the current debate over whether later medieval furnaces show an evolution towards the blast furnace. Furnaces of the Stückofen-*type of post-medieval age produced a high-carbon product – and could produce liquid iron if so desired. It is commonly assumed that later medieval furnaces may have formed part of the same evolutionary process, with the adoption of water-power being one stage in that evolution. In this instance, it is argued that the introduction of water-power appears to have affected the smelting reaction rather little, although an increase in furnace size cannot be ruled out. The slags suggest production in bloomery furnaces, with the lean ore employed leading to a rather low-iron slag – and hence possibly to a steely product.*

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The stratigraphic information for the sites is contained in the data structure reports for the two excavations (Young 2008a, 2008b). Background information for the sites is contained in the survey report (Young 2007).

All collected materials were examined visually, with a low powered binocular microscope where necessary, to identify material appropriate for further investigation.

From the materials, a selection of samples was cut (forming the numbered series of samples described below) and then a subset of these were taken forward for detailed analysis, including 9 samples from Ned's Garden and 10 samples from Cindermill (Table 1). The codes for specimens analysed were prefixed NG (for material from Ned's Garden) and FID (for material from Cindermill, which had been previously known as Fiddle).

Electron microscopy was undertaken on the LEO S360 analytical electron microscope in the School of Earth and Ocean Sciences, Cardiff University. Microanalysis was undertaken using the system's Oxford Instruments INCA ENERGY energy-dispersive x-ray analysis system (EDX). All petrographic images presented in this report are backscattered electron photomicrographs. The polished blocks for investigation on the SEM were prepared in the Earth Science Department, The Open University. Chemical analysis was undertaken using two techniques. The major elements (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, and P) were determined by X-Ray Fluorescence using fused beads on the Wavelength-Dispersive X-Ray Fluorescence (WD-XRF) system in the department of Geology, Leicester University (this also generated analyses for S, V, Cr, Sr, Zr, Ba, Ni Cu, Zn, Pb and Hf). Whole-specimen chemical analysis for minor and trace elements was undertaken using samples in solution on the ThermoElemental X-series Inductively-Coupled Plasma Mass Spectrometer (ICP-MS) in the School of Earth and Ocean Planetary Sciences, Cardiff University.

The convention adopted in this report is to describe crystalline phases by their mineral names, as is normally done in archaeometallurgy, despite those names being strictly defined only for the natural occurrences of those phases. Olivine bearing Fe, Mg, Ca and Mn is described in terms of an olivine on the forsterite-fayalite join (using the notation for instance of Fa95Fo5 for an olivine that is 95% fayalite and 5% forsterite; where Fe/(Fe+Mg) = 0.95) plus figures for the overall percentage replacement by calcium and manganese.

This project was undertaken for The Four Parishes Heritage Group.

Site background

The smelting at Ned's Garden is currently dated, on the basis of pottery (Bryant 2008), to the 13th century, just possibly commencing in the late 12th century and possibly continuing into the early 14th century. The activity at Cindermill is less certainly dated at present, but may be of 15th century date. The setting of the Ned's Garden site has suggested that the smelting there was manually blown, but the presence of the leat at Cindermill clearly indicates that part of the activity, probably the blowing of the smelting furnace, was water-powered.

It is recorded (Hereford Record Office, A63/I/399) that in 1455-6 the duke of Norfolk invested 66/8 at Stottesdon in a new pond to power a mill for iron-making, a "bloom smithy" and hired a skilled operator to run the new machinery, searching for the right man first in the forest of Dean and then in Sheffield, "for the lord's greater profit" (Dyer 2005, p. 110). It is not known if this is the Cindermill site.

Results

Description of general slag morphology

The morphology and structure of the slags tapped from the smelting furnaces at Ned's Garden and Cindermill are broadly similar. Dense tap slags of 'conventional' appearance do occur, but they are associated with larger volumes of slag that are moderately/highly vesicular and with some that are extremely vesicular (frothy; the 'honeycomb' texture of Dungworth, 2010). The moderately/highly vesicular slag frequently forms flows with broad, low-convexity flow lobes, or simply slag puddles with flat tops. The base of these flows is moderately dense, sometimes with tubular vesicles, but the vesicularity often increases abruptly upwards. The flows tend to have a rather thin upper chilled surface. These features suggest that the vesicular slag was the result of rapid tappings of large volumes of gas-rich highly fluid melt. In some cases, more conventional, denser, rather less vesicular, tap slags with narrow, high-convexity flow lobes, can be observed to have flowed over the top of the vesicular slag to form a composite cake. In these examples the large vesicles remain confined below the flat top of the honeycomb-textured cake.

The extremely highly vesicular slags form rounded masses, often of very low density, suggesting flows of a much more viscous nature. Some of these pieces are of 'runner'-like form, others are more globular. The extremely highly vesicular slags tend to be mainly greenish to greenish-yellow in colour, as opposed to the denser slags that are grey.

Most of the slag cakes are highly fragmented, but some individual examples are reasonably complete examples, one of which (a tapped slag of composite texture from Cindermill [c1009]) weighed approximately 8.5kg.

It would appear, therefore, that at both sites a moderately/highly vesicular grey slag was the dominant variety. The gradational vesicularity in the larger cakes suggests that the gas bubbles were able to rise through the slag after tapping, but not, in general, escape to the surface. The occurrence of tap slags of more conventional appearance later in the smelt might be due to a change in slag composition – but equally may be due to improved degassing at lower rates of slag production.

A few examples of fragments of very dense, plano-convex, slag puddles, with large rounded tabular vesicles in their upper parts were found – notably as surface finds in Ned's Garden west, but also as rare stratified finds (e.g. sample NG3 see below). Despite being incomplete, these show some similarity to slag cakes from other places (particularly Ireland; the 'thick-crust' SHCs of Young in press), that have been interpreted as being produced during bloom-refining. It is equally possible however, that they represent puddles of highly fluid slag that were able to degas more efficiently than typical.

Description of sampled material

Ned's Garden

NG1 (C106/113; no analysis)

This was from a large190x1260x140mm block of vesicular, 'honeycomb' type frothy slag, with a slightly greenish, pale grey colour. The outside shows at least one original surface with crude lobing or folding, but no internal structure follows this, so the external texture may not reflect true flow lobes.

NG2 (C106; Plate A8 a-h, Plate A9 a-e)

This was from the lower angle of a block of low density, 'honeycomb'-texture slag. The basal (?) surface is rough, with included sediment grains and passes via a rounded angle onto a maroon-surfaced side folded into multiple lobes (similar to that observed in NG1 above). The basal 5mm of slag is more compact, but the remainder of the internal structure is open and 'frothy'.

The section shows very long skeletal olivine crystals (up to 2mm x 30µm) which support the frothy texture, but most olivine crystals are much smaller – and form 'bundles' between the larger ones. Many of the olivine crystals show an unusual 'blocky' growth form (Plate A8h and Plate A9e).

The olivine crystals occur with a simple interstitial glass, which also bears droplets of iron.

The olivine is of composition Fa94-97 with up to 0.6% Ca and 2.1-2.5%Mn substitution. Where fresh the iron blebs show no other detectable elements. One bleb is altered and shows the development of iron oxides and also contains an iron sulphide inclusion

NG3 (C113; Plate A10 a-e)

This was an extremely dense, broadly plano-convex slag block. The lower surface is grey, extremely shiny and shows an irregular charcoal-moulded contact. The upper surface is formed by a fracture passing through multiple very large (<50mm wide) tabular rounded vesicles with maroon surfaces. Internally the piece is formed of two units, with a slightly vesicular zone along their contact. Each zone shows large olivines (up to 20mm) mainly broadly perpendicular to the base.

Within the polished block, the longest observed olivine was approximately 8mm in length and 200µm in width. The main generation of olivine grades from Fa94 with 0.3-0.7% Ca and 1.4% Mn substitution, through to Fa98-Fa99 with similar substitutions. A second generation of olivine forms skeletal crystals and dendrites within the interstitial areas - and is typically Fa99-100 with 0.9-1.3% Ca and 1.3% Mn substitution. This late olivine is intimately associated with hercynite, which occurs in small (10µm) equant grains and associated dendrites. Both of these late minerals occur within an interstitial glass which bears a third, even finer, generation of dendritic growths, too small to analyse, but probably of olivine and hercynite.

The hercynitic spinels have cores rich in magnetite (44-47%), but the outsides are poorer in magnetite, decreasing to about 28% magnetite. There are low degrees of Mn and Ti substitution. This trend is the opposite of that observed in several other specimens.

NG4 (C113; chemical analysis only)

This sample came from the margin of a very thick lobe with a resemblance to a tapped slag. The upper surface is maroon, slightly convex and strongly wrinkled – possibly indicating deflation. The lower surface is irregular a sandy/gravelly contact. The slag is vesicular throughout, particularly just below the top where there are even some tubular vesicles. Slag pale grey in colour.

NG5 (C115; Plate A11 a-h, Plate A12 a-b)

This was a block of conventional tapslag forming a fragment of a slag cake 150mm wide and up to 50mm on one edge, thinning towards an original margin. The sheet shows perhaps 5-6 layers of individual lobes at any point. The lower lobes contain large central voids in places, but the upper flows are more finely vesicular, mainly towards the base of each lobe. The upper surface has well-formed flow lobes with a slightly wrinkled surface. The base is suggestive of a mainly charcoal contact of leaden grey slag, or a sandy contact locally under the centre of the cake. The upper surface is very dark grey with a hint of maroon. The slag contains multiple inclusions of reduced fired (locally bleached) clay, which is very fine grained, with no sand and a sparse organic temper.

The section shows multiple flow lobes with chilled and oxidised margins.

The largest olivines (300µm wide by several mm in length) in the lobe cores show centres of Fa91with 0.5% Ca and1.8% Mn substitution, grading outwards to Fa97 0.8Ca and 1.7Mn. The interstitial areas have fine dendrites of Fa98-100 with 1-4% Ca and 1.5-1.9% Mn. These are accompanied by dendrites of hercynite with 20-30% magnetite. The interstitial glass also bears even finer dendrites that are too small to analyse. This texture resembles that seen in NG3

The margins of the flow lobes have an altered surficial layer, possibly including magnetite (maximum 5% hercynite) over olivine (Fa91 with 1.6-1.9% Ca and 2.5-2.6% Mn). The chilled surface also supports inward-growing dendrites of magnetite with 21-22% hercynite.

NG6 (C115; Plate A13 a-g)

This slag piece shows a very irregular basal contact with fine charcoal dimples. Internally there are a few charcoal inclusions of small (<5mm) size. The top surface on one side of the cake is a variable, irregular maroon surface, with a smooth drape over the underlying complexities, which becomes buried under a second iteration of the texture on the other side. The upper part of the slag cake is reasonably dense, but with the fayalite crystals it contains extending down 20mm into a zone where there are voids between the large crystals. There are clearly textural similarities between this apparently slightly low density slag and the very high density slag of NG3.

The longest olivine crystals observed in the polished section were approximately 9mm in length, but only approximately 100µm in width. Between the larger fayalite crystals, there were sheaves of smaller, parallel crystals. Dendrites, often of curved form, arose from various points on the larger crystals into the interstitial spaces. The texture was mainly very simple, with olivine of an almost constant composition (Fa96-98 with 1.0-1.7% Ca and 2.2% Mn substitution).

NG7 (C115; no analysis)

A simple tapslag block, lobes piled high in the centre and with a base that appears to have been on charcoal. Slag is dense and only sparsely vesicular in the upper lobes, slightly more vesicular in the lower lobes. Coarsest textures appear to be in the uppermost lobes with fayalite to 6mm.

NG8 (C115; no analysis)

This was a rather weathered large flow lobe. The base was convex and rough, and was overlain by 5-10mm of denser slag. The core of the piece was vesicular, with one large cavity with a smooth maroon surface, opening through one end of the piece. The upper surface was altered, but seemed to be a dense slag with fine vesicles. The piece appears to have formed a large bulbous single flow lobe, with the open end of the central cavity possibly indicating it was torn from the adjacent slag when hot.

NG9 (C301; chemical analysis only)

Section from a wide flat slag cake, with neat, but low convexity base, with some charcoal impressions. Above the base, the slag is pale and has small tubular vesicles (layer <5mm thick), but most of the lower 35mm of the slag is dense grey slag, quite coarse grained, with few vesicles. At the top there are abundant vesicles in a zone 10mm thick, below a rough maroon upper surface, which looks as if it was not the original top (it resembles other examples where the lower puddle is overlain by lobate denser slags).

NG10 (C114; chemical analysis only)

This is a fragment of a fine-grained fired clay, with moulds suggestive of organic inclusions. There are also small (sub-mm) angular voids, presumably also from loss of a temper – but which are now mainly filled with secondary iron oxides. The material contains no significant sand temper and resembles daub.

NG11 (C111; chemical analysis only)

Sample was cut from a curved concretion with a brown surface. Slightly reddened inside but it is not clear if this was a roasted piece. If so, it can only have been lightly roasted. The interior of the nodule is pale and shows some bioturbation

NG12 (surface find, E side in fallen tree roots at large MS anomaly; chemical analysis only)

This specimen appeared to be a dense or lump with a smooth iron rich external coating. On cutting it was found to be rather variable, with the bulk of the specimen being an iron-poor siltstone or fine sandstone.

Cindermill

FID1 (C1005; Plate A1 a-d)

This is a thin sheet of vesicular but dense slag. The lower surface is very irregular, suggesting a rather unwetting flow over irregular charcoal. In contrast the top is almost planar, with a slight marginal lip and local wrinkling, suggesting dragging of a solidified crust by continued movement below (or alternatively deflation of the lobe). The slag has a local development of vesicularity, but mostly the vesicles are fine and concentrated in a zone just below the top (suggesting impeded upward migration).

The polished block shows a chilled and oxidised flow lobe margin, with the slag in the lobe coarsening away from the margin. The main texture showed long thin olivine crystals (up to 1mm long) forming a meshwork, within which there were bundles of parallel smaller crystals. The interstitial spaces were occupied by glass bearing fine equant crystals and even finer dendrites of hercynite.

The olivine was a relatively magnesian fayalite (Fa89-91) with 0.3-0.6% Ca substitution and 1.3-1.6% Mn substitution. The hercynite was 7-8% magnetite, with usual levels of substation of Ti and Mn (2% and 1% respectively of their appropriate sites), but also with detectable levels of Cr and V (approximately 1% of each in their respective sites). The microstructure included sparse small vesicles and rare blebs of iron.

FID2 (1005; no analysis)

This piece forms part of a flow 40mm thick, with a wrinkled upper matt maroon surface suggesting a single lobe at least 70mm wide (and probably much more). The material itself appears to be similar to that of the tapslags, with moderate vesicularity, particularly in the mid- to upper-part of the flow. The largest rounded vesicles are just below the upper surface. The basal 10mm or so is of fairly low vesicularity. The base is irregularly lobate with smooth lobes indicating a non-wetting flow, some areas with charcoal dimples and some clasts of stone. The very edge of the cake is not well-preserved, but appears to show some folding of the surface, as seen in some of the very low density cakes.

FID3 (C1006; no analysis)

This was an extremely rust-coated slag block, probably with an iron particle not revealed in the section. Slag section shows an external contact with clay on two perpendicular sides. Internally the fayalite is coarse and curved within the angle. The slag is dark grey and finely vesicular.

FID4 (C1008; Plate A2 a-d)

The sample is a part of an apparent 'runner' in highly frothy 'honeycomb' texture slag. The two supposed lower surfaces meet at an approximate right angle. They are smooth to very slightly dimpled, with no lobing. The upper part of one face shows some folds (cf. NG1, NG2). The slag is mainly a dark slate grey, but paler, greener colours are present in the lower part of the section, close to rusted areas, and are probably zones of weathering. The top shows some areas of smooth, slightly maroon crust, similar to that on the sides, but is poorly-preserved.

The slag shows a high level of vesicularity with the slag supported around the vesicles by long thin olivines of up to 5mm length. The olivine is, however, in comparison to other similar samples in this assemblage of a rather uniform size. The interstitial glass bears a few dendritic outgrowths from the olivine, together with small angular dendrites of hercynite.

The cores of the olivines were of about Fa86-90, with 0.6-0.8% Ca substitution and 2.6% Mn substitution. The hercynite contains about 6% magnetite.

FID5 (C1008; chemical analysis only)

This sample was taken from a highly vesicular, frothy, 'honeycomb' type slag. The slag was in the form of a crude sheet 40-70mm thick, with a planar base and crudely lobate upper surface. The base was micro-dimpled, of a leaden grey colour, with some dimples containing small clay particles. The top was also leaden grey, with rather wispy, insubstantial raised lobes, with some fuel impressions. There is a general textural resemblance to a thick fuel-ash slag layer.

FID6 (C1010; Plate A3 a-f)

This piece is in a crude plano-convex mass 140mm in diameter and 70mm deep. The top and bottom surfaces are pink, but internally the matrix is pale grey (mainly bluish, but sometimes yellow) with darker grains, often a dark bluish grey, sometimes with some reddening. There are small angular chips of stone present too.

In section the material can be seen to be a sandy sediment bearing grains of probable iron ore (with a strange reticulated texture) and just possibly weathered iron (with an irregular, locally botryoidal texture).

FID 7 (C1013; no analysis)

This rounded lump with adhering accretions is a lump of pat-reacted iron ore with concentrically-zoned alteration. The surface is pale brown alteration, over a thick layer coloured dark grey. The core of the piece has a violet colour. There are several large cracks, probably from dehydration/decarboxylation, which cut the interior but are sealed by the outer layer.

FID8 (C1013; no analysis)

This was a rounded nub of dense grey vesicular slag with abundant charcoal inclusions. It is presumably a hearth or furnace slag, but the form of the piece gives no better indication of origin. The surface was rather weathered

FID9 (C1015; no analysis)

This sample was cut from a large (>100 x 160mm) lobe of dense slag. The lobe is mainly about 25mm thick and shows a small central void. The slag is dense, moderately coarse (fayalite up to 6mm?), somewhat vesicular, with a local entrainment of both vesicles and charcoal fragments below the upper surface. The upper surface is smooth, but irregular, and maroon, except in hollows below charcoal moulds where it is grey (suggesting partial coverage y fuel during cooling). The lower surface is micro-dimpled. The densest and coarsest parts of the cake approach the homogeneous structure of NG3, but remain significantly finer-grained.

FID10 (C1015; chemical analysis only)

This was a large angular fragment (c. 100mm across) of charcoal-rich grey slag, weathered at the margins and with some granular sedimentary accretion. At one end there is a maroon, denser portion with flow lobes, together with a large lump of pale furnace ceramic. The base below this area comprises flow lobes dropping into charcoal, with further ceramic debris.

These textures suggest this is either a furnace slag or one formed by cooling within the tap-arch.

FID11 (C1017; Plate A4 a-c, Plate A5 a-b)

This is a section from large, plano-convex slag cake. The base is grey and finely dimpled to irregular, but very neatly rounded. The top is almost planar and maroon over most of the area, but at one end a lower, flow-lobed, surface is shown. The cake has three layers internally; a grey basal layer up to 25mm thick, moderately coarse-grained and finely vesicular, following the base of the cake, a middle zone up to 40mm thick, with an open, 'clotted' texture, with moderately large rounded vesicles which increase in size upwards, and an upper, darker, dense zone, with tabular large rounded vesicles, but a denser slag between. The exposed lobed surface can be seen to be formed by the bubbles in the upper part of the middle zone.

The cake was at least 240mm wide and 80mm deep overall.

The cake was sampled from its base, middle and top for samples for chemical analysis:

A: very dense slag at the bottom of cake
B: porous middle of cake
C: dense top of cake

The polished block for the SEM analysis was taken from the lower part of the cake, broadly equivalent to the location of chemical analysis FID11A.

The polished section shows a coarse-grained microstructure with olivine crystals up to several mm in length and 0.5mm in width. The inner parts of this main generation of olivine were moderately magnesian, with a recorded composition of Fa94 with 0.8% Ca and 1.3% Mn substitution in a central location and analyses of Fa100 with 3.8% Ca and 1.0% Mn substitution on the margins. This olivine was closely associated with euhedral equant hercynite, with 4-16% magnetite (with the proportion of magnetite increasing outwards). Where such hercynite grains occur outside the main olivines, they show continued outwards growth into a zone comprising hercynite with about 23% magnetite in a blocky intergrowth with a titaniferous spinel that can be expressed as magnetite with 38% hercynite and 15% ulvopsinel.

These late spinels are associated with rounded grains of leucite (though with uncertain precise relationship) and are overgrown by elongate crystals of rhönite. The remainder of the interstitial space is occupied by late-stage calcic olivine (typically Fa100 with 12.5% Ca and 1.0% Mn substitution), a finely lamellar (?) calcium phosphate and glass.

Some of the vesicles are surrounded by areas richer in leucite (including a leucite – wustite or leucite – fayalite cotectic), occasionally with leucite dendrites..

FID12 (C1021; Plate A6 a-h, Plate A7 a-d)

This sample comes from a section of conventional tapslag cake, 140mm wide and 60mm deep centrally. The internal structure shows a stack of lobes, at least 8 thick. The lowest lobes locally show a central cavity, the higher ones are typically more dense, with local fine vesicularity. The upper surface shows mainly smooth-surfaced lobes, with occasional wrinkles.

The mineralogy is unusual. The flow lobes show chilled oxide margins (of uncertain precise mineralogy, but largely magnetite) closely associated with euhedral hercynite (with 9% magnetite) of approximately 10-15µm. The hercynite is overgrown by sparse dendrites of magnetite with approximately 33% hercynite. The aluminous magnetite is followed by fine-grained olivine (Fa90 with 0.9% Ca and 2.1% Mn substitution). The interstitial glass appears to bear a very fine crystalline phase – possibly an olivine.

Within the flow lobes the texture is slightly heterogeneous. Again, the primary phase appears to be euhedral hercynite, with a grain size of up to at least 80 µm. The hercynite shows strong zonation. The cores are typically around 8% magnetite, rising to 13% near the margins. The distribution of hercynite shows a strong relationship to that of early wustite dendrites, which show arrays of up to about 500 µm. These two early phases are followed by sheaves of long (locally >1mm) fayalite crystals which contain cotectitic wustite and hercynite.

FID13 (C1008; chemical analysis only)

A white fired clay with abundant tiny charcoal fragments and some mould of larger organic temper (straw?) as well as a few small slag fragments

FID14 (C1015; chemical analysis only)

A fine pale clay mixed with abundant very fine grained (<3mm) charcoal fragments. This material does not appear to be fired.

FID27 (C1013; chemical analysis only)

This was a bulk sample of small (c. 8mm) ore particles, from the red 'floor' above [c1021].

Chemical composition

The suites of smelting slags from the two sites show compositions within two distinct fields, differentiated by differing Si:Al ratios. This ratio is much higher (Fig. 1a,b) for slags from Ned's Garden (3.4 to 5.1) than for those from Cindermill (2.3-3.3).

The Si:Al ratio of a smelting slag will be controlled by the relative proportions of these elements in the both the ore and the furnace lining, together with the mix of these components in the slag-forming reaction (Thomas & Young 1999a, 1999b).

Interpretation of the values reported here is hampered by the rather wide spread of values for the content of silica and alumina in the ore samples. Indeed, if only the higher grade ore samples are considered, the single good ore from Cindermill has a Si:Al ratio close to that of the slag from Ned's Garden, and the single good ore from Ned's Garden is similarly close to the ratio in the slags from Cindermill.

In contrast, the small numbers of technical ceramic from the two sites cluster closely in terms of silica and alumina contents.

It is clear that meaningful consideration of the details of the chemistry of the smelting process must await the acquisition of additional compositional data from ore samples from the two sites. However, despite the limited analytical data obtained from ores in this project, it is likely that the dominant control on the Si:Al ratio in the slag on the two sites will have been the ore composition, with that utilised at Ned's Garden being more relatively siliceous than that at Cindermill (i.e. the ore samples analysed here are not representative of the ores employed).

The Cindermill slags are also richer in Mg, Ca, Ba and P than those from Ned's Garden (e.g. Figure 1c). A clear difference is also visible in the upper crust-normalised REE profiles, with those from Cindermill showing a slight MREE hump (Figure 2c), whereas for Ned's Garden the profiles are approximately horizontal through the MREE and HREE (Figure 2d).

The ceramic samples show inclined profiles with progressive depletion towards the LREE (Figure 2a).

The ore samples show relatively flat MREE/HREE for the good Cindermill sample, an inclined profile close to the ceramic samples for the clay-rich roasted ore cake from Cindermill, and with more humped profiles for samples from Ned's Garden – again emphasising how the ore samples are a mismatch with the slag samples (Figure 2b).

The interpretation of bulk analyses illustrated in Figure 1 is complicated by the variation between samples in the iron content. To allow more direct comparison of the non-ferrous component of the slags, the binary plots in Figures 3 and 4 are for analyses normalised to exclude iron.

These plots show more clearly the relationship between the two slag suites. For many 'immobile' trace elements (U, Th, the REE, Y , Zr) there is substantial overlap between the two sites – presumably reflecting the broad similarity of the ores. For the alkali and alkaline earth elements (K, Mg, Ca, Ba) there is much less overlap. This reflects a more significant difference between the sites, which is discussed below.

Interpretation

The total of the contents of alumina, silica and iron oxide amounts to approximately 90% of the slag analyses. This means that the use of the ternary system SiO_2-Al_2O_3-FeO is too unreasonable a basis for the discussion of slag chemistry and relationships. The other elements will, in many cases, modify slightly the relationships and alter the liquidus temperature, but the broad relationships will hold.

The analyses from this project are displayed in this system in Figure 5. The smelting process may be regarded as firstly a mixing of ore and furnace lining to produce a theoretical mixture (which will lie on a join between those compositions, close to the composition of the ore), followed by extraction of iron from the mixture (as a metal), leading to the production of slag along an array of points trending directly away from the FeO pole and from the mixture composition.

In this case, the slags from Ned's Garden and from Cindermill each form a linear array – with those from Ned's Garden lying mainly with the fayalite field and those from Cindermill lying along the fayalite-hercynite join.

Given the uncertainties over the precise ore composition, it is not possible to construct a robust mass balance description of the smelting reaction. However, if any furnace lining contribution is ignored, the production of slags with 46-62% FeO from an ore with 73% FeO implies removal of 40 to 63% of the iron in the ore. The actual extractive efficiency, once the furnace lining contribution to the mix is taken into consideration, would be rather lower than this. This level of extractive efficiency is broadly comparable to that derived by Thomas (2000) for smelting from much richer initial ores in the Bristol Channel Orefield.

These figures can be used to provide a very approximate model for the iron yield. A slag with 46% FeO represents a loss of 500g of FeO per 1000g of ore (with its iron expressed as FeO; roughly 1.08kg if the ore is expressed as Fe_2O_3, i.e. its roasted state). A slag with 62% FeO represents a loss of 290g of FeO per 1000g of ore. The starting weight of 1000g of reduced ore would produce 710g of slag at 62% FeO or 500g of slag at 46% FeO. If those figures are inverted, then the range of 46-62% FeO indicates the use of 2.2kg to 1.5kg of roasted ore per kg of slag produced, yielding between and 460 and 540g of iron. In other words, the simple, rough, balance for these sites is that the weight of smelting slag is broadly equivalent to 60% of the weight of ore smelted and double the potential weight of raw iron produced.

The subtle differences between the two sites are picked out by a difference in silica:alumina ratio and a difference in the abundance of some alkali and alkaline earth elements. The silica:alumina ratio is likely to reflect a variation in the grain size of the sediment hosting the iron ore. The Ned's Garden ores are the more siliceous – and indeed the low grade ores noted on the surface in Ned's Garden East were described as being siltstones or fine sandstones. The Cindermill ores would have been more clay-rich – which would also be likely to lead to enhanced concentrations of potassium and titanium, amongst other elements.

The higher levels of calcium and magnesium in the Cindermill ores are a slight, but important feature. The elevated contents of these elements in bloomery slag usually require explanation with one of three approaches. Firstly, there is what might be deemed the 'obvious' explanation – that is to say that material (usually either interpreted as limestone or shells) has been deliberately added to a the smelt as a flux. The action of the lime might be either to be able to react with the silicate material in the smelting mixture, allowing more of the iron to be extracted. This is an important process within the blast furnace, but has not been demonstrated to be significant in bloomeries. A second reason for increasing the lie content is to enhance the ability of the slag to fix phosphorus. Fluxing with lime has been favoured by those who see the later evolution of the bloomery as approaching the chemistry of the blast furnace. Morton & Wingrove (1972) favoured a small addition of lime as being the best explanation for the chemistry of the slags from the late medieval site at Rushall (West Midands). Dungworth (2010) recently reinvestigated material from this site and made the same compositional observation, but urged caution in its interpretation.

The second interpretation often offered is that these elements are derived from the fuel ash, and so their increased abundance in some sites indicates a process with a higher degree of capture of the fuel ash into the bloomery slag. The problem with this explanation is that the pattern of elemental enrichment does not actually match the composition of wood ash. In particular wood ash analyses do not usually indicate very high degrees of enrichment of magnesium; calcium and potassium are usually the dominant elements (e,g Thomas 2000).

The third explanation is that these elements are all associated with the ore being used. Importantly, calcium and magnesium are often present in roughly equal proportions in impure siderite (though incorporation of an ankeritic component in the siderite). Oxidation of the siderite through weathering will lead to loss of these elements. Similarly if roasted ores are allowed to be washed or leached, then the alkaline earths will be lost in solution. It is easy therefore for quarried, variably weathered and variably roasted ore to show a significant range in calcium and magnesium contents. This has been demonstrated in the present series through qualitative analysis of iron ore nodules from Ned's Garden; their central, unweathered, grey cores were rich in calcium and magnesium, which were almost absent in the outer, brown, weathered crusts. This third explanation is this that preferred here.

In summary, the slags from the water-powered site at Cindermill cannot be differentiated from those from the manually blown site at Ned's Garden, by texture or by any chemical characteristic that cannot be attributed to a slight difference in ore chemistry. There are subtle differences in chemical composition between the two suites of slags which appear to be due to differences in the ores employed at the two sites. Unfortunately the limited number of ore analyses do not detect the same trends. It is not impossible that the data on ore composition are influenced by the finds of ore of being rejected material.

Discussion

The slight difference in the Si:Al ratio between the slags of the two sites means that the analyses form two coherent and sub-parallel trends in the FeO – Al_2O_3 – SiO_2 system. The Ned's Garden slags lie on a trend-line passing through the fayalite field, whereas the trend line for the Cindermill samples lies approximately along the eutectic line between the fayalite and hercynite fields. Interestingly only a single sample, the most iron-rich sample from Cindermill, contains wustite (and lies just on the wustite side of the highest temperature point on the fayalite-hercynite eutectic line. The slag suites from both sites therefore approach the system of 'Optimum 1' (surrounding the melting point minimum of the fayalite-tridymite-hercynite system) rather than 'Optimum 2' (surrounding the melting point minimum of the fayalite-wustite-hercynite system) of Rehren *et al.* 2007.

Charlton *et al.* (2010) considered 'Optimum 1' as indicating a high yield and stated that "given the potential pitfalls, high yielding bloomery recipes are best suited to economies where the demand and price of iron are high and competition is steep". Both Charlton *et al.* (2010) and Rehren *et al*. (2007) discuss the concept of 'choices' in iron-making, but it is clear that given the composition of the local ore, in this case there is no possibility of smelting with the production of a slag bearing a significant level of wustite, unless the yield of iron was miniscule. The ore compositions lie further from the iron oxide apex of the FeO-SiO_2-Al_2O_3 system than does 'Optimum 2'. Indeed the ore composition lies very close to the limit of melt compositions likely to generate wustite on cooling (the fayalite – hercynite join on Figure mm). In practice the actual bulk smelting system will have a composition further from the FeO apex, because of the admixing of some melted furnace lining (and a minor contribution from fuel ash); but as iron is extracted during the smelting process, the slag composition must be driven even further away from the FeO apex.

The lack of wustite in these slags is interesting, for it has been suggested (e.g. Charlton *et al.* 2010; Rehren *et al.* 2007; Sauder & Williams 2002) that wustite plays an important role in the control of carbon in the nascent bloom. It is suggested that despite the greater yield of iron that may be possible at 'Optimum 1', there is a potential for the production of high carbon steely blooms or even of cast iron.

There has been much debate over what is/was meant by the term bloomsmithy. The term appears to have applied to sites both with and without water power. The term was applied to the site at Timberholme, N. Yorkshire, that has been variously interpreted as a water-powered bloomery, a 'high-bloomery' (Vernon *et al.* 1999) and a proto-blast furnace (McDonnell pers. comm. 2011). Unfortunately, there are no published descriptions of slags from this site that would clearly demonstrate the production of liquid iron. Within continental Europe various descriptions of high bloomeries (*Stückofen*) have tantalisingly referred to the presence of *laitiers* (= blast furnace slags), but again there are no clear published examples known to the author.

If the iron produced at these sites was a high-carbon variety, as has been suggested for some the *Stückofen*-types of furnace (e.g. the Finnish *harkhyttor*, Percy 1864 p.325) then it is possible a remelting or refining process might have been required – for which field evidence might be sought.

In Britain, a progressive medieval exploitation of coal measures ironstones has been described (e.g. Morton & Wingrove 1967, 1972) and, as described above for samples from the sites described here, this inevitably pushed the slag generated towards low-iron compositions. The theory would suggest this alone would make the production of liquid iron a more likely event, but it remains uncertain whether there was much, if any, deliberate production of cast iron at this period.

The only site with well-studied slag from a similar period and geological setting, is the possible water-powered bloomery at Goscote (or Rushall), near Walsall (Monrton & Wingrove 1972; Dungworth 2010). The tapped slags from this site show some compositional similarity with those of the sites considered here, and in particular those of Cindermill. They have a somewhat aluminous composition, leading to a spinel-rich mineralogy, and include 'honeycomb-textured' variants. The slags were richer in both calcium and magnesium than the material described here – perhaps as the result of the smelting of a rather ankerite-rich siderite ore. Investigation of iron blebs within the slags suggested to Dungworth that the product of the smelt was high-carbon iron, including hypereutectoid steel . A similar range of compositions for the residues from medieval bloomeries from Germany was recorded by Kronz (2003).

The major contribution of this study is to have demonstrated that similar slags were generated by the earlier manually blown bloomery at Ned's Garden and by the later, water-powered, site at Cindermill. There is no reason necessarily to posit, therefore, a different form of iron product from the two sites. Whilst the discussion of the implications of the introduction of water-power to smelting are very important, it is important to separate the evidence for water-power from that for the expansion of bloomery smelting into areas with lean, aluminous ores.

Summary

The morphology and structure of the slags tapped from the smelting furnaces at Ned's Garden and Cindermill are broadly similar. Dense tap slags of 'conventional' appearance do occur, but are associated with large volumes of slag which are highly vesicular (the 'honeycomb' texture of Dungworth, 2010). The vesicular slag frequently forms flows with broad, low-convexity flow lobes, or simply slag puddles with flat tops. The base of these flows is moderately dense, sometimes with tubular vesicles. The vesicularity often increases abruptly upwards. The flows tend to have a rather thin upper chilled surface. These features suggest that the vesicular slag was the result of rapid tappings of large volumes of highly fluid melt. In some cases, the conventional dense, tap slags with narrow, high-convexity flow lobes, can be observed to have flowed over the top of the vesicular slag to form a composite cake. In these examples the vesicles remain confined below the flat top of the honeycomb-textured cake.

The chemical compositions of the two suites of slag were broadly similar but differed in detail. These differences are attributable to a slight difference in iron ore. There is no evidence to relate to any variation in the slag chemistry to an evolution in bloomery technique between the periods represented to the two sites or to the introduction to water. There is no evidence for the use of deliberate calcareous fluxes.

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Illustration Captions

Figures

Figure 1. Binary scatter plots – bulk chemical composition:
A. Al_2O_3 (wt%) v SiO_2 (wt%)
B. SiO_2/Al_2O_3 v Eu_N/Lu_N (where E_N is the upper crust normalised concentration of element E).
C. MgO (wt%) v CaO (wt%)
D. U (ppm) v (Th (ppm)

Figure 2. Upper crust normalised rare earth element profiles:
A. Furnace ceramics
B. Ore
C Slag from Cindermill
D. Slag from Ned's Garden
(normalisation factors after Taylor & McLennan 1981)

Figure 3. Binary scatter plots – analyses normalised to exclude iron.
A. MgO (wt%) v CaO (wt%)
B. K_2O (wt%) v CaO (wt%)
C. P_2O_5 (wt%) v CaO (wt%)
D. Ba (ppm) v Sr (ppm)

Figure 4. Binary scatter plots – analyses normalised to exclude iron.
A. U (ppm) v Th (ppm)
B. U (ppm) v total REE (ppm)
C. TiO_2 (wt%) v K_2O (wt%)
D. Zr (ppm) v Y (ppm)

Figure 5. Ternary diagram of FeO – SiO_2 – Al_2O_3 system, showing residues by site and type. Inset diagram shows the locations of optima 1 and 2 after Charlton *et al.* (2010)

Archive Plates

Plate A1: FID1, BSEM images
a. FID1-SOI1. Scale bar 600µm.
b. FID1-SOI2. Scale bar 600µm.
c. FID1-SOI3. Scale bar 600µm.
d. FID1-SOI4. Scale bar 60µm.

Plate A2: FID4, BSEM images
a. FID4-SOI2. Scale bar 4mm.
b. FID4-SOI3. Scale bar 600µm.
c. FID4-SOI4. Scale bar 600µm.
d. FID4-SOI5. Scale bar 70µm.

Plate A3: FID6, BSEM images
a. FID6-SOI1. Scale bar 60µm.
b. FID6-SOI2. Scale bar 200µm.
c. FID6-SOI3. Scale bar 1mm.
d. FID6-SOI4. Scale bar 300µm.
e. FID6-SOI5. Scale bar 1mm.
f. FID6-SOI6. Scale bar 200µm.

Plate A4: FID11, BSEM images
a. FID11-SOI1. Scale bar 1mm.
b. FID11-SOI2. Scale bar 100µm.
c. FID11. Montage of SOI3-SOI8. Scale bar 600µm.

Plate A5: FID11, BSEM images
a. FID11-SOI9. Scale bar 200µm.
b. FID11-SOI11. Scale bar 80µm.

Plate A6: FID12, BSEM images
a. FID12-SOI1. Scale bar 600µm.
b. FID12-SOI2. Scale bar 100µm.
c. FID12-SOI3. Scale bar 600µm.
d. FID12-SOI4. Scale bar 100µm.
e. FID12-SOI5. Scale bar 600µm.
f. FID12-SOI6. Scale bar 100µm.
g. FID12-SOI7. Scale bar 600µm.
h. FID12-SOI8. Scale bar 600µm.

Plate A7: FID12, BSEM images
a. FID12-SOI1. Scale bar 5mm.
b. FID12-SOI2. Scale bar 70µm.
c. FID12-SOI3. Scale bar 40µm.
d. FID12-SOI4. Scale bar 60µm.

Plate A8: NG2, BSEM images
a. NG2-SOI1. Scale bar 600µm.
b. NG2-SOI2. Scale bar 600µm.
c. NG2-SOI3. Scale bar 600µm.
d. NG2-SOI4. Scale bar 2mm.
e. NG2-SOI5. Scale bar 100µm.
f. NG2-SOI6. Scale bar 100µm.
g. NG2-SOI7. Scale bar 600µm.
h. NG2-SOI10. Scale bar 90µm.

Plate A9: NG2, BSEM images
a. NG2-SOI11. Scale bar 40µm.
b. NG2-SOI12. Scale bar 70µm.
c. NG2-SOI13. Scale bar 50µm.
d. NG2-SOI14. Scale bar 100µm.
e. NG2-SOI15. Scale bar 100µm.

Plate A10: NG3, BSEM images
a. NG3-SOI1. Scale bar 600µm.
b. NG3-SOI2. Scale bar 100µm.
c. NG3-SOI3. Scale bar 300µm.
d. NG3-SOI4. Scale bar 80µm.
e. NG3-SOI5. Scale bar 100µm.

Plate A11: NG5, BSEM images
a. NG5-SOI1. Scale bar 3mm.
b. NG5-SOI2. Scale bar 600µm.
c. NG5-SOI3. Scale bar 90µm.
d. NG5-SOI4. Scale bar 200µm.
e. NG5-SOI5. Scale bar 700µm.
f. NG5-SOI6. Scale bar 100µm.
g. NG5-SOI7. Scale bar 600µm.
h. NG5-SOI8. Scale bar 40µm.

Plate A12: NG5, BSEM images
a. NG5-SOI9. Scale bar 300µm.
b. NG5-SOI10. Scale bar 50µm.

Plate A13: NG6, BSEM images
a. NG5-SOI1. Scale bar 6mm.
b. NG5-SOI2. Scale bar 600µm.
c. NG5-SOI3. Scale bar 200µm.
d. NG5-SOI4. Scale bar 40µm.
e. NG5-SOI5. Scale bar 5mm.
f. NG5-SOI6. Scale bar 1mm.
g. NG5-SOI7. Scale bar 100µm.

Table 1: Sample details

code	*context*	*type*	*location*	*material*	*slag paragenesis*
Ned's Garden					
NG2	106	slag	trench 1: slag dump	low density slag with visible flows on the upper surface	open F + glass + iron
NG3	113	slag	trench 1: slag dump	very dense slag	F - K / H - glass
NG4	113	slag	trench 1: slag dump	slag with 'wrinkles'; dense with very small vesicles in the top part	n/a
NG5	115	slag	trench 1: slag dump	dense slag with visible flow layers in the section	F - K / H - glass
NG6	115	slag	trench 1: slag dump	slag with large crystals; very porous at top/bottom; middle more solid	open F + glass
NG9	301	slag	trench 3: upper deposit	dense slag with bubbles layer in the top part	n/a
NG10	114	clay	trench 1: working levels	clay	
NG11	111	ore	trench 1: below cottage floor	small ore lump	
NG12	NG East	ore	surface: big MS anomaly	large ore lump	
Cindermill					
FID1	1005	slag	trench 1: upper slag dump	high density slag with 'wrinkles'	open F (and H?) - H dendritesi n glass
FID4	1008	slag	trench 1: middle slag dump	low density slag	open F (and H?) - H dendritesi n glass
FID5	1008	slag	trench 1: middle slag dump	low density slag; very light; vesicles in the upper part	n/a
FID10	1015	slag	trench 1: slumped deposits	low density slag; large charcoal pieces inside	n/a
FID11A	1017	slag	trench 1: working deposits on N	very dense slag at the bottom of cake	primary H-M then F-H - rhonite/apatite - leucite wth L-F or L-W
FID11B	1017	slag	trench 1: working deposits on N	porous middle of cake	n/a
FID11C	1017	slag	trench 1: working deposits on N	dense top of cake	n/a
FID12	1021	slag	trench 1: slag 'floor'	high density slag with visible flow layers in the lower part	primary H-M + W then F/W and F/H
FID13	1008	clay	trench 1: middle slag dump	clay	
FID14	1015	clay	trench 1: slumped deposits	clay	
FID27	1013	ore	trench 1: red floor fines above 1021	bulk sample of small c. 8mm particles	
FID6	1010	ore	trench 1: slumped floor fines	ore roasting cake/concretion	

Table 2: Major element chemical analyses (by XRF) expressed as wt% oxides. Columns in tone indicate alternative values recalculated with the iron expressed as FeII. LOI = loss on ignition

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI 100% FeIII	LOI 100% FeII	total
NG2	39.38	8.12	46.44	41.80	1.19	1.21	1.47	<0.009	1.15	0.50	0.17	-3.58	1.06	99.81
NG3	27.53	5.81	60.57	54.51	0.78	0.80	1.11	<0.009	0.88	0.36	0.25	-5.69	0.37	98.38
NG4	34.05	7.33	51.50	46.35	0.98	1.20	1.34	<0.009	1.16	0.43	0.21	-5.04	0.11	98.51
NG5	28.40	7.40	56.68	51.02	1.02	1.34	1.79	<0.009	0.95	0.40	0.31	-5.13	0.54	98.48
NG6	32.42	6.37	55.41	49.87	0.87	0.96	1.15	<0.009	0.84	0.41	0.39	-5.13	0.41	99.01
NG9	26.62	7.81	57.72	51.95	0.81	1.53	1.36	0.01	1.10	0.46	0.47	-5.22	0.55	98.12
NG10	63.40	23.93	4.13	3.72	0.08	0.94	0.25	<0.009	1.94	1.26	0.04	2.48	2.89	98.65
NG11	12.46	6.13	56.23	50.61	1.07	0.18	0.17	<0.009	0.17	0.08	0.03	22.49	28.11	99.07
NG12	32.58	5.69	41.91	37.72	0.69	0.67	0.34	<0.009	0.55	0.26	0.25	15.21	19.40	98.31
FID1	31.87	10.24	48.13	43.31	1.15	1.67	2.80	0.03	1.68	0.53	0.53	-4.64	0.17	98.91
FID4	33.18	11.76	44.37	39.93	1.37	2.04	3.01	<0.009	1.93	0.59	0.61	-4.16	0.28	99.36
FID5	35.24	11.64	44.88	40.39	1.00	1.86	1.59	<0.009	1.49	0.58	0.36	-3.73	0.76	98.97
FID10	25.63	10.80	54.01	48.61	1.28	2.51	1.96	<0.009	1.06	0.44	0.78	-1.60	3.80	98.72
FID11A	25.69	8.02	59.27	53.35	0.70	1.34	1.88	<0.009	1.18	0.41	0.68	-5.67	0.26	99.52
FID11B	25.61	8.20	58.30	52.47	0.69	1.24	1.99	0.01	1.25	0.43	0.69	-5.78	0.05	98.78
FID11C	24.80	7.60	58.70	52.83	0.74	1.53	1.79	0.01	1.02	0.40	0.64	-5.67	0.20	97.57
FID12	21.73	8.39	63.50	57.15	0.98	1.72	1.56	<0.010	0.87	0.41	0.68	-4.47	1.88	100.06
FID13	62.77	22.54	8.40	7.56	0.12	0.61	0.19	<0.009	1.01	1.16	0.09	0.83	1.68	97.99
FID14	57.07	16.84	11.60	10.44	0.18	0.67	0.64	<0.009	1.02	0.88	0.08	9.85	11.01	99.28
FID27	18.61	4.02	67.83	61.05	1.04	0.33	0.23	<0.009	0.37	0.24	0.27	4.61	11.40	98.09
FID6	41.84	15.76	32.46	29.21	0.34	0.80	0.39	<0.009	1.17	0.75	0.12	5.13	8.38	99.19

Table 3: Minor and trace element chemical analyses (by XRF) expressed as wt% oxides.

	SO_3	V_2O_5	Cr_2O_3	SrO	ZrO_2	BaO	NiO	CuO	ZnO	PbO	HfO_2
NG2	0.02	0.022	0.015	0.021	0.030	0.051	<0.003	<0.002	0.002	0.016	<0.005
NG3	0.07	0.019	0.012	0.014	0.019	0.112	<0.003	0.004	0.008	0.017	0.006
NG4	0.11	0.022	0.011	0.015	0.025	0.117	<0.003	<0.003	0.004	0.017	0.01
NG5	0.05	0.025	0.010	0.015	0.020	0.035	<0.003	<0.003	0.004	0.014	<0.005
NG6	0.03	0.018	0.009	0.015	0.022	0.052	0.019	<0.003	0.015	0.018	<0.005
NG9	0.07	0.017	0.005	0.012	0.019	0.081	<0.003	<0.003	0.006	0.016	<0.005
NG10	0.02	0.033	0.020	0.005	0.036	0.045	<0.002	<0.002	0.019	0.014	0.00
NG11	0.01	0.009	0.006	0.002	0.004	-0.004	<0.004	<0.003	0.033	0.012	<0.006
NG12	0.03	0.016	0.005	0.003	0.013	0.013	<0.003	<0.002	0.080	0.012	<0.005
FID1	0.03	0.025	0.008	0.022	0.022	0.161	<0.003	<0.002	<0.002	0.015	<0.005
FID4	0.03	0.029	0.016	0.025	0.019	0.345	<0.003	0.003	0.005	0.016	0.01
FID5	0.08	0.028	0.011	0.019	0.023	0.137	<0.003	0.004	0.016	0.016	0.01
FID10	0.08	0.033	0.012	0.016	0.015	0.081	<0.003	0.003	0.005	0.013	<0.005
FID11A	0.02	0.018	0.006	0.019	0.018	0.232	<0.003	<0.003	0.011	0.015	0.01
FID11B	0.02	0.019	0.008	0.019	0.019	0.247	<0.003	<0.003	0.009	0.015	<0.005
FID11C	0.05	0.021	0.010	0.013	0.017	0.201	0.009	<0.003	0.009	0.015	<0.005
FID12	0.03	0.025	0.008	0.018	0.012	0.103	<0.004	<0.003	0.009	0.017	<0.005
FID13	0.00	0.033	0.014	0.006	0.036	0.134	<0.002	0.005	0.008	0.037	<0.004
FID14	0.08	0.029	0.012	0.013	0.033	0.254	<0.002	0.005	0.009	0.015	<0.004
FID27	0.07	0.010	0.007	0.014	0.012	0.362	<0.004	<0.003	0.014	0.045	<0.006
FID6	0.02	0.028	0.015	0.016	0.023	0.238	<0.003	0.006	0.071	0.019	<0.005

Table 4: Major element chemical analyses (by ICP-MS) expressed as wt% oxides. SiO_2 values here are essentially qualitative only

	SiO_2	TiO_2	Fe_2O_3	MnO	P_2O_5
NG2	32.42	0.55	47.02	1.06	0.16
NG3	16.29	0.43	64.54	0.71	0.26
NG4	27.37	0.51	56.62	0.95	0.19
NG5	26.34	0.46	57.04	0.89	0.29
NG6	27.15	0.49	60.74	0.81	0.34
NG9	20.03	0.53	62.44	0.78	0.53
NG10	53.34	1.32	4.34	0.06	0.03
NG11	29.69	0.14	59.94	1.02	0.01
NG12	41.85	0.33	45.41	0.63	0.25
FID1	24.68	0.62	52.32	1.09	0.58
FID4	29.71	0.64	45.37	1.23	0.61
FID5	40.29	0.58	43.50	0.82	0.32
FID10	27.28	0.56	56.87	1.20	0.79
FID11A	19.98	0.54	65.67	0.65	0.73
FID11B	21.96	0.58	67.16	0.67	0.77
FID11C	20.97	0.49	67.51	0.73	0.69
FID12	16.81	0.50	69.87	0.96	0.71
FID13	61.80	1.30	9.44	0.10	0.07
FID14	59.05	0.97	11.90	0.15	0.07
FID27	24.96	0.27	67.65	0.92	0.25
FID6	27.94	0.79	33.80	0.29	0.10

Table 5: Trace element chemical analyses (by ICP-MS) expressed as ppm.

	Sc	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Sn	Cs	Ba
NG2	17.821	121.627	44.842	11.073	36.300	20.197	40.742	6.754	62.120	107.445	47.523	300.752	9.227	0.717	1.749	4.097	658.153
NG3	14.816	89.349	38.446	74.466	34.798	39.351	93.058	7.615	39.627	88.025	43.540	240.544	7.975	0.656	1.704	2.746	1263.371
NG4	18.413	107.792	35.292	8.689	10.366	34.524	33.659	6.551	52.093	131.043	46.824	240.545	7.542	0.547	0.806	3.883	1331.016
NG5	17.078	116.579	34.233	11.277	32.429	82.571	47.016	7.187	44.531	128.056	45.128	199.359	7.409	0.588	1.943	2.981	518.427
NG6	15.569	100.860	33.976	28.095	18.083	14.885	131.206	7.910	48.504	114.878	35.887	250.677	7.207	0.726	1.700	3.079	710.597
NG9	18.141	83.011	15.667	56.949	20.241	22.215	68.676	9.161	61.212	81.987	43.820	232.852	8.292	0.597	1.642	4.197	975.225
NG10	23.298	177.993	83.974	17.635	163.204	34.456	154.256	30.008	133.485	46.976	43.940	337.926	18.595	0.779	2.901	12.029	603.289
NG11	8.655	43.732	10.144	105.965	32.390	23.888	247.243	4.881	11.998	14.805	27.164	103.667	1.981	0.681	1.200	0.766	134.184
NG12	14.165	70.641	18.121	34.579	24.153	23.246	582.056	6.828	31.271	25.849	36.405	155.547	4.197	0.576	1.327	1.846	313.261
FID1	22.032	133.178	41.270	7.313	24.230	25.871	20.282	7.830	77.656	142.314	49.589	231.445	8.950	0.590	1.433	4.781	3016.443
FID4	25.814	181.162	40.139	6.967	16.184	29.784	58.438	7.145	85.453	212.100	59.846	206.884	8.443	0.576	1.956	5.563	5508.981
FID5	21.852	162.294	37.845	12.841	23.778	43.207	146.318	8.324	71.945	106.659	49.522	193.941	7.421	0.507	1.706	5.420	1323.548
FID10	20.870	220.868	85.014	50.055	164.938	30.094	47.311	10.749	64.184	90.581	40.422	180.055	7.051	0.551	0.994	4.386	895.955
FID11A	17.566	120.621	27.724	19.355	20.489	31.148	100.383	9.945	58.547	125.446	41.365	200.932	7.016	0.405	1.014	3.472	4292.829
FID11B	18.135	120.200	32.491	19.743	51.236	24.061	100.530	9.887	61.737	169.713	43.319	218.492	7.946	0.428	0.747	3.788	4640.091
FID11C	18.315	128.122	29.783	15.412	16.960	40.886	128.135	9.138	54.370	150.132	37.998	195.587	6.589	0.458	1.226	3.385	3923.815
FID12	22.452	149.016	31.458	32.669	32.881	18.956	74.365	9.312	50.269	130.978	38.128	176.829	7.058	0.465	1.072	3.285	1222.836
FID13	25.547	238.908	70.955	18.102	41.809	39.098	81.775	25.801	79.748	55.676	35.793	340.086	14.166	0.649	1.997	6.907	1468.011
FID14	19.974	175.766	59.390	22.569	45.580	29.214	61.307	18.907	72.381	91.251	30.893	281.080	10.794	0.949	1.102	5.257	4599.566
FID27	9.237	67.163	19.021	128.607	63.208	34.049	121.569	6.028	25.586	83.277	26.457	155.777	4.348	2.455	1.453	2.223	5763.548
FID6	21.986	193.317	49.926	83.570	63.528	74.741	531.120	20.291	82.029	103.520	48.820	259.691	12.391	0.875	3.360	8.013	4178.473

Table 6: Trace element chemical analyses (by ICP-MS) expressed as ppm.

	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	Pb	Th	U
NG2	33.374	65.823	7.824	30.269	6.358	1.536	6.674	1.073	6.646	1.317	3.939	0.616	3.913	0.585	7.474	0.611	6.892	5.509	2.158
NG3	20.492	42.448	5.216	20.710	4.544	1.189	5.035	0.839	5.449	1.138	3.529	0.557	3.523	0.533	5.914	0.527	15.239	4.408	1.816
NG4	27.460	58.875	7.318	29.104	6.214	1.601	6.605	1.085	6.728	1.323	3.994	0.609	3.983	0.580	6.064	0.543	5.704	5.167	2.022
NG5	24.543	49.970	6.203	24.798	5.391	1.379	6.050	0.992	6.259	1.238	3.717	0.563	3.660	0.534	5.036	0.516	4.268	4.509	2.162
NG6	27.450	53.269	6.201	23.786	4.774	1.199	5.116	0.814	5.128	1.010	3.077	0.470	3.042	0.453	6.304	0.500	18.127	4.452	2.149
NG9	24.474	50.050	6.404	25.368	5.597	1.487	6.115	0.987	6.141	1.189	3.548	0.530	3.407	0.507	5.886	0.537	4.577	5.265	1.594
NG10	40.367	79.992	9.790	36.656	6.855	1.645	6.901	1.080	6.679	1.304	4.075	0.640	4.265	0.644	8.901	1.348	23.321	13.431	3.289
NG11	15.597	30.002	3.875	16.094	3.328	0.821	3.742	0.567	3.554	0.697	2.027	0.284	1.657	0.230	2.587	0.153	8.032	1.372	0.462
NG12	23.883	56.290	7.299	29.294	6.125	1.527	6.211	0.951	5.644	1.067	3.140	0.451	2.902	0.417	3.892	0.305	13.181	2.925	1.156
FID1	30.485	62.748	8.005	32.279	7.369	1.916	8.279	1.290	7.741	1.413	4.077	0.605	3.837	0.562	5.948	0.655	5.399	6.558	2.784
FID4	30.616	62.203	7.932	32.488	7.350	1.984	8.579	1.365	8.461	1.612	4.728	0.687	4.492	0.649	5.392	0.640	6.411	6.669	2.922
FID5	27.537	55.426	7.079	28.825	6.383	1.694	7.020	1.113	6.842	1.328	3.950	0.580	3.756	0.560	4.978	0.561	10.101	5.847	1.995
FID10	22.333	46.080	6.103	25.796	6.265	1.687	7.226	1.100	6.254	1.141	3.176	0.450	2.864	0.429	4.581	0.479	3.732	4.713	1.816
FID11A	21.891	44.281	5.651	23.351	5.381	1.409	6.270	1.001	6.043	1.139	3.200	0.464	3.017	0.452	5.083	0.533	7.720	4.872	2.429
FID11B	23.229	46.993	6.001	25.019	5.807	1.503	6.601	1.080	6.436	1.182	3.431	0.502	3.107	0.471	5.531	0.536	6.311	5.114	2.462
FID11C	19.692	40.115	5.115	21.311	4.992	1.306	5.680	0.950	5.624	1.049	3.046	0.439	2.862	0.428	4.937	0.458	8.299	4.432	2.134
FID12	21.178	43.311	5.629	23.305	5.465	1.494	6.134	0.998	5.924	1.091	3.197	0.467	3.037	0.450	4.466	0.489	7.272	4.907	1.940
FID13	22.067	39.862	4.413	16.056	3.086	0.865	3.615	0.671	4.803	0.990	3.295	0.516	3.390	0.545	9.026	1.148	137.622	12.384	3.216
FID14	26.330	51.201	6.037	22.859	4.349	1.001	4.542	0.723	4.589	0.902	2.876	0.452	2.942	0.460	7.113	0.878	11.946	9.118	2.518
FID27	12.836	32.526	3.572	14.847	3.543	0.937	3.894	0.656	4.098	0.787	2.304	0.341	2.274	0.326	3.831	0.327	245.259	2.718	1.039
FID6	29.523	56.865	7.282	28.211	5.768	1.390	6.344	1.028	6.617	1.374	4.182	0.639	4.269	0.633	6.508	0.799	46.984	9.000	2.867

Table 7: EDS microanalyses expressed as atom%, normalised to 100%. < = below detection

			material	detail	Atom%																
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba
NG2	SOI 11	# 1	glass		62.00	0.18	0.12	8.06	18.24	0.09	<		1.02	1.45	0.35			0.24	8.24		
NG2	SOI 11	# 2	glass		61.59	0.30	0.16	8.18	18.33	0.08	0.07		1.07	1.51	0.35			0.29	8.07		
NG2	SOI 11	# 3	olivine	Fa96 0.3Ca 2.3Mn	56.78	<	1.15	0.23	14.24	<	<		<	0.09	<			0.67	26.83		
NG2	SOI 11	# 4	olivine	Fa94 0.3Ca 2.2Mn	56.45	<	1.71	0.17	14.12	<	<		<	0.07	<			0.65	26.83		
NG2	SOI 12	# 1	outer rim		67.08			1.44	4.05	0.15	<		0.08	0.20					26.99		
NG2	SOI 12	# 2	inner rim		67.51			0.13	0.61	<	<		<	<					31.76		
NG2	SOI 12	# 3	point in 'iron'		59.46			<	0.89	<	<		<	<					39.65		
NG2	SOI 12	# 4	point in 'iron'		57.21			0.14	0.16	<	<		<	<					42.49		
NG2	SOI 12	# 5	point in 'iron'		57.95			<	1.23	<	<		<	<					40.82		
NG2	SOI 12	# 6	point in 'iron'		57.81			<	1.06	<	<		<	<					41.13		
NG2	SOI 12	# 7	hole?		65.75			<	1.41	<	<		<	<					32.84		
NG2	SOI 12	# 8	area of 'iron'		57.42			<	0.69	<	<		<	<					41.88		
NG2	SOI 13	# 1	area of 'iron'																100.00		
NG2	SOI 14	# 1	area of 'iron'		2.95			<	<	<	<			<					97.05	0.00	
NG2	SOI 14	# 2	FeS		4.56			<	<	<	45.87			<					49.28	0.29	
NG2	SOI 14	# 3	point in 'iron'		2.33			<	<	<	<			<					97.67	0.00	
NG2	SOI 14	# 4	alteration		57.29			0.25	0.11	<	0.11			0.32					41.80	0.13	
NG2	SOI 14	# 5	alteration		66.31			0.47	0.26	0.20	0.40			0.21					32.15	0.00	
NG2	SOI 15	# 1	glass		61.64	0.21	0.11	8.11	18.69	0.07			1.13	1.43	0.33			0.24	8.04		
NG2	SOI 15	# 2	glass		61.99	0.16	0.15	8.42	18.83	0.12			1.32	1.47	0.30			0.23	7.01		
NG2	SOI 15	# 3	olivine	Fa94 2.5Mn	56.61	<	1.67	0.11	14.33	<			<	0.00	0.06			0.73	26.49		
NG2	SOI 15	# 4	olivine	Fa97 0.6Ca 2.4Mn	56.23	<	0.86	1.24	15.02	<			0.13	0.16	0.09			0.65	25.60		

			material	detail	Atom%																
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba
NG2	SOI 15	# 5	olivine	Fa94 0.6Ca 2.1Mn	56.47	<	1.63	0.27	14.42	<			0.15	0.19	<			0.61	26.27		
NG2	SOI 15	# 6	olivine	Fa95 2.4Mn	56.17	<	1.54	0.18	14.25	<			<	0.00	<			0.72	27.14		
NG2	SOI 15	# 7	olivine	Fa95 0.3Ca 2.2Mn	56.34	<	1.54	0.14	14.29	<			<	0.08	<			0.64	26.97		
NG3	SOI 3	# 1	olivine	Fa97 0.7Ca 1.3Mn	55.84		0.85	1.47	14.24				0.16	0.20				0.37	26.88		
NG3	SOI 3	# 2	olivine	Fa94 0.6Ca 1.4Mn	56.22		1.72	0.37	14.10				<	0.17				0.40	27.02		
NG3	SOI 3	# 3	olivine	Fa95 0.4Ca 1.4Mn	56.05		1.50	0.19	14.32				<	0.11				0.41	27.41		
NG3	SOI 3	# 4	olivine	Fa94 0.3Ca 1.4Mn	55.84		1.66	0.25	14.16				<	0.09				0.41	27.59		
NG3	SOI 3	# 5	olivine	Fa95 0.3Ca 1.5Mn	55.80		1.50	0.20	14.33				<	0.08				0.44	27.65		
NG3	SOI 3	# 6	olivine	Fa98 0.4Ca 1.1Mn	55.81		0.56	0.18	14.35				<	0.11				0.33	28.65		
NG3	SOI 4	# 1	olivine	Fa99 0.6Ca 1.5Mn	55.65	<	0.29	0.31	14.33	<	<		<	0.16	<	<		0.46	28.79		
NG3	SOI 4	# 2	hercynite	H 23% mag	57.01	<	<	19.41	3.02	0.07	<		0.63	0.14	0.63	<		0.13	18.97		
NG3	SOI 4	# 3	hercynite	H32% M	55.87	<	0.15	18.58	0.68	<	<		<	0.00	0.90	0.08		0.13	23.62		
NG3	SOI 4	# 4	hercynite	H 30% mag	55.96	<	<	19.20	0.39	<	<		0.07	0.06	1.02	<		0.08	23.23		
NG3	SOI 4	# 5	hercynite	H 29% mag	56.25	<	0.15	18.87	1.16	<	0.08		0.14	0.11	1.05	<		0.14	22.00		
NG3	SOI 4	# 6	hercynite	F 36% mag	55.95	<	0.15	17.54	0.69	<	<		0.07	0.00	0.96	<		0.12	24.52		
NG3	SOI 4	# 7	glass		60.73	0.53	<	8.57	17.53	0.44	0.16		2.85	2.87	0.33	<		0.00	5.99		
NG3	SOI 4	# 8	glass		59.99	0.41	<	8.54	16.92	0.42	0.21		2.49	3.19	0.40	<		0.11	7.32		
NG3	SOI 4	# 9	glass		60.32	0.42	<	9.01	16.39	0.37	0.13		2.15	3.33	0.34	<		0.09	7.45		
NG3	SOI 4	# 10	late olivine	Fa100 1.0Ca 1.3Mn	55.68	<	<	0.24	14.42	0.10	<		<	0.29	0.07	<		0.39	28.80		
NG3	SOI 4	# 11	late olivine	Fa99 0.9Ca 1.2Mn	55.85	<	0.21	0.29	14.25	0.18	<		<	0.26	<	<		0.36	28.61		
NG3	SOI 4	# 12	late olivine	Fa99 0.9Ca 1.3Mn	56.09	<	0.19	0.20	14.26	0.11	<		<	0.26	<	<		0.38	28.51		
NG3	SOI 4	# 13	olivine	Fa98 0.4Ca 1.3Mn	55.76	<	0.71	0.17	14.48	<	<		<	0.11	<	<		0.38	28.38		
NG3	SOI 4	# 14	late olivine	Fa99 0.5Ca 1.3Mn	55.93	<	0.27	0.23	14.38	0.10	<		<	0.15	<	<		0.37	28.58		
NG3	SOI 4	# 15	hercynite	H 43% mag	55.98	<	0.21	15.10	0.61	<	<		<	0.07	1.27	<		0.09	26.67		
NG3	SOI 4	# 16	hercynite	H 28% mag	56.37	<	<	19.94	0.46	<	<		<	0.00	0.76	<		0.12	22.26		
NG3	SOI 4	# 17	hercynite	H 34% mag	55.96	<	0.15	18.23	0.36	0.07	<		<	0.00	0.83	0.07		0.11	24.23		
NG3	SOI 4	# 18	hercynite	H 47% mag	56.27	<	0.15	13.46	1.07	<	<		0.13	0.14	1.26	0.13		0.15	27.23		

			material	detail	Atom%																
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba
NG3	SOI 5	# 1	olivine	Fa99 0.7Ca 1.2Mn	55.86	<	0.16	0.18	14.36	0.10			<	0.20	<			0.37	28.77		
NG3	SOI 5	# 2	olivine	Fa99 0.9Ca 1.4Mn	55.53	<	0.15	0.24	14.39	0.08			<	0.25	<			0.41	28.95		
NG3	SOI 5	# 3	olivine	Fa99 1.4Ca 1.3Mn	56.57	<	<	0.48	14.17	0.13			0.18	0.40	0.07			0.35	27.56		
NG3	SOI 5	# 4	hercynite	mag 44% h	55.61	<	<	12.74	0.73	<			<	<	1.42			0.11	29.38		
NG3	SOI 5	# 5	hercynite	h 39% mag	55.77	<	<	16.45	0.49	<			<	0.06	1.29			0.13	25.81		
NG3	SOI 5	# 6	olivine	Fa100 3.9Ca 1.0Mn	57.80	<	<	1.53	14.63	0.23			0.69	0.98	0.11			0.25	23.78		
NG3	SOI 5	# 7	glass		61.62	<	<	35.88	1.13	0.16			0.15	0.25	<			<	0.72		
NG5	SOI 8	# 1	magnetite?	Mag 5%h	55.62	<	0.46	1.38	1.86	<			<	0.18	<			0.25	40.25		
NG5	SOI 8	# 2	olivine?	Fa91 1.6Ca 2.5Mn	56.08	<	2.72	1.14	12.46	<			0.09	0.47	<			0.75	26.29		
NG5	SOI 8	# 3	magnetite?	Mag 5%h	55.56	<	0.51	1.43	2.30	<			<	0.20	<			0.25	39.76		
NG5	SOI 8	# 4	olivine?	Fa91 1.9Ca 2.6Mn	56.02	<	2.58	0.97	13.63	0.13			0.17	0.54	<			0.74	25.21		
NG5	SOI 8	# 5	Al-magnetite	mag 21%h	56.55	<	0.33	5.50	2.54	<			0.18	0.20	0.57			0.20	33.92		
NG5	SOI 8	# 6	Al-magnetite	mag 22%h	55.88	<	0.38	5.95	2.64	<			0.14	0.13	0.69			0.19	33.99		
NG5	SOI 8	# 7	olivine mixture?		56.59	<	1.06	4.55	11.29	0.16			0.29	0.57	0.15			0.45	24.91		
NG5	SOI 8	# 8	olivine mixture?		55.16	<	2.29	1.20	13.36	0.11			0.14	0.53	<			0.76	26.44		
NG5	SOI 8	# 9	olivine mixture?		56.20	<	2.41	1.13	13.78	0.16			0.18	0.59	<			0.70	24.84		
NG5	SOI 8	# 10	olivine mixture?		56.83	0.27	0.48	4.26	11.04	0.15			0.65	1.32	0.07			0.32	24.60		
NG5	SOI 9	# 1	olivine	Fa91 0.5Ca 1.8Mn	55.34	<	2.53	0.35	14.42				<	0.15				0.54	26.66		
NG5	SOI 9	# 2	olivine	Fa91 0.5Ca 1.9Mn	55.87	<	2.52	0.39	14.27				<	0.16				0.56	26.23		
NG5	SOI 9	# 3	olivine	Fa93 2.0Ca 1.6Mn	56.96	<	1.99	0.63	14.24				0.30	0.56				0.45	24.87		
NG5	SOI 9	# 4	olivine	Fa91 0.6Ca 1.8Mn	55.69	<	2.68	0.45	14.21				<	0.18				0.53	26.26		
NG5	SOI 9	# 5	olivine	Fa97 0.8Ca 1.7Mn	55.86	<	0.84	0.38	14.17				0.07	0.22				0.51	27.95		
NG5	SOI 10	# 1	hercynite	H 19% mag	56.60	<	0.13	21.82	0.85	0.07	<		0.13	0.22	0.93	<		0.20	19.06		
NG5	SOI 10	# 2	olivine	Fa99 1.7Ca 1.7Mn	56.21	<	0.32	0.33	14.35	0.14	<		0.14	0.48	0.07	<		0.49	27.48		
NG5	SOI 10	# 3	hercynite	H 28% mag	55.14	<	0.30	19.62	0.99	0.09	<		<	0.06	1.04	0.10		0.15	22.49		
NG5	SOI 10	# 4	olivine	Fa99 3.9Ca 1.9Mn	56.67	<	0.15	0.72	14.34	0.08	<		0.43	1.07	0.06	<		0.53	25.93		

			material	detail	Atom%																
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba
NG5	SOI 10	# 5	olivine	Fa98 1.0Ca 1.8Mn	55.68	<	0.70	0.49	14.19	0.11	<		0.08	0.29	0.07	<		0.53	27.84		
NG5	SOI 10	# 6	glass plus...		57.52	0.52	<	8.16	16.87	0.39	0.10		2.20	3.42	0.30	<		0.20	10.33		
NG5	SOI 10	# 7	olivine	Fa100 3.8Ca 1.5Mn	56.48	<	<	1.52	15.09	0.21	<		0.44	0.99	<	<		0.40	24.87		
NG6	SOI 7	# 1	olivine	Fa96 0.6Ca 1.5Mn	56.55	<	1.09	0.96	14.56	0.11			0.15	0.17	<			0.41	25.99		
NG6	SOI 7	# 2	olivine	Fa97 0.3Ca 1.6Mn	55.81	<	0.89	0.14	14.27	<			<	0.08	<			0.48	28.33		
NG6	SOI 7	# 3	olivine	Fa98 0.3Ca 1.3Mn	57.12	<	0.48	0.43	14.39	0.13			<	0.07	0.06			0.37	26.94		
NG6	SOI 7	# 4	olivine	Fa97 0.3Ca 1.4Mn	56.22	<	0.96	0.25	14.01	0.18			<	0.10	<			0.41	27.87		
NG6	SOI 7	# 5	glass		60.21	0.19	<	7.13	16.61	0.28			0.84	1.37	0.34			0.23	12.80		
NG6	SOI 7	# 6	glass		60.60	0.27	<	8.23	16.97	0.24			1.06	1.41	0.42			0.20	10.61		
FID1	SOI 4	# 1	hercynite	H 7% mag	55.19	<	1.77	25.17	0.38	<			<	0.05	0.47	0.21	0.46	0.22	16.09		
FID1	SOI 4	# 2	glass		59.91	0.35	<	10.19	16.11	0.34			1.64	3.41	0.38	<	<	0.21	7.46		
FID1	SOI 4	# 3	olivine	Fa90 1.0Ca 2.2Mn	55.22	<	2.94	0.62	14.53	<			<	0.30	0.08	<	<	0.66	25.66		
FID1	SOI 4	# 4	olivine	Fa89 1.7Ca 2.2Mn	56.09	<	2.97	1.43	14.45	0.12			0.22	0.46	0.08	<	<	0.61	23.56		
FID1	SOI 4	# 5	olivine	Fa91 0.6Ca 2.2Mn	55.56	<	2.55	0.23	14.47	0.12			<	0.19	<	<	<	0.64	26.24		
FID1	SOI 4	# 6	hercynite	H 8%mag	55.21	<	1.04	25.47	0.88	<			0.09	0.06	0.45	0.15	0.15	0.17	16.33		
FID1	SOI 4	# 7	hercynite	H 7% mag	55.55	<	1.68	24.15	2.22	0.07			0.33	0.10	0.32	0.15	0.21	0.19	15.04		
FID4	SOI 5	# 1	hercynite	H 6%mag	58.30	<	0.59	22.10	3.65	0.10	<		0.64	0.59	0.54			0.22	13.27		
FID4	SOI 5	# 2	olivine	Fa95 0.9Ca 2.6Mn	56.79	<	1.34	0.21	14.16	<	<		<	0.25	0.07			0.74	26.45		
FID4	SOI 5	# 3	olivine core	Fa90 1.2Ca 2.6Mn	56.92	<	2.72	1.27	14.14	0.19	<		0.22	0.32	0.06			0.71	23.45		
FID4	SOI 5	# 4	olivine core	Fa90 0.7Ca 2.6Mn	55.96	<	2.78	0.26	14.55	0.10	<		<	0.20	<			0.75	25.39		
FID4	SOI 5	# 5	olivine core	Fa91 0.8Ca 2.6Mn	56.28	0.24	2.46	0.22	14.24	<	<		<	0.22	0.06			0.76	25.51		
FID4	SOI 5	# 6	olivine	Fa97 7.8Ca 2.7Mn	59.92	0.20	0.54	3.38	15.09	0.20	<		0.97	1.57	0.18			0.54	17.41		
FID4	SOI 5	# 7	olivine core	Fa86 0.6Ca 2.2Mn	56.46	<	4.02	0.35	14.02	0.12	0.09		<	0.19	0.09			0.65	24.01		
FID4	SOI 5	# 8	late olivine	Fa97 1.9Ca 3.0Mn	55.79	<	0.72	1.12	14.85	0.16	<		0.09	0.54	0.07			0.84	25.83		
FID4	SOI 5	# 9	glass		59.86	0.42	0.12	8.21	17.55	0.39	0.08		2.11	3.97	0.45			0.25	6.61		
FID4	SOI 5	# 10	glass		60.65	0.20	0.12	7.18	17.94	0.42	0.10		1.93	3.89	0.38			0.26	6.92		

			material	detail	Atom%																
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba
FID4	SOI 5	# 11	hercynite	H 8%mag	56.39	<	0.52	24.06	2.05	0.08	<		0.32	0.36	0.70			0.23	15.28		
FID11	SOI 2	# 1	olivine inner	Fa94 0.8Ca 1.3Mn	56.21	<	1.76	0.23	14.25	0.10	<		<	0.25	<			0.39	26.81		<
FID11	SOI 2	# 2	olivine margin	Fa100 3.8Ca 1.0Mn	56.63	<	<	0.19	14.09	0.14	<		<	1.09	<			0.28	27.57		<
FID11	SOI 2	# 3	hercynite	H 15%mag	56.40	<	0.67	23.71	0.24	<	<		<	<	0.58			0.13	18.27		<
FID11	SOI 2	# 4	hercynite	H 14% mag	56.31	<	0.46	24.35	0.15	<	<		<	<	0.31			0.11	18.32		<
FID11	SOI 2	# 5	hercynite	H 23%mag	56.36	<	0.19	21.24	0.21	<	<		<	<	0.98			0.07	20.95		<
FID11	SOI 2	# 6	rhonite		59.52	<	<	7.61	10.83	0.18	<		<	5.53	1.82			<	14.51		<
FID11	SOI 2	# 7	late olivine	Fa100 6.3Ca 0.9Mn	57.66	<	<	0.22	13.89	0.32	<		0.06	1.76	<			0.26	25.83		<
FID11	SOI 2	# 8	leucite		60.11	0.89	<	10.26	19.31	0.11	<		8.12	0.11	<			<	0.51		0.58
FID11	SOI 2	# 9	glass?		60.81	1.66	<	6.33	14.67	1.54	0.30		0.47	8.65	0.14			0.08	5.01		0.33
FID11	SOI 2	# 10	rhonite		58.89	0.23	<	7.88	10.53	0.18	<		<	5.61	2.04			<	14.64		<
FID11	SOI 2	# 11	glass?		60.16	0.48	<	5.23	12.24	3.98	0.07		0.28	12.55	0.14			<	4.75		0.12
FID11	SOI 2	# 12	rhonite		59.54	0.29	<	7.61	10.76	0.18	<		<	5.49	1.92			0.07	14.15		<
FID11	SOI 2	# 13	leucite		59.77	0.37	<	9.85	19.31	0.08	<		9.77	<	<			<	0.44		0.42
FID11	SOI 2	# 14	late olivine	Fa100 9.4Ca 0.9Mn	58.03	0.27	<	0.55	13.67	0.42	<		0.09	2.53	<			0.25	24.19		<
FID11	SOI 2	# 15	rhonite		59.41	0.28	<	7.91	10.79	0.18	<		0.06	5.43	1.64			<	14.30		<
FID11	SOI 2	# 16	Al-magnetite	Mag 38%H 15%Ulvo	57.51	0.00	<	10.65	0.22	<	<		0.00	0.08	4.21			0.12	27.21		<
FID11	SOI 2	# 17	mixed sulphide		37.68	0.40	<	11.34	11.99	0.69	8.59		2.47	3.39	<			<	12.63		10.83
FID11	SOI 2	# 18	rhonite		58.69	0.42	<	8.18	12.47	0.21	<		0.97	4.93	1.38			0.06	12.69		<
FID11	SOI 2	# 19	glass?		61.36	0.53	<	4.37	10.36	4.90	0.15		0.31	13.43	0.11			<	4.37		0.11
FID11	SOI 2	# 20	rhonite		58.98	0.47	0.13	7.89	12.01	0.19	<		0.13	5.58	1.26			<	13.36		<
FID11	SOI 2	# 21	glass?		58.30	1.27	<	6.25	14.46	3.31	0.18		0.51	10.71	<			0.08	4.57		0.36
FID11	SOI 2	# 22	late olivine	Fa100 4.0Ca 0.9Mn	57.15	<	<	0.21	13.88	0.22	<		0.08	1.14	<			0.26	27.05		<
FID11	SOI 2	# 23	Al-magnetite	H 40%Mag 11%Ulvo	57.31	<	0.15	13.79	0.43	<	<		0.08	<	3.01			0.13	25.10		<
FID11	SOI 2	# 24	glass?		62.60	0.44	<	4.48	10.45	4.37	0.24		0.52	12.46	<			<	4.22		0.22
FID11	SOI 2	# 25	glass?		60.31	1.76	<	7.12	15.76	0.62	0.23		0.48	7.25	0.13			0.06	5.90		0.38

			material	detail	Atom%																
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba
FID11	SOI 10	# 1	late olivine	Fa100 12.8Ca 1.0Mn	58.78	<	<	0.51	12.93	0.91	<	<	<	3.43	<	<	<	0.26	23.18		<
FID11	SOI 10	# 2	rhonite		58.93	0.25	0.11	8.14	10.72	0.20	<	<	<	5.60	1.57	<	<	0.06	14.41		<
FID11	SOI 10	# 3	rhonite		58.82	0.24	<	7.90	11.27	0.14	<	<	0.09	5.67	1.49	<	<	0.07	14.32		<
FID11	SOI 10	# 4	glass		59.76	1.87	<	6.74	15.97	0.54	1.01	<	0.61	6.86	<	<	<	<	6.06		0.57
FID11	SOI 10	# 5	mixed phosphate		58.70	0.53	<	2.41	7.67	8.35	<	<	0.34	16.89	0.14	<	<	<	4.83		0.13
FID11	SOI 10	# 6	rhonite		58.71	0.24	<	7.74	10.71	0.39	<	<	0.09	6.25	1.47	<	<	0.10	14.29		<
FID11	SOI 10	# 7	late olivine	Fa100 12.5Ca 0.9Mn	58.28	0.24	<	0.61	13.50	0.87	<	<	<	3.32	<	<	<	0.24	22.94		<
FID11	SOI 10	# 8	hole		51.22	0.00	<	7.38	11.18	2.92	0.12	0.15	0.59	12.83	<	<	<	0.11	13.24		0.27
FID11	SOI 10	# 9	mixed phosphate		60.95	0.44	<	2.75	7.83	7.41	0.07	<	0.40	17.12	<	<	<	<	2.82		0.22
FID11	SOI 10	# 10	rhonite		60.44	0.30	<	6.83	9.70	1.16	<	<	<	7.29	1.35	<	<	<	12.92		<
FID11	SOI 10	# 11	mixed rhonite		60.62	0.48	<	7.47	11.05	1.53	0.09	<	0.30	7.78	0.63	<	<	0.06	9.97		<
FID11	SOI 10	# 12	glass/phosphate		60.37	1.76	<	7.92	15.70	0.90	0.24	<	1.14	6.49	<	<	<	<	4.57		0.91
FID11	SOI 10	# 13	glass		59.84	1.91	<	7.46	15.76	0.70	0.27	<	0.51	7.16	0.13	<	<	0.06	5.80		0.39
FID11	SOI 10	# 14	glass		62.87	1.75	<	7.10	15.94	0.56	0.31	<	0.56	5.84	0.09	<	<	<	4.55		0.43
FID11	SOI 10	# 15	mixed phosphate		62.33	0.47	<	2.49	7.69	7.32	0.07	<	0.25	15.35	0.07	<	<	<	3.85		0.12
FID11	SOI 10	# 16	hole		36.59	0.37	<	2.96	5.80	1.91	<	<	0.59	22.14	0.00	<	<	<	29.24		0.40
FID11	SOI 10	# 17	hercynite inner	H 5%mag	55.62	<	1.81	26.48	0.17	<	<	<	<	<	0.18	0.10	0.09	0.16	15.38		<
FID11	SOI 10	# 18	hercynite outer	H 19%mag	56.75	<	0.20	22.28	0.14	<	<	<	<	<	0.79	<	<	0.08	19.76		<
FID11	SOI 10	# 19	olivine	Fa100 2.7Ca 1.2Mn	56.44	<	<	0.21	14.21	0.20	<	<	<	0.79	<	<	<	0.34	27.82		<
FID12	SOI 10	# 1	hercynite inner	H 8%mag	57.28		2.21	24.24	0.40	<			<	0.05	0.29	0.08		0.18	15.26		
FID12	SOI 10	# 2	hercynite outer	H 13%mag	57.72		1.94	22.62	0.38	<			<	<	0.42	0.08		0.19	16.65		
FID12	SOI 10	# 3	hercynite	H 13%mag	57.65		0.41	23.72	0.26	<			0.10	0.08	0.45	<		0.18	17.16		
FID12	SOI 10	# 4	hercynite	H 17%mag	57.07		0.60	22.14	1.41	<			<	0.07	0.44	<		0.21	18.05		
FID12	SOI 10	# 5	iron		2.28		<	<	<	<			<	0.15	<	<		0.00	97.57		
FID12	SOI 10	# 6	wustite		53.08		<	0.89	0.71	<			0.26	0.18	0.65	<		0.18	44.05		
FID12	SOI 10	# 7	olivine (c. Wustite)	Fa96 1.6Ca 1.7Mn	57.10		1.13	0.69	12.45	<			<	0.46	0.28	<		0.50	27.39		
FID12	SOI 10	# 8	olivine inner	Fa93 1.2Ca 1.9Mn	57.57		1.95	0.44	13.68	0.13			<	0.34	<	<		0.54	25.35		

			material	detail	Atom%																
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba
FID12	SOI 10	# 9	olivine outer	Fa98 2.3Ca 1.9Mn	57.66		0.56	0.19	13.75	0.11			<	0.65	0.06	<		0.53	26.48		
FID12	SOI 10	# 10	olivine margin	Fa99 4.4Ca 1.8Mn	57.59		0.24	0.44	13.62	0.26			0.12	1.22	<	<		0.50	26.01		
FID12	SOI 11	# 1	hercynite	H 9%mag	58.09	0.17	2.25	23.36	0.30	0.07	0.00		0.00	0.00	0.25		0.17	0.17	15.16		
FID12	SOI 11	# 2	Al-magnetite	Mag 33%H	57.83	0.00	0.63	8.72	1.76	0.00	0.00		0.27	0.22	0.50		0.00	0.16	29.91		
FID12	SOI 11	# 3	Al-magnetite	Mag 33%H	58.79	0.00	0.58	8.23	2.74	0.00	0.00		0.35	0.24	0.47		0.00	0.24	28.35		
FID12	SOI 11	# 4	olivine	Fa90 0.9Ca 2.1Mn	58.06	0.00	2.80	0.52	12.97	0.12	0.00		0.00	0.26	0.08		0.00	0.58	24.62		
FID12	SOI 11	# 5	glass plus...		61.66	0.58	0.17	5.75	15.77	0.60	0.10		3.33	4.93	0.11		0.00	0.15	6.86		
FID12	SOI 11	# 6	glass		63.58	0.50	0.09	6.97	15.78	0.55	0.15		3.55	3.27	0.15		0.00	0.09	5.32		
FID12	SOI 11	# 7	olivine?	Fa93 3.1Ca 2.1Mn	57.53	0.00	2.18	0.83	10.40	0.10	0.00		0.09	0.96	0.00		0.00	0.66	27.25		
FID12	SOI 11	# 8	magnetite	Mag 2%h	53.39	0.00	0.57	0.47	0.86	0.00	0.00		0.00	0.24	0.00		0.00	0.44	44.03		
FID12	SOI 11	# 9	magnetite	Mag 1%h	53.40	0.00	0.60	0.30	0.40	0.00	0.00		0.00	0.10	0.00		0.00	0.39	44.83		
FID12	SOI 11	# 10	mixed?		58.95	0.00	1.66	4.05	10.64	0.25	0.00		1.13	1.21	0.16		0.00	0.44	21.51		
FID12	SOI 11	# 11	glass		60.41	0.46	0.18	6.19	15.04	0.50	0.06		2.76	5.22	0.13		0.00	0.23	8.83		
FID12	SOI 11	# 12	magnetite/haematite	Mag 5%h	57.59	0.00	0.35	1.37	0.56	0.00	0.00		0.07	0.15	0.00		0.00	0.21	39.70		
FID12	SOI 12	# 1	olivine (c. Wustite)	Fa87 0.9Ca 1.9Mn	57.74	<	3.67	0.34	12.71	0.19	<		<	0.25	<		<	0.57	24.54		
FID12	SOI 12	# 2	olivine inner	Fa95 1.4Ca 2.3Mn	58.25	<	1.21	0.18	13.70	0.08	<		<	0.39	<		<	0.64	25.55		
FID12	SOI 12	# 3	olivine outer	Fa99 7.0Ca 1.7Mn	59.99	0.21	0.14	2.59	13.31	0.48	<		1.10	1.56	0.08		<	0.37	20.17		
FID12	SOI 12	# 4	olivine outer	Fa99 2.9Ca 1.8Mn	59.06	<	0.36	0.26	13.18	0.28	<		0.09	0.78	0.06		<	0.49	25.44		
FID12	SOI 12	# 5	hercynite	H 15%Mag	58.29	<	0.46	22.47	0.69	0.07	<		<	<	0.55		<	0.16	17.31		
FID12	SOI 12	# 6	mixed late olivine		59.37	0.32	<	2.84	13.38	0.58	<		1.05	1.80	0.09		<	0.35	20.21		
FID12	SOI 12	# 7	glass		60.03	0.46	<	7.77	13.06	1.00	0.18		3.85	4.77	0.33		<	0.07	8.49		
FID12	SOI 12	# 8	hercynite	H 8%mag	57.85	0.16	2.10	24.04	0.32	<	<		<	<	0.28		0.09	0.14	15.03		
FID12	SOI 12	# 9	hercynite	H 12%mag	58.65	<	2.00	22.23	0.71	0.11	<		<	<	0.34		<	0.16	15.80		
FID12	SOI 12	# 10	magnetite (!)	Mag 4%h	53.45	<	<	1.32	1.21	<	<		0.30	0.19	0.61		<	0.13	42.79		
FID12	SOI 12	# 11	glass plus...		60.61	0.43	<	6.95	13.48	0.98	0.22		2.99	5.60	0.28		<	0.15	8.30		
FID12	SOI 12	# 12	wustite/magnetite	Mag 4%h	51.66	<	<	1.35	0.39	<	<		<	0.07	0.44		<	0.23	45.86		

Table 7: EDS microanalyses expressed as wt%

			Wt%																	
			O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba	*Total*
NG2	SOI 11	# 1	42.65	0.18	0.13	9.35	22.03	0.12	<		1.71	2.51	0.72			0.57	19.79			*99.75*
NG2	SOI 11	# 2	42.51	0.30	0.17	9.52	22.21	0.11	0.10		1.81	2.61	0.71			0.68	19.45			*100.18*
NG2	SOI 11	# 3	31.96	<	0.98	0.22	14.07	<	<		<	0.13	<			1.30	52.72			*101.38*
NG2	SOI 11	# 4	31.75	<	1.46	0.16	13.94	<	<		<	0.10	<			1.26	52.69			*101.36*
NG2	SOI 12	# 1	40.28			1.46	4.27	0.17	<		0.12	0.31					56.58			*103.19*
NG2	SOI 12	# 2	37.16			0.12	0.59	<	<		<	<					61.01			*98.88*
NG2	SOI 12	# 3	30.34			<	0.80	<	<		<	<					70.62			*101.76*
NG2	SOI 12	# 4	27.83			0.11	0.14	<	<		<	<					72.15			*100.23*
NG2	SOI 12	# 5	28.78			<	1.07	<	<		<	<					70.77			*100.63*
NG2	SOI 12	# 6	28.02			<	0.90	<	<		<	<					69.58			*98.50*
NG2	SOI 12	# 7	33.51			<	1.26	<	<		<	<					58.43			*93.21*
NG2	SOI 12	# 8	27.98			<	0.59	<	<		<	<					71.24			*99.82*
NG2	SOI 13	# 1															101.45			*101.45*
NG2	SOI 14	# 1	0.85			<	<	<	<			<					97.63	0.00		*98.48*
NG2	SOI 14	# 2	1.68			<	<	<	33.93			<					63.49	0.42		*99.53*
NG2	SOI 14	# 3	0.71			<	<	<	<			<					104.02	0.00		*104.73*
NG2	SOI 14	# 4	27.00			0.20	0.09	<	0.10			0.38					68.77	0.24		*96.77*
NG2	SOI 14	# 5	33.91			0.40	0.24	0.20	0.41			0.28					57.38	0.00		*92.81*
NG2	SOI 15	# 1	42.98	0.21	0.12	9.53	22.87	0.09			1.93	2.49	0.69			0.58	19.56			*101.06*
NG2	SOI 15	# 2	41.97	0.15	0.16	9.61	22.39	0.16			2.18	2.50	0.61			0.54	16.56			*96.82*
NG2	SOI 15	# 3	31.44	<	1.41	0.10	13.97	<			<	0.00	0.10			1.39	51.34			*99.75*
NG2	SOI 15	# 4	31.69	<	0.74	1.18	14.86	<			0.18	0.23	0.15			1.27	50.38			*100.69*

			Wt%																	
			O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba	*Total*
NG2	SOI 15	# 5	30.25	<	1.33	0.24	13.56	<			0.19	0.25	<			1.13	49.12			*96.07*
NG2	SOI 15	# 6	32.38	<	1.35	0.18	14.42	<			<	0.00	<			1.42	54.61			*104.36*
NG2	SOI 15	# 7	32.41	<	1.35	0.13	14.43	<			<	0.12	<			1.27	54.15			*103.87*
NG3	SOI 3	# 1	29.70		0.69	1.32	13.29				0.21	0.26				0.68	49.90			*96.05*
NG3	SOI 3	# 2	29.96		1.40	0.34	13.19				<	0.22				0.73	50.26			*96.09*
NG3	SOI 3	# 3	30.11		1.22	0.17	13.50				<	0.15				0.76	51.39			*97.31*
NG3	SOI 3	# 4	29.96		1.35	0.23	13.34				<	0.12				0.76	51.67			*97.43*
NG3	SOI 3	# 5	30.03		1.23	0.18	13.53				<	0.11				0.82	51.93			*97.84*
NG3	SOI 3	# 6	29.86		0.46	0.16	13.48				<	0.15				0.61	53.50			*98.22*
NG3	SOI 4	# 1	29.48	<	0.23	0.28	13.33	<	<		<	0.22	<	<		0.83	53.24			*97.62*
NG3	SOI 4	# 2	33.72	<	<	19.36	3.13	0.08	<		0.91	0.20	1.11	<		0.27	39.15			*97.93*
NG3	SOI 4	# 3	31.50	<	0.13	17.66	0.67	<	<		<	0.00	1.52	0.14		0.26	46.47			*98.35*
NG3	SOI 4	# 4	31.81	<	<	18.41	0.39	<	<		0.09	0.08	1.73	<		0.16	46.08			*98.75*
NG3	SOI 4	# 5	32.88	<	0.13	18.60	1.19	<	0.09		0.21	0.16	1.83	<		0.27	44.89			*100.36*
NG3	SOI 4	# 6	32.44	<	0.13	17.15	0.71	<	<		0.10	0.00	1.66	<		0.24	49.63			*102.06*
NG3	SOI 4	# 7	41.96	0.53	<	9.99	21.26	0.59	0.22		4.81	4.97	0.68	<		0.00	14.46			*99.47*
NG3	SOI 4	# 8	40.29	0.39	<	9.68	19.95	0.55	0.29		4.09	5.37	0.80	<		0.25	17.15			*98.80*
NG3	SOI 4	# 9	40.29	0.40	<	10.15	19.22	0.48	0.17		3.52	5.57	0.68	<		0.20	17.37			*98.05*
NG3	SOI 4	# 10	30.37	<	<	0.22	13.81	0.11	<		<	0.40	0.12	<		0.74	54.84			*100.61*
NG3	SOI 4	# 11	30.25	<	0.17	0.26	13.55	0.18	<		<	0.35	<	<		0.66	54.08			*99.50*
NG3	SOI 4	# 12	30.22	<	0.16	0.18	13.48	0.12	<		<	0.36	<	<		0.70	53.62			*98.84*
NG3	SOI 4	# 13	30.50	<	0.59	0.16	13.90	<	<		<	0.15	<	<		0.71	54.18			*100.19*
NG3	SOI 4	# 14	30.28	<	0.22	0.21	13.67	0.11	<		<	0.20	<	<		0.69	54.01			*99.39*
NG3	SOI 4	# 15	30.73	<	0.17	13.98	0.59	<	<		<	0.09	2.09	<		0.17	51.11			*98.94*
NG3	SOI 4	# 16	33.30	<	0.00	19.87	0.48	<	<		0.13	0.00	1.34	<		0.24	45.90			*101.26*
NG3	SOI 4	# 17	31.80	<	0.13	17.48	0.35	0.08	<		<	0.00	1.41	0.12		0.21	48.06			*99.65*
NG3	SOI 4	# 18	30.70	<	0.12	12.39	1.02	<	<		0.18	0.19	2.06	0.23		0.28	51.85			*99.02*

			Wt%																	
			O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba	*Total*
NG3	SOI 5	# 1	30.42	<	0.13	0.17	13.73	0.11			<	0.27	<			0.69	54.69			*100.20*
NG3	SOI 5	# 2	29.43	<	0.12	0.21	13.39	0.08			<	0.34	<			0.74	53.55			*97.86*
NG3	SOI 5	# 3	30.14	<	<	0.43	13.26	0.14			0.24	0.54	0.11			0.65	51.26			*96.76*
NG3	SOI 5	# 4	28.27	<	<	10.92	0.65	<			<	<	2.17			0.19	52.14			*94.35*
NG3	SOI 5	# 5	29.33	<	<	14.59	0.45	<			<	0.08	2.03			0.23	47.38			*94.10*
NG3	SOI 5	# 6	31.65	<	<	1.41	14.06	0.24			0.92	1.34	0.19			0.47	45.45			*95.74*
NG3	SOI 5	# 7	50.41	<	<	49.50	1.62	0.26			0.30	0.52	<			<	2.06			*104.67*
NG5	SOI 8	# 1	27.62	<	0.35	1.16	1.62	<			<	0.22	<			0.43	69.77			*101.17*
NG5	SOI 8	# 2	31.10	<	2.30	1.07	12.13	<			0.12	0.65	<			1.42	50.90			*99.69*
NG5	SOI 8	# 3	27.58	<	0.38	1.20	2.00	<			<	0.25	<			0.42	68.91			*100.74*
NG5	SOI 8	# 4	31.96	<	2.24	0.93	13.66	0.15			0.23	0.78	<			1.46	50.21			*101.62*
NG5	SOI 8	# 5	29.03	<	0.26	4.76	2.29	<			0.23	0.25	0.87			0.35	60.77			*98.81*
NG5	SOI 8	# 6	28.44	<	0.30	5.11	2.36	<			0.18	0.17	1.05			0.33	60.38			*98.30*
NG5	SOI 8	# 7	31.01	<	0.88	4.20	10.86	0.17			0.39	0.78	0.24			0.84	47.64			*96.99*
NG5	SOI 8	# 8	31.04	<	1.96	1.14	13.19	0.13			0.19	0.75	<			1.46	51.93			*101.78*
NG5	SOI 8	# 9	31.85	<	2.07	1.08	13.70	0.18			0.25	0.84	<			1.36	49.13			*100.48*
NG5	SOI 8	# 10	31.66	0.22	0.40	4.01	10.79	0.17			0.89	1.84	0.13			0.61	47.85			*98.56*
NG5	SOI 9	# 1	29.66	<	2.06	0.32	13.57				<	0.21				0.99	49.88			*96.68*
NG5	SOI 9	# 2	30.50	<	2.09	0.36	13.67				<	0.22				1.05	49.98			*97.87*
NG5	SOI 9	# 3	32.14	<	1.71	0.60	14.11				0.41	0.79				0.87	48.99			*99.61*
NG5	SOI 9	# 4	29.90	<	2.18	0.41	13.39				<	0.24				0.99	49.23			*96.34*
NG5	SOI 9	# 5	30.92	<	0.70	0.36	13.77				0.09	0.31				0.97	54.00			*101.12*
NG5	SOI 10	# 1	34.96	<	0.12	22.73	0.92	0.08	<		0.19	0.34	1.71	<		0.43	41.08			*102.57*
NG5	SOI 10	# 2	31.57	<	0.27	0.31	14.15	0.15	<		0.19	0.67	0.11	<		0.95	53.88			*102.26*
NG5	SOI 10	# 3	31.93	<	0.26	19.16	1.01	0.11	<		<	0.09	1.81	0.19		0.30	45.47			*100.32*
NG5	SOI 10	# 4	30.79	<	0.12	0.66	13.68	0.09	<		0.57	1.46	0.10	<		0.99	49.17			*97.63*

			Wt%																	
			O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba	*Total*
NG5	SOI 10	# 5	30.18	<	0.58	0.45	13.50	0.12	<		0.11	0.40	0.11	<		0.99	52.67			*99.11*
NG5	SOI 10	# 6	37.35	0.48	<	8.93	19.23	0.49	0.13		3.49	5.57	0.59	<		0.44	23.41			*100.11*
NG5	SOI 10	# 7	32.43	<	<	1.47	15.21	0.23	<		0.62	1.42	<	<		0.79	49.85			*102.02*
NG6	SOI 7	# 1	31.56	<	0.92	0.90	14.27	0.12			0.20	0.24	<			0.78	50.64			*99.65*
NG6	SOI 7	# 2	30.03	<	0.73	0.13	13.48	<			<	0.11	<			0.89	53.21			*98.58*
NG6	SOI 7	# 3	32.84	<	0.42	0.42	14.53	0.14			<	0.11	0.10			0.74	54.07			*103.36*
NG6	SOI 7	# 4	31.55	<	0.82	0.23	13.80	0.19			<	0.14	<			0.79	54.60			*102.13*
NG6	SOI 7	# 5	39.22	0.18	<	7.84	18.99	0.35			1.34	2.24	0.66			0.51	29.12			*100.44*
NG6	SOI 7	# 6	40.71	0.26	<	9.32	20.01	0.31			1.74	2.37	0.84			0.46	24.87			*100.90*
FID1	SOI 4	# 1	33.62	<	1.64	25.86	0.40	<			<	0.08	0.85	0.40	0.91	0.46	34.21			*98.42*
FID1	SOI 4	# 2	39.44	0.33	<	11.31	18.62	0.43			2.65	5.62	0.75	<	<	0.47	17.14			*96.76*
FID1	SOI 4	# 3	30.22	<	2.45	0.57	13.96	0.00			<	0.41	0.12	<	<	1.23	49.01			*97.97*
FID1	SOI 4	# 4	31.82	<	2.56	1.37	14.39	<			0.31	0.65	0.14	<	<	1.19	46.66			*99.23*
FID1	SOI 4	# 5	30.29	<	2.11	0.21	13.85	0.13			<	0.26	<	<	<	1.20	49.94			*97.99*
FID1	SOI 4	# 6	33.63	<	0.96	26.17	0.95	<			0.13	0.10	0.82	0.29	0.29	0.36	34.71			*98.41*
FID1	SOI 4	# 7	34.94	<	1.60	25.62	2.45	0.08			0.51	0.15	0.61	0.30	0.43	0.40	33.03			*100.14*
FID4	SOI 5	# 1	38.77	<	0.60	24.79	4.26	0.13	<		1.04	0.98	1.07			0.50	30.80			*102.93*
FID4	SOI 5	# 2	30.87	<	1.11	0.19	13.51	<	<		<	0.35	0.11			1.38	50.19			*97.71*
FID4	SOI 5	# 3	32.23	<	2.34	1.21	14.06	0.21	<		0.31	0.46	0.11			1.38	46.34			*98.64*
FID4	SOI 5	# 4	30.62	<	2.32	0.24	13.97	0.11	<		<	0.27	<			1.41	48.50			*97.44*
FID4	SOI 5	# 5	31.19	0.19	2.07	0.20	13.86	<	<		<	0.30	0.10			1.45	49.36			*98.73*
FID4	SOI 5	# 6	38.19	0.18	0.52	3.63	16.88	0.25	<		1.52	2.51	0.33			1.18	38.74			*103.93*
FID4	SOI 5	# 7	32.15	<	3.48	0.34	14.02	0.14	0.10		<	0.26	0.15			1.27	47.73			*99.63*
FID4	SOI 5	# 8	30.76	<	0.60	1.04	14.37	0.17	<		0.11	0.75	0.12			1.58	49.71			*99.22*
FID4	SOI 5	# 9	39.54	0.40	0.12	9.14	20.35	0.49	0.10		3.40	6.56	0.89			0.57	15.23			*96.80*
FID4	SOI 5	# 10	40.53	0.19	0.13	8.09	21.05	0.54	0.13		3.15	6.52	0.77			0.61	16.14			*97.84*

			Wt%																	
			O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba	*Total*
FID4	SOI 5	# 11	35.55	<	0.49	25.58	2.27	0.10	<		0.50	0.57	1.32			0.50	33.64			*100.52*
FID11	SOI 2	# 1	30.90	<	1.47	0.21	13.75	0.11	<		<	0.34	<			0.73	51.44		<	*98.95*
FID11	SOI 2	# 2	30.75	<	<	0.17	13.44	0.15	<		<	1.49	<			0.53	52.26		<	*98.79*
FID11	SOI 2	# 3	33.36	<	0.60	23.66	0.25	<	<		<	<	1.02			0.26	37.72		<	*96.87*
FID11	SOI 2	# 4	33.51	<	0.41	24.43	0.15	<	<		<	<	0.55			0.22	38.05		<	*97.33*
FID11	SOI 2	# 5	32.69	<	0.16	20.78	0.21	<	<		<	<	1.70			0.14	42.42		<	*98.11*
FID11	SOI 2	# 6	36.40	<	<	7.85	11.63	0.21	<		<	8.48	3.33			<	30.98		<	*98.88*
FID11	SOI 2	# 7	31.83	<	<	0.21	13.46	0.34	<		0.08	2.43	<			0.50	49.77		<	*98.61*
FID11	SOI 2	# 8	40.72	0.87	<	11.72	22.97	0.14	<		13.44	0.19	<			<	1.20		3.40	*94.65*
FID11	SOI 2	# 9	40.61	1.60	<	7.13	17.19	1.99	0.41		0.77	14.47	0.28			0.18	11.69		1.86	*98.18*
FID11	SOI 2	# 10	36.13	0.20	<	8.15	11.34	0.22	<		<	8.62	3.74			<	31.34		<	*99.75*
FID11	SOI 2	# 11	40.26	0.46	<	5.90	14.37	5.16	0.09		0.45	21.04	0.28			<	11.10		0.69	*99.81*
FID11	SOI 2	# 12	37.34	0.26	<	8.05	11.84	0.22	<		<	8.63	3.60			0.15	30.98		<	*101.06*
FID11	SOI 2	# 13	40.36	0.36	<	11.21	22.89	0.10	<		16.12	<	<			<	1.03		2.43	*94.49*
FID11	SOI 2	# 14	33.64	0.23	<	0.53	13.91	0.47	<		0.13	3.67	<			0.49	48.95		<	*102.03*
FID11	SOI 2	# 15	37.81	0.26	<	8.49	12.06	0.22	<		0.09	8.66	3.12			<	31.78		<	*102.48*
FID11	SOI 2	# 16	30.91	<	<	9.66	0.21	0.00	<		<	0.11	6.77			0.22	51.04		<	*98.92*
FID11	SOI 2	# 17	8.60	0.13	<	4.37	4.81	0.30	3.93		1.38	1.94	<			<	10.07		21.24	*56.76*
FID11	SOI 2	# 18	38.71	0.40	<	9.10	14.44	0.27	<		1.56	8.14	2.73			0.14	29.21		<	*104.70*
FID11	SOI 2	# 19	40.12	0.50	<	4.82	11.89	6.20	0.19		0.50	22.00	0.22			<	9.98		0.63	*97.05*
FID11	SOI 2	# 20	38.26	0.44	0.12	8.64	13.68	0.24	<		0.20	9.07	2.45			<	30.26		<	*103.36*
FID11	SOI 2	# 21	37.25	1.17	<	6.74	16.23	4.09	0.23		0.80	17.15	<			0.17	10.19		1.98	*95.99*
FID11	SOI 2	# 22	31.01	<	<	0.19	13.22	0.23	<		0.11	1.55	<			0.49	51.24		<	*98.04*
FID11	SOI 2	# 23	31.60	<	0.12	12.82	0.42	<	<		0.11	<	4.97			0.25	48.31		<	*98.60*
FID11	SOI 2	# 24	42.58	0.43	<	5.14	12.48	5.75	0.32		0.87	21.24	<			<	10.02		1.29	*100.12*
FID11	SOI 2	# 25	39.21	1.65	<	7.81	17.99	0.78	0.30		0.77	11.80	0.24			0.14	13.38		2.14	*96.21*
FID11	SOI 10	# 1	34.01	<	<	0.50	13.14	1.02	<	<	<	4.97	<	<	<	0.53	46.81		<	*100.98*

			Wt%																	
			O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba	*Total*
FID11	SOI 10	# 2	36.48	0.22	0.11	8.50	11.66	0.24	<	<	<	8.68	2.92	<	<	0.14	31.13		<	*100.08*
FID11	SOI 10	# 3	36.52	0.22	<	8.27	12.28	0.17	<	<	0.13	8.81	2.77	<	<	0.14	31.04		<	*100.35*
FID11	SOI 10	# 4	38.85	1.75	<	7.38	18.23	0.68	1.32	<	0.96	11.18	<	<	<	<	13.75		3.17	*97.27*
FID11	SOI 10	# 5	34.11	0.44	<	2.37	7.83	9.40	<	<	0.49	24.59	0.25	<	<	<	9.79		0.66	*89.93*
FID11	SOI 10	# 6	34.35	0.21	<	7.63	11.00	0.44	<	<	0.13	9.16	2.57	<	<	0.20	29.19		<	*94.89*
FID11	SOI 10	# 7	33.17	0.20	<	0.59	13.49	0.96	<	<	<	4.73	<	<	<	0.47	45.56		<	*99.15*
FID11	SOI 10	# 8	16.58	0.00	<	4.03	6.35	1.83	0.08	0.11	0.47	10.41	<	<	<	0.12	14.96		0.74	*55.67*
FID11	SOI 10	# 9	37.29	0.39	<	2.84	8.41	8.77	0.08	<	0.60	26.23	<	<	<	<	6.03		1.17	*91.80*
FID11	SOI 10	# 10	37.35	0.27	<	7.12	10.53	1.39	0.00	<	<	11.29	2.50	<	<	0.00	27.88		<	*98.32*
FID11	SOI 10	# 11	39.35	0.45	<	8.18	12.59	1.92	0.12	<	0.48	12.66	1.23	<	<	0.13	22.60		<	*99.72*
FID11	SOI 10	# 12	39.45	1.66	<	8.72	18.02	1.14	0.31	<	1.83	10.63	<	<	<	<	10.42		5.09	*97.26*
FID11	SOI 10	# 13	39.84	1.83	<	8.38	18.42	0.90	0.37	<	0.83	11.94	0.26	<	<	0.13	13.48		2.20	*98.59*
FID11	SOI 10	# 14	46.74	1.87	<	8.90	20.81	0.80	0.46	<	1.02	10.87	0.20	<	<	<	11.82		2.72	*106.22*
FID11	SOI 10	# 15	42.60	0.46	<	2.87	9.22	9.69	0.09	<	0.42	26.28	0.15	<	<	<	9.18		0.68	*101.63*
FID11	SOI 10	# 16	4.81	0.07	<	0.66	1.34	0.49	<	<	0.19	7.29	0.00	<	<	<	13.42		0.45	*28.71*
FID11	SOI 10	# 17	33.88	<	1.67	27.20	0.19	<	<	<	<	<	0.33	0.20	0.19	0.33	32.71		<	*96.69*
FID11	SOI 10	# 18	33.81	<	0.18	22.38	0.14	<	<	<	<	<	1.41	<	<	0.16	41.09		<	*99.19*
FID11	SOI 10	# 19	30.04	<	<	0.18	13.28	0.20	<	<	<	1.06	<	<	<	0.63	51.69		<	*97.08*
FID12	SOI 10	# 1	37.42		2.19	26.71	0.46	<			<	0.09	0.58	0.18		0.41	34.80			*102.83*
FID12	SOI 10	# 2	37.06		1.89	24.49	0.42	<			<	<	0.81	0.17		0.41	37.33			*102.60*
FID12	SOI 10	# 3	36.79		0.40	25.52	0.29	<			0.15	0.12	0.86	<		0.38	38.21			*102.72*
FID12	SOI 10	# 4	35.83		0.58	23.44	1.56	<			<	0.11	0.83	<		0.45	39.56			*102.37*
FID12	SOI 10	# 5	0.67		<	<	<	<			<	0.11	<	<		0.00	99.88			*100.66*
FID12	SOI 10	# 6	25.34		<	0.71	0.59	<			0.30	0.22	0.93	<		0.30	73.40			*101.80*
FID12	SOI 10	# 7	33.00		0.99	0.67	12.63	<			<	0.67	0.48	<		0.99	55.26			*104.69*
FID12	SOI 10	# 8	32.87		1.69	0.42	13.71	0.15			<	0.49	<	<		1.07	50.53			*100.92*
FID12	SOI 10	# 9	32.46		0.48	0.18	13.59	0.12			<	0.92	0.10	<		1.02	52.04			*100.93*
FID12	SOI 10	# 10	32.39		0.20	0.42	13.45	0.28			0.16	1.72	<	<		0.97	51.06			*100.65*

			Wt%																	
			O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Ba	*Total*
FID12	SOI 11	# 1	38.86	0.17	2.29	26.36	0.36	0.09	<		<	<	0.50		0.36	0.40	35.40			*104.80*
FID12	SOI 11	# 2	32.00	<	0.53	8.13	1.71	<	<		0.36	0.31	0.83		<	0.31	57.78			*101.96*
FID12	SOI 11	# 3	34.07	<	0.52	8.04	2.79	<	<		0.49	0.35	0.82		<	0.47	57.34			*104.90*
FID12	SOI 11	# 4	33.71	<	2.47	0.51	13.22	0.13	<		0.00	0.37	0.14		<	1.16	49.90			*101.62*
FID12	SOI 11	# 5	43.36	0.59	0.18	6.82	19.46	0.82	0.14		5.72	8.68	0.24		<	0.36	16.83			*103.20*
FID12	SOI 11	# 6	47.81	0.55	0.10	8.84	20.83	0.79	0.23		6.52	6.17	0.33		<	0.22	13.96			*106.35*
FID12	SOI 11	# 7	33.68	<	1.94	0.82	10.69	0.12	<		0.14	1.40	<		<	1.32	55.69			*105.79*
FID12	SOI 11	# 8	25.52	<	0.42	0.38	0.72	<	<		<	0.29	<		<	0.72	73.47			*101.52*
FID12	SOI 11	# 9	25.61	<	0.44	0.24	0.33	<	<		<	0.12	<		<	0.63	75.05			*102.42*
FID12	SOI 11	# 10	36.61	<	1.57	4.24	11.60	0.30	<		1.71	1.88	0.29		<	0.94	46.63			*105.78*
FID12	SOI 11	# 11	40.95	0.45	0.18	7.08	17.90	0.65	0.08		4.57	8.87	0.27		<	0.53	20.89			*102.42*
FID12	SOI 11	# 12	29.24	<	0.27	1.18	0.50	<	<		0.08	<	<		<	0.36	70.36			*102.18*
FID12	SOI 12	# 1	34.17	<	3.30	0.34	13.20	0.21	<		<	0.37	<		<	1.15	50.69			*103.43*
FID12	SOI 12	# 2	34.42	<	1.09	0.18	14.21	0.09	<		<	0.58	<		<	1.31	52.70			*104.57*
FID12	SOI 12	# 3	39.42	0.20	0.14	2.87	15.36	0.61	<		1.77	2.57	0.16		<	0.84	46.25			*110.18*
FID12	SOI 12	# 4	35.05	<	0.32	0.26	13.73	0.32	<		0.13	1.15	0.10		<	1.00	52.69			*104.78*
FID12	SOI 12	# 5	37.84	<	0.45	24.60	0.79	0.09	<		<	<	1.07		<	0.36	39.22			*104.42*
FID12	SOI 12	# 6	38.32	0.30	<	3.09	15.16	0.73	<		1.65	2.92	0.17		<	0.79	45.54			*108.66*
FID12	SOI 12	# 7	41.60	0.46	<	9.08	15.88	1.35	0.26		6.52	8.28	0.68		<	0.17	20.53			*104.79*
FID12	SOI 12	# 8	38.70	0.15	2.13	27.12	0.37	<	<		<	<	0.56		0.19	0.32	35.10			*104.64*
FID12	SOI 12	# 9	39.06	<	2.02	24.97	0.83	0.15	<		<	<	0.69		<	0.37	36.73			*104.81*
FID12	SOI 12	# 10	26.37	<	<	1.10	1.05	<	<		0.36	0.23	0.89		<	0.22	73.68			*103.92*
FID12	SOI 12	# 11	42.14	0.43	<	8.15	16.45	1.31	0.30		5.09	9.76	0.58		<	0.37	20.16			*104.76*
FID12	SOI 12	# 12	23.56	<	<	1.04	0.32	<	<		<	0.09	0.59		<	0.35	73.00			*98.95*

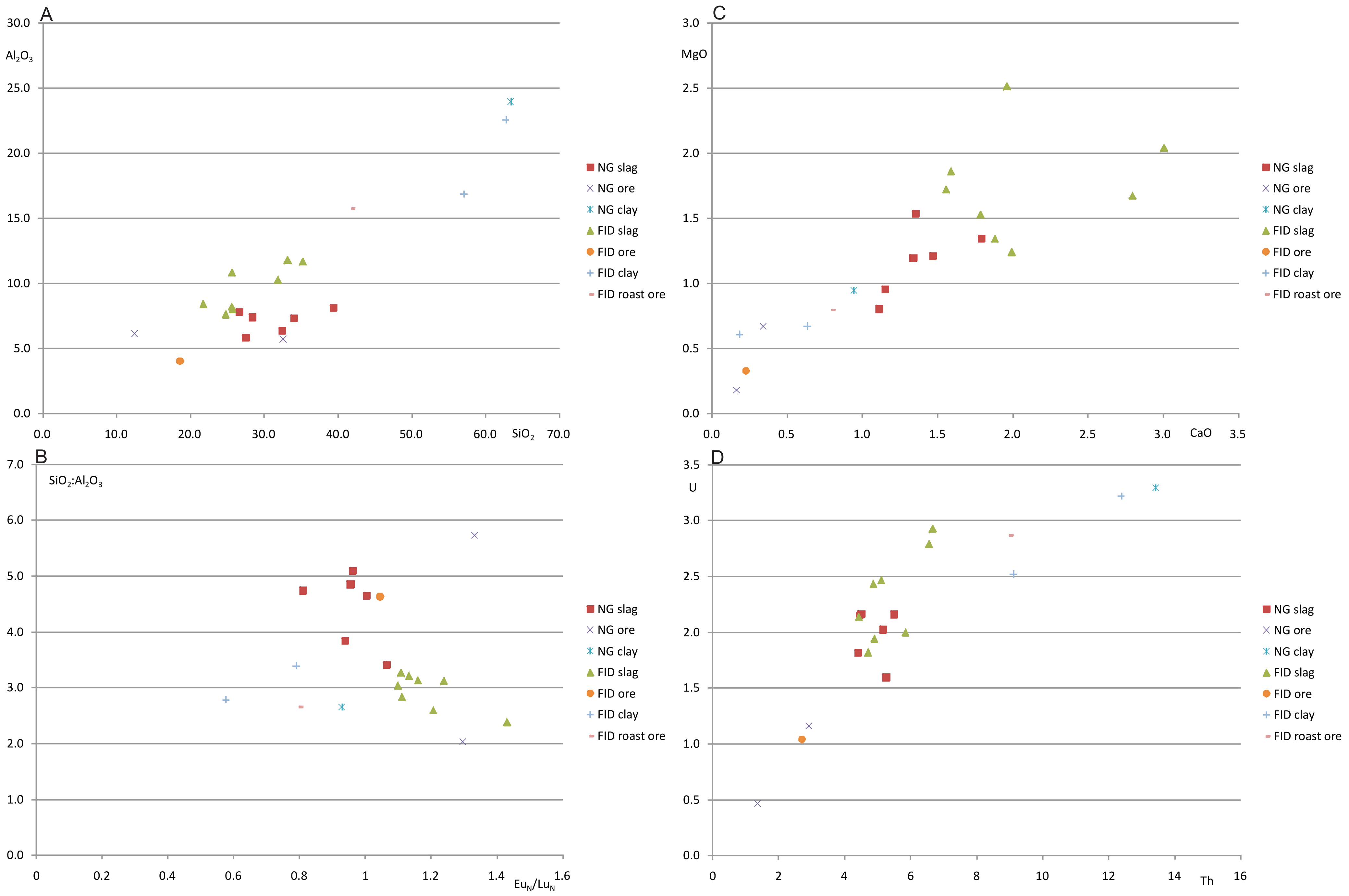
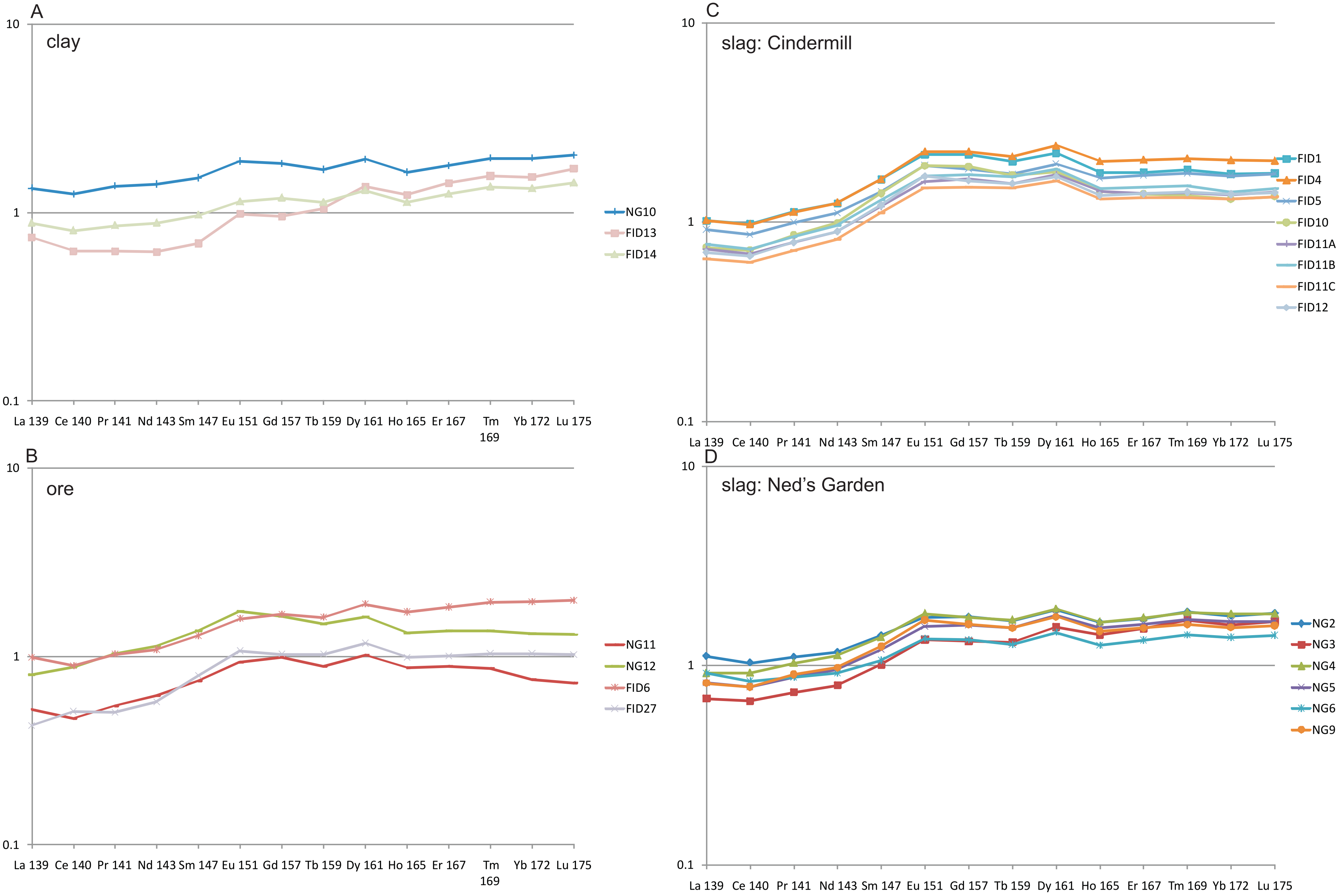

A
Al$_2$O$_3$
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
SiO$_2$
70.0
C
MgO
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
CaO
3.5
B
SiO$_2$:Al$_2$O$_3$
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Eu$_N$/Lu$_N$
D
U
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
14
Th
16
NG slag
NG ore
NG clay
FID slag
FID ore
FID clay
FID roast ore

Figure 1

Figure 2


A
clay
10
1
0.1
La 139
Ce 140
Pr 141
Nd 143
Sm 147
Eu 151
Gd 157
Tb 159
Dy 161
Ho 165
Er 167
Tm 169
Yb 172
Lu 175
NG10
FID13
FID14
B
ore
NG11
NG12
FID6
FID27
C
slag: Cindermill
FID1
FID4
FID5
FID10
FID11A
FID11B
FID11C
FID12
D
slag: Ned’s Garden
NG2
NG3
NG4
NG5
NG6
NG9

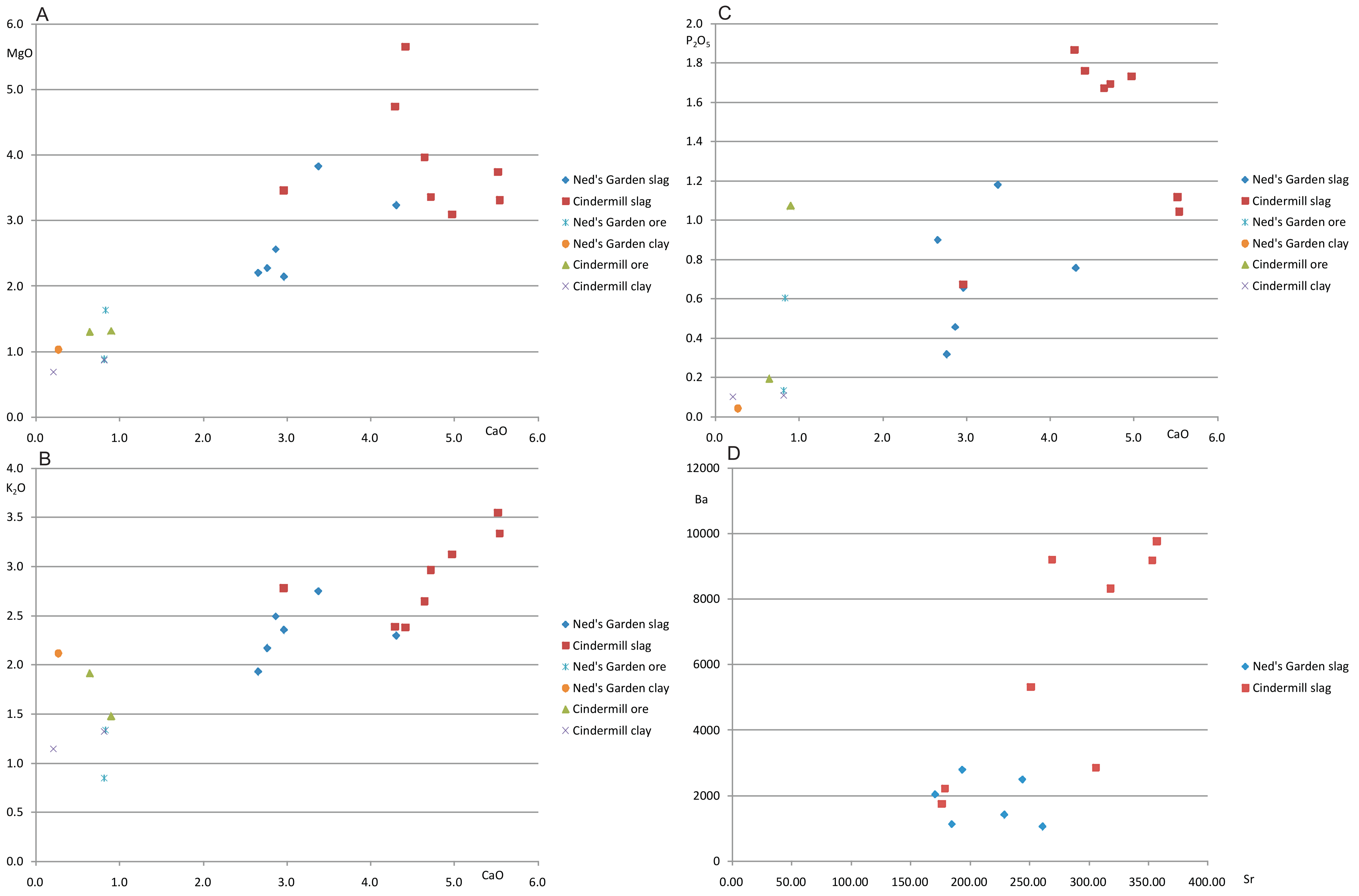

A
MgO
6.0
5.0
4.0
3.0
2.0
1.0
0.0
CaO
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Ned's Garden slag
Cindermill slag
Ned's Garden ore
Ned's Garden clay
Cindermill ore
Cindermill clay
B
K_2O
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
CaO
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Ned's Garden slag
Cindermill slag
Ned's Garden ore
Ned's Garden clay
Cindermill ore
Cindermill clay
C
P_2O_5
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
CaO
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Ned's Garden slag
Cindermill slag
Ned's Garden ore
Ned's Garden clay
Cindermill ore
Cindermill clay
D
Ba
12000
10000
8000
6000
4000
2000
0
Sr
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
Ned's Garden slag
Cindermill slag

Figure 3

Figure 4

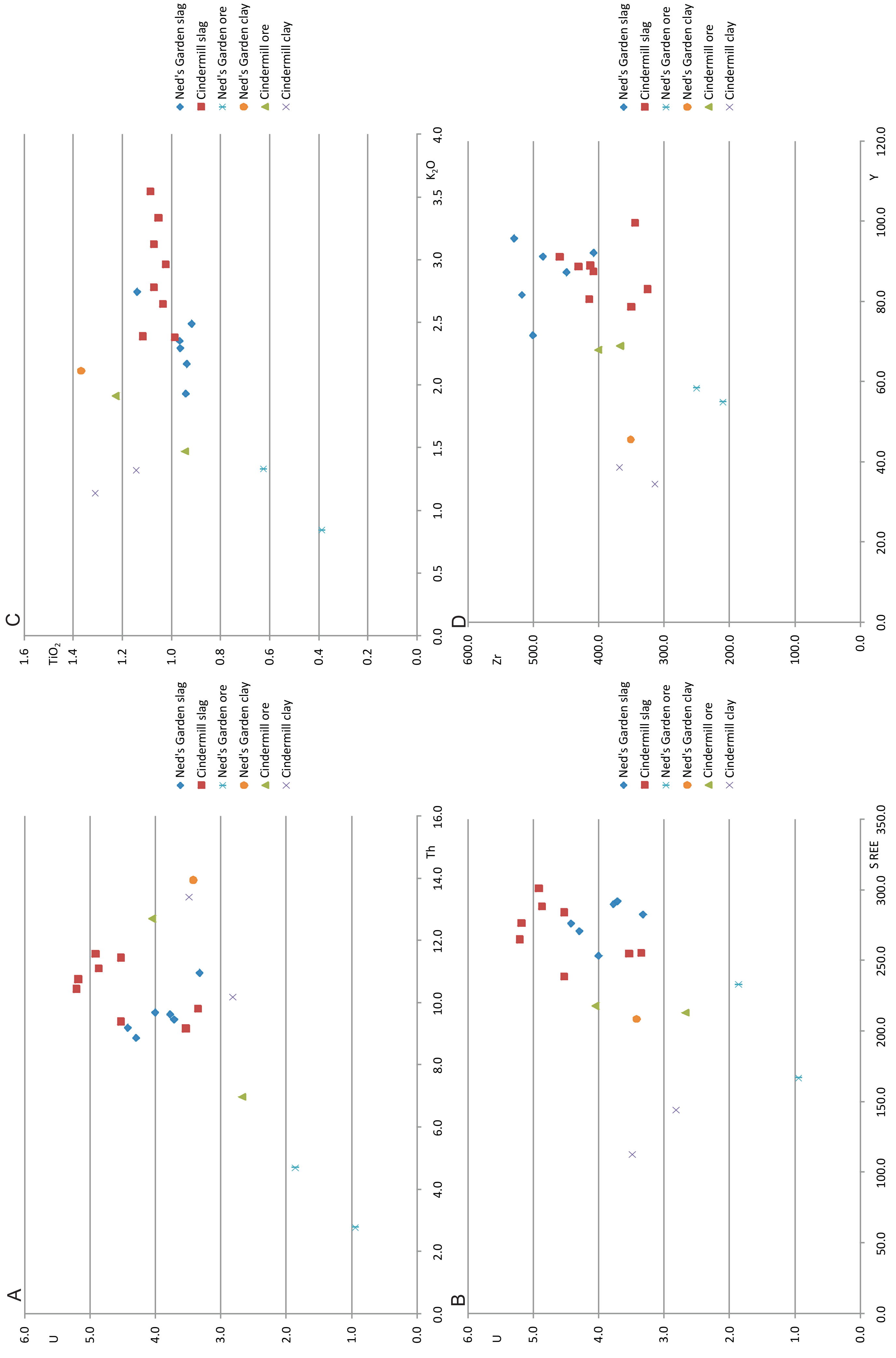
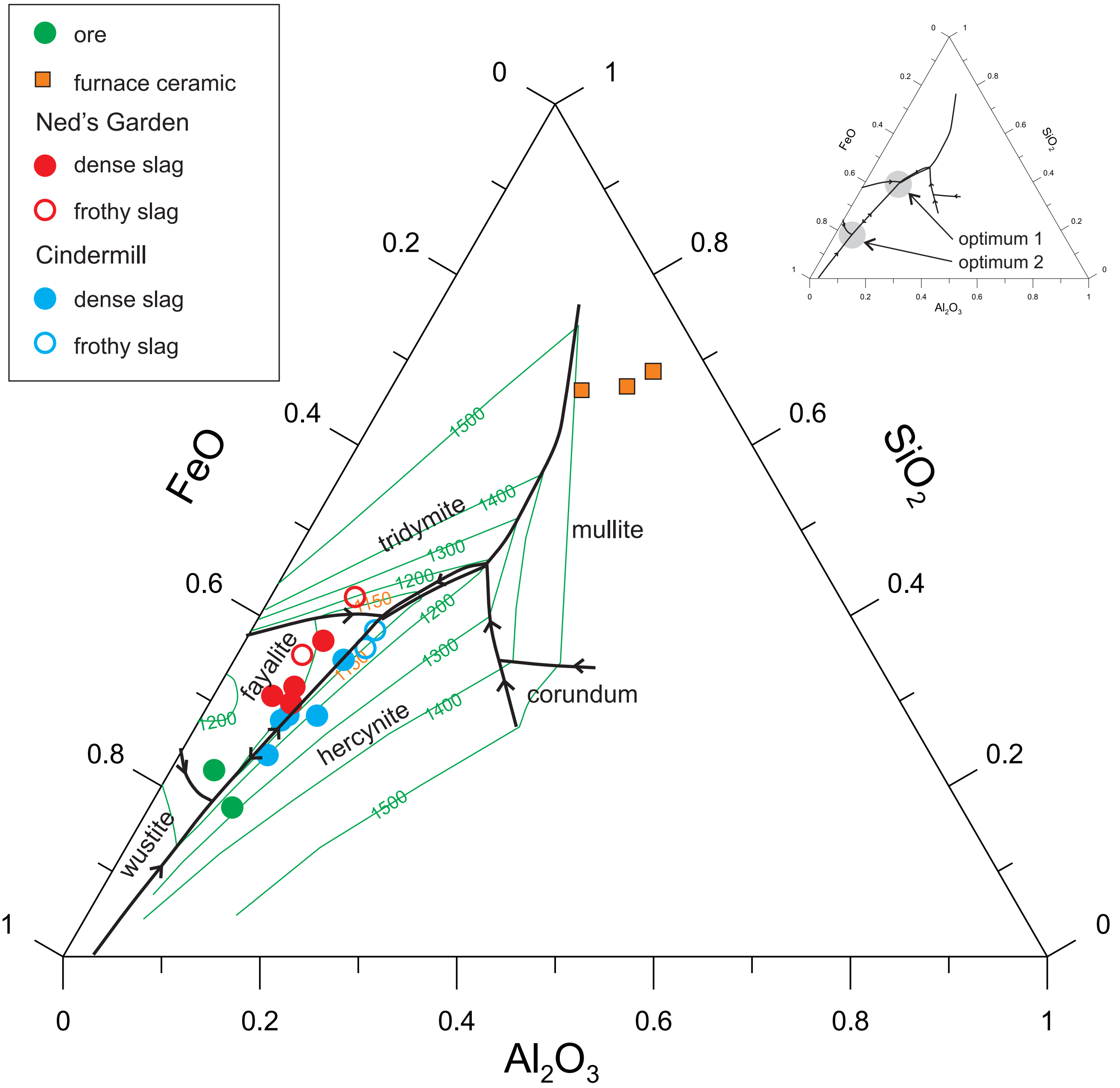

A
U
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Th
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
B
U
6.0
5.0
4.0
3.0
2.0
1.0
0.0
S REE
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
C
TiO_2
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
K_2O
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
D
Zr
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Y
0.0
20.0
40.0
60.0
80.0
100.0
120.0
◆ Ned's Garden slag
■ Cindermill slag
✳ Ned's Garden ore
● Ned's Garden clay
▲ Cindermill ore
× Cindermill clay

Figure 5



● ore
■ furnace ceramic
Ned's Garden
● dense slag
○ frothy slag
Cindermill
● dense slag
○ frothy slag
FeO
SiO2
Al2O3
0
0.2
0.4
0.6
0.8
1
tridymite
mullite
fayalite
hercynite
corundum
wustite
1500
1400
1300
1200
1150
optimum 1
optimum 2

Plate A1

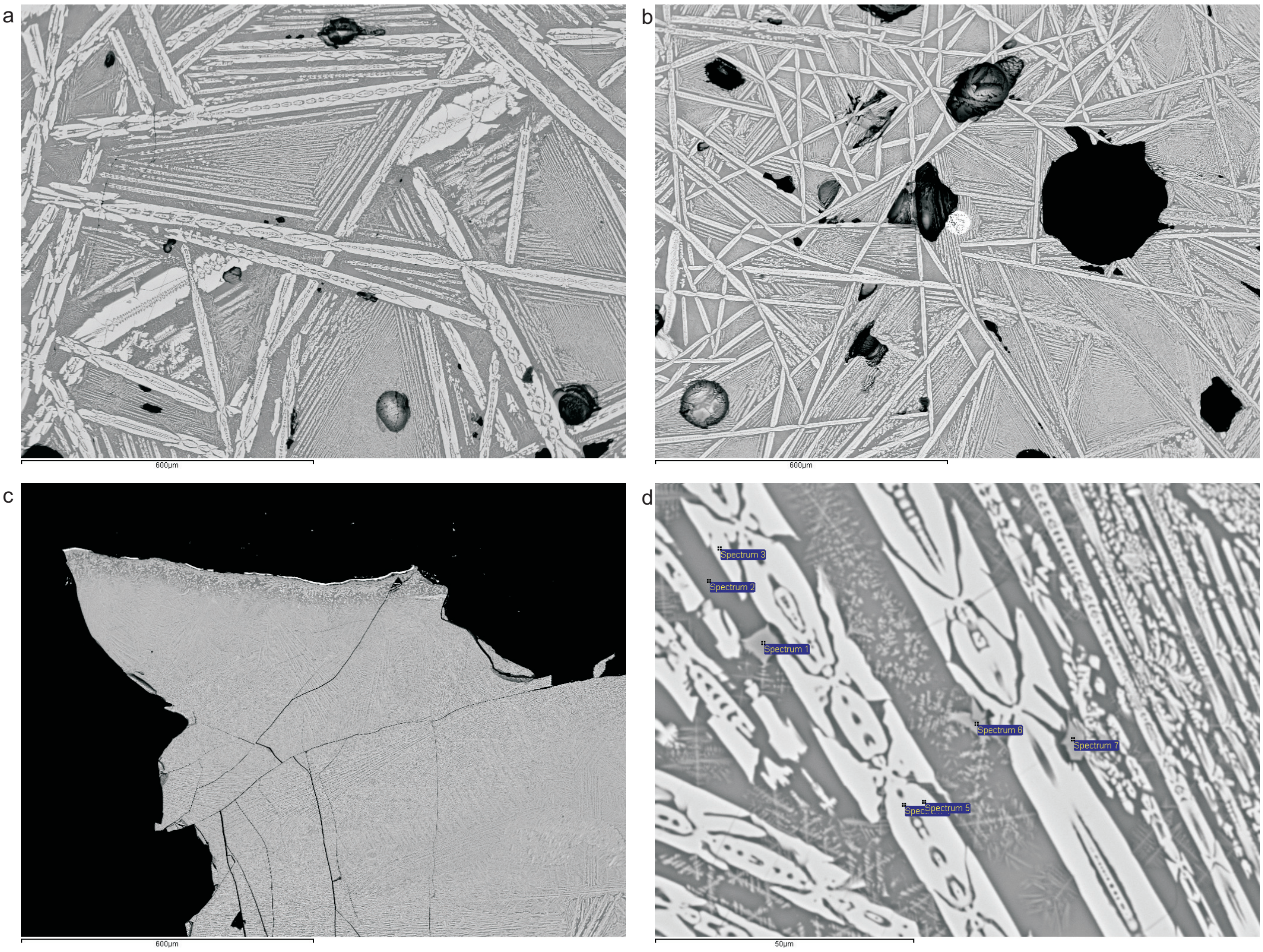

a
600µm
b
600µm
c
600µm
d
Spectrum 3
Spectrum 2
Spectrum 1
Spectrum 6
Spectrum 7
Spectrum 5
50µm

Plate A2

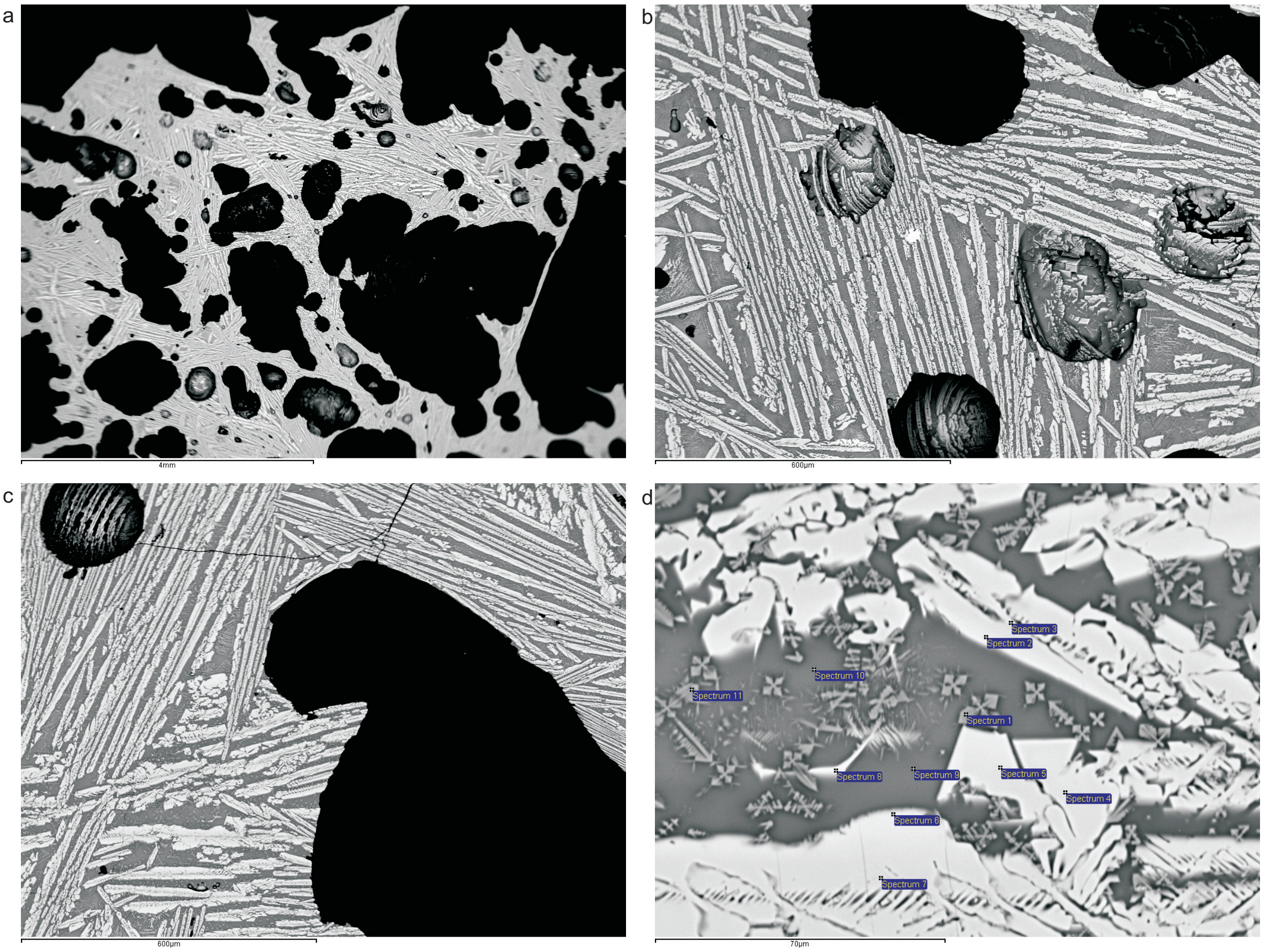

a
4mm
b
600µm
c
600µm
d
Spectrum 3
Spectrum 2
Spectrum 10
Spectrum 11
Spectrum 1
Spectrum 8
Spectrum 9
Spectrum 5
Spectrum 4
Spectrum 6
Spectrum 7
70µm

Plate A3

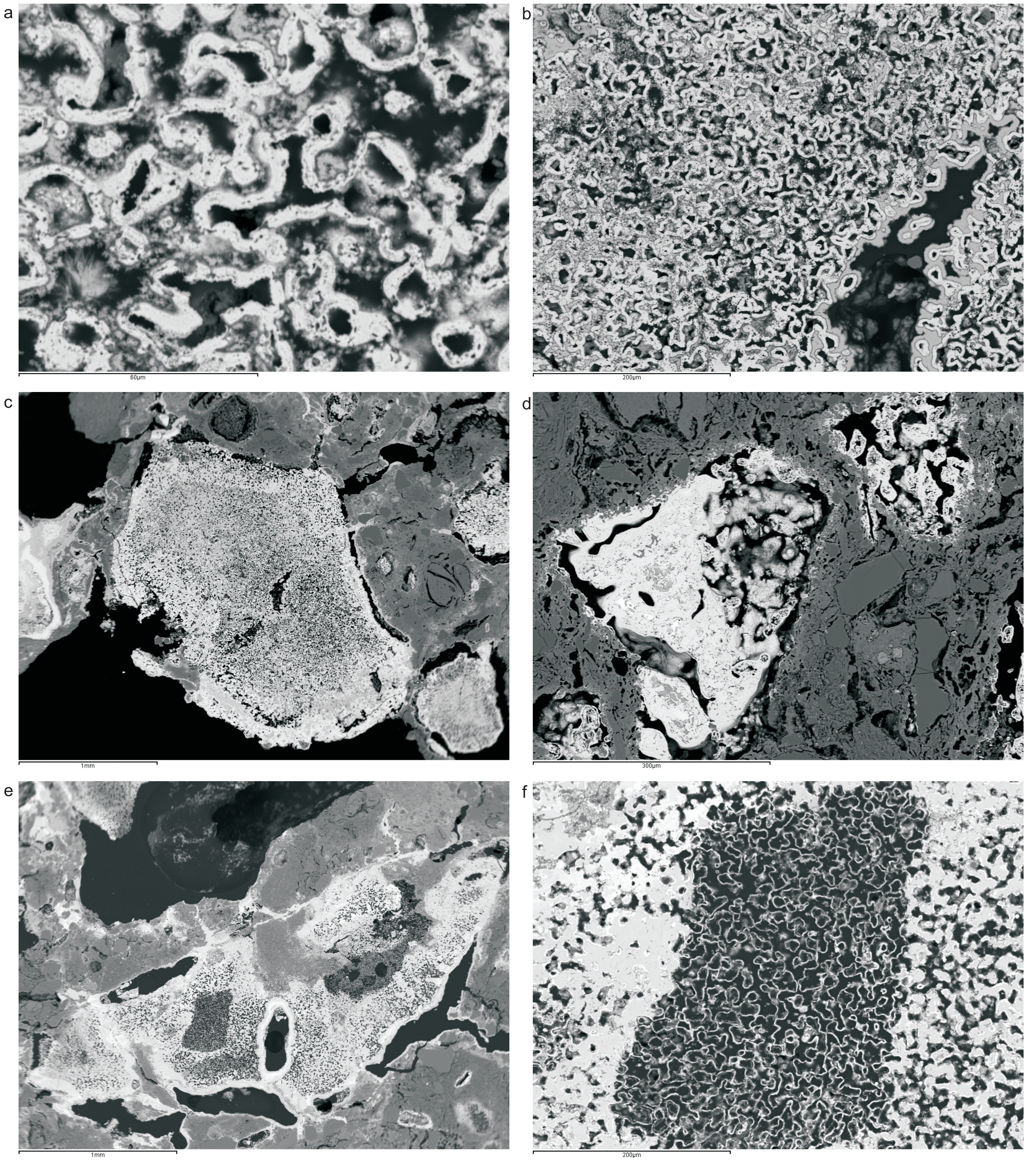
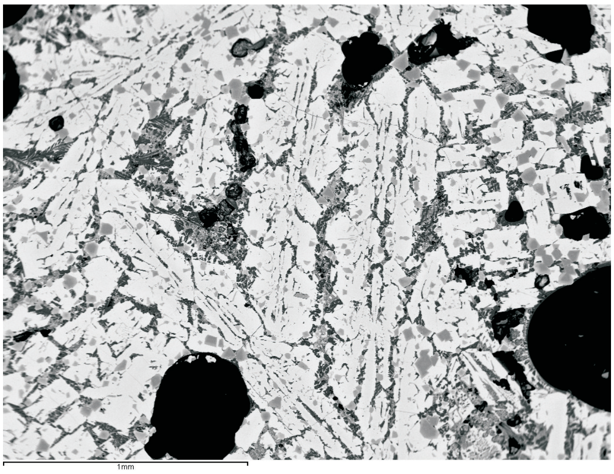
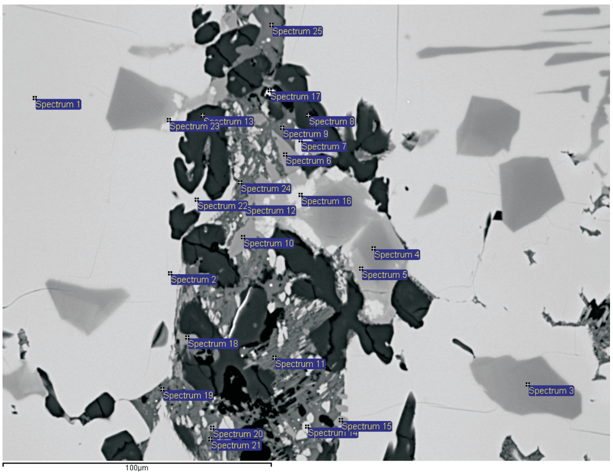


Plate A4

a


1mm

b


Spectrum 25
Spectrum 1
Spectrum 17
Spectrum 23
Spectrum 13
Spectrum 8
Spectrum 9
Spectrum 7
Spectrum 6
Spectrum 24
Spectrum 22
Spectrum 12
Spectrum 16
Spectrum 10
Spectrum 4
Spectrum 2
Spectrum 5
Spectrum 18
Spectrum 11
Spectrum 19
Spectrum 3
Spectrum 20
Spectrum 21
Spectrum 14
Spectrum 15
100µm

c

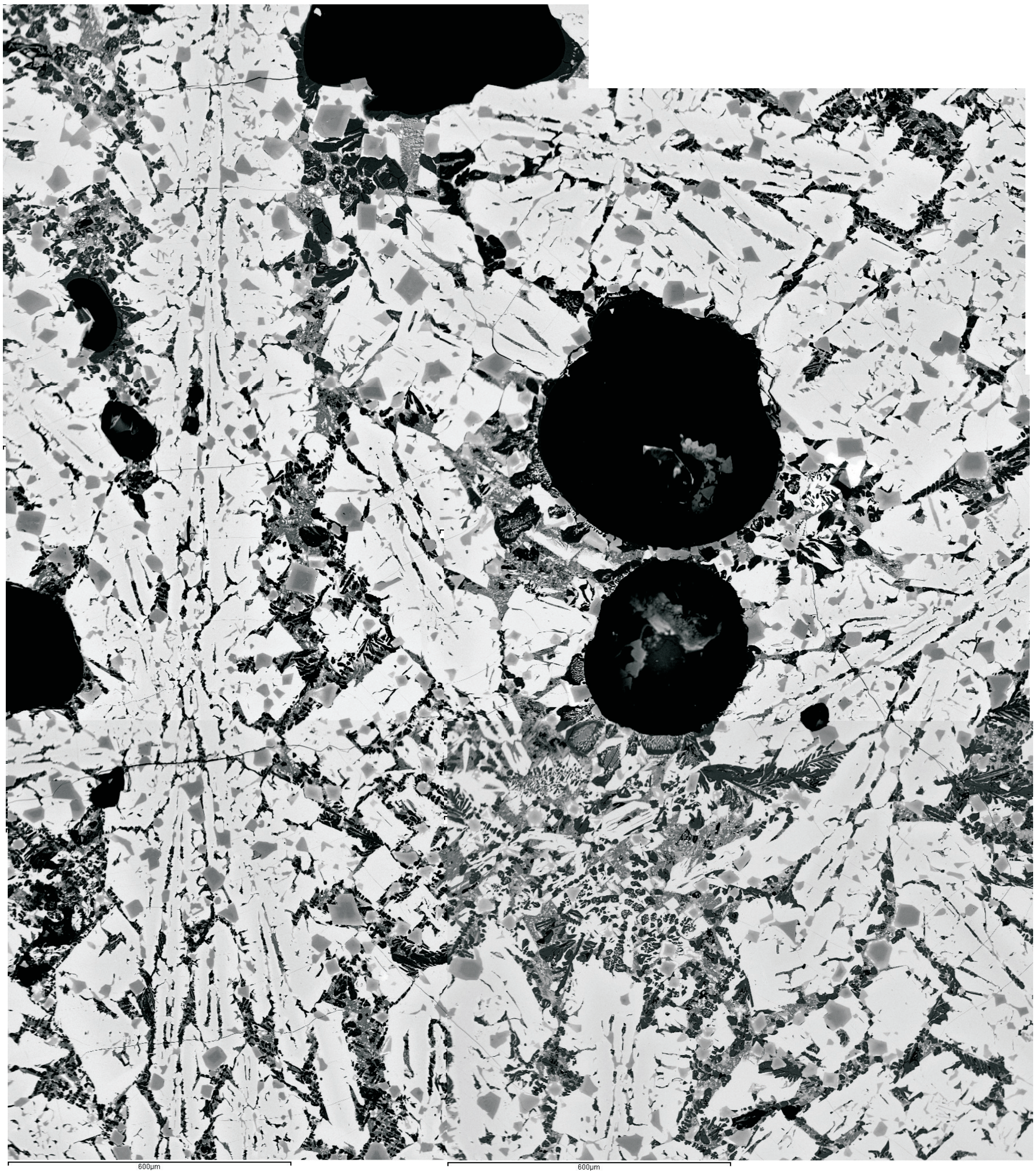

600µm
600µm

Plate A5

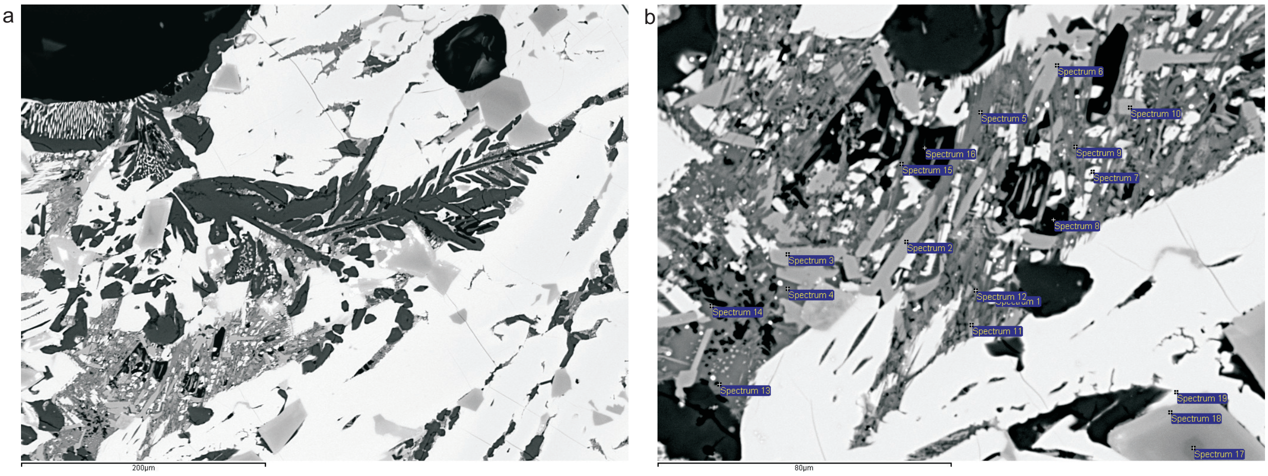

a
200µm
b
Spectrum 6
Spectrum 5
Spectrum 10
Spectrum 16
Spectrum 9
Spectrum 15
Spectrum 7
Spectrum 8
Spectrum 3
Spectrum 2
Spectrum 4
Spectrum 12
Spectrum 1
Spectrum 14
Spectrum 11
Spectrum 13
Spectrum 19
Spectrum 18
Spectrum 17
80µm

Plate A6

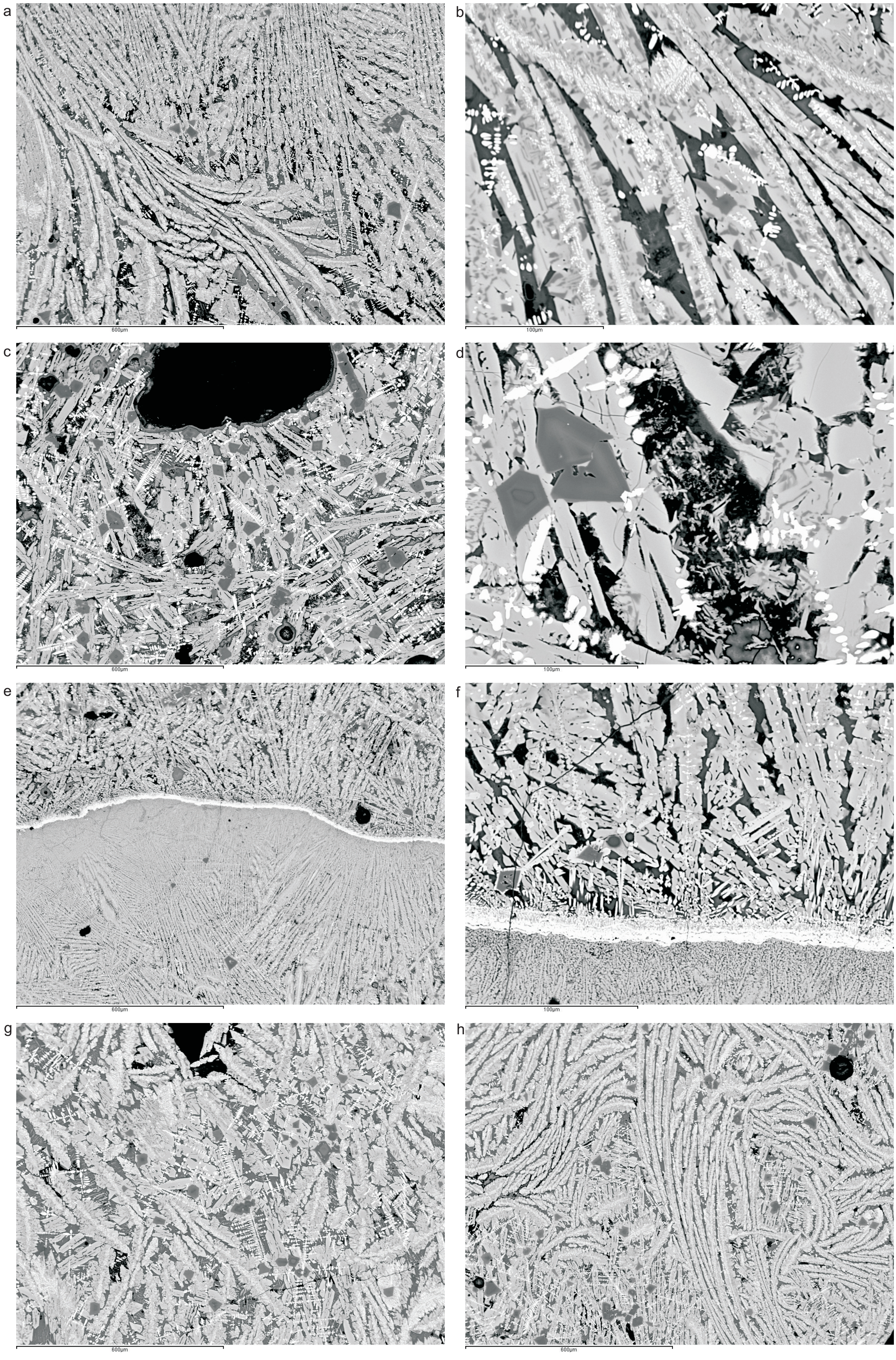


Plate A7

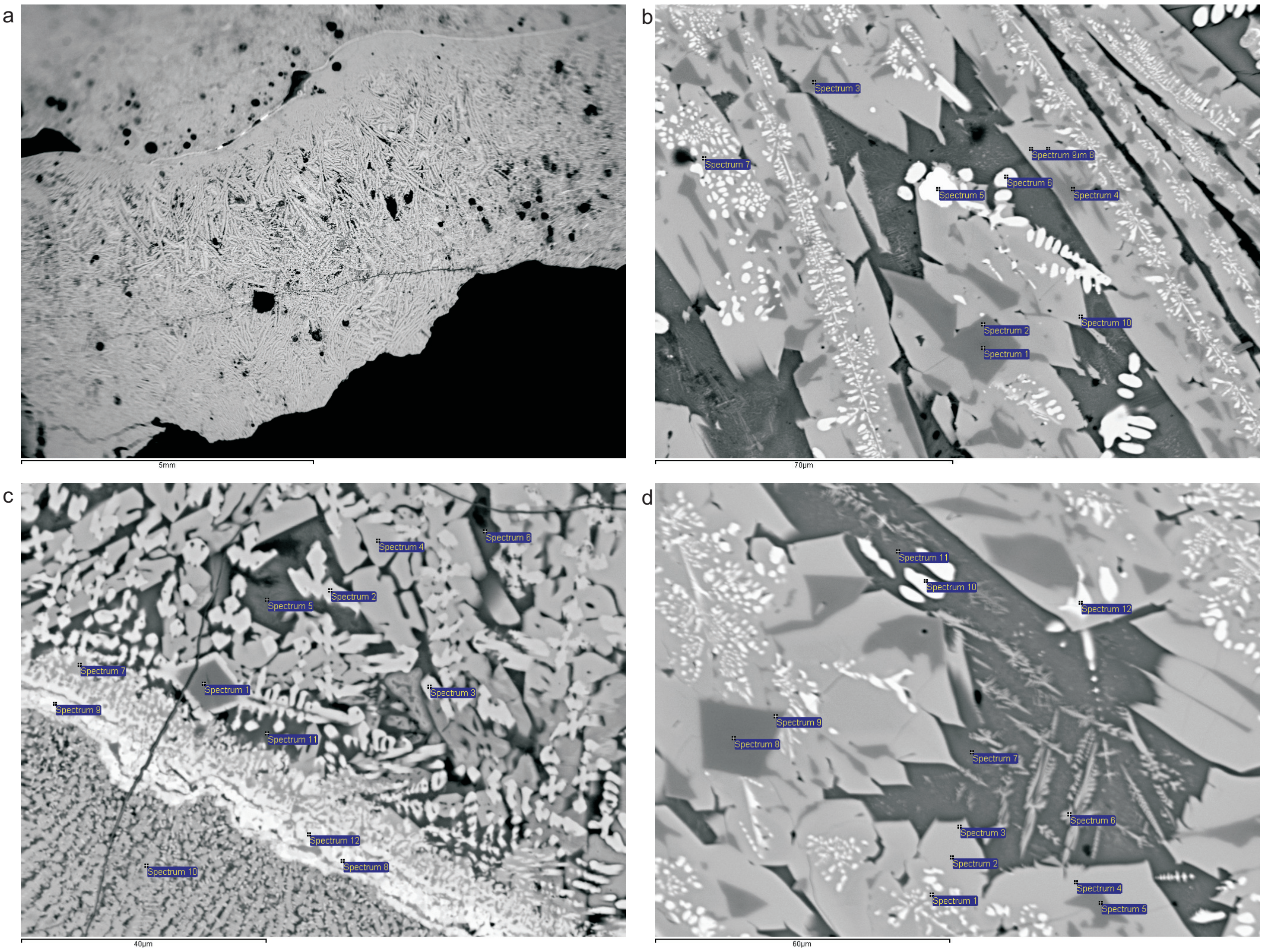

a
5mm
b
Spectrum 3
Spectrum 7
Spectrum 9ım 8
Spectrum 6
Spectrum 5
Spectrum 4
Spectrum 10
Spectrum 2
Spectrum 1
70µm
c
Spectrum 6
Spectrum 4
Spectrum 2
Spectrum 5
Spectrum 7
Spectrum 1
Spectrum 3
Spectrum 9
Spectrum 11
Spectrum 12
Spectrum 8
Spectrum 10
40µm
d
Spectrum 11
Spectrum 10
Spectrum 12
Spectrum 9
Spectrum 8
Spectrum 7
Spectrum 3
Spectrum 6
Spectrum 2
Spectrum 4
Spectrum 1
Spectrum 5
60µm

Plate A8

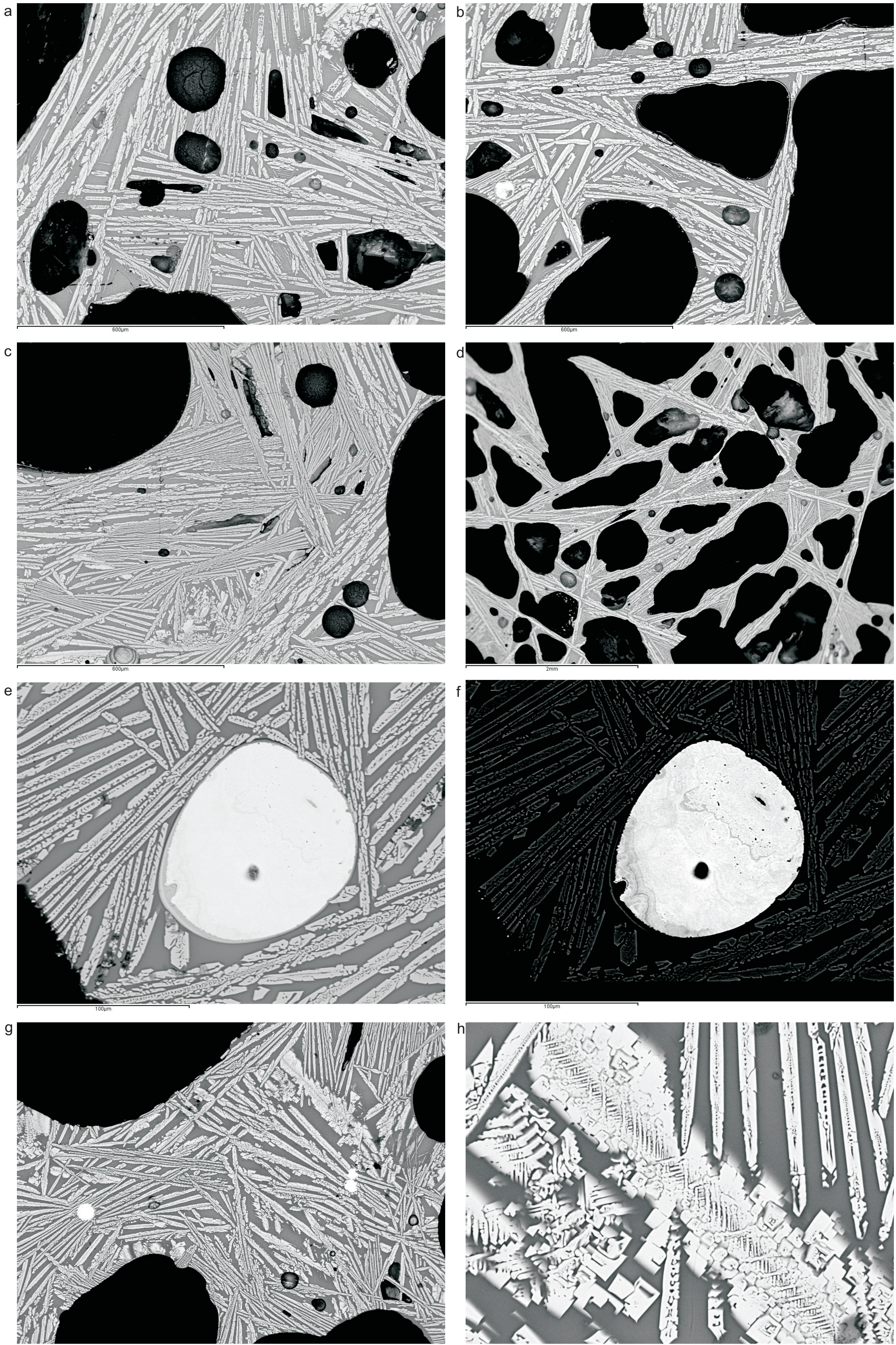
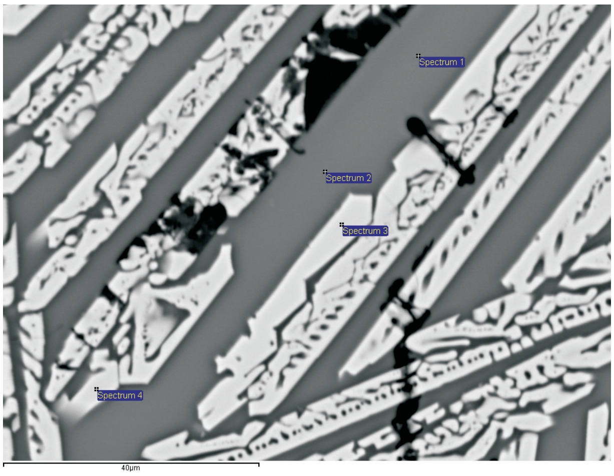
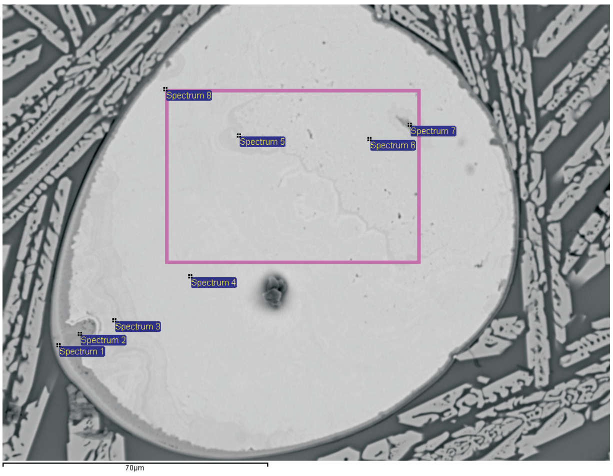


Plate A9

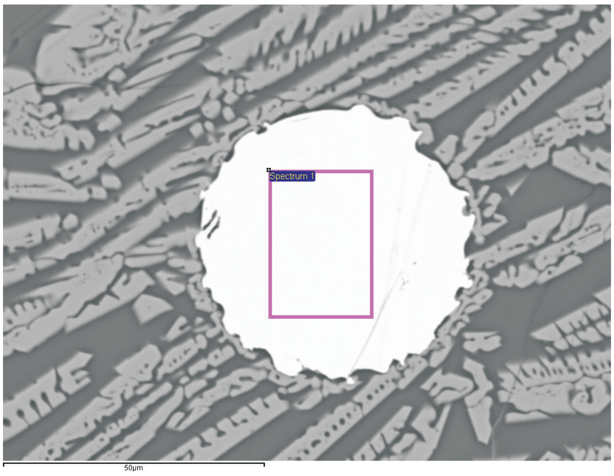
a



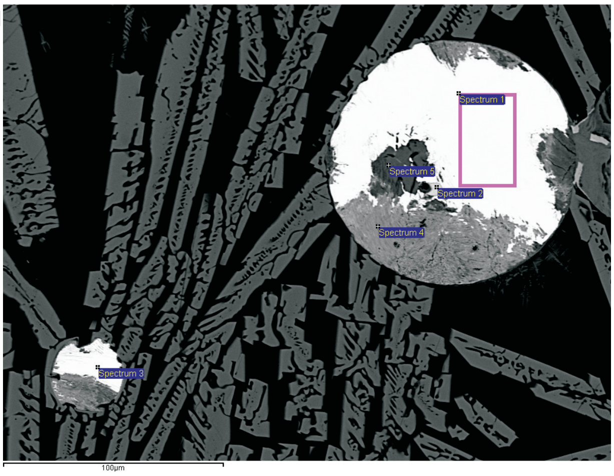
b



c



d



e

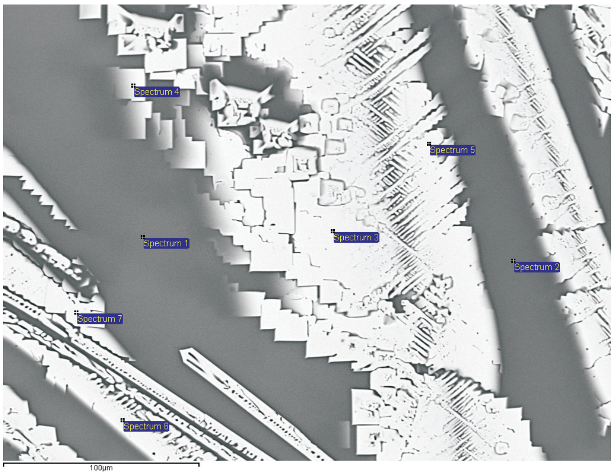


Plate A10

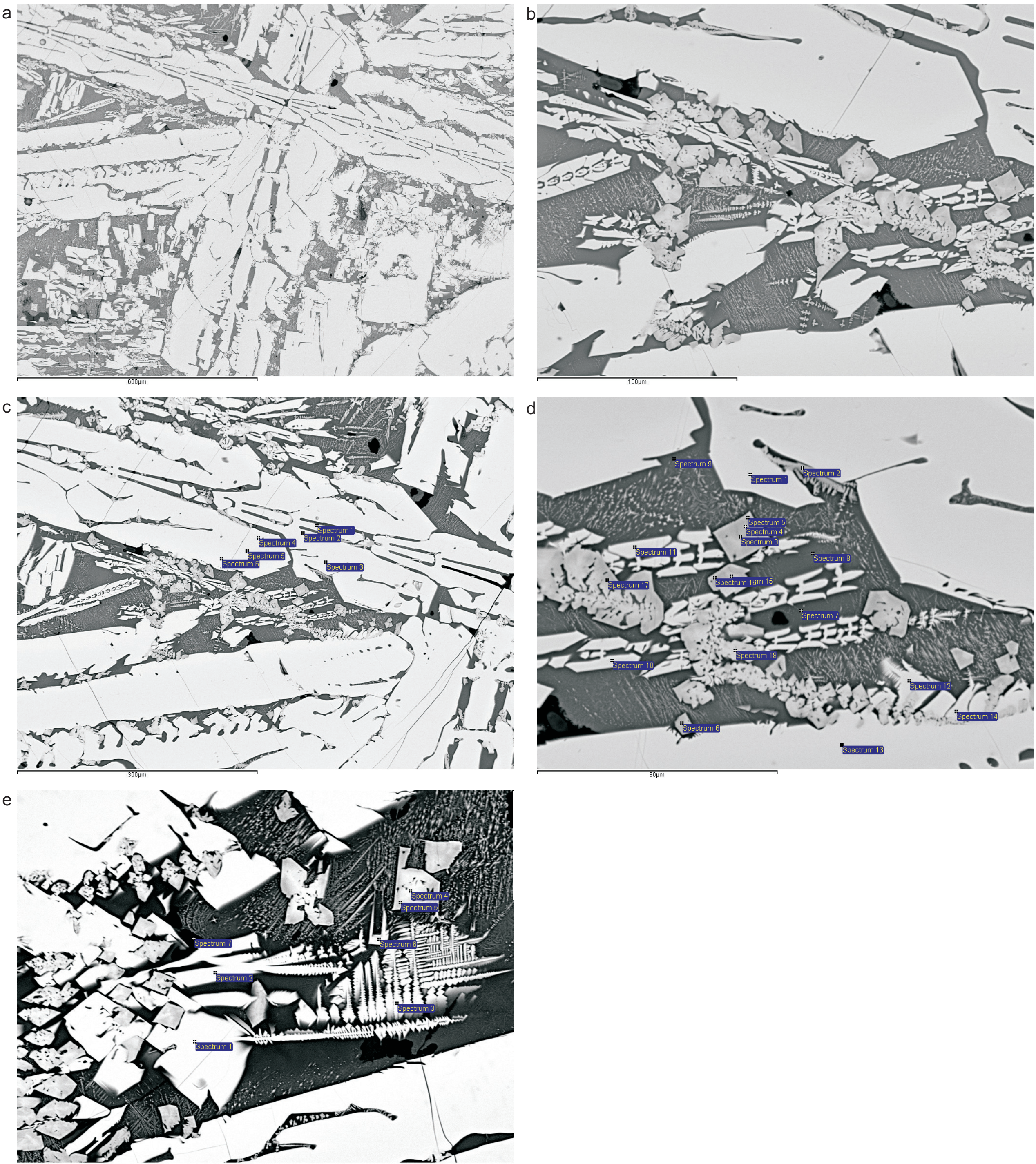

a
600µm
b
100µm
c
Spectrum 1
Spectrum 2
Spectrum 4
Spectrum 5
Spectrum 6
Spectrum 3
300µm
d
Spectrum 9
Spectrum 1
Spectrum 2
Spectrum 5
Spectrum 4
Spectrum 3
Spectrum 11
Spectrum 8
Spectrum 17
Spectrum 16m 15
Spectrum 7
Spectrum 18
Spectrum 10
Spectrum 12
Spectrum 14
Spectrum 6
Spectrum 13
80µm
e
Spectrum 4
Spectrum 5
Spectrum 6
Spectrum 7
Spectrum 2
Spectrum 3
Spectrum 1
100µm

Plate A11

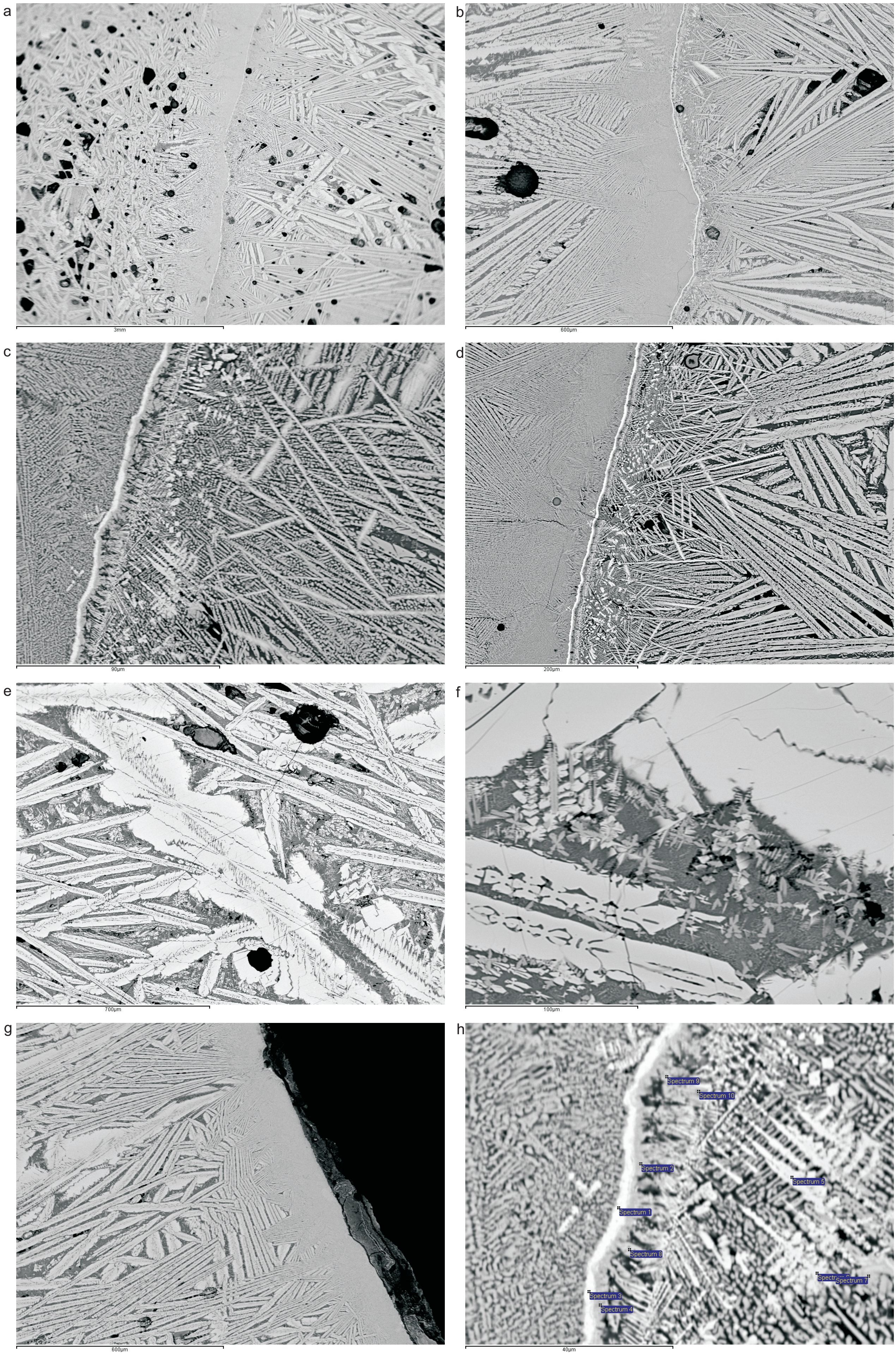

a
3mm
b
600µm
c
90µm
d
200µm
e
700µm
f
100µm
g
600µm
h
Spectrum 9
Spectrum 10
Spectrum 2
Spectrum 5
Spectrum 1
Spectrum 8
Spectrum 6
Spectrum 7
Spectrum 3
Spectrum 4
40µm

Plate A12

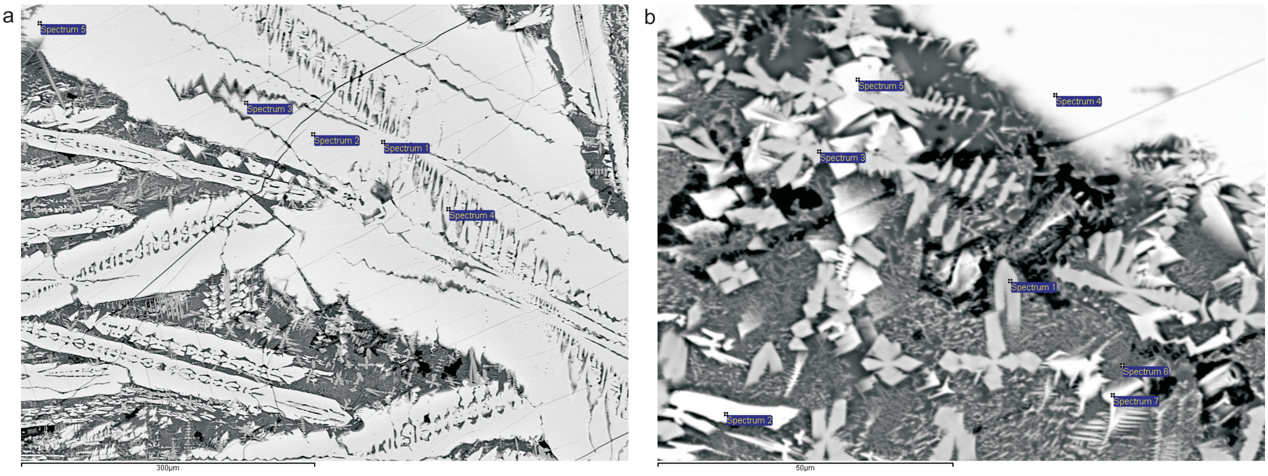
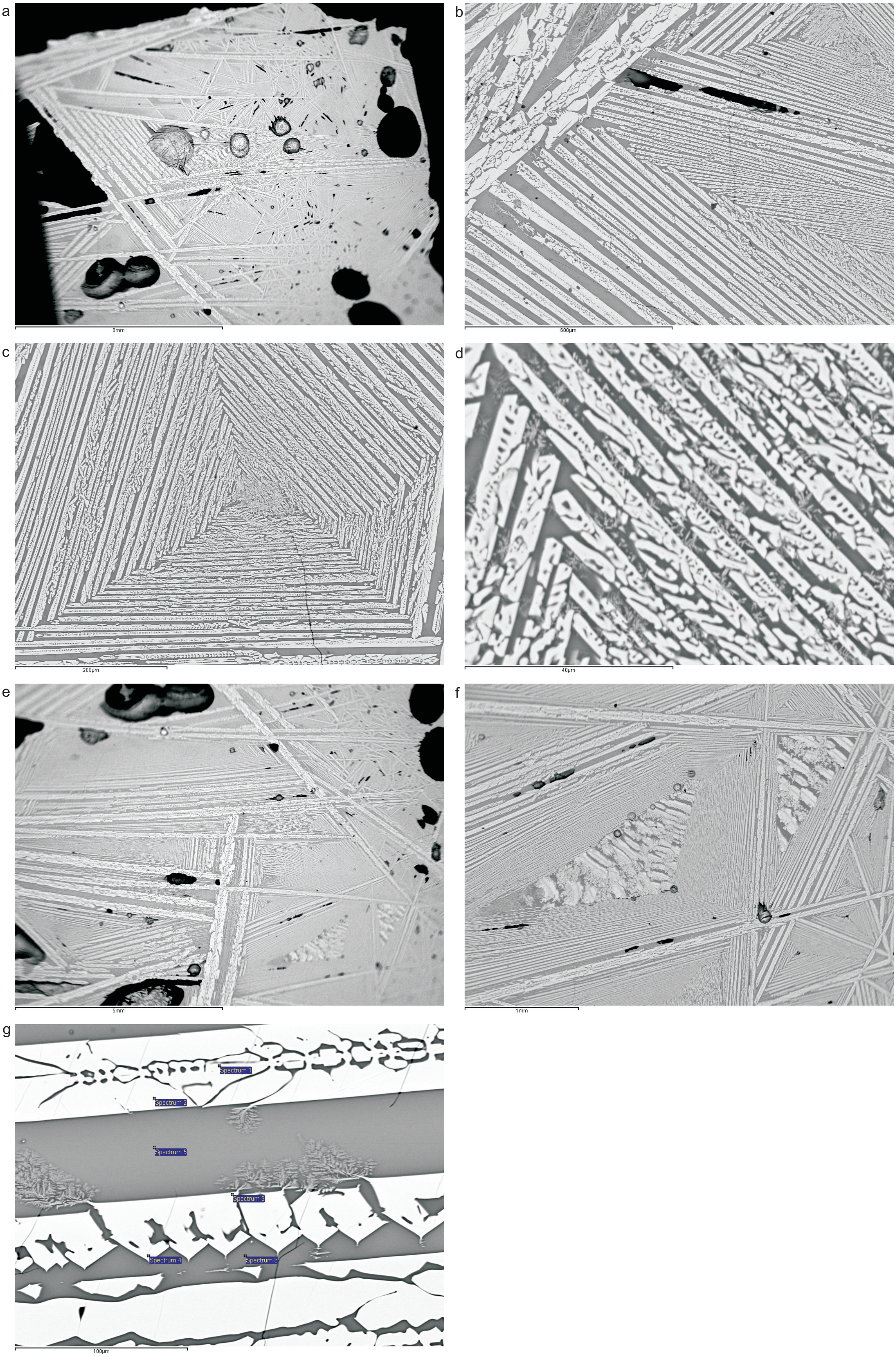

a
Spectrum 5
Spectrum 3
Spectrum 2
Spectrum 1
Spectrum 4
300µm
b
Spectrum 5
Spectrum 4
Spectrum 3
Spectrum 1
Spectrum 6
Spectrum 7
Spectrum 2
50µm

Plate A13


a
6mm
b
600µm
c
200µm
d
40µm
e
5mm
f
1mm
g
Spectrum 1
Spectrum 2
Spectrum 5
Spectrum 3
Spectrum 4
Spectrum 6
100µm

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