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Archaeometallurgical residues from Little Furnace Wood, Mayfield, East Sussex

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Abstract

Some 74kg of material hand-picked from excavations was submitted for investigation, including iron smelting slags, structural elements from smelting furnaces, iron ores and iron working slags. A variety of analytical techniques (bulk chemical composition by XRF and ICP-MS; textural and microanalytical studies by SEM with EDS) were applied to samples taken from the collection.

The smelting slags formed the core of the investigation and ranged from dense examples with narrow flow lobes, through to lower-density, vesicular, examples with broad flow lobes, often showing surficial ridging or corrugation. The iron ores analysed were single samples of fresh and weathered varieties of a shelly ironstone. The chemical composition of the weathered ore proved very similar to some of the samples of ore previously submitted by WIRG from elsewhere in the Weald. The weathering process apparently involved the loss of most of the calcium from the ore, but also some of the iron and manganese.

Detailed consideration of the chemical composition of the new analyses was hindered by their relatively small number spread over various disparate materials. Incorporation of the analyses published by Paynter (2006) increased the size of dataset sufficiently to permit a much enhanced level of interpretation. Analyses of smelting slags formed three distinct compositional trends (Groups 1-3) interpreted as representing smelting of three different ores (particularly marked by varying calcium contents). The analyses also clustered into three regions of the CaO-SiO_2-FeO diagram (Fields A-C).

Field A represented tapped slags from the dominant smelting process – with mass balance calculations suggesting reduction to metal of 50%-60% of the iron in the ore. Slags of compositions in Groups 1, 2 and 3 occurred in this field. The indicated yields are similar to those calculated for Roman bloomeries in the Bristol Channel area.

Some of the tapped slags from the rather calcic Group 3 also occurred in Field B. This indicated a higher degree of iron extraction (70%-80% of the iron in the ore) permitted by the low liquidus temperatures of those iron-poor compositions with elevated calcium contents. Although this residue would have resulted from high-yield smelts, it is possible that the low iron content of the slag would have resulted in elevated carbon in the iron. It is also possible that these tapped slags are not representative of the overall bulk composition of residue from a smelt.

Field C included iron-rich examples of slags from Groups 1 and 3, together with an example of a slag 'rod' which did not fit within the identified compositional groups of tapped slags. These slags, if representative of a smelt, would be indicative of a low yield (20-30% of the iron in the ore), but again are not necessarily representative of a bulk residue composition; averaging all Group 3 slag compositions gives a mean close to Field A.

These observations permit some speculation over the utility of the dome form of furnace: the dome may have reduced the level of involvement of the furnace structure in the reaction (aiding furnace efficiency) and its large floor area may have allowed internal flow and accumulation of the possibly slightly viscous slags produced.

One example of a smithing hearth cake was analysed, as was one example of an unusual extremely coarse-grained slag. Both slags had a composition close to that of fayalite. Coarse fayalitic slags from elsewhere have been tentatively proposed as residues from bloom remelting processes, but there is insufficient evidence to confirm that possibility with the present material.

Contents

Methods

All materials were examined visually with a low-powered binocular microscope. All material was weighed, described and recorded to a database (Table 1). During the evaluation phase, the materials were not subjected to any high-magnification optical inspection, not to any form of instrumental analysis. The identifications of materials in the summary catalogue are therefore necessarily limited and must be regarded as provisional.

From the materials examined for the evaluation, a variety of samples were selected as being possibly suitable for analysis. These were cut and inspected and a sub-selection of eleven samples (Table 2) was taken forward for detailed analysis.

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 Sciences, Cardiff University.

Throughout this report standard mineral terminology is applied to both natural and anthropogenic materials – although artificial phases are no longer strictly considered to be minerals.

The convention adopted in this report is to describe olivine bearing Fe, Mg, Ca and Mn 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 report was undertaken for the Wealden Iron Research Group. The assistance of Sarah Paynter with provision of a spreadsheet for viscosity calculations and for discussion of Wealden iron making is very gratefully acknowledged.

Results

General description of residues

Iron Ore
The collected material included 13.1kg of iron ore, ranging from very small fragments to large chunks which weighed up to 480g. The majority was roasted, although a few fragments showed no signs of heat treatment. While the total quantity of ore recovered is large for sites of this period, it does not necessarily

represent the actual type ore being smelted and may represent material which was deemed unsuitable and therefore discarded.

The ore included both apparently simple claystone ironstones and varieties with a high proportion of shells (present as either calcareous, possibly original, shell material or as moulds).

Iron smelting slag
The majority of the slag in the collection could be attributed with confidence to an origin iron smelting. In general slag preservation was rather poor, with deep alteration, particularly involving the loss of any glass phase and deposition of the secondary iron oxides. Although careful selection of samples for analysis avoided much of the weathering, it was still observed (e.g. a superficial loss of glass visible in Plate 11).

The most obvious class of the smelting slags is the broadly horizontally-flowed material with discrete slag rivulets and lobes that is generally assumed to represent tapped slag. This facies of slag was quite variable in both composition and morphology. Samples with a low vesicularity (and hence high bulk density) typically showed smooth, narrow lobes and mostly formed rather small slag masses. Lower density (mainly reduced bulk density because of increased vesicularity) examples often showed broad flows with ridged or corrugated surfaces, and occurred in rather larger masses. There were no examples of the large tapped slag cakes common on many other sites.

Many of the lower density slag flows showed a dark glassy outer layer, quite different from the finely crystalline dense slags.

The surface weathering prevented in most instances certain identification of the slightly maroon (haematised) surface layer seen on conventional tapped slags that have cooled in air. This leads to an ambiguity in the interpretation of these flowed slags – and an uncertainty over whether many of them were truly tapped from the furnace, or whether some may have cooled within the furnace.

As well as the classic type of tap slag described above, also present were approximately 0.8kg of fragments of slag rods. These are cylindrical rods of slag with diameters of between 10-20mm. Their mode of formation is not certain, however it is possible that they form as a result of a basal slag crust in the bottom of the furnace being penetrated with a tool such as a poker, in order to allow slag to be tapped from the furnace.

Vitrified lining
A large quantity of vitrified lining was present in the collection. Much of this was present as collapse within and immediately outside the furnace. In general, the furnace material was intensely altered by vitrification and by the fluxing effects of the furnace contents. Many of the larger pieces (e.g. Plates 13 and 14) show quite marked fissuring, leading to failure (or incipient failure) along surface parallel cracks, themselves showing vitrified surfaces. These intensely vitrified materials are likely to have formed the lining of the furnace over many smelting events.

Slag rods
The collection included 35 fragments of dense, dark slag with a rod like morphology. Most of these fragments had a diameter of approximately 15mm, but some were larger, locally widening to 30mm by 20mm. The longest fragment, bounded by fractures, was 120mm in length but most pieces were only half of this.

Smithing slags
Two smithing hearth cakes were positively identified; both were estimated as being approximately 80% complete and weighted 776g [C2] and 525g [C26] respectively. One of the cakes (that from C26) contained charcoal moulds and inclusions on both upper and lower surfaces.

Smithing microresidues were also seen, with both spheroidal and flakes hammerscale being present in sieved samples from C48 (TP1; the main fill of forging pit C36), C59 (TP4; lower fill of pit C54), C63 (TP7; soil layer above natural) and C68 (TP8; charcoal rich soil above dense slag layer C76).

Coarse-grained slag
A single fragment of dense slag with a very coarse grained structure was recovered from the topsoil (C1). This piece had a dimpled lower surface, suggesting a non-wetted contact with either fine fuel or loose sediment. The lower part of the specimen is a sheet with large olivine crystals mainly perpendicular to the base and up to 15mm in length. The upper surface is a fracture surface with, in different areas very coarse (~10mm) olivine crystals protruding into a void, or (probably overlying the void) a coarsely vesicular (vesicles <15mm?) slag with very large olivine crystals lining the vesicles, with crystal faces imparting a mirror finish to the vesicle surfaces. This slag was unlike any conventional iron smelting or smithing slag, and was therefore selected for further investigation despite its unstratified context.

Indeterminate slag
Some items of slag were not classifiable within any of the above categories. These were typically fragments that were too small to show appropriate textural features, but also some slags that are rich in charcoal are difficult to discriminate; slags formed within the fuel in the lower part of the bloomery furnace are identical in appearance to some smithing residues.

General distribution of residues

Little can be said about the general distribution of residue classes. Most of the vitrified furnace materials came from tumble or other debris directly associated with Furnace 1. Compared with some sites, the general slag deposits appeared to contain a low proportion of furnace material, but this may be due to sampling bias.

Although one of the occurrences of smithing micro-residues was directly associated with a feature attributed to smithing (C36), the other occurrences are more suggestive of general rubbish deposits. The number of identified SHCs was very low (only 1 in a stratified context), which may suggest that on-site forging was limited to initial bloom compaction and not to the onward forging of blooms to bar iron.

Most of the iron ore in the assemblage derives from pit (54), which may have been associated with ore roasting (although it also contained a significant quantity of hammerscale).

Description of analysed specimens

LFW4 (c18; Plate1 a-e, Plate 2 a-g)

This is a block of flowed ('tapped') slag with a rather irregular, dendritic form. It represents a rather sparse cake suggesting a fairly low-volume flow. The slag has a mid-grey colour, is fine grained and has surfaces that are coloured brownish (as a result of weathering). The surfaces of the flow lobes are finely wrinkled. The slag is dense, with a few large vesicles, but lacking the fine vesicularity of LWF6. The bulk analysis shows this to be one of the high-Ca/ high-Mn slags.

Plate 1a shows a section through one of the flow lobes approximately 5mm in thickness. The slag shows rare small vesicles. The upper and lower flow margins (Plate 1b, e) are both rather diffuse bands of iron oxides. This zone is accompanied by dendrites of (probably) hercynite extending down into the flow below and some primary equant hercynite just above the boundary. The hercynite dendrites are overlain by wustite, and throughout the remainder of the lobe the wustite dendrites, with arrays of up to 200µm, are the primary phase. The wustite forms less than 5% of the bulk. The wustite shows approximately 1% substitution of Mn for Fe.

The major mineral phase is an olivine. This shows a variety of morphologies, but is typically in a rather stout crystal for a tap slag (500 -1000 µm in length and 50-150 µm wide). The olivine is strongly zoned, with cores of Fa86Fo14 with about 6% each of manganese and calcium substitution. The calcium content rises sharply towards the outside with much of the later parts of the crystals highly kirschsteinitic (60-75% kirschsteinite). The late kirschsteinite is commonly associated with leucite – either directly as a probable cotectic (in which the two minerals often show a lamellar habit), or as a zone of equant grains immediately overlying the kirschsteinite (in which case the leucite, 5-10 µm, is typically associated with rhönite up to 20 µm). The leucite rich zone is followed by an interstitial glass – which may conceal a further crystalline phase to judge from its fracture.

LFW6 (c22; Plate 3 a-h)

This material is an agglomeration of flows, each 20-30mm wide, into compact, but highly vesicular, mass. The slag is pale grey in section, with a moderately coarse grain. The surface of the flows is smooth and shows some areas with a thin matt iron oxide layer, with a slight reddish colour, but is mostly weathered and somewhat etched. The base shows multiple inclusions, including sandstone, reduced fired ceramic and some possible flake hammerscale. The bulk analysis shows it to be a low Ca / low Mn slag.

In section, one end of the cut sample is/was vesicular, with some surviving vesicles, others slag filled but marked by rims of leucite. The body of the slag shows sheaves of olivine crystals.

The olivine has cores close to end-member fayalite (<2%Fo), with slight calcium substitution (<3%) towards the margins. The interstitial glass bears fine dendrites of a spinel with about 50% magnetite and 46% hercynite.

LFW10 (c76; Plate 4 a-g)

This specimen was a broad (at least 100mm across) lobe of slag up to 45mm thick, with a smoothly dimpled base and an upper wrinkled surface. The main slag mass is coarsely crystalline olivine with fine vesicles, There are some oblate large voids just below the top up to 40mm across. The top of the flow is a dark brown glass, which appears devitrified on the surface.

This polished mount (from the core of the specimen) has a quenched texture of long thin olivine in glass (apparently approximately equal proportions at the resolution of the SEM). The olivine cores are around Fa87 with 4-5% of both Mn and Ca substitution. The margins of larger olivines rise to about 16% Ca substitution in Fa93. The glass contains 11-12% CaO.

LFW11 (c105; Plate 5 a-h)

This sample shows a dense mass of flow lobes, typically 40x15mm, Each lobe has a grey, slightly vesicular slag with a thin (1mm) dark more glassy rim. These glassy patches appear to be thickest on some of the lobe margins on the base of the flow, which appear to have rested on a clay-rich surface, possibly with some charcoal on it. Externally, the flow lobes have a brown, finely wrinkled surface.

This slag is texturally very similar to LFWE 10 in section, but includes some difficult fine textures on its chilled margin. The olivine compositions are also remarkably similar, with cores of Fa87, 4%Mn and 6% Ca substitution, with margins of Fa91 with similar Ca and Mn. Late olivines appear to have Ca substitutions rising to 17%

LFW12 (c2; Plate 6 a-h, Plate 7 a-h, Plate 8 a-g, Plate 9 a-e)

This sample is taken from a steep-sided bun-shaped concavo-convex slag cake approximately 150mm in diameter and 70mm deep. The upper part is vesicular and rich in inclusions of ceramic. These inclusions are also present near the sides where they show a slight layering. The core of the cake is massive slag, without vesicles and with visible olivine grains on the cut surface of up to 7mm. The basal zone of the slag bears very rare tubular vesicles. The basal surface is rough with ceramic or stone inclusions. The upper surface is glassy in areas, but dominated by ceramic material.

In section, the specimen contains some considerable amount of relict part-reacted/melted scale. The scale includes relict wustite, magnetite (mainly in a rather equant, rounded form) and iscorite, which appears to infill gaps in the pre-existing granular structure. The iscorite and magnetite are generally encased in the large main-stage olivine (which is close to end-member fayalite). Late-stage minerals include further fayalite, sometimes distinctly more calcic (up to 10% Ca substitution), a spinel (40-60% hercynite) and rhönite (in large subhedral grains). The materials are associated with, or more generally overlain by a zone with rounded leucite and interstitial glass.

Away from the centre of the dense scale fragments, skeletal magnetite (13-17% hercynite) may contain some relict wustite in the core (of the in a framework structure suggesting the core of the magnetite is transformed wustite, rather than simply all being an overgrowth – this is well seen in SOI16). Arrays of

wustite in SOI16 may be scale or even an incipient dendrite, but are overgrown by iscorite – which forms lamellar out-growths.

Away from the scale altogether, the primary phase is a magnetite (with about 12% hercynite, rising to 20% on the margins), forming equant euhedral grains with outgrowths into the interstitial glass. The interstitial magnetite is associated with, and overgrown by a phase forming elongate hollow prisms, too fine for meaningful analysis, but which might be rhönite. The dominant phase in the slag is an olivine, which clearly overgrows the magnetite. The main olivine shows a very restricted range in composition between Fa97 and Fa100, with negligible Ca and Mn substitution. The latest olivine appears to be Fa100 with up to 10% Ca substitution, but the higher levels of Ca substitution seem to be restricted to those olivines closely associated with leucite.

LFW13 (c1; Plate 10 a-h)

This specimen shows elongate olivine growing from an irregularly-rounded chilled margin. The margin is seen in hand specimen to be a non-wetted, dimpled contact surface of polished appearance. The slag sheet bears some large tubular vesicles. The upper surface is formed of olivine crystals with faces parallel to the elongation of the sheet and at least 6mm across, imparting a mirror-like appearance. This is clearly not the original top to the slag mass; the sheet is simply the slag below an interior cavity.

The olivine crystals are at least 4mm long (in the polished mount) and probably much larger (from the hand specimen, where they appear to exceed 10mm). There is a very sparse development of wustite (<1%), with the wustite dendrites possibly swept aside by olivine growth rather than being simply overgrown.

The olivines are again close to end-member fayalite, with only low degrees of manganese (typically below detection and always <1%) and calcium substitution (up to 1%), until the very last olivines, associated with the leucite. The interstitial zones include wide interstices, in which small skeletal olivines (3-10% Ca substitution) often overlie and overgrow the wustite dendrites, and narrow interstices, which are typically dominated by arrays of rounded leucite, associated with possible rhönite, and a glass, occasionally bearing iron sulphide blebs.

LFW19 (c39; Plate 11, Plate 12 a-g).

This was a sample taken from one of the smaller examples of a slag rod. As with many of the rods, this example had a persistent cavity, a smooth upper (?) surface and suggestions of lobes or folds on the sides. The external surface of all but the upper side was rough.

In polished specimen the texture was seen to comprise a primary wustite, with delicate dendritic arrays of up to at least 1mm, followed by delicate elongate olivine up to 3mm in length. In many areas, but particularly towards the top, the olivine is present as an olivine-wustite cotectic. The olivines show a uniform 2% manganese substitution and range from Fa95 with 3% calcium substitution to Fa100 with 7% Ca substitution. The interstitial glass bears some late stage very fine crystals of probable rhönite and the surface of exposed wustite dendrites may show small blebs of (probably) iron sulphide.

Chemical composition of analysed specimens

Smelting residues

The chemical composition of the analysed specimens will be considered in conjunction with the analyses presented by Paynter (2006) of tapslags from the site. Data previously analysed from the Weald by Gary Thomas using samples supplied by WIRG in 1996 (samples labelled Cd) are also combined. This substantially increases the database of major element analyses (Paynter's data are presented in blue diamonds, the earlier WIRG slag analyses in orange stars and the earlier WIRG ore analyses as pink rectangles on Figures 1and 2).

The relationships between pairs of major element oxides are presented in Figure 1. These plots show a good linear relationship between MgO and CaO in the slags, and a similar, if slightly less tight correlation between MnO and CaO. The correlation between silica and alumina is good, with an average ratio of silica to alumina (by weight) of 4.1.

Much of the variation of major elements in smelting slags is simply due to the variable degree of extraction of iron. These trends are removed in Figure 2, which illustrates data recast without any iron oxide (i.e. the variables are the wt% of the oxides on an iron-free basis). These bivariate plots show a more clustered distribution of data, reflecting the composition of the *smelting mixture* - the mix of ore, furnace lining and fuel ash from which the iron was extracted.

In Figure 2, the tapped slag analyses resolve into three distinct clusters. The first group (Group 1; including sample LFW6) of smelting slags has very low calcium, manganese and magnesium oxides, but very high silica and, in some samples at least, an elevated silica to alumina ratio (range 3.7 to 8.1; mean 5.6). The trend of analyses within this group is shared with the analyses of the two 'secondary' slags, one a certain SHC, the other possibly so. This trend can be interpreted as showing a stronger influence of the ceramic hearth/furnace materials, mixed with iron, but lacking a strong influence of the elements present in the fresh ore (calcium, magnesium and manganese). The ratio of lime to silica ($CaO:SiO_2$) ranges from 0.03 to 0.08 with a mean of 0.06.

The second group (Group 2; includes no samples from the present project) of smelting slags show a rather aluminous composition (with a silica to alumina ratio ranging from 2.9 to 3.5; mean of 3.2), with a moderate content of calcium, manganese and magnesium oxides. The ratio of lime to silica ($CaO:SiO_2$) ranges from 0.08 to 0.16 with a mean of 0.13.

The third group (Group 3; including samples LFW4, 10, 11) has the highest contents of calcium, magnesium and manganese, with a silica to alumina ratio mainly in the range of 3.4 to 5.3 with a mean of 4.2. The ratio of lime to silica ($CaO:SiO_2$) ranges from 0.24 to 0.36 with a mean of 0.28.

The interpretation of this pattern would suggest that the second and third groups represent smelting of ores in which the most calcium-rich examples are also more aluminous. There was little change in the silica to alumina ratio of the analysed ore material, so it seems unlikely that weathering could provide the sole explanation. One of the previously-analysed ore samples from WIRG (examined in 1996) was distinctly more aluminous and also high in calcium, so it would

appear more likely that there are other ores providing the variability. The fact that the datapoints from these groups do not form a linear array on these diagrams indicates that discrete types of source material were involved, not simply the mixing of two end-members.

In comparison to the interesting patterns shown by the major elements, the trace elements provide little additional information. In general the trace elements (particularly the so-called immobile elements: Nb, Y, Zr, the rare earth elements, Th and U) seem to be strongly influenced by the nature of the host sediment – and appear to have been little altered by the diagenetic processes that generated the ironstones.

The rare earth elements show Upper Crust-normalised profiles (Figure 3) that are close to horizontal. The weathered ore sample ores (LFW9b; Figure 3 upper diagram) show a close similarity with those of two of the earlier (unprovenanced) ore samples supplied by WIRG (Cd2 and Cd3) and is completely distinct from the other two earlier samples (Cd 5 and Cd7). These weathered ore profiles are very similar to (albeit slightly elevated from) the two samples of furnace ceramic (LFW1 and 3). The weathered ores have concentrations of REE approximately twice that of the fresh ore sample.

Tapped slags LFW4, 10 and 11 (members of Group 3 above) have similar profiles to each other, and their average REE concentration is 2.2 to 2.5 times that of the weathered ores.

Tapped slag LFW6 (a member of Group 1 above) shows a parallel profile, but much diluted compared to the weathered ores.

The key feature of these results is that the smelting slags cannot all be derived from precisely the same ore, but that all the smelting slags and ores discussed, with the exception of samples Cd5 and Cd7 are closely related.

Other residues

The analyses of the two slags that are interpreted not to be smelting slags, together with the slag rod (LFW12, 13 and 19 respectively) are all relatively high-iron slags.

The slag rod plots away from the three groups of smelting slags (Figure 5) in terms of its major element composition. In contrast, the smithing slag (LFW12) and the coarse-grained slag (LFW13) show major element compositional similarity with Group 1 of the smelting slags.

The slag rod (LFW19) has an even more depleted REE profile than the Group 1 smelting slag, LFW6, with just 1.1 to 1.2 times the REE concentrations recorded in the fresh ore sample.

The most diluted REE concentrations are to be found in the probable secondary slags, LFW12 (the SHC sample) and LFW13 (the very coarse-grained slag).

Interpretation

The CaO- SiO_2-FeO- ternary phase diagram

One useful tool for the investigation of the slags is the CaO-SiO_2-FeO ternary phase diagram (Bowen *et al.* 1933; Levin *et al.* 1964, Fig. 268). Use of this diagram obviously does not take into account the alumina in the slags (typically 3-7%), but it provides a good first approximation to their behaviour. The analysed smelting slags from this study and those of Paynter (2006) fall in a triangular region within which the liquidus lies at below 1200C (Figure 4) and within this region are clustered into three distinct fields:

- Firstly there is the major group of analyses (Field 'A' on Figure 4). These analyses correspond to slags formed in a reaction in which 50-60% of the iron has been removed from the *smelting mixture* (the mix of iron ore, fuel ash and furnace lining forming the overall melt). In this particular system, because of the variability of calcium in the ore, the role of fuel ash (dominated by calcium oxide) is very difficult to determine. Fuel ash has therefore been excluded from the interpretation process, but in practice, some of the calcium which is here attributed to ore will, in fact, have been derived from the fuel ash. The role of fuel ash in the generation of the melt is, however, probably fairly small (Thomas 2000 showed a contribution of <2% in his mass balance models). At the most calcium-poor end of the compositions within this group, the value of 60% extraction of iron from the ore is approximately the maximum possible under bloomery conditions because of very rapid rise in liquidus temperatures (from below1200C to over 1400C) as the proportion of silica exceeds 40%.

- Secondly a group of slags with high calcium contents analyses (Field 'B' on Figure 4), many of which were significantly glassy, show a higher degree of iron extraction, in the range of 70-80% of the iron in the *smelting mixture* having been extracted. These too are close to the limits of composition of a liquid at 1200C, but because of the elevated calcium content, these may be much more siliceous (>45%) than for the low-calcium slags described above.

- The third group of analyses (Field 'C' on Figure 4) lie on the eutectic composition between wustite and fayalite. The only example of a slag in this group analysed in the present study was the slag rod (LFW19). Unfortunately, it is not known whether the other examples of slag rod from the site have similar compositions. This group corresponds in location to an extraction of around 20-30% of the iron from the ore, but since that location plots close to that of the estimated ore, the uncertainty inherent in the estimate of ore compositions leads to uncertainty in the interpretation of this slag group.

The two slag samples analysed in the present programme that are not, or may not, be smelting slags – the smithing hearth cake and the very coarse-grained slag, plot together on this diagram and close to the location of fayalite, between the smelting slag fields 'A' and 'C'.

The overall region of the CaO-SiO_2-FeO ternary diagram occupied by Fields 'A', 'B' and 'C' is bounded by the two dark arrows of Figure 4c. These radiate from the FeO pole and indicate paths of slag compositional evolution as iron is removed from the *smelting mixture* as iron metal. These lines will therefore also bound the compositional field of the

original *smelting mixture* (the grey area on Figure 4b and c marks the expected position of this).

The distal bounding line of the field of slag compositions is the zone of rapidly increasing liquidus temperature once the stability field of tridymite is reached. On the SiO_2-FeO join, the tridymite-fayalite eutectic (1178C) lies at 38wt%SiO_2 and 62wt% FeO, but the field of cristobalite is reached at 1470C, at only 43% SiO_2 – a rise of 292C over a range of just 5wt%.

Mass balance modelling

Attempts to produce a mass balance description of the Little Furnace Wood slags following the methodology of Thomas & Young (1999a and 1999b) were not successful. The trace element distributions in the clay and ore are so similar that the modelling is not sufficiently sensitive. Modelling using major elements alone gave some approximation to a solution, but a good match could not be obtained; in particular it proved impossible to satisfactorily balance the calcium and magnesium contents at the same time as effecting a good match for the silica and alumina. Given the identification of the distinct chemical groups within the tapslags (see above), the problem with establishing a convincing mass balance solution lies with the poor correlation between the various components and products. In general it would appear that the solution probably requires at least 94% ore to 6% furnace lining.

The significance of compositional Groups 1-3

When the CaO-SiO_2-FeO ternary diagram of Figure 4 is replotted to show the distribution of the three groups of analyses identified on the recast, iron-free, bivariate plots, the three groups form arrays in the direction of slag evolution (Figure 5). Group 1 includes analyses that lie in Field A and Field C, Group 2 slags lie in Field B only, and Group 3 tapslags include examples in Fields A and B. This strongly suggests that the observed slags derive from the smelting of three distinct ore types (or mixtures). The assignation of samples to groups and fields is given in Figure 6.

All three of these ores are likely to have lain broadly within a range approximately between the composition of the weathered ore sample LFW9b and one in which the weathered ore is mixed with 20% by weight of the fresh ore sample (LFW9a). Such a mixture does not, however, adequately explain all the slag compositions and a wider variety of actual detailed ore compositions must have been involved within this small area of CaO:SiO_2:FeO space.

It is not intended to suggest that such a mixture need have been a deliberate act. The existing dataset is too small to be more precise about the details of the ore employed at present. The composition of naturally-occurring bulk ore collections has not been determined, nor has the natural range of compositions of the shelly ironstones. It also has to be remember that the effect of roasting ores has not been investigated either. Such investigations could form the basis of future work.

Slag viscosity

Although the dataset has now been described in terms of pattern and pathway, it is somewhat more difficult to interpret in terms of bloomery process and technique. One factor which may potentially be of significance is slag viscosity.

Paynter (2007) modelled slag viscosity using a model based on that of Bottinga and Weill (1972), derived for geological materials with >35mol% silica. Craddock *et al.* (1985) demonstrated the accuracy of this model to be within a factor of 2.

The viscosity of the analysed slag samples was modelled using this technique (Table 10) at temperatures of 1200, 1250 and 1400 °C. At high temperature (1400°C) the slags were all suggested to be of low viscosity (0.4 to 1.7 poise), but at 1200 °C the estimated viscosity for these showed a much higher range of 2.1 to 13.4 poise.

An alternative approach for viscosity estimation using the algoNess 'slag liquid viscosity calculation tool' (www.algoness.co.za; based on the Urbain formalism after Mills 1995), suggested a viscosity range of 21-40 poise at 1200C and 31 to 62 poise at 1150C (Table 11). These estimates are almost an order of magnitude higher than those from the Bottinga & Weill technique.

Unfortunately there seems to be a lack of published measured liquid (either slag or magma) viscosities within the range of compositions of interest here, so it is difficult to assess the accuracy of the modelled results. If the viscosities at temperatures of 1200C, particularly for the iron-poor slags, are as high as they are modelled by the algoness tool, then there might be significant issues with slag flow at tapping temperature.

Slag composition and texture

Some correlation may be made between the observed slag textures and the compositional grouping of the samples.

Those samples in Group 3 and Field B (LFW 10 and 11) show strongly zoned olivines in glass. The zoning is associated with the high relatively concentrations of calcium, magnesium and manganese in these samples. When compared (Figure 7) with the CaO-SiO_2-FeO ternary diagram of Bowen *et al.* (1933), these analyses plot in the field of β $CaSiO_3$, so the occurrence of olivine indicates an enhanced olivine stability field in the presence of the other elements present in the sample (but not in the CaO-SiO_2-FeO system). The high proportion of glass in these samples reflects the proximity to the fields of the silica polymorphs.

The sample from Group C and Field A (LFW 4) shows some primary wustite, which would also not have been predicted by reference to the simple CaO-SiO_2-FeO system, although the wustite field is close.

Discussion

The analyses of the smelting slags presented above show that the site was involved in the smelting of several distinct iron ore types or mixes. The data also showed a series of fields indicating that the smelting slags were produced by processes with distinct yields. The incorporation of all of Paynter's (2006) analyses as individual points, rather than presenting the average of points from sample, may have accentuated the clustered distribution, but has not generated it. However, the nature of the rather small tapped slag pieces meant that it was not possible to determine whether the bulk residues from entire smelts corresponded to these different fields, or whether a

single smelt might, during its course, produce slags spread over more than one of the fields.

The ore type with the highest calcium contents was capable of producing slags indicative of a very high yield (70%-80% of the iron present in the ore). However, the slags from this group (Group 3) were present in all three of the compositional fields. This suggests that either smelting was undertaken to produce a high yield only intermittently, even with a suitable ore feed, or, perhaps more likely, that a proportion of slags from a smelt with a more modest bulk yield, were produced by of higher degrees of local reduction. If this is the case then the bulk residue composition of each of smelts from each of Groups 1-3 might have been close to that of Field A – which corresponds broadly to furnace extractive efficiencies of 50%-60%, similar to those seen in contemporary furnaces elsewhere (e.g. Thomas 2000). Although possible, on balance it seems unlikely that this furnace was deliberately exploiting high-calcium ores to improve its extractive efficiency.

The presence of slag with a composition suggestive of a high degree of iron extraction does raise further questions. The creation of a slag with a low iron oxide content reduces the ability of the slag to limit the uptake of carbon by the metallic iron. Although the creation of bloomery steel can be a desired outcome, if soft iron is required (as is the usual case), then steely blooms are a problem and can be difficult to forge. Any further progression towards the production of cast iron in the bloomery can be highly undesirable. The limiting of iron extraction to a degree to preserve sufficient iron in the slag to keep the carbon levels of the iron within acceptable bounds would have had to be balanced against the increased yield of higher-carbon iron.

Modelling of the viscosity of the high-calcium slags gave ambiguous results with different tools, but the textures of the more glassy slags were distinct and suggestive of a higher viscosity melt. It is possible that the dome-shaped furnace would have allowed such slag to flow from the bloom, but remain at high temperature within the furnace to keep its viscosity low. It is possible that some, or even possibly all, of the presumed tapped slags actually cooled within the furnace. Some evidence for cooling of at least some of the slag within the furnace may be indicated by the slags sampled from within and below the furnace floor. Similar furnace- floor flows were recorded from the larger domed furnace at Laxton (Crew 1998). If the furnace was not strictly slag- tapping, then the use of the arch for both blowing and furnace clearance might explain the lack of a blowhole/tuyère elsewhere in the structure.

The slag assemblage from the site is characterised by numerous examples of small slag tubes or rods. It was hoped that analysis of the slag might help interpret these enigmatic residues. In fact, the slag from the analysed rod did not correspond to any of the compositional groups of smelting slags. Although it remains likely that it is indeed a smelting residue, this was not proven in the present work. The low degree of iron extraction suggested by the analysis of this sample, if general, might suggest that these rods do not derive from the simple tapping of typical smelting slags, but might either arise early in the smelt (before a steady bloom-producing reaction has been developed) or through extraction of slag high in the furnace, perhaps above bloom level. Further work to determine slag rod composition on a broader basis would clearly be desirable.

The analysed smithing slag (LFW12) produced evidence for a rather strongly oxidising environment, with both magnetite and iscorite as significant phases. Although the relatively large size of the piece would suggest that it is a smithing hearth cake from a bloom smithing operation, the oxidising environment is unusual. Further work on the possible smithing residues from such sites would be desirable to ascertain what processes were actually being undertaken close to the furnaces.

Further evidence for the possible secondary processing techniques, albeit somewhat inconclusive, is provided by the very coarse-grained slag (LFW13). The large size of the crystals of olivine in this slag (up to 15mm) indicates that it formed from the cooling of a substantial slag puddle. Such materials are rare in general, but somewhat similar materials do occur in the early medieval of Ireland (e.g. Young in press) where they have been tentatively attributed to processes of bloom refining involving remelting, rather than simply bloomsmithing. One potential reason for a more complex process of bloom refining might be the need to compensate for an elevated carbon content in the bloom. Percy (1864, p. 326) referred to the occasional need to refine blooms from the *stuckofen* which had gained too much carbon.

It is clear that secondary processing of blooms did occur on this site (with hammerscale and smithing slags as evidence), but the volume of secondary processing waste appears small, and most bloom refining may have taken place off-site, or at least outside the excavated area. Should significant bloomsmithing/bloom refining deposits from such a furnace be discovered, then their careful investigation may well assist in the interpretation of the product.

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Illustration Captions

Figure 1. Bivariate plots of major elements presented as wt% oxides.

Figure 2. Bivariate plots of major elements presented as wt% oxides from analyses recast to exclude iron.

Figure 3. Rare earth element (REE) profiles, normalised to the Upper Crust standard (normalisation factors after Taylor and McLennan 1981).

Figure 4. Modelling slag evolution using the CaO-SiO_2-FeO ternary diagram.

Figure 5. Modelling slag evolution using the CaO-SiO_2-FeO ternary diagram. Diagram as Figure 4B, but with analytical data from the smelting slags replotted by chemical group. Group 1- blue crosses; Group 2 – green triangles; Group 3 – red diamonds; slag tube – black triangle; possible smithing slags – black circles.

Figure 6. Tale showing the allocation of the specimens of tapslags analysed in this study (LFW 4, 6,10 & 11) and by Paynter (2006; SP 1- 8) together with the slag rod analysed in this project (LFW 19) to the compositional trend groups (1-3) and the fields on the CaO-SiO_2-FeO ternary diagram (A-C).

Figure 7. The CaO-SiO_2-FeO ternary diagram (after Bowen *et al.* 1933; Levin *et al.* 1964, Fig. 268). Superimposed analytical data as Figure 4 A.

Plate 1: LFW4; Backscattered electron photomicrographs.

a. section through flow lobe (SOI1 to SOI12). Scale bar 1mm.

b. LFW4, SOI1. Scale bar 300µm.

c. LFW4, SOI5. Scale bar 300µm.

d. LFW4, SOI8. Scale bar 300µm.

e. LFW4, SOI11. Scale bar 300µm.

Plate 2: LFW4; Backscattered electron photomicrographs.

a. LFW4, SOI14. Scale bar 90µm.

b. LFW4, SOI14 (with microanalysis locations). Scale bar 90µm.

c. LFW4, SOI15. Scale bar 100µm.

d. LFW4, SOI15 (with microanalysis locations). Scale bar 100µm.

e. LFW4, SOI16. Scale bar 90µm.

f. LFW4, SOI16 (with microanalysis locations). Scale bar 90µm.

g. LFW4, SOI13. Scale bar 400µm.

Plate 3: LFW6; Backscattered electron photomicrographs.

a. LFW6, SOI1. Scale bar 1mm.

b. LFW6, SOI2. Scale bar 1mm.

c. LFW6, SOI3. Scale bar 1mm.

d. LFW6, SOI4. Scale bar 4mm.

e. LFW6, SOI5. Scale bar 300µm.

f. LFW6, SOI5 (with microanalysis locations). Scale bar 300µm.

g. LFW6, SOI6. Scale bar 100µm.

h. LFW6, SOI6 (with microanalysis locations). Scale bar 100µm.

Plate 4: LFW10; Backscattered electron photomicrographs.

a. LFW10, SOI2. Scale bar 600µm.

b. LFW10, SOI3. Scale bar 100µm.

c. LFW10, SOI4. Scale bar 60µm.

d. LFW10, SOI4 (with microanalysis locations). Scale bar 60µm.

e. LFW10, SOI5. Scale bar 60µm.

f. LFW10, SOI5 (with microanalysis locations). Scale bar 60µm.

g. LFW10, SOI1. Scale bar 600µm.

Plate 5: LFW11; Backscattered electron photomicrographs.

a. LFW11, SOI1. Scale bar 600µm.

b. LFW11, SOI2. Scale bar 600µm.

c. LFW11, SOI3. Scale bar 600µm.

d. LFW11, SOI5. Scale bar 40µm.

e. LFW11, SOI4. Scale bar 40µm.

f. LFW11, SOI4 (with microanalysis locations). Scale bar 40µm.

g. LFW11, SOI6. Scale bar 40µm.

h. LFW11, SOI6 (with microanalysis locations). Scale bar 40µm.

Plate 6: LFW12; Backscattered electron photomicrographs.

a. LFW12, SOI1. Scale bar 700µm.

b. LFW12, SOI2. Scale bar 600µm.
c. LFW12, SOI3. Scale bar 100µm.

d. LFW12, SOI4. Scale bar 400µm.

e. LFW12, SOI5. Scale bar 1mm.

f. LFW12, SOI6. Scale bar 3mm.

g. LFW12, SOI7. Scale bar 100µm.

h. LFW12, SOI7 (with microanalysis locations). Scale bar 100µm.

Plate 7: LFW12; Backscattered electron photomicrographs.

a. LFW12, SOI9. Scale bar 30µm.

b. LFW12, SOI9 (with microanalysis locations). Scale bar 30µm.

c. LFW12, SOI10. Scale bar 30µm.

d. LFW12, SOI10 (with microanalysis locations). Scale bar 30µm.

e. LFW12, SOI11. Scale bar 100µm.

f. LFW12, SOI11 (with microanalysis locations). Scale bar 100µm.

g. LFW12, SOI8. Scale bar 600µm.

h. LFW12, SOI13. Scale bar 300µm.

Plate 8: LFW12; Backscattered electron photomicrographs and elemental maps.

a. LFW12, SOI12. Scale bar 50µm.

b. LFW12, SOI12 (with microanalysis locations). Scale bar 50µm.

c. LFW12, SOI12. Element map – silicon. Scale bar 50µm.

d. LFW12, SOI12. Element map – aluminium. Scale bar 50µm.

e. LFW12, SOI12. Element map – potassium. Scale bar 50µm.

f. LFW12, SOI12. Element map – iron. Scale bar 50µm.

g. LFW12, SOI12. Element map – calcium. Scale bar 50µm.

Plate 9: LFW12; Backscattered electron photomicrographs.

a. LFW12, SOI15. Scale bar 100µm.

b. LFW12, SOI15 (with microanalysis locations). Scale bar 100µm.

c. LFW12, SOI16. Scale bar 100µm.

d. LFW12, SOI16 (with microanalysis locations). Scale bar 100µm.

e. LFW12, SOI14. Scale bar 300µm.
Plate 10: LFW13; Backscattered electron photomicrographs.

a. LFW13, SOI1. Scale bar 600µm.

b. LFW13, SOI4. Scale bar 3mm.

c. LFW13, SOI2. Scale bar 600µm.

d. LFW13, SOI2 (with microanalysis locations). Scale bar 600µm.

e. LFW13, SOI3. Scale bar 60µm.

f. LFW13, SOI3 (with microanalysis locations). Scale bar 60µm.

g. LFW13, SOI5. Scale bar 200µm.

h. LFW13, SOI6 (with microanalysis locations). Scale bar 60µm.

Plate 11: LFW19: Backscattered electron photomicrographs.

Composite of section (SOI5-SOI38).

Plate 12: LFW19; Backscattered electron photomicrographs.

a. LFW19, SOI3. Scale bar 100µm.

b. LFW19, SOI3 (with microanalysis locations). Scale bar 100µm.

c. LFW13, SOI4. Scale bar 60µm.

d. LFW13, SOI4 (with microanalysis locations). Scale bar 60µm.

e. LFW13, SOI40. Scale bar 600µm.

f. LFW13, SOI41. Scale bar 100µm.

g. LFW13, SOI2. Scale bar 3mm.

Plate 13: Sample LFW1, before cutting

Plate 14: Sample LFW3, before cutting

Plate 15: Sample LFW4, before cutting

Plate 16: Sample LFW6, before cutting

Plate 17: Sample LFW9, before cutting

Plate 18: Sample LFW10, before cutting

Plate 19: Sample LFW11, before cutting

Plate 20: Sample LFW12, before cutting

Plate 21: Sample LFW13, before cutting

Plate 22: Sample LFW19, before cutting

Table 1: Summary catalogue of examined material

Context	Area	context type	context description	weight (g)	description
1	TP3/all	layer	topsoil	147	7 fragments of slag rods
1	TP3/all	layer	topsoil	15	1 dense fragment of flowed slag
1	TP3/all	layer	topsoil	132	iron ore
1	TP3/all	layer	topsoil	44	1 fragment of dense slag
1	TP3/all	layer	topsoil	4	flint
1	TP4	layer	topsoil	1560	c. 15 fragments of iron ore; 2 small fragments of oxidised fired clay
1		layer	topsoil	193	1 fragment of iron ore
1		layer	topsoil	785	large dense lump of corroded iron
1		layer	topsoil	375	dense fragment of slag – well- formed large olivine crystals **[sample LFW13]**
1		layer	topsoil	710	large fragment of lining slag
1	all	layer	topsoil	200	1 fragment of dense slag, iron rich upper surface
1	all	layer	topsoil	88	1 fragment of slag rod
1	all	layer	topsoil	33	2 fragments of platy slag, 1 with blebby base
1	all	layer	topsoil	149	1 fragment of vesicular flowed slag
1	all	layer	topsoil	435	1 fragment of slag with roughly v-shaped cross section, occasional charcoal moulds, rusty appearance
1	all	layer	topsoil	21	iron rich concretion
1	all	layer	topsoil	32	2 fragments of iron ore
1	all	layer	topsoil	337	2 fragments of flowed slag - gravelly base
1	all	layer	topsoil	78	2 fragments of slag rods
1	all	layer	topsoil	219	4 fragments of relatively dense slag
1	all	layer	topsoil	1475	12 fragments of fired clay, vary from 20-50mm in thickness - furnace superstructure
1	all	layer	topsoil	775	natural stone
2		layer	general soil layer - above 1	776	fragment of dense roughly plano-convex SHC, 110x70x50mm, (60% complete) **[sample LFW12]**
2		layer	general soil layer - above 1	11	1 fragment of oxidised fired clay
2		layer	general soil layer - above 1	112	2 fragments of iron ore
2		layer	general soil layer - above 1	300	9 fragments of flowed slag, 2 are rod-like
2		layer	general soil layer - above 1	141	2 fragments of slag with small amounts of clay and unreacted ore, 1 has frequent charcoal moulds
2		layer	general soil layer - above 1	385	4 fragments of dense slag, 1 has lining attached
4	TP1	fill	fill of (7) animal disturbance	46	1 fragment of roughly 'tubular' slag
6	TP1	layer	upper fill of furnace 1	146	1 fragment of slag with lobe textures on upper surface - tapslag
6	TP1	layer	upper fill of furnace 1	138	3 fragments of slag, 1 quite dense with blebby upper surface, 1 has small amount of lining attached
10	TP1	fill	fill of furnace 1	525	5 fragments of relatively low density slag with occasional charcoal moulds and inclusions, 1 piece has clay attached

Context	Area	context type	context description	weight (g)	description
10	TP1	fill	fill of furnace 1	1330	6 fragments of dense lining slag, blistered texture on one side, clay on the other
10	TP1	fill	fill of furnace 1	725	1 large fragment (160x120x25mm) slightly curved, slagged lining **[sample LFW1]**
10	TP1	fill	fill of furnace 1	112	4 fragments of lining, approx 5mm thick - vitrified on one side
10	TP1	fill	fill of furnace 1	226	2 dense fragments of slag
10	TP1	fill	fill of furnace 1	66	6 fragments of broken lobes of slag
11 J/K				24	3 small fragment of indeterminate slag, 1 quite blebby
12	TP1	fill	lower fill in furnace 1, above floor (13)	144	2 fragments of vitrified lining (approx. 1 cm thick)
12	TP1	fill	lower fill in furnace 1, above floor (13)	135	wet sieved residue - numerous small fragments of slag, includes broken flows, blebs and 'coffee bean' spheroids
12	TP1	fill	lower fill in furnace 1, above floor (13)	129	wet sieved residue - very small fragments of indeterminate slag, includes some prill and runs
12	TP1	fill	lower fill in furnace 1, above floor (13)	221	wet sieved residue - 6 fragment of lining - vitrified on one side
18	TP1	layer	below clay floor of furnace 1	625	large fragment of tap slag **[sample LFW4]**
19	TP1	layer	rubble fill in front bottom of furnace 1	1050	2 large fragments of lining slag, 1 with oxidised lining attached
19	TP1	layer	rubble fill in front bottom of furnace 1	87	5 fragments of vitrified lining (2 conjoining)
19	TP1	layer	rubble fill in front bottom of furnace 1	39	3 small fragments of indeterminate slag
19	TP1	layer	rubble fill in front bottom of furnace 1	485	1 fragment of low density clay and charcoal rich slag, 1 charcoal inclusion approx. 40 mm long
19	TP1	layer	rubble fill in front bottom of furnace 1	800	5 fragments of low density, highly vesicular, brittle slag. Largest fragment has 1 large charcoal mould (60mm), 1 small piece has small fragment of corroded iron
19	TP1	layer	rubble fill in front bottom of furnace 1	67	1 fragment of vitrified lining
19	TP1	layer	rubble fill in front bottom of furnace 1	63	1 fragment of slag (quite glassy)
19	TP1	layer	rubble fill in front bottom of furnace 1	77	4 broken prills of slag
19	TP1	layer	rubble fill in front bottom of furnace 1	370	8 fragments of vitrified lining, 10-25mm thick
19	TP1	layer	rubble fill in front bottom of furnace 1	450	2 dense fragments of slag
19	TP1	layer	rubble fill in front bottom of furnace 1	1200	1 large fragment of lining slag (190x130mm) **[sample LFW3]**
19	TP1	layer	rubble fill in front bottom of furnace 1	800	large fragment of lining slag
20	TP2	layer	compact layer of slag	923	1 fragment of clay rich slag - probably furnace slag
20	TP2	layer	compact layer of slag	16	1 fragment of glassy slag
20	TP2	layer	compact layer of slag	66	1 fragment of clay rich dense slag
22	TP1	layer	layer of soil outside furnace 1	1205	fragment of dense iron rich slag cake (approx. 130x100x50mm)
22	TP1	layer	layer of soil outside furnace 1	475	fragment of flowed slag **[sample LFW6]**
22	TP1	layer	layer of soil outside furnace 1	279	8 fragments of indeterminate slag
22	TP1	layer	layer of soil outside furnace 1	17	small fragment of dense slag; 1 small broken flow

Context	Area	context type	context description	weight (g)	description
23	TP1	layer	rubble fill in front of bottom of furnace 1	46	2 fragments of flowed slag
23	TP1	layer	rubble fill in front of bottom of furnace 1	5	2 fragments of indeterminate slag, 1 is clay rich
26	TP3	fill	main fill of cut (25)	177	fragment of iron ore
26	TP3	fill	main fill of cut (25)	2.6	charcoal
26	TP3	fill	main fill of cut (25)	152	fragment of slag, mixed with clay, 1 charcoal inclusions approx 30mm
26	TP3	fill	main fill of cut (25)	387	fragment of slag, convex base with thin layer of clay, with rough upper surface - purplish tinge
26	TP3	fill	main fill of cut (25)	71	fragment of slag with small quantity of unreacted ore
26	TP3	fill	main fill of cut (25)	575	1 natural stone, several smoothed surfaces – grind/hone stone
26	TP3	fill	main fill of cut (25)	14	small fragment of flowed slag
26	TP3	fill	main fill of cut (25)	121	2 fragments of flag slag
26	TP3	fill	main fill of cut (25)	525	small SHC (100x95x25mm), moderate charcoal inclusions in upper and lower surfaces, moderate clay attached to base, rusty in appearance (80% complete)
26	TP3	fill	main fill of cut (25)	345	(wet sieved residue) numerous fragments of slag, broken blebs and lobes; approx. 5 small fragments of fired clay
26	TP3	fill	main fill of cut (25)	376	fragment of dense slag cake, some lining attached, occasional charcoal moulds
26	TP3	fill	main fill of cut (25)	484	iron ore
26	TP3	fill	main fill of cut (25)	52	lining slag, oxidised fired clay on one side
26	TP3	fill	main fill of cut (25)	22	1 fragment of slag flow
26	TP3	fill	main fill of cut (25)	123	4 fragments of slag rods
26	TP3	fill	main fill of cut (25)	140	7 fragments of fairly dense lobes of slag
26	TP3	fill	main fill of cut (25)	63	1 flat fragment of slag with blistered base
26	TP3	fill	main fill of cut (25)	141	1 fragment of dense blebby slag
26	TP3	fill	main fill of cut (25)	142	1 fragment of lining slag
26	TP3	fill	main fill of cut (25)	492	1 fragment of dense slag (27mm thick), large vesicles on one surface
26	TP3	fill	main fill of cut (25)	66	2 small fragments of probable lining, vitrified on one side, oxidised fired clay on the other
26	TP3	fill	main fill of cut (25)	59	fragment of natural stone
26	TP3	fill	main fill of cut (25)	135	1 fragment of lining slag, grey clay on one side, frothy slag on the other
26	TP3	fill	main fill of cut (25)	142	1 fragment of dense flowed slag - cone shaped
26	TP3	fill	main fill of cut (25)	81	1 fragment of dense slag
26	TP3	fill	main fill of cut (25)	113	1 fragment of flowed slag with upper lobes, clay rich lower surface
26	TP3	fill	main fill of cut (25)	15	1 fragment of indeterminate slag
26	TP3	fill	main fill of cut (25)	480	1 large fragment of ore
26	TP3	fill	main fill of cut (25)	226	wet sieved - includes flake and spheroidal hammerscale; small fragment of slag, fired clay and ore
27	TP1	fill	tumble of fill in furnace 1	18	1 fragment of low density, frothy, brittle slag
27	TP1	fill	tumble of fill in furnace 1	6	small fragment of charcoal and clay
28	TP1	fill	fil in base of furnace 1	650	1 fragment of lining slag
34	TP1	layer	probable tumble in front of furnace 1	29	1 fragment of flowed slag

Context	Area	context type	context description	weight (g)	description
34	TP1	layer	probable tumble in front of furnace 1	66	2 fragments of indeterminate slag
34	TP1	layer	probable tumble in front of furnace 1	720	2 fragments of clay rich lining slag **[sample LFW1]**
34	TP1	layer	probable tumble in front of furnace 1	1985	3 large fragments of clay rich lining slag
35	TP1	fill	uper fill of (36)	752	10 fragments of lining slag - slag/clay mix, 1 fragment has frequent charcoal inclusions
35	TP1	fill	uper fill of (36)	250	1 fragment of lining slag
35	TP1	fill	uper fill of (36)	117	1 fragment of charcoal and clay rich slag
38	TP3	fill	fill of south edge of pit (25)	106	2 conjoining pieces of lining
38	TP3	fill	fill of south edge of pit (25)	140	(wet sieved residue) small fragments of slag
38	TP3	fill	fill of south edge of pit (25)	19	1 small fragment of dense blebby slag
38	TP3	fill	fill of south edge of pit (25)	71	fragment of slag with smooth upper surface, crystalline base
38	TP3	fill	fill of south edge of pit (25)	63	wet sieved residue - magnetic material - includes flake and spheroidal hammerscale and larger fragment of magnetic material
39	TP1	fill	upper fill of cut (42)	725	(wet sieved residue) numerous small fragments of slag, includes several broken lobes and flowed pieces
39	TP1	fill	upper fill of cut (42)	137	3 concretions surrounding corroded iron
39	TP1	fill	upper fill of cut (42)	250	5 fragments of slag rods; 2 fragments of flowed slag **[sample LFW19]**
39	TP1	fill	upper fill of cut (42)	80	fragment of flowed slag with smooth upper surface
39	TP1	fill	upper fill of cut (42)	284	fragment of iron ore
39	TP1	fill	upper fill of cut (42)	274	fragment of lining slag
39	TP1	fill	upper fill of cut (42)	318	fragment of lining slag, occasional charcoal moulds
39	TP1	fill	upper fill of cut (42)	75	fragment of indeterminate slag, vitrified in areas, possible lining slag
39	TP1	fill	upper fill of cut (42)	86	possible natural stone/concretion (quartz rich)
39	TP1	fill	upper fill of cut (42)	173	1 fragment of iron ore
39	TP1	fill	upper fill of cut (42)	480	wet sieved - mostly fine material, includes flake and spheroidal hammerscale, small fragments of iron rich slag and fragments of slag
41	TP1	layer	thin layer above natural in front of furnace 1	13	5 very small fragments of iron ore
41	TP1	layer	thin layer above natural in front of furnace 1	25	1 fragment of iron ore
41	TP1	layer	thin layer above natural in front of furnace 1	197	5 fragments of dense slag, 2 are broken lobes
45	TP3	layer	general soil layer	12	iron ore
45	TP3	layer	general soil layer	19	oxidised fired clay
45	TP3	layer	general soil layer	76	lining slag
45	TP3	layer	general soil layer	80	6 small fragments of dense slag; 1 broken lobe; 1 fragment of slag rod
45	TP3	layer	general soil layer	56	1 slag/clay rich concretion with small amounts of hammerscale in matrix, occasional charcoal moulds
45	TP3	layer	general soil layer	23	natural stone
45	TP3	layer	general soil layer	9	fragment of iron ore
45	TP3	layer	general soil layer	45	1 fragment of slag rod

Context	Area	context type	context description	weight (g)	description
45	TP3	layer	general soil layer	81	1 fragment of dense slag, smooth upper surface
45	TP3	layer	general soil layer	49	1 fragment of indeterminate slag
47	TP4/6	layer	topsoil in TP4	26	fragments of blebby slag
47	TP4/6	layer	topsoil in TP4	62	iron ore
47	TP4/6	layer	topsoil in TP4	54	lining slag
47	TP4/6	layer	topsoil in TP4	56	natural stone
47	TP4/6	layer	topsoil in TP4	350	8 fragments of iron ore
48	TP1	fill	main fill of forging hearth pit (36)	426	(wet sieved residue) numerous small fragments of slag and fired clay
48	TP1	fill	main fill of forging hearth pit (36)	3625	c.200 fragments of low density slag, mostly small fragments, some larger pieces also low density with occasional charcoal moulds; 5 fragments of iron ore
48	TP1	fill	main fill of forging hearth pit (36)	220	wet sieved - includes flake and spheroidal hammerscale; small fragments of slag
53	TP3	fill	fill in SW part of pit (25) adj (38)	254	5 fragments of flowed slag; 3 small fragments of dense slag
53	TP3	fill	fill in SW part of pit (25) adj (38)	68	1 fragment of clay rich slag
55	TP4	fill	upper fill of pit (54)	195	fragments of iron ore
55	TP4	fill	upper fill of pit (54)	12	oxidised fired clay
55	TP4	fill	upper fill of pit (54)	33	3 small fragments of indeterminate slag
55	TP4	fill	upper fill of pit (54)	18.5	fragment of corroded iron
55	TP4	fill	upper fill of pit (54)	57	4 fragments of oxidised fired clay
55	TP4	fill	upper fill of pit (54)	1080	c. 35 fragments of iron ore
55	TP4	fill	upper fill of pit (54)	1272	1 large fragment of iron ore; c. 26 smaller fragments **[sample LFW9]**
55	TP4	fill	upper fill of pit (54)	28	1 fragment of indeterminate slag
55	TP4	fill	upper fill of pit (54)	825	flake and spheroidal hammerscale, small fragments of slag, ore and fired clay
55	TP4	fill	upper fill of pit (54)	605	flake and spheroidal hammerscale, small fragments of slag, ore and fired clay
59	TP4	fill	lower fill of pit (54) contains carbonised logs	776	16 fragments of iron ore; 1 fragment of slag (77g)
59	TP4	fill	lower fill of pit (54) contains carbonised logs	580	coarse and fine flake hammerscale, occasional spheroids; small fragments of iron rich slag, ore and oxidised fired clay
63	TP7	layer	thin layer charcoal rich soil above natural	455	fragments of iron ore
53	TP7	layer	thin layer charcoal rich soil above natural	123	fragments of dense indeterminate slag
63	TP7	layer	thin layer charcoal rich soil above natural	126	5 small fragments of indeterminate slag; 6 small fragments of possible ore
63	TP7	layer	thin layer charcoal rich soil above natural	350	predominately flake hammerscale, occasional spheroidal hammerscale; small fragments of slag, ore and oxidised fired clay
65	TP7	layer	layer of compact slag	80	2 fragments of iron ore
65	TP7	layer	layer of compact slag	25	oxidised fired clay

Context	Area	context type	context description	weight (g)	description
65	TP7	layer	layer of compact slag	30	concretion surrounding corroded iron
65	TP7	layer	layer of compact slag	262	3 small fragments of dense slag, 1 with flowed texture on surface
65	TP7	layer	layer of compact slag	269	3 fragments of 'flat' or 'plate' slag, 1 with small amount of oxidised fired clay attached
65	TP7	layer	layer of compact slag	750	3 fragments of lining slag
65	TP7	layer	layer of compact slag	157	9 small fragments of slag, mostly broken runs
65	TP7	layer	layer of compact slag	44	4 fragments of iron ore
65	TP7	layer	layer of compact slag	43	3 fragments of broken runs of slag, 1 is small rod (26g)
65	TP7	layer	layer of compact slag	183	fragment of slag with clay, occasional charcoal moulds and inclusions
65	TP7	layer	layer of compact slag	600	1 fragment of slag, mostly smooth surfaces, occasional upper lobes, very glassy
65	TP7	layer	layer of compact slag	191	1 fragment of slag with rusty appearance, flow structures on one surface
65	TP7	layer	layer of compact slag	76	1 fragment of slag with rough texture
65	TP7	layer	layer of compact slag	206	fragment of stone
68	TP8	layer	charcoal rich soil above compact slag layer	100	3 fragments of ore
68	TP8	layer	charcoal rich soil above compact slag layer	1150	15 dense fragments of flowed slag, including 1 rod of slag
68	TP8	layer	charcoal rich soil above compact slag layer	490	indeterminate slag - 2 fragments are charcoal rich
68	TP8	layer	charcoal rich soil above compact slag layer	67	1 fragment of lining slag
68	TP8	layer	charcoal rich soil above compact slag layer	40	wet sieved residue - 4 fragments of clay and charcoal rich concretions
68	TP8	layer	charcoal rich soil above compact slag layer	24	wet sieved residue - 4 small fragments of ore
68	TP8	layer	charcoal rich soil above compact slag layer	400	wet sieved residue - fragments of dense indeterminate slag
68	TP8	layer	charcoal rich soil above compact slag layer	510	c.19 fragments of dense slag, several are broken flows and lobes
68	TP8	layer	charcoal rich soil above compact slag layer	59	wet sieved - predominately flake hammerscale, occasional spheroidal hammerscale - all quite fine
70	TP4	fill	possibly disturbed fill on west side of (54)	51	iron ore
74	TP4	layer	disturbed (roots) area on north edge of (54)	390	1 large, 1 small fragment of ore, outer thin weathered crust - pale orangish interior
74	TP4	layer	disturbed (roots) area on north edge of (54)	131	7 small fragments of dense slag
75	TP4	fill	compact fill of roasted ore in pit (54)	3090	7 large chunks of (roasted) ore
76	TP8	layer	compact area of slag	2150	1 long fragment of lining slag (250x80-120mm)
76	TP8	layer	compact area of slag	400	1 fragment of dense slag with upper lobate surface, lower surface appears very glassy
76	TP8	layer	compact area of slag	550	fragment of slag, small blebby flow structures and occasional charcoal moulds on base
76	TP8	layer	compact area of slag	200	slag/clay/stone concretion
76	TP8	layer	compact area of slag	460	1fragment of lining slag, slightly curved, 2 smaller fragments
76	TP8	layer	compact area of slag	13	slag/clay/charcoal concretion
76	TP8	layer	compact area of slag	340	fragment of lining slag
76	TP8	layer	compact area of slag	64	fragment of lining slag
76	TP8	layer	compact area of slag	1473	8 fragment of dense slag, several fragments have very glassy fracture in areas, various flow structures from thin ropey textures to broader types **[sample LFW10]**

Context	Area	context type	context description	weight (g)	description
76	TP8	layer	compact area of slag	182	fragment of less dense, flowed slag
92	TP11	layer	soil layer	1200	2 conjoining pieces of flowed slag - tap slag; 1 broken run of slag
95	TP4	fill	lower fill of pit (54) between (97) and (98)	1550	approx. 42 fragments of ore
101	TP6?			32	2 fragments of thin grey slag
101	TP6?			113	2 substantial pieces and some fragments from tuyères. Diameter approximately 25mm.
101	TP6?			296	4 slag rods, one double.
101	TP6?			242	2 pieces of ore
101	TP6?			2136	8 bowl-shaped slag fragments, 6 with attached white clay, 2 with orange/brown clay
101	TP6?			579	Bowl-shaped rusty slag with integral slag rod
101	TP6?			778	6 slag fragments, one with flows - 3 low density, 3 high density
?101				430	2 fragments of furnace lining, 1 shows evidence of repair and reuse
105	TP8	fill	fill in (111)	3125	3 large dense slabs with lobed texture on upper surface, very glassy in areas - tap slag **[sample LFW11]**
127	TP8	fill	fill in (111)	48	concretion surrounding fragment of corroded iron
127	TP8	fill	fill in (111)	112	fragment of slag rod, approx. 20mm diameter
127	TP8	fill	fill in (111)	159	2 fragments of fired clay, 1 fragment is possible organic rich daub becoming rapidly vesicular as it moves away from central depression
127	TP8	fill	fill in (111)	49	fragment of stone with clay and charcoal rich concretion
127	TP8	fill	fill in (111)	48	fragment of dense indeterminate slag
131	TP8a	fill	fill of forging hearth	300	c.8 fragments of indeterminate slag, occasional charcoal and clay inclusions
131	TP8a	fill	fill of forging hearth	200	c.30 small fragment of friable fired clay with occasional charcoal inclusions
134	TP8a	fill	fill in (111)	1655	2 possibly conjoining pieces of clay concretions surrounding fairly large, possibly flat, fragment of iron, occasional charcoal inclusions in clay
?	?	?	(LFW03)	434	Dense slag with flow texture on upper surface
?	TP7	?	(LFW05?)	146	Fragment of slag rod
?	TP10	?	(LFW05?)	292	9 slag fragments, 2 larger (146g and 80g) dense with flat top and base with charcoal imprints.

Table 2: Sampled material

sample	***year***	***context***	***area***	***context type***	***context description***	***Simple description***	***type of analyses***	
LFW1	LFW04	34	TP1	layer	probable tumble in front of furnace 1	block of furnace for clay	Bulk chemical	
LFW3	LFW03	19	TP1	layer	rubble fill in front bottom of furnace 1	slagged wall	Bulk chemical	
LFW4	LFW03	18	TP1	layer	below clay floor of furnace 1	tapped slag	Bulk chemical	SEM
LFW6	LFW03	22	TP1	layer	layer of soil outside furnace 1	tapped slag with lobes	Bulk chemical	SEM
LFW9a	LFW05	55	TP4	fill	upper fill of pit (54)	iron ore - fresh	Bulk chemical	
LFW9b	LFW06	55	TP4	fill	upper fill of pit (54)	iron ore - weathered	Bulk chemical	
LFW10	LFW05	76	TP8	layer	compact area of slag	dense vesicle slag flow	Bulk chemical	SEM
LFW11	LFW06	105	TP8	fill	fill in (111)	dense vesicle slag flow	Bulk chemical	SEM
LFW12	LFW03	2		layer	general soil layer - above 1	smithing slag	Bulk chemical	SEM
LFW13	LFW04	1		layer	topsoil	slag with crystals	Bulk chemical	SEM
LFW19	LFW03	39	TP1	fill	upper fill of cut (42)	slag rod	Bulk chemical	SEM

Table 3: Major elements determined by XRF (expressed at wt% oxide). Analyses calculated with iron as Fe_2O_3, but also expressed recalculated with iron expressed as FeO (gold columns). 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
LFW1	clay	90.70	4.43	3.83	3.45	0.06	0.09	0.07	<0.009	0.51	0.52	0.05	0.78	1.16	100.35
LFW3	wall	77.20	4.00	11.85	10.67	0.55	0.38	2.12	<0.009	0.67	0.45	0.20	-0.76	0.42	97.59
LFW4	dense tapslag	27.20	5.16	52.12	46.91	2.42	1.31	9.43	<0.009	0.70	0.39	0.66	-3.62	1.59	100.03
LFW6	dense tapslag	29.05	6.02	59.39	53.45	0.17	0.39	0.99	0.01	1.17	0.50	0.40	-4.54	1.40	98.34
LFW9a	fresh ore	4.52	1.22	47.81	43.03	1.33	1.58	10.73	<0.009	0.16	0.10	0.29	30.94	35.72	99.40
LFW9b	weathered ore	9.00	2.47	70.31	63.28	1.92	0.40	0.31	<0.009	0.31	0.18	0.45	12.58	19.61	98.01
LFW10	vesicular flow	33.60	6.95	42.59	38.33	2.11	1.69	9.91	0.02	1.05	0.51	0.52	-3.97	0.29	99.55
LFW11	vesicular flow	33.16	7.03	41.22	37.10	2.20	1.81	10.41	0.02	1.03	0.50	0.51	-3.90	0.22	98.29
LFW12	SHC	25.78	2.96	67.56	60.81	0.35	0.39	1.36	<0.009	0.77	0.29	0.22	-5.29	1.47	99.84
LFW13	coarse slag	26.08	2.73	67.21	60.49	0.23	0.37	1.42	<0.009	0.69	0.23	0.26	-6.27	0.45	99.34
LFW19	slag rod	21.27	3.80	67.20	60.48	1.00	0.62	3.34	<0.009	0.78	0.32	0.35	-5.51	1.21	99.01

Table 4: Minor elements determined by XRF (expressed at wt% oxide).

	SO_3	V_2O_5	Cr_2O_3	SrO	ZrO_2	BaO	NiO	CuO	ZnO	PbO	HfO_2
LFW1	0.02	0.01	0.02	0.00	0.06	<0.006	0.01	<0.002	0.00	0.01	<0.003
LFW3	0.09	0.01	0.01	0.01	0.04	<0.006	0.02	0.00	<0.001	0.01	<0.004
LFW4	0.52	0.01	0.01	0.03	0.02	0.03	0.02	<0.003	<0.002	0.01	0.01
LFW6	0.16	0.01	0.02	0.02	0.03	<0.007	0.00	<0.003	<0.002	0.01	<0.005
LFW9a	0.67	0.00	0.01	0.02	0.01	0.01	<0.004	<0.003	<0.002	0.01	<0.006
LFW9b	0.02	0.01	0.01	0.01	0.01	0.04	0.03	<0.003	0.01	0.01	<0.006
LFW10	0.45	0.01	0.01	0.02	0.03	0.04	0.02	<0.002	<0.002	0.02	<0.005
LFW11	0.25	0.01	0.01	0.02	0.03	0.04	0.01	<0.002	<0.001	0.01	<0.005
LFW12	0.10	0.01	0.01	0.02	0.03	<0.007	0.01	0.00	<0.002	0.01	<0.005
LFW13	0.09	0.01	0.01	0.01	0.02	<0.007	<0.003	0.00	<0.002	0.02	<0.005
LFW19	0.27	0.01	0.02	0.02	0.02	0.00	<0.003	<0.003	<0.002	0.01	<0.005

Table 5. Major elements determined by ICP-MS (expressed as wt% oxide).

	MnO	Fe_2O_3	TiO_2	P_2O_5
	wt%	wt%	wt%	wt%
LFW1	0.03	3.64	0.54	0.03
LFW3	0.49	11.17	0.49	0.15
LFW4	2.16	47.61	0.39	0.55
LFW6	0.14	58.28	0.51	0.36
LFW9a	1.24	45.54	0.11	0.25
LFW9b	1.92	72.77	0.20	0.38
LFW10	2.00	41.83	0.52	0.46
LFW11	1.90	36.27	0.49	0.41
LFW12	0.33	69.64	0.34	0.21
LFW13	0.21	67.73	0.27	0.25
LFW19	0.88	61.54	0.31	0.30

Table 6: Minor and trace elements determined by ICP-MS (expressed as elemental ppm).

	Sc	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Sn	Cs	Ba
LFW1	4.7	34.9	40.1	4.09	14.2	21.3	39.6	5.9	31.0	19.7	19.5	379.4	10.99	1.27	0.53	2.02	124.2
LFW3	4.9	30.6	37.6	3.63	35.4	34.7	30.6	7.4	54.4	54.1	22.0	302.4	10.46	1.01	0.92	5.55	213.8
LFW4	7.4	42.6	28.2	1.67	28.5	52.6	65.0	8.0	47.7	134.0	26.9	153.5	9.56	0.59	1.25	3.75	435.3
LFW6	6.5	41.2	36.0	2.39	13.0	39.5	55.5	7.3	53.4	72.0	17.0	193.3	11.56	0.23	1.23	3.50	298.1
LFW9a	2.2	12.3	12.7	3.73	49.2	54.5	60.8	2.9	12.9	103.0	14.8	70.7	3.54	0.48	0.94	0.88	225.1
LFW9b	6.7	32.2	30.5	7.83	61.0	64.2	230.3	5.1	27.1	25.9	30.4	82.3	6.34	1.37	6.68	2.47	591.9
LFW10	9.0	51.2	43.6	3.01	54.1	93.8	107.7	8.0	69.1	137.1	31.6	195.1	12.44	0.45	1.50	5.22	548.5
LFW11	8.2	40.0	35.0	2.57	27.0	151.6	51.8	7.3	61.8	137.2	29.1	166.9	10.73	0.44	1.19	4.61	619.0
LFW12	3.6	22.6	23.0	23.00	61.5	79.5	63.9	6.9	35.9	67.3	12.2	176.8	7.33	1.96	1.34	1.79	338.6
LFW13	3.4	21.6	22.3	4.77	41.5	28.0	81.5	7.3	26.8	62.1	9.9	156.2	6.40	0.60	0.72	1.03	199.1
LFW19	5.0	35.5	31.2	1.85	23.4	38.0	75.2	6.7	35.8	76.4	13.3	136.1	7.32	0.40	0.67	2.06	274.6

	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	Pb	Th	U
LFW1	24.93	50.44	6.03	22.46	4.26	0.83	4.03	0.59	3.48	0.67	2.03	0.29	2.11	0.33	9.53	0.83	2.45	6.11	1.89
LFW3	26.25	49.43	5.86	21.08	4.12	0.82	3.85	0.56	3.44	0.65	1.99	0.29	1.94	0.29	7.20	0.77	1.78	5.34	1.78
LFW4	30.93	55.55	6.74	25.47	4.87	1.14	4.90	0.74	4.26	0.80	2.24	0.31	2.05	0.32	4.10	0.64	10.47	5.58	2.44
LFW6	23.09	43.15	5.22	18.89	3.61	0.77	3.52	0.52	3.11	0.58	1.71	0.25	1.70	0.27	5.00	0.78	10.90	6.57	1.30
LFW9a	15.03	24.10	2.87	11.07	2.26	0.49	2.36	0.35	2.06	0.40	1.17	0.16	1.00	0.16	1.56	0.24	10.77	1.55	0.31
LFW9b	28.35	48.56	5.80	21.94	4.40	0.96	4.70	0.72	4.26	0.82	2.37	0.32	2.21	0.36	2.15	0.39	20.52	2.78	1.06
LFW10	38.05	67.06	7.86	29.65	5.90	1.22	5.74	0.83	4.73	0.90	2.71	0.38	2.57	0.40	4.79	0.88	9.59	7.19	2.13
LFW11	35.06	60.03	7.22	26.92	5.46	1.15	5.29	0.76	4.30	0.81	2.43	0.33	2.27	0.35	4.18	0.78	13.73	6.50	1.95
LFW12	15.19	28.61	3.33	12.13	2.40	0.50	2.19	0.32	1.98	0.38	1.18	0.17	1.10	0.18	4.37	0.51	2.94	3.68	0.98
LFW13	13.52	22.95	2.97	10.82	2.01	0.43	1.91	0.29	1.79	0.35	1.00	0.15	1.05	0.16	4.03	0.44	2.55	3.05	0.75
LFW19	17.03	29.52	3.61	13.63	2.58	0.57	2.48	0.36	2.21	0.43	1.20	0.17	1.25	0.20	3.68	0.51	8.96	4.06	1.03

Table 7: Microanalyses by EDS. Data expressed as elemental wt%.

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW4	SOI 14	# 1	wustite		20.23											0.97	78.20			99.39
LFW4	SOI 14	# 2	magnetite		26.28			2.50	0.32							0.61	69.39			99.09
LFW4	SOI 14	# 3	wustite		20.30											1.25	76.51			98.05
LFW4	SOI 14	# 4	fayalite around oxide		30.61		2.66		14.67					4.45		3.56	43.11			99.05
LFW4	SOI 14	# 5	fayalite around oxide		31.47		2.52		14.61					5.15		3.99	43.23			100.98
LFW4	SOI 14	# 6	fayalite margin		32.67		0.50		14.46	0.27				15.29		2.13	35.30			100.61
LFW4	SOI 14	# 7	magnetite *		28.03			3.75	2.00					0.99	0.79	0.81	65.37			101.74
LFW4	SOI 14	# 8	altered glass?		37.56			5.17	18.44	1.08				16.11		0.86	20.46			99.67
LFW4	SOI 14	# 9	rhonite?		35.02			8.53	12.74					9.59	0.93	0.52	32.73			100.06
LFW4	SOI 14	# 10	altered glass?		36.27			5.74	17.24	1.30				16.59		0.55	17.85			95.53
LFW4	SOI 14	# 11	leucite		41.59	0.64		11.72	23.84				15.71	1.11			2.83		0.75	98.21
LFW4	SOI 14	# 12	fayalite* (assoc L)		35.55			6.68	13.57				0.86	10.47	0.59	0.75	30.80			99.27
LFW4	SOI 14	# 13	fayalite around oxide		29.73		2.70		13.86					4.66		3.90	40.84			95.68
LFW4	SOI 14	# 14	outer fayalite		31.73		0.50		14.16					14.54		2.24	34.70			97.88
LFW4	SOI 14	# 15	inner fayalite		31.05		1.73	0.41	13.99					6.54		3.40	39.82			96.94
LFW4	SOI 14	# 16	outer fayalite		30.12		0.59		14.03					13.23		2.22	35.20			95.40
LFW4	SOI 14	# 17	outer fayalite		30.90		0.45		13.84					14.87		2.18	33.13			95.36
LFW4	SOI 14	# 18	rhonite?		36.45			6.92	15.79	0.42				13.09		0.70	26.16			99.52
LFW4	SOI 14	# 19	altered glass?		38.30			5.32	17.03	1.71				18.10		0.48	17.82			98.75
LFW4	SOI 14	# 20	magnetite		29.97			3.48	3.85		1.51			3.76	0.68	0.97	55.45			99.68
LFW4	SOI 14	# 21	magnetite		25.15			3.91	0.37					0.28			65.58			95.29
LFW4	SOI 14	# 22	Al-magnetite		28.10			10.19	0.46					0.64	1.72	1.00	54.22			96.32
LFW4	SOI 14	# 23	fayalite around oxide		31.49		2.06		14.47					5.27		3.35	43.72			100.36
LFW4	SOI 14	# 24	outer fayalite		30.61		0.51		14.23	0.17				14.23		2.26	34.80			96.80
LFW4	SOI 14	# 25	outer fayalite		29.73		0.48		13.77	0.17				14.20		2.05	34.32			94.71
LFW4	SOI 14	# 26	fayalite around oxide		29.63		2.60		14.11					4.75		3.91	40.61			95.60
LFW4	SOI 14	# 27	wustite		19.80		0.37									1.08	76.89			98.14
LFW4	SOI 14	# 28	magnetite		27.66			4.45	2.18					2.36	1.08	0.77	59.11			97.61
LFW4	SOI 14	# 29	magnetite		25.89			3.88	1.13					0.63	1.11	0.48	64.95			98.06
LFW4	SOI 14	# 30	rhonite?*		29.54			7.50	8.53					5.09	0.99	0.52	48.39			100.55
LFW4	SOI 14	# 31	altered glass?		35.20			6.15	16.82	0.71				13.53	0.31	0.63	26.17			99.51
LFW4	SOI 14	# 32	altered glass?		37.07			5.44	16.76	1.83				17.77		0.56	18.00			97.43
LFW4	SOI 14	# 33	altered glass?		37.21			5.12	18.30	0.59				15.08		0.89	21.36			98.55
LFW4	SOI 14	# 34	rhonite?		33.82			8.16	12.92					9.50	0.74	0.59	31.81			97.55
LFW4	SOI 14	# 35	leucite		40.06	0.38		10.77	23.61				15.72	1.31			3.03		0.66	95.54
LFW4	SOI 14	# 36	leucite*		38.47	0.87		8.93	21.29	0.33			8.86	6.56		0.77	13.94			100.04

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt%															
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW4	SOI 14	# 37	rhonite/Al-magnetite?		39.69	0.32	0.20	11.69	10.39	0.52	0.26		1.32	8.17	0.62	0.64	25.21			99.03
LFW4	SOI 14	# 38	Al-magnetite		29.12			9.64	0.72					0.99	1.76	0.70	54.79			97.73
LFW4	SOI 14	# 39	magnetite *		26.03		0.55	3.96	3.95					2.27	1.02	1.17	58.78			97.72
LFW4	SOI 14	# 40	leucite		38.55	0.54		9.22	17.72	0.76			1.31	12.59	0.26	0.67	16.60			98.22
LFW4	SOI 14	# 41	outer fayalite		31.08		0.29	0.93	14.55	0.30			0.60	14.50		1.72	32.01			95.99
LFW4	SOI 14	# 42	inner fayalite		29.46		2.12		13.76					5.59		3.96	40.52			95.41
LFW4	SOI 14	# 43	magnetite/fayalite		25.74		0.84	1.73	5.68					4.42		1.83	54.84			95.08
LFW4	SOI 14	# 44	magnetite		25.16			3.96	0.69					0.46	0.28	0.94	63.92			95.40
LFW4	SOI 14	# 45	rhonite?		26.67			7.61	10.36					8.49	2.21	0.64	29.78			85.75
LFW4	SOI 15	# 1	inner fayalite		30.83		3.05		14.40					2.51		3.22	44.91			98.92
LFW4	SOI 15	# 2	inner fayalite		30.77		2.94		14.39					2.49		3.30	44.98			98.88
LFW4	SOI 15	# 3	inner fayalite		29.58		2.56		14.15					2.39		3.25	45.60			97.53
LFW4	SOI 15	# 4	middle fayalite		30.53		3.05	0.21	14.40					3.03		3.38	44.42			99.02
LFW4	SOI 15	# 5	middle fayalite		30.06		2.18		14.01					4.06		3.18	44.44			97.93
LFW4	SOI 15	# 6	middle fayalite		29.89		1.48		14.13					5.34		3.06	43.60			97.51
LFW4	SOI 15	# 7	outer fayalite		31.12		0.27		14.19	0.16				13.51		1.77	36.71			97.74
LFW4	SOI 15	# 8	glass?		36.50			7.17	17.74	0.63				15.88	0.20	0.58	17.71			96.41
LFW4	SOI 15	# 9	glass?		37.23			6.59	18.17	0.75				15.81	0.30	0.46	17.78			97.08
LFW4	SOI 15	# 10	rhonite?		35.95			7.83	13.24	0.78			0.23	12.06	1.35	0.43	26.76			98.63
LFW4	SOI 15	# 11	rhonite?		31.11			8.30	10.19					8.16	2.68	0.50	32.71			93.64
LFW4	SOI 15	# 12	rhonite?		32.19		0.27	7.89	11.27					9.07	2.63	0.44	31.38			95.13
LFW4	SOI 15	# 13	rhonite?		39.06			9.66	15.77				2.98	8.26	1.63	0.36	27.56			105.28
LFW4	SOI 15	# 14	glass?		39.74		0.21	7.49	17.78	1.19				16.98	0.29	0.45	17.27			101.40
LFW4	SOI 15	# 15	glass?		35.17			7.19	16.31	0.24			1.98	4.69		0.30	16.42			82.29
LFW4	SOI 15	# 16	leucite		39.49	0.47		10.93	22.62	0.23			15.21	1.90			1.91		0.86	93.61
LFW4	SOI 15	# 17	wustite*		21.97			0.96	0.19					0.26	0.85	0.75	72.42			97.40
LFW4	SOI 15	# 18	outer fayalite		31.86		0.67	0.43	14.04	0.30				8.24		2.26	40.79			98.57
LFW4	SOI 15	# 19	weathering?		34.31			7.85	16.22	0.20			0.43	1.76		0.32	15.34			76.43
LFW4	SOI 15	# 20	weathering?		40.47	0.40		6.81	19.18	0.19			7.43	1.21			13.91			89.60
LFW4	SOI 15	# 21	weathering?		36.71		0.21	6.42	17.31	0.23			0.42	2.55		0.40	22.91			87.17
LFW4	SOI 15	# 22	middle fayalite		29.58		2.18		13.67					4.01		3.18	42.63			95.25
LFW4	SOI 15	# 23	outer fayalite		30.24		0.48		14.05					13.41		2.08	35.16			95.42
LFW4	SOI 15	# 24	outer fayalite		33.56			1.35	15.19	0.27			0.57	7.48		1.08	32.60			92.10
LFW4	SOI 15	# 25	rhonite?		31.99		0.23	7.90	11.51					8.92	2.42	0.56	30.85			94.38
LFW4	SOI 15	# 26	glass?		36.23			6.09	15.82	2.02				18.14		0.33	15.63			94.27
LFW4	SOI 15	# 27	glass?		33.93			6.66	16.91	1.11			0.61	15.58	0.25	0.45	16.96			92.47
LFW4	SOI 15	# 28	glass?		36.71			6.14	18.08	1.20				15.01		0.57	17.67			95.39

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW4	SOI 16	# 1	glass		36.96			6.04	17.21	1.25				16.67	0.35	0.49	17.33			96.30
LFW4	SOI 16	# 2	leucite		39.53	0.44		10.37	21.35				13.24	1.56			3.24		1.04	90.78
LFW4	SOI 16	# 3	rhonite?		32.48		0.28	8.11	11.30					8.90	2.20	0.52	31.92			95.69
LFW4	SOI 16	# 4	rhonite?		33.65		0.23	8.23	11.95					8.95	1.80	0.49	31.92			97.21
LFW4	SOI 16	# 5	rhonite?		33.27		0.28	8.73	10.96					8.93	1.72	0.61	31.96			96.47
LFW4	SOI 16	# 6	Ca-fayalite		30.72		0.47	0.96	13.45	0.24				13.04		1.89	36.19			96.96
LFW4	SOI 16	# 7	Al-magnetite		29.97			13.96	0.37					0.34	2.09	0.68	51.63			99.05
LFW4	SOI 16	# 8	rhonite?		31.22		0.41	8.60	10.99					9.06	1.75	0.59	32.21			94.82
LFW4	SOI 16	# 9	Ca-fayalite		30.93		0.40		14.11					13.07		1.98	37.45			97.93
LFW4	SOI 16	# 10	hercynite		30.14		0.31	19.31	0.25					0.23	1.28	0.74	44.82			97.07
LFW4	SOI 16	# 11	wustite		19.75			0.21						0.33	0.26	0.62	75.56			96.73
LFW4	SOI 16	# 12	inner fayalite		29.26		2.07		13.70					4.19		3.22	41.66			94.10
LFW4	SOI 16	# 13	inner fayalite		29.70		2.15		13.85					4.07		3.07	42.50			95.34
LFW4	SOI 16	# 14	late fayalite (with L)		29.62		0.27	0.57	13.47					8.14		1.78	39.75			93.59
LFW4	SOI 16	# 15	hole		31.50		0.17	0.71	23.81	0.18				3.34		0.84	18.42			78.97
LFW4	SOI 16	# 16	hole		33.12			2.75	14.47				0.22	3.75		0.82	31.20			86.34
LFW4	SOI 16	# 17	late fayalite (with L)		30.11		0.39	0.21	13.55					8.76		1.85	41.01			95.88
LFW4	SOI 16	# 18	iron sulphide*		20.84	0.36	0.32	2.94	10.60	0.28	11.25		0.30	7.02	0.19	1.20	38.84			94.15
LFW4	SOI 16	# 19	Al-magnetite		30.98		0.27	13.97	1.96					1.64	1.25	0.75	49.68			100.49
LFW4	SOI 16	# 20	Ca-fayalite		30.87		0.33		14.17					12.98		1.78	36.80			96.93
LFW4	SOI 16	# 21	Ca-fayalite		31.09		0.38	0.29	13.58	0.30				11.74		1.87	38.60			97.85
LFW4	SOI 16	# 22	wustite		21.16			0.63	0.29					0.56		0.65	74.42			97.71
LFW6	SOI 5	# 1	fayalite centre		27.83		0.53		12.73								49.93			91.03
LFW6	SOI 5	# 2	fayalite centre		27.24		0.54		12.43								49.84			90.06
LFW6	SOI 5	# 3	fayalite outer		26.25				12.33					0.16		0.23	49.71			88.69
LFW6	SOI 5	# 4	fayalite centre		27.72		0.43		12.38								50.59			91.12
LFW6	SOI 5	# 5	fayalite centre		29.30		0.38	1.86	13.33				0.80	0.52			45.42			91.61
LFW6	SOI 5	# 6	fayalite outer		28.42		0.31		12.62					0.18			51.48			93.01
LFW6	SOI 5	# 7	fayalite carious margin		32.27			1.33	14.10	0.17			1.31	1.01	0.17		43.53			93.89
LFW6	SOI 5	# 8	fayalite carious margin		30.94		0.30	1.33	15.22				0.49	0.41			50.65			99.34
LFW6	SOI 5	# 9	glass		40.36	0.60		8.28	22.40	0.70			5.23	3.30	0.31		17.50			98.68
LFW6	SOI 5	# 10	glass		40.63	0.53		7.62	22.47	0.47	0.13		5.06	2.93	0.37		19.42			99.63
LFW6	SOI 5	# 11	fine ?hercynite		31.22			8.62	9.70				1.44	0.59	1.73		38.01			91.32
LFW6	SOI 5	# 12	interstitial area	area	39.50	0.46		10.78	18.95	0.48			4.07	2.80	0.98		22.19			100.20
LFW6	SOI 5	# 13	interstitial area	area	41.36	0.47		8.98	22.38	0.45			4.10	4.61	0.47		17.26			100.08
LFW6	SOI 5	# 14	interstitial area	area	34.00	0.41		8.57	15.37	0.31			3.30	1.92	0.95		25.77			90.60
LFW6	SOI 5	# 15	bulk area	area	34.55			5.65	16.11	0.35			2.00	1.36	0.42		38.09			98.54

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW6	SOI 6	# 1	euhedral hercynite		34.17			27.13							1.27		36.31			98.88
LFW6	SOI 6	# 2	euhedral hercynite		35.66			29.31	0.22						0.92		37.01			103.13
LFW6	SOI 6	# 3	interstitial hercynite		34.26			27.67	0.29						1.75		37.47			101.44
LFW6	SOI 6	# 4	olivine on margin		28.60		0.27	1.50	12.48				0.75	0.97	0.20		43.49			88.27
LFW6	SOI 6	# 5	olivine on margin		28.15		0.40		12.90					0.15			52.85			94.44
LFW6	SOI 6	# 6	leucite		39.96			11.41	24.66				17.40				0.86			94.29
LFW6	SOI 6	# 7	leucite		45.87	1.03		12.23	25.22				15.65				1.20			101.19
LFW6	SOI 6	# 8	outer fayalite in ves		27.89		0.29		12.63					0.14			51.61			92.56
LFW6	SOI 6	# 9	iron		9.18			0.35	3.68			0.24					82.22			95.67
LFW6	SOI 6	# 10	outer fayalite in ves		29.20				13.71					0.23			55.01			98.15
LFW6	SOI 6	# 11	main olivine		30.78				13.99					0.20			56.49			101.46
LFW6	SOI 6	# 12	late olivine		28.45			0.43	13.25	0.16				0.21	0.22		53.36			96.08
LFW6	SOI 6	# 13	interstitial area in ves	area	36.18	0.68		8.57	17.20	0.49			1.57	4.43	1.05		25.87			96.03
LFW6	SOI 6	# 14	bulk area	area	34.34	1.03		6.71	15.54	0.29			1.20	1.57	0.50		37.75			98.93
LFW10	SOI 4	# 1	glass		36.37		0.31	5.56	17.46	0.26	0.29		1.11	11.67	0.60	1.08	21.64			96.35
LFW10	SOI 4	# 2	olivine inner		30.68		2.79		14.12					1.53		2.79	45.84			97.75
LFW10	SOI 4	# 3	olivine outer		30.96		2.55		14.45					1.88		2.56	46.59			98.99
LFW10	SOI 4	# 4	olivine inner		29.92		3.05		14.16					1.41		2.51	45.67			96.72
LFW10	SOI 4	# 5	glass area		36.09		0.23	5.86	17.74	0.29	0.22		1.29	11.71	0.53	0.96	21.48			96.40
LFW10	SOI 4	# 6	bulk area		36.09		0.92	4.76	17.06	0.19			1.12	8.15	0.33	1.54	29.49			99.65
LFW10	SOI 4	# 7	olivine outer		28.90		2.04		13.70					2.05		2.59	46.17			95.46
LFW10	SOI 4	# 8	olivine margin		31.29		1.98	0.38	14.67					2.05		2.47	46.29			99.12
LFW10	SOI 5	# 1	olivine inner		31.49		2.67	0.70	14.09	0.19			0.18	2.22		2.57	42.82			96.93
LFW10	SOI 5	# 2	olivine inner		29.84		2.82		13.82					1.45		2.53	44.91			95.36
LFW10	SOI 5	# 3	olivine margin		28.26		1.97		13.32					1.73		2.45	45.40			93.12
LFW10	SOI 5	# 4	olivine margin		32.81		1.62	0.36	15.29					2.60		2.54	47.65			102.87
LFW10	SOI 5	# 5	olivine inner		31.77		2.92		14.25					1.74		2.41	46.95			100.05
LFW10	SOI 5	# 6	olivine margin		34.21		2.28	1.68	15.20	0.17			0.55	3.83	0.20	2.16	41.23			101.51
LFW10	SOI 5	# 7	late olivine		31.46		1.77	0.33	14.70					2.26		2.44	46.50			99.46
LFW10	SOI 5	# 8	late olivine		35.58		1.27	2.37	15.91	0.25			0.50	5.88	0.24	2.00	38.08			102.10
LFW10	SOI 5	# 9	glass area		38.15		0.38	6.59	18.21	0.38	0.13		1.58	11.12	0.51	0.94	19.96			97.94
LFW10	SOI 5	# 10	interstitial area	area	35.86		0.60	4.63	16.86	0.22			0.96	8.75	0.44	1.34	28.43			98.08
LFW10	SOI 5	# 11	bulk area	area	36.19		0.85	5.20	16.87	0.27	0.18		1.20	8.23	0.42	1.46	28.49			99.36
LFW10	SOI 5	# 12	glass		36.96		0.29	6.06	17.95	0.28	0.24		1.43	10.82	0.47	1.07	20.97			96.54
LFW10	SOI 5	# 13	glass		38.61		0.26	6.65	18.40	0.34	0.31		1.52	11.62	0.59	0.86	19.86			99.02
LFW11	SOI 4	# 1	olivine*		32.56		1.54	2.55	15.47	0.21			0.95	5.59		2.09	34.54	0.38		95.89

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LFW11	SOI 4	# 2	olivine*		33.23		1.54	2.88	15.46	0.19	0.15		0.97	6.09	0.18	2.00	33.89			96.57
LFW11	SOI 4	# 3	glass*		32.70	0.30	0.56	5.80	17.06	0.26	0.29		1.69	9.38	0.30	1.30	22.05			91.68
LFW11	SOI 4	# 4	bulk area	area	33.88		1.09	4.31	16.23	0.30			1.07	7.97	0.40	1.70	29.61			96.57
LFW11	SOI 6	# 1	bulk area	area	34.71		1.28	4.03	16.04	0.21			0.83	6.87	0.25	1.68	31.68			97.58
LFW11	SOI 6	# 2	olivine outer		32.25		2.95	0.54	14.08	0.18			0.22	2.88		2.50	41.53			97.13
LFW11	SOI 6	# 3	olivine core		31.90		2.55	1.04	14.17				0.29	2.81		2.60	41.86			97.23
LFW11	SOI 6	# 4	olivine core		31.96		2.69	0.42	13.77				0.20	2.84		2.51	41.89			96.28
LFW11	SOI 6	# 5	olivine outer		31.12		2.56		14.05					1.97		2.71	45.04			97.44
LFW11	SOI 6	# 6	olivine margin		31.85		2.02		14.77	0.15				2.51		2.57	44.81			98.68
LFW11	SOI 6	# 7	olivine outer		30.61		2.30		13.93					2.55		2.58	43.88			95.84
LFW11	SOI 6	# 8	olivine core		31.03		3.05	0.64	13.99				0.30	2.44		2.70	41.59			95.74
LFW11	SOI 6	# 9	late olivine		34.01		1.17	2.67	15.67	0.23			0.72	6.20	0.26	2.21	37.26			100.39
LFW11	SOI 6	# 10	late olivine		31.73		1.35	1.72	14.69	0.20			0.38	4.79		2.38	40.26			97.50
LFW11	SOI 6	# 11	glass area		36.95	0.25	0.20	6.41	17.93	0.35	0.29		1.38	12.64	0.59	0.86	17.20			95.05
LFW11	SOI 6	# 12	glass area	area	36.99		0.23	6.73	18.00	0.29	0.24		1.54	12.11	0.59	0.84	17.13			94.70
LFW12	SOI 7	# 1	olivine core		30.91		0.62		13.56					0.28		0.38	54.52			100.28
LFW12	SOI 7	# 2	olivine margin		29.43				13.22					0.46		0.29	53.73			97.14
LFW12	SOI 7	# 3	spinel inner		26.14			2.91	0.43						1.71		65.22			96.40
LFW12	SOI 7	# 4	spinel inner		26.84			2.89	0.35						1.77		66.39			98.24
LFW12	SOI 7	# 5	spinel outer		26.38			3.43	0.40						1.96		65.46			97.63
LFW12	SOI 7	# 6	spinel margin		25.68			4.78	0.59					0.17	1.66		62.74			95.62
LFW12	SOI 7	# 7	interstitial olivine		31.12				13.54					0.97			53.25			98.88
LFW12	SOI 7	# 8	interstitial olivine		29.24				13.27					0.90		0.35	52.94			96.70
LFW12	SOI 7	# 9	interstitial olivine		30.61			0.83	13.94				0.87	1.67		0.28	46.75			94.95
LFW12	SOI 7	# 10	interstitial olivine		29.42				12.97					0.90			52.48			95.78
LFW12	SOI 7	# 11	interstitial spinel		29.33			6.61	1.30				0.23	0.43	1.96		57.77			97.63
LFW12	SOI 7	# 12	interstitial olivine		28.98				13.02					0.96			50.65			93.62
LFW12	SOI 7	# 13	glass area	area	40.45	0.43		8.59	20.97	0.54			4.21	7.78	0.17		11.57			94.72
LFW12	SOI 7	# 14	glass area	area	41.76	0.48		9.09	22.43	0.58			5.45	7.06			10.60			97.46
LFW12	SOI 7	# 15	spinel margin		30.24			4.93	0.39						1.76		61.73			99.06
LFW12	SOI 7	# 16	interstitial spinel		29.73			6.07	1.00				0.37	0.52	1.93		56.68			96.29
LFW12	SOI 7	# 17	spinel margin		27.60			3.24	0.63						1.73		62.35			95.55
LFW12	SOI 9	# 1	spinel outer		29.14			4.94	0.25						1.97		61.03			97.34
LFW12	SOI 9	# 2	interstitial spinel		31.46			7.29	2.42				0.53	0.92	1.90		54.26			98.79
LFW12	SOI 9	# 3	interstitial spinel		31.18			7.44	3.75				0.61	1.16	1.64		52.45			98.24
LFW12	SOI 9	# 4	late olivine		29.59			0.55	13.36				0.52	1.35		0.36	47.70			93.44

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt%															
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW12	SOI 9	# 5	late olivine		33.70			3.04	15.48	0.28			1.77	3.00		0.27	38.27			95.83
LFW12	SOI 9	# 6	hollow prism		39.87	0.25		8.41	18.32	0.37			2.96	7.65	0.56		20.76			99.15
LFW12	SOI 9	# 7	hollow prism		37.08	0.24		7.78	18.36	0.32			2.97	7.42	0.42		20.91			95.49
LFW12	SOI 9	# 8	glass		39.47			8.06	20.55	0.53			3.76	8.22	0.17		12.72			93.49
LFW12	SOI 9	# 9	hollow prism		40.50	0.33		8.30	19.27	0.34			3.95	6.67	0.44		17.91			97.71
LFW12	SOI 9	# 10	interstitial spinel		29.21			6.63	1.10				0.18	0.36	1.94		56.45			95.86
LFW12	SOI 9	# 11	spinel margin		31.21			5.41	2.74				0.75	1.29	1.31		52.56			95.27
LFW12	SOI 10	# 1	late spinel		31.31			5.99	3.88				0.94	1.13	1.62		52.31			97.17
LFW12	SOI 10	# 2	late spinel		27.65			4.75	1.75				0.46	0.58	1.31		56.87			93.37
LFW12	SOI 10	# 3	interstitial bright		38.38			7.15	16.25	0.21			2.22	7.15	0.37		24.66			96.40
LFW12	SOI 10	# 4	interstitial bright		35.36	0.32		6.75	16.55				2.69	6.35	0.28		24.87			93.17
LFW12	SOI 10	# 5	interstitial bright		35.89			6.90	15.99	0.24			3.02	6.63	0.29		22.98			91.94
LFW12	SOI 10	# 6	glass		39.29	0.42		8.28	20.90	0.57	0.17		4.03	7.98	0.16		10.83			92.63
LFW12	SOI 10	# 7	glass		39.03	0.28		7.06	20.89	0.66	0.27		3.96	7.64			12.57			92.35
LFW12	SOI 10	# 8	interstitial bright		33.63	0.40		4.88	17.47	0.39			3.24	3.68		0.25	27.13			91.08
LFW12	SOI 10	# 9	interstitial bright		37.57			6.75	17.48	0.29			2.69	6.17	0.31		19.90			91.16
LFW12	SOI 10	# 10	late spinel		34.88	0.32		3.77	17.09	0.28			1.74	2.53			38.43			99.04
LFW12	SOI 10	# 11	late spinel		38.63	0.33		6.30	19.27	0.44			3.52	4.07			24.49			97.04
LFW12	SOI 11	# 1	olivine		30.47		0.68		13.97					0.45		0.39	54.69			100.65
LFW12	SOI 11	# 2	olivine		29.45		0.64		13.30					0.48		0.37	52.51			96.75
LFW12	SOI 11	# 3	olivine		28.20		0.66		12.74					0.29		0.28	50.68			92.85
LFW12	SOI 11	# 4	iscorite		25.25			0.45	4.13								66.82			96.64
LFW12	SOI 11	# 5	iscorite		24.72			0.64	3.99								64.69			94.04
LFW12	SOI 11	# 6	iscorite		27.16			0.45	4.45								68.92			100.98
LFW12	SOI 11	# 7	iscorite		26.61			0.68	4.57								69.00			100.86
LFW12	SOI 11	# 8	rounded magnetite		26.49			0.89	0.21								74.73			102.32
LFW12	SOI 11	# 9	rounded magnetite		25.29			0.71	0.25								71.48			97.73
LFW12	SOI 11	# 10	rounded magnetite		24.98			0.73									72.52			98.23
LFW12	SOI 11	# 11	wustite relict		20.98				0.25								77.13			98.35
LFW12	SOI 11	# 12	wustite relict		20.45				0.26								75.95			96.65
LFW12	SOI 11	# 13	wustite relict		20.89				0.21								74.34			95.43
LFW12	SOI 11	# 14	hole		34.29		0.24	3.58	14.90	0.85	0.15	0.19	1.36	0.95			30.84			87.34
LFW12	SOI 11	# 15	leucite		45.82	0.34		11.84	26.35	0.14			16.74	0.80			3.73			105.76
LFW12	SOI 11	# 16	leucite*		31.04	1.04		6.51	16.91		0.37	0.23	6.19	0.68	0.00		28.41		1.07	92.46
LFW12	SOI 11	# 17	wustite relict		20.86				0.20								76.28			97.34
LFW12	SOI 11	# 18	olivine		34.71		0.27		12.22	0.68				1.92			44.42			94.23

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW12	SOI 12	# 1	iscorite		25.43			0.48	4.06								68.07			98.04
LFW12	SOI 12	# 2	iscorite		25.40			0.45	4.24								68.95			99.03
LFW12	SOI 12	# 3	iscorite		24.90			0.47	4.31								67.94			97.63
LFW12	SOI 12	# 4	iscorite		25.39			0.53	4.27								67.51			97.71
LFW12	SOI 12	# 5	rounded core		26.13			0.66	0.23								71.52			98.54
LFW12	SOI 12	# 6	bright inner		25.43			0.81	0.22								72.03			98.48
LFW12	SOI 12	# 7	bright inner		25.45			0.67	0.20								70.68			97.00
LFW12	SOI 12	# 8	bright inner		25.09			0.87	0.33								70.64			96.93
LFW12	SOI 12	# 9	wustite		21.07				0.27								75.83			97.17
LFW12	SOI 12	# 10	wustite		21.29				0.21								77.27			98.77
LFW12	SOI 12	# 11	wustite		21.01				0.25								76.62			97.87
LFW12	SOI 12	# 12	wustite		21.48				0.26								77.27			99.02
LFW12	SOI 12	# 13	marginal		29.91			0.82	5.42				0.21				66.46			102.82
LFW12	SOI 12	# 14	dark outer		29.68			1.01	5.50								60.52			96.71
LFW12	SOI 12	# 15	bright		25.39			1.07	0.85								68.07			95.38
LFW12	SOI 12	# 16	bright		24.98			1.18	1.39					0.18	0.18		66.92			94.84
LFW12	SOI 12	# 17	ol mix		28.05			0.64	7.29				0.24	0.68			64.51			101.41
LFW12	SOI 12	# 18	ol mix		27.48			1.07	5.86				0.37				63.52			98.29
LFW12	SOI 12	Sum Spectrum		Area	25.23		0.08	0.83	2.20	0.05		0.06	0.07	0.16	0.06	0.06	67.93			96.79
LFW12	SOI 15	# 1	skeletal spinel		25.12			4.05	0.50						1.60		62.36			93.62
LFW12	SOI 15	# 2	olivine		28.72		0.33		13.05					0.37		0.38	52.65			95.50
LFW12	SOI 15	# 3	rhonite		33.92			8.36	11.00					8.43	0.64		33.13			95.48
LFW12	SOI 15	# 4	rhonite		36.03			8.72	11.35					8.70	0.89		33.56			99.25
LFW12	SOI 15	# 5	leucite		41.71	0.48		10.92	23.17	0.42			13.95	3.33			4.74			98.71
LFW12	SOI 15	# 6	olivine (assoc leucite)		29.38				13.31				0.14	1.44		0.34	52.65			97.26
LFW12	SOI 15	# 7	iscorite		26.52			1.44	4.20						0.47		65.85			98.49
LFW12	SOI 15	# 8	fayalite		33.50			0.21	13.83	0.37				4.29		0.28	49.76			102.23
LFW12	SOI 15	# 9	glass		38.39	0.52		4.86	16.87	1.91	0.41		0.41	15.94			18.13			97.45
LFW12	SOI 15	# 10	fayalite		31.75			0.00	13.59	0.25				2.74		0.37	51.90			100.59
LFW12	SOI 15	# 11	rhonite		36.06			8.33	11.38					8.03	0.73		36.04			100.57
LFW12	SOI 15	# 12	rhonite		33.08			8.14	10.97					8.46	0.87		33.26			94.78
LFW12	SOI 15	# 13	fayalite		28.77			0.22	12.72	0.16				2.33		0.33	51.09			95.62
LFW12	SOI 15	# 14	iscorite		25.22			1.30	4.04						0.45		63.88			94.89
LFW12	SOI 15	# 15	iscorite		25.52			1.43	4.08						0.38		63.85			95.26
LFW12	SOI 15	# 16	olivine (assoc leucite)		31.33				13.48					3.63		0.23	48.36			97.02
LFW12	SOI 15	# 17	rhonite		34.02			8.23	10.96					8.43	0.61		32.79			95.04
LFW12	SOI 15	# 18	iscorite		26.02			1.30	4.10					0.20	0.45		63.02			95.10
LFW12	SOI 15	# 19	iscorite		25.99			1.57	4.09						0.40		62.51			94.56

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW12	SOI 15	# 20	olivine (assoc leucite)		28.56				12.52	0.21				2.12		0.30	48.97			92.67
LFW12	SOI 15	# 21	hercynite (in fayalite)		28.75			8.57	0.36						2.35		55.15			95.18
LFW12	SOI 15	# 22	fayalite margin		29.14			0.22	12.55					1.09		0.28	49.94			93.22
LFW12	SOI 15	# 23	fayalite core		28.04		0.25		12.46					0.50		0.37	49.81			91.43
LFW12	SOI 15	# 24	hercynite outer		25.33			5.86	0.46						1.73		57.87			91.25
LFW12	SOI 15	# 25	olivine (assoc leucite)		28.60		0.15	0.00	12.46					1.87		0.30	49.26			92.64
LFW12	SOI 15	# 26	glass		36.90	0.58		5.42	15.96	1.43	0.36		0.53	13.92			16.99			92.10
LFW12	SOI 15	# 27	leucite		38.60	0.26		10.33	21.14	0.23	0.08	0.13	12.39				2.58			85.72
LFW12	SOI 15	# 28	rhonite		34.45			7.36	12.03	0.18				8.36	0.25		32.07			94.71
LFW12	SOI 15	# 29	rhonite		36.02			8.98	11.41				0.69	8.42	1.32		32.16			98.99
LFW12	SOI 15	# 30	olivine outgrowth		30.21			0.16	13.44					1.78		0.27	53.16			99.02
LFW12	SOI 15	# 31	olivine		30.24		0.45	0.12	13.42					0.40		0.37	54.22			99.22
LFW12	SOI 15	# 32	iscorite		25.49			1.36	4.06						0.42		63.61			94.93
LFW12	SOI 15	# 33	olivine (assoc leucite)		29.55			0.20	12.76	0.16				1.44		0.26	51.46			95.83
LFW12	SOI 15	# 34	glass		38.18	0.80		8.02	16.71	1.19	0.23		0.78	14.30			15.15			95.35
LFW12	SOI 15	# 35	glass		42.14	0.44		5.01	17.23	1.95	0.38		0.33	16.07			18.13			101.69
LFW12	SOI 15	# 36	hercynite (in fayalite)		31.20			15.60	1.48					0.62	0.49		48.55			97.93
LFW12	SOI 15	# 37	magnetite inside hercynite		25.57			4.08	0.35						1.56		60.35			91.91
LFW12	SOI 15	# 38	skeletal spinel		24.57			3.03	1.39						1.12		62.34			92.45
LFW12	SOI 16	# 1	equant spinel outer		25.91			6.52	0.60						1.79		57.12			91.94
LFW12	SOI 16	# 2	mag assoc wustite relict		22.84			2.09	0.65						0.91		64.38			90.86
LFW12	SOI 16	# 3	equant spinel outer		28.10			4.19	0.29						1.90		62.65			97.13
LFW12	SOI 16	# 4	wustite relict		20.52				0.36								72.52			93.39
LFW12	SOI 16	# 5	iscorite		25.37			1.25	4.04						0.36		64.97			95.98
LFW12	SOI 16	# 6	wustite rounded		22.28				0.26								73.99			96.53
LFW12	SOI 16	# 7	wustite relict		22.46			0.21	0.29								72.40			95.36
LFW12	SOI 16	# 8	hercynite on elongate mag		28.92			9.63	0.70					0.20	1.44		52.91			93.80
LFW12	SOI 16	# 9	olivine on elongate mag		29.10				12.78					2.83		0.26	48.03			93.00
LFW12	SOI 16	# 10	rhonite on elongate mag		32.44			7.80	10.75					8.25	0.70		32.01			91.94
LFW12	SOI 16	# 11	iscorite		25.41			1.20	4.04						0.35		64.82			95.81
LFW12	SOI 16	# 12	wustite		20.84				0.25								72.01			93.11
LFW12	SOI 16	# 13	equant spinel rim		27.37			9.43	0.59						2.26		52.55			92.21
LFW12	SOI 16	# 14	fayalite		28.98		0.52		12.78					0.41		0.40	51.72			94.81
LFW12	SOI 16	# 15	hercynite		27.39			9.85	0.90						1.26		54.36			93.76
LFW12	SOI 16	# 16	hercynite on magnetite		30.01			8.91	1.50					0.32	1.16		56.13			98.02

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW13	SOI 2	# 1	fayalite outer		31.36				15.07					0.64			60.13			107.20
LFW13	SOI 2	# 2	fayalite inner		30.76		0.68		14.81					0.28		0.29	57.52			104.33
LFW13	SOI 2	# 3	fayalite inner		29.13		0.41		13.69					0.35			54.77			98.37
LFW13	SOI 2	# 4	fayalite inner		26.70		0.74		12.90					0.15		0.25	50.28			91.02
LFW13	SOI 2	# 5	fayalite outer		27.16				12.97					0.42			52.57			93.12
LFW13	SOI 2	# 6	fayalite, assoc w		28.21				13.50					0.47			53.90			96.08
LFW13	SOI 2	# 7	fayalite inner		23.14		0.52		10.76					0.23			43.19			77.85
LFW13	SOI 3	# 1	main olivine margin		27.46				13.02					0.89			51.82			93.20
LFW13	SOI 3	# 2	hercynite inner		27.56			11.16	0.29						2.57		53.92			95.50
LFW13	SOI 3	# 3	hercynite margin (streaky)		30.09			15.68	0.27						1.79		49.42			97.24
LFW13	SOI 3	# 4	fayalite o/g on w		29.25			0.68	14.27	0.18			0.24	1.46			52.88			98.96
LFW13	SOI 3	# 5	fayalite o/g on w		28.27				13.63	0.16				1.33			53.78			97.18
LFW13	SOI 3	# 6	wustite		22.90			0.29	0.29						0.30		75.70			99.48
LFW13	SOI 3	# 7	w with exsolved m	area	23.25			1.83	0.37						1.05		72.59			99.08
LFW13	SOI 3	# 8	glass		38.39	0.63		9.30	19.12	0.90	0.37		7.11	7.86			12.79			96.46
LFW13	SOI 3	# 9	late fayalite		32.44			2.08	15.21	0.22			1.29	3.19			46.95			101.37
LFW13	SOI 3	# 10	late fayalite		29.60			1.17	13.80	0.20			0.96	2.19			47.65			95.58
LFW13	SOI 6	# 1	ol core		27.44				13.01					0.47		0.30	52.16			93.38
LFW13	SOI 6	# 2	ol inner		27.53			0.19	12.95					0.72			52.82			94.21
LFW13	SOI 6	# 3	ol outer		28.20				13.30					3.88			49.16			94.54
LFW13	SOI 6	# 4	margin of ol - altered?		29.28				13.87	0.37				13.58			37.35			94.45
LFW13	SOI 6	# 5	rhonite or glass		33.60			8.00	12.32	0.46				9.45	1.78		31.47			97.08
LFW13	SOI 6	# 6	sulphide bleb*		17.73			5.39	7.98	0.40	21.67		1.30	1.32			47.24			103.02
LFW13	SOI 6	# 7	wustite		21.09			0.29	0.20						0.29		74.87			96.74
LFW13	SOI 6	# 8	leucite		40.17	0.73		11.59	23.86				16.40		0.25		1.00			94.02
LFW13	SOI 6	# 9	rhonite or glass		39.50	1.24		9.70	20.05	0.60	0.32		3.17	11.20	0.23		13.29			99.29
LFW13	SOI 6	# 10	sulphide bleb		9.62			1.11	2.64		27.71			1.87			57.83	0.46		101.25
LFW13	SOI 6	# 11	sulphide bleb		17.92			3.13	7.15	1.47	20.64		0.18	7.24			44.99			102.73
LFW13	SOI 6	# 12	sulphide bleb		13.18			1.32	5.58	0.24	23.05		0.22	3.26			53.62			100.46
LFW19	SOI 3	# 1	ol core		29.80		1.17		13.64					1.08		1.14	51.55			98.38
LFW19	SOI 3	# 2	ol inner		30.35		1.03		13.71					1.03		1.24	50.98			98.34
LFW19	SOI 3	# 3	ol outer		30.64		1.08	0.24	13.68					1.14		1.22	51.69			99.69
LFW19	SOI 3	# 4	ol margin		31.44		0.33	0.56	14.00					2.72		1.08	50.42			100.56
LFW19	SOI 3	# 5	ol inner		30.37		1.17	0.23	13.64					1.16		1.21	50.47			98.24
LFW19	SOI 3	# 6	ol outer		30.33		1.01		13.51					1.18		1.25	50.29			97.58

sample	area	anal.	Identification (* = probably mixed)	Point/ area?	wt%															
					O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba	Total
LFW19	SOI 3	# 7	ol margin		29.21		0.35	0.40	13.22					1.70		1.13	51.48			97.50
LFW19	SOI 3	# 8	ol margin		29.84		0.38	0.61	13.45					1.86		1.09	50.19			97.42
LFW19	SOI 3	# 9	ol outer		29.63		0.99	0.33	13.48					1.13		1.16	50.06			96.79
LFW19	SOI 3	# 10	ol inner		30.02		1.01	0.23	13.44					1.15		1.14	49.88			96.88
LFW19	SOI 3	# 11	ol core		30.87		1.04	0.36	13.51				0.33	1.67		1.15	48.54			97.47
LFW19	SOI 3	# 12	ol inner		29.89		1.08	0.21	13.48					1.13		1.18	51.08			98.06
LFW19	SOI 3	# 13	ol outer		30.12		0.95	0.20	13.67					1.13		1.11	51.21			98.39
LFW19	SOI 3	# 14	wustite		22.68			0.72							0.49		73.88			97.77
LFW19	SOI 3	# 15	wustite		22.22			0.63						0.19	0.65		73.50			97.19
LFW19	SOI 3	# 16	late ol		31.46		0.29	0.24	14.13					2.49		1.23	52.05			101.88
LFW19	SOI 4	# 1	rhonite*		40.72			10.83	14.32	0.42	0.16		1.67	9.54	0.56	0.25	26.82			105.29
LFW19	SOI 4	# 2	ol margin		32.41			0.54	13.70				0.21	2.73		1.04	50.98			101.61
LFW19	SOI 4	# 3	ol outer (close to speckles)		32.59		0.78		14.01					1.24		1.19	52.44			102.25
LFW19	SOI 4	# 4	ol inner		32.70		1.19	0.22	13.92					1.11		1.12	51.85			102.10
LFW19	SOI 4	# 5	ol inner		32.56		1.07		14.17					1.13		1.24	52.82			102.98
LFW19	SOI 4	# 6	glass?		40.04	0.48		10.55	15.66	0.61	0.34		4.02	10.57	0.32	0.29	19.03			101.92
LFW19	SOI 4	# 7	rhonite*		39.68	0.31		9.51	15.37	0.56	0.26		2.84	9.47	0.35	0.31	26.68			105.35
LFW19	SOI 4	# 8	late ol		33.38		0.28	0.25	14.16					2.02		1.13	51.35			102.56
LFW19	SOI 4	# 9	large wustite		23.15			0.80							0.57	0.41	74.31			99.24

Table 8: Microanalyses by EDS. Data expressed as normalised atom%.

sample	area	anal.	identification	atom%														
				O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW4	SOI 14	# 1	wustite	47.14											0.66	52.20		
LFW4	SOI 14	# 2	magnetite	54.75			3.08	0.38							0.37	41.42		
LFW4	SOI 14	# 3	wustite	47.67											0.85	51.48		
LFW4	SOI 14	# 4	fayalite around oxide	54.78		3.13		14.95					3.18		1.86	22.10		
LFW4	SOI 14	# 5	fayalite around oxide	55.16		2.90		14.59					3.60		2.04	21.71		
LFW4	SOI 14	# 6	fayalite margin	56.13		0.56		14.15	0.24				10.48		1.06	17.37		
LFW4	SOI 14	# 7	magnetite *	54.94			4.36	2.24					0.77	0.52	0.46	36.71		
LFW4	SOI 14	# 8	altered glass?	58.48			4.77	16.35	0.87				10.01		0.39	9.13		
LFW4	SOI 14	# 9	rhonite?	57.41			8.29	11.90					6.27	0.51	0.25	15.37		
LFW4	SOI 14	# 10	altered glass?	58.44			5.49	15.83	1.08				10.67		0.26	8.24		
LFW4	SOI 14	# 11	leucite	59.13	0.63		9.88	19.31				9.14	0.63			1.15		0.12
LFW4	SOI 14	# 12	fayalite* (assoc L)	58.27			6.50	12.67				0.58	6.85	0.32	0.36	14.46		
LFW4	SOI 14	# 13	fayalite around oxide	54.96		3.28		14.59					3.44		2.10	21.63		
LFW4	SOI 14	# 14	outer fayalite	56.14		0.58		14.27					10.27		1.15	17.59		
LFW4	SOI 14	# 15	inner fayalite	56.03		2.06	0.44	14.38					4.71		1.79	20.59		
LFW4	SOI 14	# 16	outer fayalite	55.25		0.72		14.66					9.69		1.19	18.50		
LFW4	SOI 14	# 17	outer fayalite	56.04		0.53		14.30					10.77		1.15	17.21		
LFW4	SOI 14	# 18	rhonite?	58.15			6.54	14.35	0.34				8.34		0.32	11.96		
LFW4	SOI 14	# 19	altered glass?	59.37			4.89	15.04	1.37				11.20		0.22	7.91		
LFW4	SOI 14	# 20	magnetite	56.68			3.90	4.15		1.43			2.84	0.43	0.54	30.04		
LFW4	SOI 14	# 21	magnetite	54.00			4.98	0.45					0.24			40.34		
LFW4	SOI 14	# 22	Al-magnetite	55.03			11.84	0.51					0.50	1.12	0.57	30.43		
LFW4	SOI 14	# 23	fayalite around oxide	55.55		2.39		14.54					3.71		1.72	22.09		
LFW4	SOI 14	# 24	outer fayalite	55.21		0.60		14.62	0.16				10.25		1.18	17.98		
LFW4	SOI 14	# 25	outer fayalite	54.98		0.58		14.50	0.16				10.49		1.10	18.18		
LFW4	SOI 14	# 26	fayalite around oxide	54.83		3.16		14.87					3.51		2.11	21.53		
LFW4	SOI 14	# 27	wustite	46.71		0.57									0.75	51.98		
LFW4	SOI 14	# 28	magnetite	55.32			5.27	2.48					1.88	0.72	0.45	33.87		
LFW4	SOI 14	# 29	magnetite	53.71			4.77	1.33					0.52	0.77	0.29	38.61		
LFW4	SOI 14	# 30	rhonite?*	53.50			8.06	8.80					3.68	0.60	0.27	25.10		
LFW4	SOI 14	# 31	altered glass?	56.79			5.88	15.46	0.59				8.71	0.17	0.30	12.10		
LFW4	SOI 14	# 32	altered glass?	58.66			5.11	15.10	1.50				11.22		0.26	8.16		
LFW4	SOI 14	# 33	altered glass?	58.71			4.79	16.45	0.48				9.50		0.41	9.65		
LFW4	SOI 14	# 34	rhonite?	56.99			8.15	12.40					6.39	0.41	0.29	15.36		
LFW4	SOI 14	# 35	leucite	58.86	0.38		9.38	19.77				9.45	0.77			1.28		0.11
LFW4	SOI 14	# 36	leucite*	57.30	0.90		7.89	18.07	0.25			5.40	3.90		0.33	5.95		

sample	area	anal.	identification	atom%														
				O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW4	SOI 14	# 37	rhonite/Al-magnetite?	61.34	0.34	0.20	10.71	9.15	0.41	0.20		0.84	5.04	0.32	0.29	11.16		
LFW4	SOI 14	# 38	Al-magnetite	55.86			10.97	0.78					0.76	1.13	0.39	30.11		
LFW4	SOI 14	# 39	magnetite *	52.67		0.73	4.75	4.55					1.84	0.69	0.69	34.08		
LFW4	SOI 14	# 40	leucite	58.87	0.57		8.35	15.42	0.60			0.82	7.67	0.13	0.30	7.26		
LFW4	SOI 14	# 41	outer fayalite	55.53		0.34	0.98	14.81	0.27			0.44	10.34		0.90	16.39		
LFW4	SOI 14	# 42	inner fayalite	54.87		2.60		14.60					4.16		2.15	21.62		
LFW4	SOI 14	# 43	magnetite/fayalite	53.00		1.14	2.11	6.66					3.63		1.10	32.35		
LFW4	SOI 14	# 44	magnetite	53.81			5.02	0.84					0.39	0.20	0.58	39.16		
LFW4	SOI 14	# 45	rhonite?	53.42			9.03	11.82					6.79	1.48	0.37	17.09		
LFW4	SOI 15	# 1	inner fayalite	55.21		3.60		14.69					1.80		1.68	23.04		
LFW4	SOI 15	# 2	inner fayalite	55.20		3.48		14.71					1.78		1.72	23.11		
LFW4	SOI 15	# 3	inner fayalite	54.49		3.10		14.84					1.75		1.74	24.07		
LFW4	SOI 15	# 4	middle fayalite	54.73		3.59	0.23	14.71					2.17		1.77	22.81		
LFW4	SOI 15	# 5	middle fayalite	54.91		2.61		14.58					2.96		1.69	23.25		
LFW4	SOI 15	# 6	middle fayalite	54.91		1.79		14.79					3.92		1.64	22.95		
LFW4	SOI 15	# 7	outer fayalite	55.68		0.32		14.46	0.15				9.65		0.92	18.81		
LFW4	SOI 15	# 8	glass?	58.09			6.77	16.09	0.52				10.09	0.11	0.27	8.07		
LFW4	SOI 15	# 9	glass?	58.62			6.15	16.29	0.61				9.94	0.16	0.21	8.02		
LFW4	SOI 15	# 10	rhonite?	58.27			7.53	12.23	0.65			0.15	7.80	0.73	0.20	12.43		
LFW4	SOI 15	# 11	rhonite?	56.06			8.87	10.46					5.87	1.61	0.26	16.88		
LFW4	SOI 15	# 12	rhonite?	56.40		0.31	8.20	11.25					6.34	1.54	0.22	15.75		
LFW4	SOI 15	# 13	rhonite?	58.44			8.57	13.44				1.83	4.94	0.81	0.16	11.81		
LFW4	SOI 15	# 14	glass?	59.30		0.21	6.63	15.12	0.91				10.11	0.14	0.19	7.38		
LFW4	SOI 15	# 15	glass?	62.45			7.57	16.50	0.22			1.44	3.32		0.15	8.35		
LFW4	SOI 15	# 16	leucite	59.00	0.48		9.69	19.25	0.18			9.30	1.13			0.82		0.15
LFW4	SOI 15	# 17	wustite*	49.93			1.30	0.25					0.24	0.64	0.50	47.15		
LFW4	SOI 15	# 18	outer fayalite	56.56		0.78	0.45	14.20	0.27				5.84		1.17	20.74		
LFW4	SOI 15	# 19	weathering?	63.93			8.67	17.22	0.19			0.33	1.31		0.17	8.19		
LFW4	SOI 15	# 20	weathering?	63.92	0.44		6.37	17.26	0.15			4.80	0.76			6.29		
LFW4	SOI 15	# 21	weathering?	62.74		0.24	6.51	16.86	0.20			0.30	1.74		0.20	11.22		
LFW4	SOI 15	# 22	middle fayalite	55.25		2.68		14.54					2.99		1.73	22.81		
LFW4	SOI 15	# 23	outer fayalite	55.40		0.58		14.66					9.80		1.11	18.45		
LFW4	SOI 15	# 24	outer fayalite	59.90			1.43	15.44	0.25			0.42	5.33		0.56	16.67		
LFW4	SOI 15	# 25	rhonite?	56.36		0.27	8.25	11.55					6.27	1.43	0.29	15.57		
LFW4	SOI 15	# 26	glass?	58.71			5.86	14.60	1.69				11.73		0.16	7.25		
LFW4	SOI 15	# 27	glass?	56.90			6.63	16.15	0.96			0.42	10.43	0.14	0.22	8.15		
LFW4	SOI 15	# 28	glass?	58.75			5.83	16.48	0.99				9.59		0.27	8.10		

sample	area	anal.	identification		atom% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW4	SOI 16	# 1	glass		58.79			5.70	15.59	1.03				10.59	0.18	0.23	7.90		
LFW4	SOI 16	# 2	leucite		60.59	0.47		9.42	18.64				8.30	0.96			1.42		0.19
LFW4	SOI 16	# 3	rhonite?		56.50		0.32	8.36	11.20					6.18	1.28	0.26	15.91		
LFW4	SOI 16	# 4	rhonite?		57.09		0.25	8.28	11.55					6.06	1.02	0.24	15.51		
LFW4	SOI 16	# 5	rhonite?		57.02		0.32	8.87	10.70					6.11	0.99	0.31	15.69		
LFW4	SOI 16	# 6	Ca-fayalite		55.34		0.56	1.02	13.81	0.22				9.38		0.99	18.68		
LFW4	SOI 16	# 7	Al-magnetite		55.21			15.25	0.39					0.25	1.28	0.37	27.25		
LFW4	SOI 16	# 8	rhonite?		55.30		0.48	9.03	11.09					6.41	1.03	0.31	16.35		
LFW4	SOI 16	# 9	Ca-fayalite		55.48		0.48		14.41					9.36		1.03	19.24		
LFW4	SOI 16	# 10	hercynite		54.30		0.37	20.63	0.25					0.17	0.77	0.39	23.13		
LFW4	SOI 16	# 11	wustite		47.12			0.30						0.31	0.21	0.43	51.63		
LFW4	SOI 16	# 12	inner fayalite		55.24		2.57		14.73					3.15		1.77	22.53		
LFW4	SOI 16	# 13	inner fayalite		55.31		2.63		14.69					3.03		1.66	22.67		
LFW4	SOI 16	# 14	late fayalite (with L)		55.93		0.34	0.64	14.48					6.13		0.98	21.50		
LFW4	SOI 16	# 15	hole		59.95		0.22	0.80	25.81	0.17				2.54		0.47	10.04		
LFW4	SOI 16	# 16	hole		61.61			3.03	15.33				0.17	2.78		0.45	16.63		
LFW4	SOI 16	# 17	late fayalite (with L)		55.76		0.48	0.23	14.29					6.48		1.00	21.76		
LFW4	SOI 16	# 18	iron sulphide*		42.26	0.51	0.43	3.54	12.25	0.29	11.39		0.25	5.68	0.13	0.71	22.57		
LFW4	SOI 16	# 19	Al-magnetite		55.24		0.32	14.77	1.99					1.16	0.74	0.39	25.38		
LFW4	SOI 16	# 20	Ca-fayalite		55.73		0.39		14.57					9.35		0.94	19.03		
LFW4	SOI 16	# 21	Ca-fayalite		55.82		0.45	0.31	13.89	0.28				8.41		0.98	19.86		
LFW4	SOI 16	# 22	wustite		48.73			0.85	0.38					0.51		0.44	49.09		
LFW6	SOI 5	# 1	fayalite centre		55.96		0.70		14.58								28.76		
LFW6	SOI 5	# 2	fayalite centre		55.64		0.73		14.46								29.16		
LFW6	SOI 5	# 3	fayalite outer		55.09				14.74					0.13		0.14	29.89		
LFW6	SOI 5	# 4	fayalite centre		55.94		0.57		14.24								29.26		
LFW6	SOI 5	# 5	fayalite centre		56.57		0.48	2.13	14.66				0.63	0.40			25.12		
LFW6	SOI 5	# 6	fayalite outer		56.13		0.40		14.20					0.14			29.13		
LFW6	SOI 5	# 7	fayalite carious margin		59.06			1.44	14.69	0.16			0.98	0.74	0.10		22.82		
LFW6	SOI 5	# 8	fayalite carious margin		55.78		0.35	1.42	15.63				0.36	0.30			26.16		
LFW6	SOI 5	# 9	glass		59.89	0.62		7.29	18.94	0.54			3.17	1.95	0.16		7.44		
LFW6	SOI 5	# 10	glass		60.14	0.55		6.69	18.95	0.36	0.10		3.06	1.73	0.19		8.24		
LFW6	SOI 5	# 11	fine ?hercynite		57.66			9.44	10.20				1.09	0.44	1.07		20.11		
LFW6	SOI 5	# 12	interstitial area	area	59.20	0.48		9.58	16.18	0.37			2.49	1.68	0.49		9.53		
LFW6	SOI 5	# 13	interstitial area	area	60.28	0.47		7.76	18.58	0.34			2.45	2.68	0.23		7.21		
LFW6	SOI 5	# 14	interstitial area	area	58.51	0.49		8.75	15.07	0.28			2.33	1.32	0.54		12.71		
LFW6	SOI 5	# 15	bulk area	area	57.90			5.62	15.38	0.30			1.37	0.91	0.24		18.29		

sample	area	anal.	identification		atom% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW6	SOI 6	# 1	euhedral hercynite		55.94			26.33							0.70		17.03		
LFW6	SOI 6	# 2	euhedral hercynite		55.65			27.12	0.20						0.48		16.55		
LFW6	SOI 6	# 3	interstitial hercynite		55.13			26.40	0.26						0.94		17.27		
LFW6	SOI 6	# 4	olivine on margin		57.21		0.36	1.78	14.22				0.61	0.78	0.13		24.92		
LFW6	SOI 6	# 5	olivine on margin		55.23		0.52		14.42					0.12			29.71		
LFW6	SOI 6	# 6	leucite		58.65			9.93	20.62				10.45				0.36		
LFW6	SOI 6	# 7	leucite		61.20	0.96		9.67	19.17				8.54				0.46		
LFW6	SOI 6	# 8	outer fayalite in ves		55.65		0.37		14.36					0.11			29.50		
LFW6	SOI 6	# 9	iron		26.12			0.60	5.96			0.31					67.02		
LFW6	SOI 6	# 10	outer fayalite in ves		55.24				14.78					0.18			29.81		
LFW6	SOI 6	# 11	main olivine		55.95				14.49					0.15			29.42		
LFW6	SOI 6	# 12	late olivine		54.94			0.49	14.58	0.16				0.16	0.14		29.52		
LFW6	SOI 6	# 13	interstitial area in ves	area	58.40	0.76		8.20	15.81	0.41			1.04	2.86	0.57		11.96		
LFW6	SOI 6	# 14	bulk area	area	57.11	1.20		6.62	14.72	0.25			0.82	1.04	0.28		17.98		
LFW10	SOI 4	# 1	glass		58.73		0.33	5.33	16.07	0.22	0.23		0.74	7.52	0.32	0.51	10.01		
LFW10	SOI 4	# 2	olivine inner		55.66		3.33		14.59					1.11		1.48	23.83		
LFW10	SOI 4	# 3	olivine outer		55.57		3.02		14.77					1.35		1.34	23.96		
LFW10	SOI 4	# 4	olivine inner		55.03		3.69		14.84					1.04		1.34	24.06		
LFW10	SOI 4	# 5	glass area		58.31		0.25	5.61	16.33	0.24	0.18		0.86	7.55	0.28	0.45	9.94		
LFW10	SOI 4	# 6	bulk area		58.16		0.98	4.55	15.66	0.16			0.74	5.24	0.18	0.72	13.62		
LFW10	SOI 4	# 7	olivine outer		54.68		2.54		14.77					1.55		1.43	25.03		
LFW10	SOI 4	# 8	olivine margin		55.90		2.33	0.40	14.93					1.46		1.29	23.69		
LFW10	SOI 5	# 1	olivine inner		56.47		3.15	0.75	14.39	0.17			0.13	1.59		1.34	22.00		
LFW10	SOI 5	# 2	olivine inner		55.52		3.45		14.64					1.07		1.37	23.94		
LFW10	SOI 5	# 3	olivine margin		54.82		2.51		14.72					1.34		1.39	25.23		
LFW10	SOI 5	# 4	olivine margin		56.35		1.83	0.37	14.96					1.79		1.27	23.45		
LFW10	SOI 5	# 5	olivine inner		56.08		3.40		14.33					1.22		1.24	23.74		
LFW10	SOI 5	# 6	olivine margin		57.29		2.51	1.67	14.50	0.15			0.38	2.56	0.11	1.05	19.78		
LFW10	SOI 5	# 7	late olivine		56.05		2.07	0.35	14.92					1.61		1.27	23.73		
LFW10	SOI 5	# 8	late olivine		58.19		1.37	2.30	14.82	0.21			0.33	3.84	0.13	0.95	17.84		
LFW10	SOI 5	# 9	glass area		59.43		0.39	6.09	16.17	0.31	0.10		1.01	6.91	0.26	0.43	8.91		
LFW10	SOI 5	# 10	interstitial area	area	58.52		0.64	4.48	15.67	0.19			0.64	5.70	0.24	0.64	13.29		
LFW10	SOI 5	# 11	bulk area	area	58.21		0.90	4.96	15.46	0.22	0.14		0.79	5.29	0.23	0.68	13.13		
LFW10	SOI 5	# 12	glass		59.04		0.31	5.74	16.33	0.23	0.19		0.93	6.90	0.25	0.50	9.60		
LFW10	SOI 5	# 13	glass		59.47		0.26	6.08	16.14	0.27	0.24		0.96	7.14	0.30	0.39	8.76		
LFW11	SOI 4	# 1	olivine*		56.89		1.78	2.65	15.40	0.19			0.68	3.90		1.07	17.29	0.17	

sample	area	anal.	identification		atom% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW11	SOI 4	# 2	olivine*		57.19		1.74	2.94	15.15	0.17	0.13		0.68	4.18	0.11	1.00	16.71		
LFW11	SOI 4	# 3	glass*		56.44	0.36	0.63	5.94	16.78	0.23	0.25		1.19	6.46	0.17	0.65	10.90		
LFW11	SOI 4	# 4	bulk area	area	57.15		1.20	4.31	15.60	0.26			0.74	5.37	0.23	0.83	14.31		
LFW11	SOI 6	# 1	bulk area	area	57.93		1.41	3.98	15.25	0.18			0.57	4.58	0.14	0.82	15.15		
LFW11	SOI 6	# 2	olivine outer		57.10		3.44	0.56	14.20	0.16			0.16	2.03		1.29	21.06		
LFW11	SOI 6	# 3	olivine core		56.70		2.98	1.10	14.35				0.21	2.00		1.35	21.31		
LFW11	SOI 6	# 4	olivine core		57.30		3.17	0.45	14.06				0.15	2.03		1.31	21.52		
LFW11	SOI 6	# 5	olivine outer		56.30		3.04		14.47					1.42		1.43	23.34		
LFW11	SOI 6	# 6	olivine margin		56.62		2.37		14.96	0.14				1.78		1.33	22.82		
LFW11	SOI 6	# 7	olivine outer		56.27		2.78		14.59					1.87		1.38	23.11		
LFW11	SOI 6	# 8	olivine core		56.23		3.63	0.69	14.45				0.23	1.76		1.42	21.59		
LFW11	SOI 6	# 9	late olivine		57.09		1.29	2.66	14.98	0.20			0.49	4.15	0.14	1.08	17.92		
LFW11	SOI 6	# 10	late olivine		56.26		1.57	1.81	14.83	0.18			0.28	3.39		1.23	20.45		
LFW11	SOI 6	# 11	glass area		59.05	0.27	0.21	6.07	16.32	0.29	0.23		0.90	8.06	0.32	0.40	7.87		
LFW11	SOI 6	# 12	glass area	area	59.21		0.25	6.39	16.42	0.24	0.19		1.01	7.74	0.32	0.39	7.85		
LFW12	SOI 7	# 1	olivine core		56.31		0.75		14.08					0.20		0.20	28.46		
LFW12	SOI 7	# 2	olivine margin		55.92				14.32					0.35		0.16	29.25		
LFW12	SOI 7	# 3	spinel inner		55.19			3.64	0.51						1.20		39.45		
LFW12	SOI 7	# 4	spinel inner		55.50			3.54	0.41						1.22		39.33		
LFW12	SOI 7	# 5	spinel outer		54.90			4.23	0.48						1.37		39.03		
LFW12	SOI 7	# 6	spinel margin		54.13			5.97	0.71					0.14	1.17		37.88		
LFW12	SOI 7	# 7	interstitial olivine		57.12				14.16					0.71			28.01		
LFW12	SOI 7	# 8	interstitial olivine		55.78				14.41					0.68		0.20	28.93		
LFW12	SOI 7	# 9	interstitial olivine		57.17			0.92	14.83				0.66	1.25		0.15	25.02		
LFW12	SOI 7	# 10	interstitial olivine		56.36				14.15					0.69			28.80		
LFW12	SOI 7	# 11	interstitial spinel		56.99			7.62	1.44				0.18	0.34	1.27		32.16		
LFW12	SOI 7	# 12	interstitial olivine		56.50				14.46					0.75			28.29		
LFW12	SOI 7	# 13	glass area	area	61.04	0.45		7.69	18.02	0.42			2.60	4.69	0.09		5.00		
LFW12	SOI 7	# 14	glass area	area	60.84	0.48		7.85	18.62	0.44			3.25	4.10			4.42		
LFW12	SOI 7	# 15	spinel margin		58.53			5.66	0.43						1.14		34.23		
LFW12	SOI 7	# 16	interstitial spinel		58.13			7.04	1.11				0.29	0.41	1.26		31.75		
LFW12	SOI 7	# 17	spinel margin		57.12			3.97	0.75						1.20		36.97		
LFW12	SOI 9	# 1	spinel outer		57.87			5.82	0.28						1.31		34.72		
LFW12	SOI 9	# 2	interstitial spinel		58.34			8.01	2.56				0.40	0.68	1.18		28.83		
LFW12	SOI 9	# 3	interstitial spinel		57.73			8.17	3.95				0.46	0.86	1.01		27.82		
LFW12	SOI 9	# 4	late olivine		56.85			0.63	14.62				0.41	1.03		0.20	26.25		

sample	area	anal.	identification	atom%														
				O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW12	SOI 9	# 5	late olivine	58.67			3.14	15.35	0.25			1.26	2.09		0.14	19.09		
LFW12	SOI 9	# 6	hollow prism	60.36	0.27		7.55	15.80	0.29			1.83	4.62	0.28		9.00		
LFW12	SOI 9	# 7	hollow prism	59.05	0.27		7.35	16.66	0.26			1.94	4.71	0.22		9.54		
LFW12	SOI 9	# 8	glass	60.95			7.38	18.08	0.42			2.38	5.07	0.09		5.63		
LFW12	SOI 9	# 9	hollow prism	61.03	0.34		7.41	16.54	0.27			2.44	4.01	0.22		7.73		
LFW12	SOI 9	# 10	interstitial spinel	57.49			7.74	1.24				0.14	0.28	1.27		31.84		
LFW12	SOI 9	# 11	spinel margin	59.68			6.13	2.99				0.59	0.98	0.84		28.79		
LFW12	SOI 10	# 1	late spinel	58.60			6.65	4.13				0.72	0.84	1.01		28.05		
LFW12	SOI 10	# 2	late spinel	56.89			5.79	2.05				0.38	0.48	0.90		33.51		
LFW12	SOI 10	# 3	interstitial bright	60.98			6.74	14.71	0.18			1.45	4.53	0.20		11.22		
LFW12	SOI 10	# 4	interstitial bright	59.07	0.37		6.68	15.75				1.84	4.23	0.16		11.90		
LFW12	SOI 10	# 5	interstitial bright	60.04			6.84	15.24	0.21			2.07	4.43	0.16		11.02		
LFW12	SOI 10	# 6	glass	60.66	0.45		7.58	18.38	0.45	0.13		2.55	4.92	0.08		4.79		
LFW12	SOI 10	# 7	glass	60.93	0.30		6.53	18.58	0.53	0.21		2.53	4.76			5.62		
LFW12	SOI 10	# 8	interstitial bright	58.39	0.48		5.02	17.28	0.35			2.30	2.55		0.13	13.50		
LFW12	SOI 10	# 9	interstitial bright	61.54			6.56	16.31	0.24			1.80	4.03	0.17		9.34		
LFW12	SOI 10	# 10	late spinel	58.19	0.37		3.72	16.23	0.25			1.19	1.68			18.36		
LFW12	SOI 10	# 11	late spinel	60.47	0.36		5.85	17.19	0.36			2.25	2.54			10.98		
LFW12	SOI 11	# 1	olivine	55.57		0.81		14.52					0.33		0.21	28.57		
LFW12	SOI 11	# 2	olivine	55.79		0.79		14.36					0.36		0.20	28.50		
LFW12	SOI 11	# 3	olivine	55.72		0.86		14.34					0.23		0.16	28.69		
LFW12	SOI 11	# 4	iscorite	53.71			0.57	5.00								40.72		
LFW12	SOI 11	# 5	iscorite	53.84			0.83	4.96								40.37		
LFW12	SOI 11	# 6	iscorite	54.64			0.54	5.10								39.72		
LFW12	SOI 11	# 7	iscorite	53.88			0.81	5.27								40.03		
LFW12	SOI 11	# 8	rounded magnetite	54.56			1.09	0.25								44.10		
LFW12	SOI 11	# 9	rounded magnetite	54.59			0.90	0.30								44.20		
LFW12	SOI 11	# 10	rounded magnetite	54.08			0.94									44.98		
LFW12	SOI 11	# 11	wustite relict	48.55				0.32								51.13		
LFW12	SOI 11	# 12	wustite relict	48.28				0.34								51.37		
LFW12	SOI 11	# 13	wustite relict	49.37				0.28								50.34		
LFW12	SOI 11	# 14	hole	61.87		0.28	3.83	15.32	0.79	0.13	0.15	1.00	0.68			15.94		
LFW12	SOI 11	# 15	leucite	59.98	0.31		9.19	19.64	0.09			8.96	0.42			1.40		
LFW12	SOI 11	# 16	leucite*	54.83	1.28		6.82	17.01		0.33	0.19	4.47	0.48	0.00		14.38		0.22
LFW12	SOI 11	# 17	wustite relict	48.71				0.27								51.02		
LFW12	SOI 11	# 18	olivine	62.31		0.32		12.50	0.63				1.38			22.85		

sample	area	anal.	identification	atom% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW12	SOI 12	# 1	iscorite	53.51			0.60	4.86								41.03		
LFW12	SOI 12	# 2	iscorite	53.10			0.56	5.05								41.29		
LFW12	SOI 12	# 3	iscorite	52.87			0.59	5.22								41.32		
LFW12	SOI 12	# 4	iscorite	53.47			0.66	5.13								40.74		
LFW12	SOI 12	# 5	rounded core	55.42			0.83	0.28								43.46		
LFW12	SOI 12	# 6	bright inner	54.48			1.03	0.27								44.22		
LFW12	SOI 12	# 7	bright inner	55.07			0.86	0.24								43.82		
LFW12	SOI 12	# 8	bright inner	54.50			1.12	0.41								43.97		
LFW12	SOI 12	# 9	wustite	49.06				0.36								50.58		
LFW12	SOI 12	# 10	wustite	48.89				0.28								50.83		
LFW12	SOI 12	# 11	wustite	48.75				0.33								50.93		
LFW12	SOI 12	# 12	wustite	49.09				0.34								50.58		
LFW12	SOI 12	# 13	marginl	56.85			0.92	5.87				0.17				36.19		
LFW12	SOI 12	# 14	dark outer	58.48			1.18	6.17								34.16		
LFW12	SOI 12	# 15	bright	55.19			1.38	1.05								42.38		
LFW12	SOI 12	# 16	bright	54.56			1.53	1.73					0.16	0.13		41.88		
LFW12	SOI 12	# 17	ol mix	54.54			0.73	8.08				0.19	0.53			35.93		
LFW12	SOI 12	# 18	ol mix	55.18			1.27	6.70				0.31				36.54		
LFW12	SOI 12	Sum Spectrum		54.06		0.11	1.05	2.68	0.06		0.05	0.06	0.14	0.04	0.04	41.70		
LFW12	SOI 15	# 1	skeletal spinel	54.36			5.20	0.61						1.16		38.66		
LFW12	SOI 15	# 2	olivine	55.54		0.42		14.37					0.28		0.22	29.16		
LFW12	SOI 15	# 3	rhonite	58.27			8.51	10.76					5.78	0.36		16.31		
LFW12	SOI 15	# 4	rhonite	59.02			8.47	10.59					5.69	0.49		15.75		
LFW12	SOI 15	# 5	leucite	59.29	0.48		9.20	18.76	0.31			8.13	1.89			1.93		
LFW12	SOI 15	# 6	olivine (assoc leucite)	55.67				14.36				0.11	1.09		0.19	28.58		
LFW12	SOI 15	# 7	iscorite	54.36			1.76	4.90						0.32		38.67		
LFW12	SOI 15	# 8	fayalite	58.02			0.21	13.64	0.33				2.97		0.14	24.69		
LFW12	SOI 15	# 9	glass	59.83	0.57		4.50	14.98	1.54	0.32		0.26	9.92			8.09		
LFW12	SOI 15	# 10	fayalite	57.01			0.00	13.90	0.23				1.96		0.19	26.70		
LFW12	SOI 15	# 11	rhonite	58.87			8.06	10.58					5.23	0.40		16.85		
LFW12	SOI 15	# 12	rhonite	57.68			8.42	10.90					5.89	0.51		16.61		
LFW12	SOI 15	# 13	fayalite	55.45			0.25	13.96	0.16				1.79		0.18	28.20		
LFW12	SOI 15	# 14	iscorite	53.95			1.65	4.92						0.32		39.15		
LFW12	SOI 15	# 15	iscorite	54.17			1.81	4.93						0.27		38.83		
LFW12	SOI 15	# 16	olivine (assoc leucite)	57.61				14.12					2.66		0.12	25.48		
LFW12	SOI 15	# 17	rhonite	58.55			8.39	10.74					5.79	0.35		16.17		
LFW12	SOI 15	# 18	iscorite	54.87			1.63	4.93					0.17	0.32		38.08		
LFW12	SOI 15	# 19	iscorite	54.96			1.97	4.92						0.28		37.87		

sample	area	anal.	identification	atom% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW12	SOI 15	# 20	olivine (assoc leucite)	56.26				14.05	0.21				1.67		0.17	27.64		
LFW12	SOI 15	# 21	hercynite (in fayalite)	56.79			10.05	0.40						1.55		31.21		
LFW12	SOI 15	# 22	fayalite margin	56.87			0.25	13.95					0.85		0.16	27.92		
LFW12	SOI 15	# 23	fayalite core	56.21		0.33		14.22					0.40		0.22	28.61		
LFW12	SOI 15	# 24	hercynite outer	54.80			7.52	0.57						1.25		35.87		
LFW12	SOI 15	# 25	olivine (assoc leucite)	56.36		0.20	0.00	13.99					1.47		0.17	27.81		
LFW12	SOI 15	# 26	glass	60.32	0.66		5.25	14.86	1.21	0.30		0.36	9.09			7.95		
LFW12	SOI 15	# 27	leucite	61.29	0.28		9.73	19.12	0.19	0.06	0.09	8.07				1.17		
LFW12	SOI 15	# 28	rhonite	59.02			7.48	11.74	0.16				5.72	0.14		15.74		
LFW12	SOI 15	# 29	rhonite	58.91			8.71	10.63				0.46	5.50	0.72		15.07		
LFW12	SOI 15	# 30	olivine outgrowth	55.97			0.17	14.18					1.32		0.15	28.21		
LFW12	SOI 15	# 31	olivine	55.94		0.54	0.13	14.15					0.29		0.20	28.74		
LFW12	SOI 15	# 32	iscorite	54.27			1.71	4.92						0.30		38.80		
LFW12	SOI 15	# 33	olivine (assoc leucite)	56.39			0.23	13.86	0.16				1.09		0.15	28.12		
LFW12	SOI 15	# 34	glass	59.56	0.87		7.42	14.84	0.96	0.18		0.50	8.91			6.77		
LFW12	SOI 15	# 35	glass	61.80	0.45		4.36	14.39	1.48	0.28		0.20	9.41			7.62		
LFW12	SOI 15	# 36	hercynite (in fayalite)	56.10			16.64	1.52					0.44	0.29		25.01		
LFW12	SOI 15	# 37	magnetite inside hercynite	55.59			5.26	0.43						1.14		37.58		
LFW12	SOI 15	# 38	skeletal spinel	54.13			3.95	1.75						0.83		39.35		
LFW12	SOI 16	# 1	equant spinel outer	55.03			8.21	0.73						1.27		34.76		
LFW12	SOI 16	# 2	mag assoc wustite relict	52.88			2.86	0.85						0.70		42.70		
LFW12	SOI 16	# 3	equant spinel outer	56.96			5.04	0.33						1.29		36.39		
LFW12	SOI 16	# 4	wustite relict	49.44				0.49								50.07		
LFW12	SOI 16	# 5	iscorite	53.81			1.57	4.88						0.25		39.48		
LFW12	SOI 16	# 6	wustite rounded	51.07				0.34								48.59		
LFW12	SOI 16	# 7	wustite relict	51.65			0.29	0.38								47.69		
LFW12	SOI 16	# 8	hercynite on elongate mag	56.99			11.25	0.79					0.16	0.95		29.87		
LFW12	SOI 16	# 9	olivine on elongate mag	56.68				14.18					2.20		0.15	26.80		
LFW12	SOI 16	# 10	rhonite on elongate mag	58.05			8.28	10.96					5.89	0.42		16.41		
LFW12	SOI 16	# 11	iscorite	53.94			1.51	4.88						0.25		39.42		
LFW12	SOI 16	# 12	wustite	50.08				0.34								49.57		
LFW12	SOI 16	# 13	equant spinel rim	55.73			11.39	0.68						1.54		30.66		
LFW12	SOI 16	# 14	fayalite	56.05		0.66		14.09					0.31		0.23	28.66		
LFW12	SOI 16	# 15	hercynite	55.07			11.74	1.03						0.85		31.31		
LFW12	SOI 16	# 16	hercynite on magnetite	56.90			10.01	1.62					0.24	0.73		30.49		
LFW13	SOI 2	# 1	fayalite outer	54.60				14.95					0.45			30.00		
LFW13	SOI 2	# 2	fayalite inner	54.62		0.80		14.98					0.20		0.15	29.26		

sample	area	anal.	identification		atom% O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW13	SOI 2	# 3	fayalite inner		54.93		0.51		14.71					0.26			29.59		
LFW13	SOI 2	# 4	fayalite inner		54.41		1.00		14.97					0.12		0.15	29.35		
LFW13	SOI 2	# 5	fayalite outer		54.57				14.84					0.34			30.26		
LFW13	SOI 2	# 6	fayalite, assoc w		54.75				14.92					0.37			29.96		
LFW13	SOI 2	# 7	fayalite inner		54.99		0.82		14.57					0.22			29.40		
LFW13	SOI 3	# 1	main olivine margin		54.84				14.81					0.71			29.64		
LFW13	SOI 3	# 2	hercynite inner		54.41			13.07	0.33						1.69		30.50		
LFW13	SOI 3	# 3	hercynite margin (streaky)		55.43			17.12	0.28						1.10		26.07		
LFW13	SOI 3	# 4	fayalite o/g on w		54.47			0.75	15.13	0.17			0.18	1.09			28.21		
LFW13	SOI 3	# 5	fayalite o/g on w		54.31				14.92	0.16				1.02			29.60		
LFW13	SOI 3	# 6	wustite		50.87			0.38	0.36						0.22		48.17		
LFW13	SOI 3	# 7	w with exsolved m	area	50.89			2.37	0.46						0.77		45.52		
LFW13	SOI 3	# 8	glass		58.53	0.67		8.41	16.61	0.71	0.28		4.43	4.78			5.59		
LFW13	SOI 3	# 9	late fayalite		56.22			2.14	15.01	0.20			0.91	2.20			23.31		
LFW13	SOI 3	# 10	late fayalite		55.66			1.31	14.79	0.19			0.74	1.65			25.67		
LFW13	SOI 6	# 1	ol core		54.81				14.80					0.37		0.18	29.84		
LFW13	SOI 6	# 2	ol inner		54.58			0.22	14.63					0.57			30.00		
LFW13	SOI 6	# 3	ol outer		54.86				14.73					3.01			27.40		
LFW13	SOI 6	# 4	margin of ol - altered?		54.74				14.77	0.35				10.14			20.00		
LFW13	SOI 6	# 5	rhonite or glass		56.96			8.04	11.90	0.40				6.40	1.01		15.29		
LFW13	SOI 6	# 6	sulphide bleb*		34.71			6.26	8.90	0.40	21.17		1.04	1.04			26.50		
LFW13	SOI 6	# 7	wustite		49.14			0.40	0.26						0.23		49.97		
LFW13	SOI 6	# 8	leucite		58.88	0.75		10.07	19.92				9.83		0.12		0.42		
LFW13	SOI 6	# 9	rhonite or glass		58.38	1.27		8.50	16.88	0.46	0.23		1.92	6.61	0.11		5.63		
LFW13	SOI 6	# 10	sulphide bleb		22.35			1.53	3.50		32.12			1.73			38.49	0.27	
LFW13	SOI 6	# 11	sulphide bleb		35.31			3.65	8.03	1.50	20.28		0.15	5.70			25.39		
LFW13	SOI 6	# 12	sulphide bleb		28.95			1.72	6.98	0.28	25.27		0.19	2.85			33.75		
LFW19	SOI 3	# 1	ol core		55.32		1.43		14.42					0.80		0.62	27.41		
LFW19	SOI 3	# 2	ol inner		55.98		1.26		14.40					0.76		0.66	26.94		
LFW19	SOI 3	# 3	ol outer		55.81		1.29	0.26	14.19					0.83		0.65	26.97		
LFW19	SOI 3	# 4	ol margin		56.33		0.39	0.59	14.29					1.95		0.56	25.88		
LFW19	SOI 3	# 5	ol inner		55.91		1.41	0.25	14.31					0.85		0.65	26.62		
LFW19	SOI 3	# 6	ol outer		56.24		1.23		14.27					0.88		0.67	26.71		
LFW19	SOI 3	# 7	ol margin		55.15		0.44	0.45	14.22					1.28		0.62	27.84		
LFW19	SOI 3	# 8	ol margin		55.72		0.47	0.67	14.30					1.39		0.59	26.85		
LFW19	SOI 3	# 9	ol outer		55.61		1.22	0.36	14.41					0.85		0.63	26.91		

sample	area	anal.	identification	atom%														
				O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Ba
LFW19	SOI 3	# 10	ol inner	56.05		1.24	0.26	14.30					0.85		0.62	26.68		
LFW19	SOI 3	# 11	ol core	56.63		1.26	0.39	14.12				0.25	1.22		0.61	25.51		
LFW19	SOI 3	# 12	ol inner	55.52		1.32	0.24	14.26					0.84		0.64	27.18		
LFW19	SOI 3	# 13	ol outer	55.69		1.16	0.21	14.39					0.84		0.60	27.12		
LFW19	SOI 3	# 14	wustite	51.04			0.97							0.37		47.63		
LFW19	SOI 3	# 15	wustite	50.57			0.85						0.17	0.49		47.92		
LFW19	SOI 3	# 16	late ol	56.08		0.34	0.25	14.35					1.77		0.64	26.58		
LFW19	SOI 4	# 1	rhonite*	59.86			9.44	11.99	0.32	0.12		1.01	5.60	0.27	0.11	11.29		
LFW19	SOI 4	# 2	ol margin	57.24			0.57	13.78				0.15	1.93		0.53	25.79		
LFW19	SOI 4	# 3	ol outer (close to speckles)	57.23		0.90		14.01					0.87		0.61	26.38		
LFW19	SOI 4	# 4	ol inner	57.20		1.37	0.22	13.87					0.77		0.57	25.99		
LFW19	SOI 4	# 5	ol inner	56.85		1.22		14.09					0.79		0.63	26.42		
LFW19	SOI 4	# 6	glass?	59.28	0.50		9.26	13.21	0.47	0.25		2.43	6.25	0.16	0.12	8.07		
LFW19	SOI 4	# 7	rhonite*	58.78	0.32		8.35	12.97	0.43	0.19		1.72	5.60	0.17	0.13	11.32		
LFW19	SOI 4	# 8	late ol	57.93		0.32	0.25	14.00					1.40		0.57	25.53		
LFW19	SOI 4	# 9	large wustite	51.20			1.04							0.42	0.26	47.08		

Table 9: Catalogue of slag rods/tubes

C.	area	wt	no	Description
	TP?7	146	1	146g,120mm long, 25x15 diameter, and on the wider end 30x15
1	TP3/ all	147	1	56g, 50mm long, 20mm diameter, dense;
				30g, 50mm long, approx. diameter 15mm, dense slag rod with vesicle in the middle;
				18g, 40mm long, 15 diameter, dense with very small gas bubbles
				9.92g, 25mm long, 15mm diameter, dense with vesicle inside and large crystals
				3.65g, 10mm long, 15mm diameter, dense with little gas bubbles
				10.55g, 25mm long, 15mm diameter, dense with little gas bubbles and flow lobes
				8.88g, 42 long, 15mm diameter, dense
1	all	88	1	88g, 90mm long, 20mm diameter on the thin end, 25mm diameter on the thicker end, dense rusty with vesicles
1	all	78	2	
2			3	56g, 80mm long, 20x10 diameter, dense bent and flat rod with flow
				72g, 70mm long, diameter on the thicker end 40x20mm, diameter on the other end 20x10mm, dense and bit flat slag rod
				32g, 65mm long, 15mm and 10mm diameter, dense double slag rod with small gas bubbles
4	TP1	46	1	46g, 70mm long, 20mm diameter, low density slag with crystals, very rough surface with charcoal prints
26	TP3	123	4	64g, 65mm long, 15mm diameter of smaller end, 30mm diameter of bigger end, dense and rusty stag rod
				18g, 35mm long, 15mm diameter, dens slag with black glossy flows
				26g, 55mm long, 15mm diameter, dense slag with flows
				15g, 30mm long, 10x20 diameter, dense black and rusty flat slag rod
34	TP1	76	2	30g, 55mm long, 10mm diameter of the smaller end, 10x20mm diameter of the larger flat end, dens and rusty slag rod
				46g, 60mm long, 10mm of smaller end diameter, 20mm of the larger end, dense and little bent slag rod
39	TP1	200	5	26g, 55mm long, 15mm diameter, dense and rusty slag rod
				30g, 50mm long, 15mm diameter, dense slag rod
				28g, 65mm long, 15mm diameter, dense slag rod with small vesicles
				38g, 45mm long, 20mm diameter, dense slag with flows and glossy black surface
				78g, 60mm long, 30x20mm on flat end, dense slag with large vesicle inside and flows on the black surface
45	TP3	6.85	1	6.85g, 30mm long, 10mm diameter, dense slag with vesicle inside
45	TP3	46	1	46g, 60mm long, 20mm diameter, dense slag rod with large vesicle and rusty surface
68	TP8	42	1	42g, 60mm long, 15mm diameter, dense slag rod with vesicle
92	TP11	94	1	94g, 80mm long, 28mm diameter, 45mm diameter of wider end, dense slag rod with occasionally glossy surface
127	TP8	112	1	112g, 90mm long, approx.20mm diameter, charcoal and clay fragment attached to the surface
101		296	4	58g, 79mm long, approx. diameter 20mm
				66g, 100mm long, approx. diameter 20mm, one flat end
				80g, 100mm long, approx. diameter 40mm, rod density double slag rod
				92g, 55mm long, approx. diameter 15mm, dense double rod

Table 10. Calculated viscosities for the analysed slags, using the Bottinga & Weill (1972) model following Paynter (2007).

		1200C	1250C	1400C
LFW4	tapped slag	6.12	1.20	0.89
LFW6	tapped slag with lobes	4.07	2.00	0.77
LFW10	dense vesicular slag flow	12.68	2.31	1.61
LFW11	dense vesicular slag flow	13.42	2.27	1.65
LFW12	smithing slag	2.39	1.13	0.51
LFW13	slag with bladed crystal	2.44	1.14	0.52
LFW19	slag rod	2.12	0.78	0.40

Table 11. Calculated viscosities for the analysed slags, using the algoNess 'slag liquid viscosity calculation tool'.

		1150C	1200C	1250C	1300C	1350C	1400C
LFW9a	tapped slag	30.9	20.8	14.3	10.2	7.4	5.4
LFW9b	tapped slag with lobes	45.7	30.1	20.4	14.2	10.1	7.3
LFW10	dense vesicular slag flow	61.6	39.9	26.6	18.2	12.8	9.2
LFW11	dense vesicular slag flow	62.2	40.2	26.8	18.4	12.9	9.2
LFW12	smithing slag	22.6	15.5	10.9	7.8	5.7	4.3
LFW13	slag with bladed crystal	22.8	15.6	10.9	7.9	5.8	4.3
LFW19	slag rod	19.2	13.2	9.4	6.8	5	3.8

Figure 1

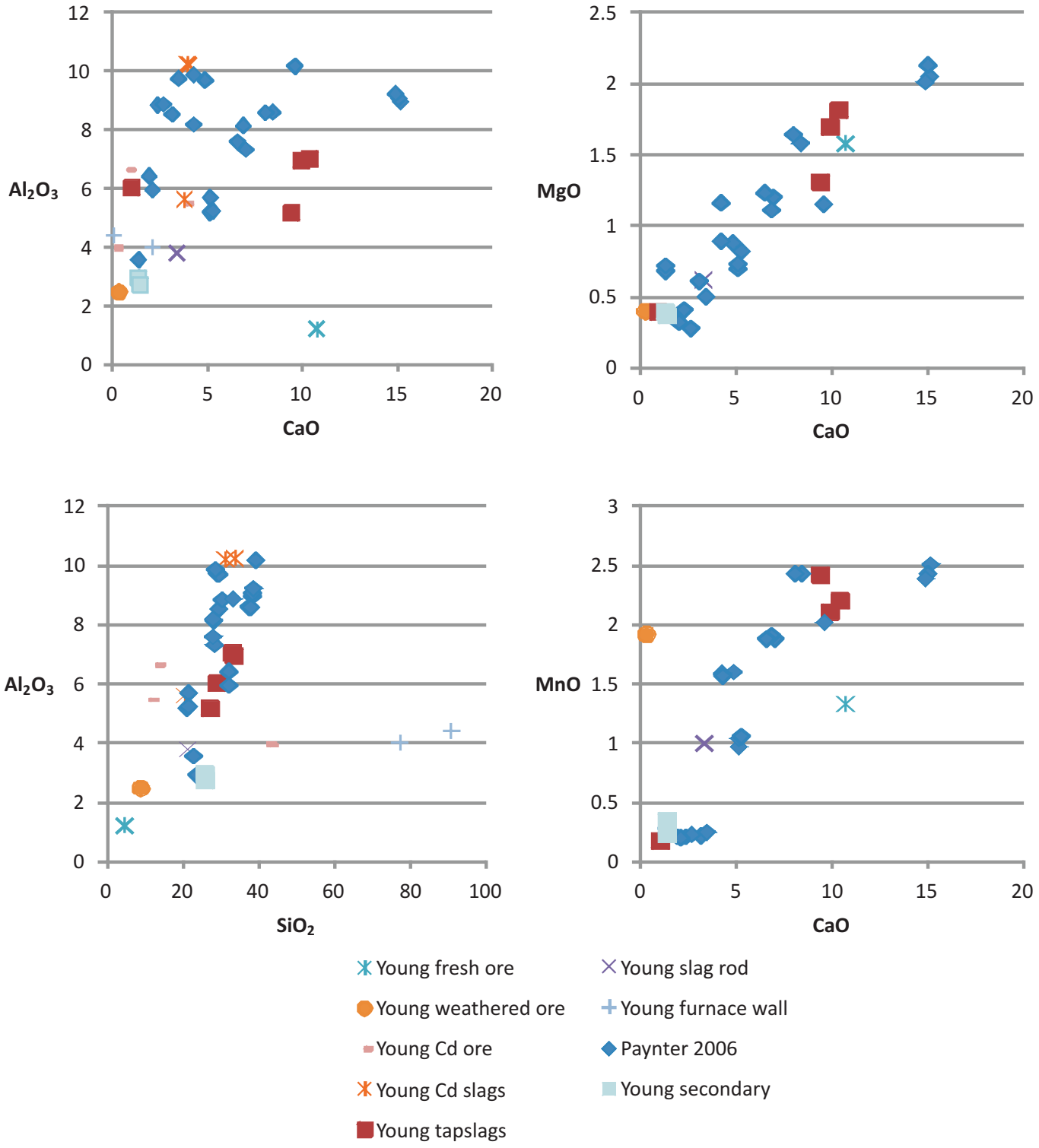

Al2O3
CaO
MgO
CaO
Al2O3
SiO2
MnO
CaO
Young fresh ore
Young weathered ore
Young Cd ore
Young Cd slags
Young tapslags
Young slag rod
Young furnace wall
Paynter 2006
Young secondary

Figure 2

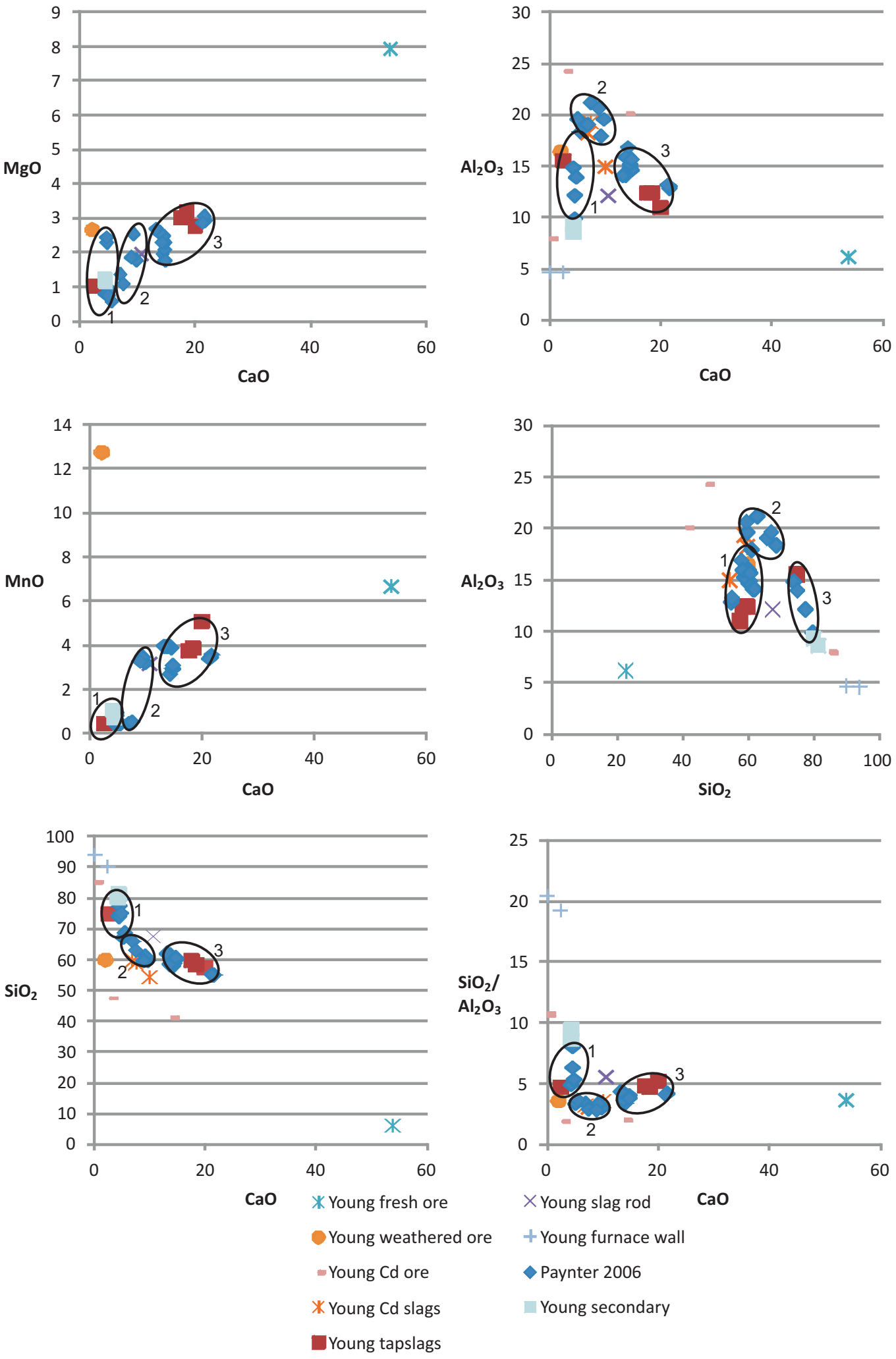

MgO
CaO
Al_2O_3
CaO
MnO
CaO
Al_2O_3
SiO_2
SiO_2
CaO
SiO_2/ Al_2O_3
CaO
1
2
3
Young fresh ore
Young slag rod
Young weathered ore
Young furnace wall
Young Cd ore
Paynter 2006
Young Cd slags
Young secondary
Young tapslags

Figure 3

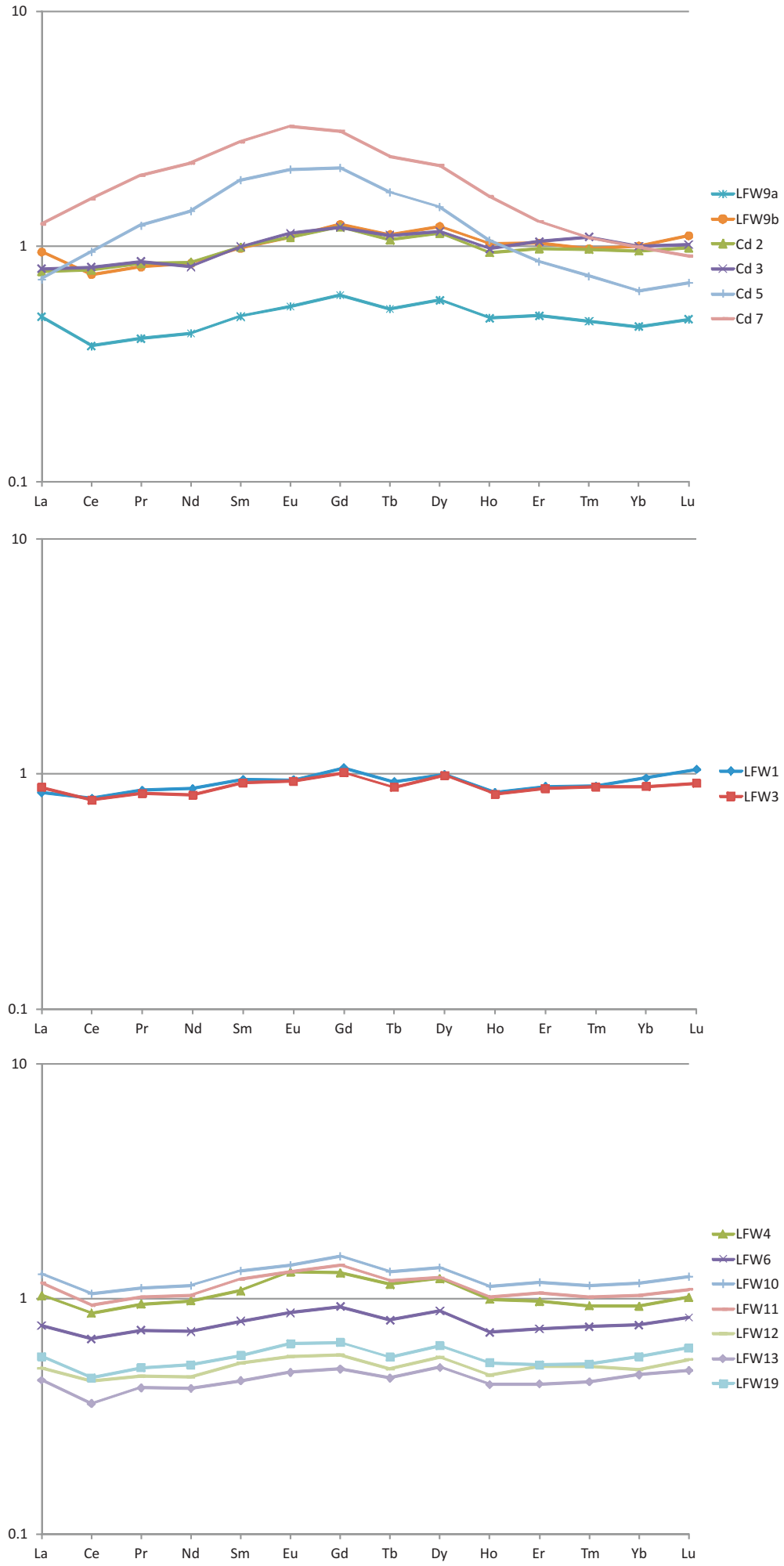

10
1
0.1
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
LFW9a
LFW9b
Cd 2
Cd 3
Cd 5
Cd 7
LFW1
LFW3
LFW4
LFW6
LFW10
LFW11
LFW12
LFW13
LFW19

Figure 4

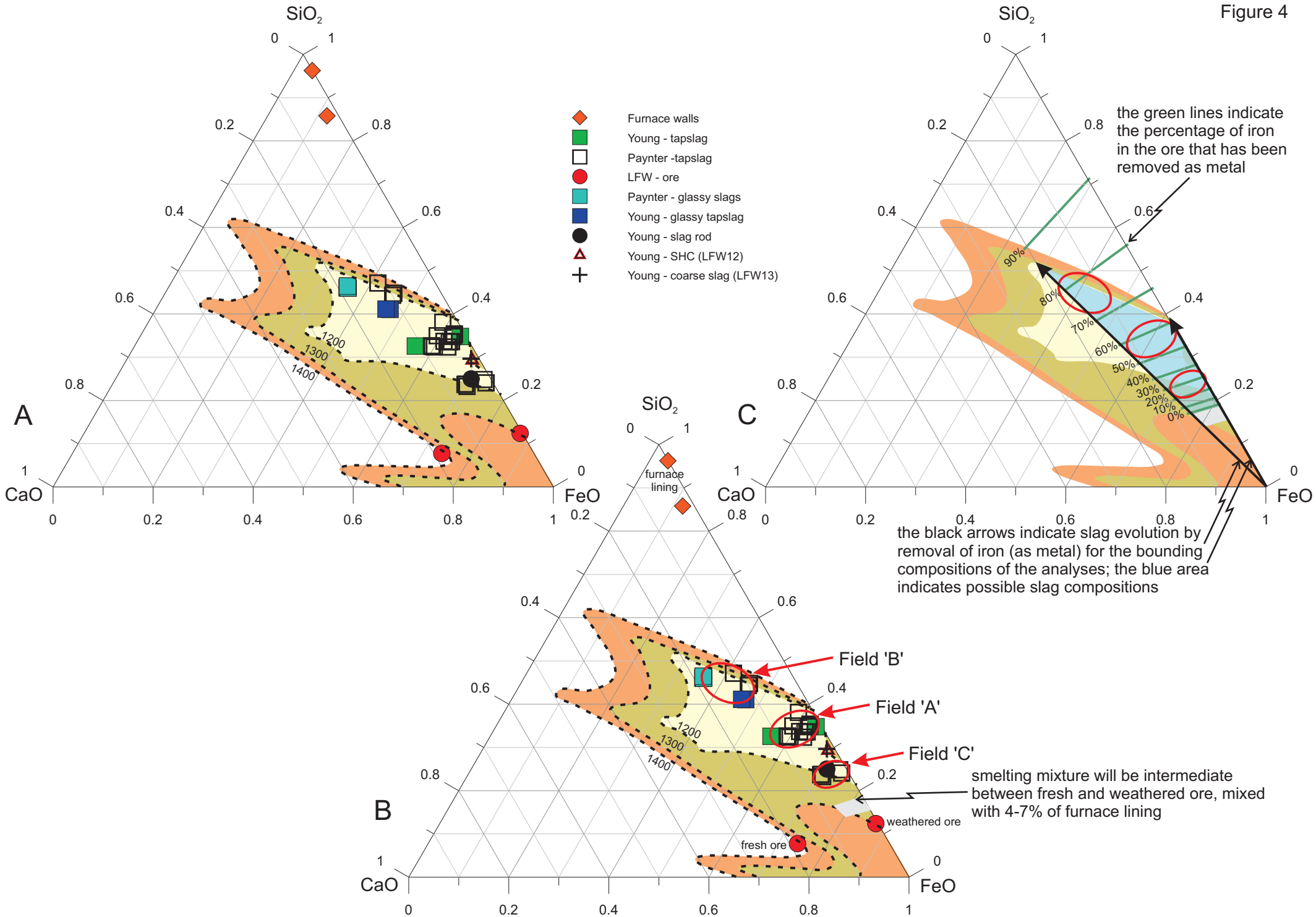

A
B
C
SiO2
CaO
FeO
Furnace walls
Young - tapslag
Paynter -tapslag
LFW - ore
Paynter - glassy slags
Young - glassy tapslag
Young - slag rod
Young - SHC (LFW12)
Young - coarse slag (LFW13)
1200
1300
1400
furnace lining
weathered ore
fresh ore
Field 'B'
Field 'A'
Field 'C'
smelting mixture will be intermediate between fresh and weathered ore, mixed with 4-7% of furnace lining
the green lines indicate the percentage of iron in the ore that has been removed as metal
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
the black arrows indicate slag evolution by removal of iron (as metal) for the bounding compositions of the analyses; the blue area indicates possible slag compositions

Figure 5

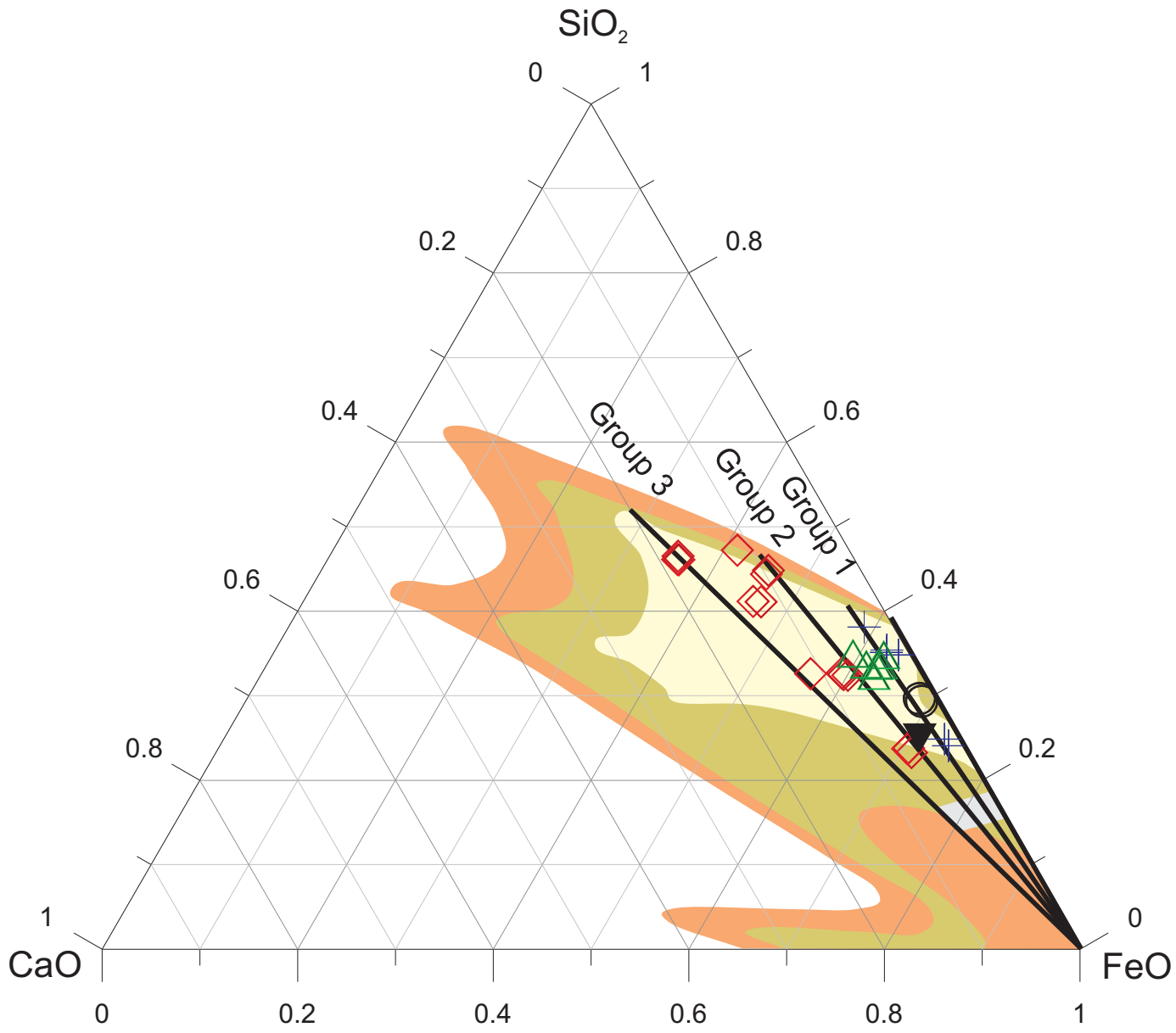

SiO2
0
1
0.2
0.8
0.4
0.6
0.6
0.4
0.8
0.2
1
0
CaO
FeO
0
0.2
0.4
0.6
0.8
1
Group 3
Group 2
Group 1

Figure 6

Groups (associated with ore chemistry)		Fields (associated with degree of iron extraction)		
		B FeO <50%	A FeO 55-65%	C FeO >65%
1	CaO/SiO_2 = 0.03 - 0.08		LFW 6 SP 7	SP 4
2	CaO/SiO_2 = 0.08 - 0.16		SP 3 SP 8	[LFW 19]
3	CaO/SiO_2 = 0.21 - 0.39	LFW 10 LFW 11 SP 5 SP 6	LFW 4 SP 2	SP 1

Figure 7

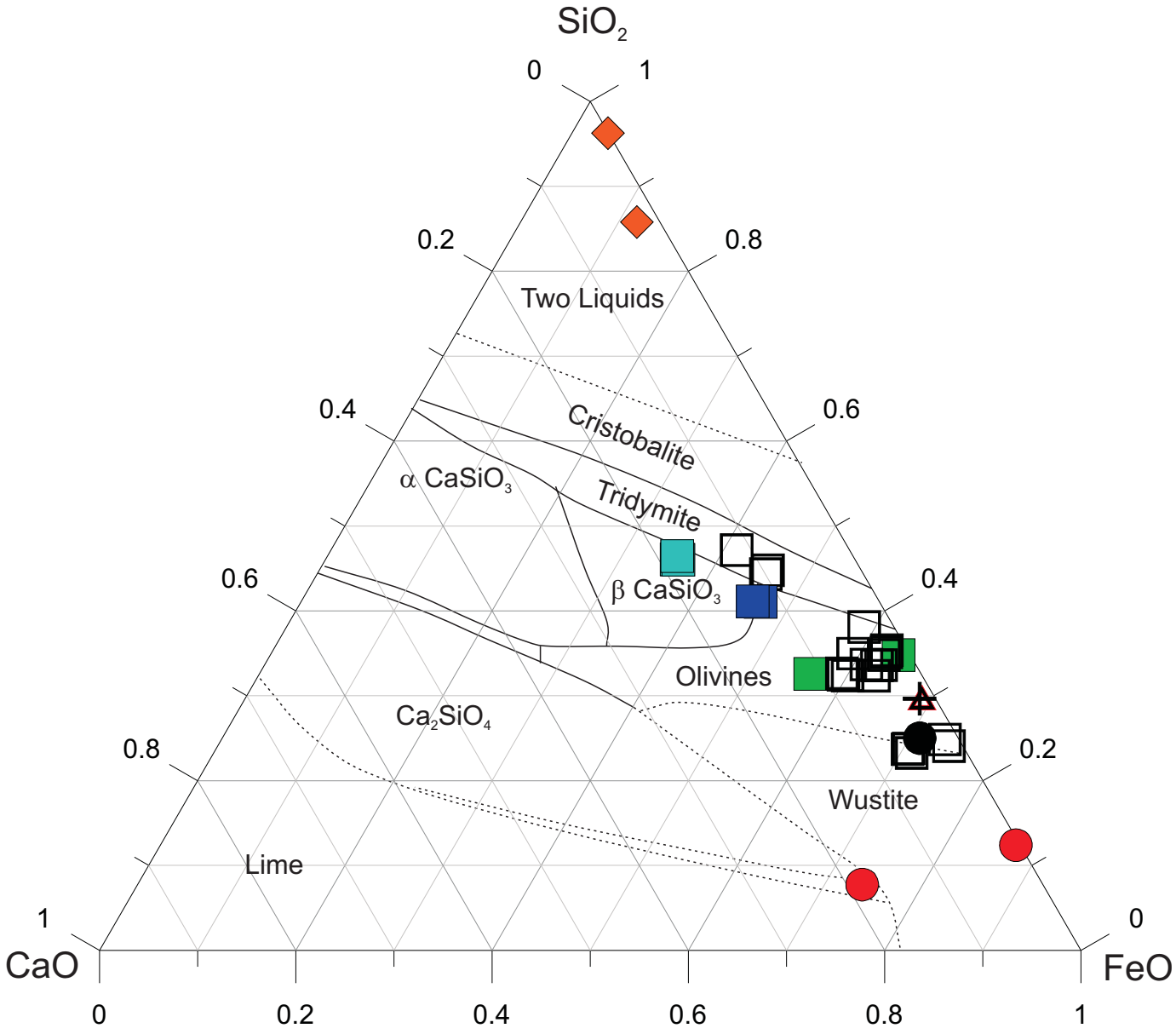

SiO2
0
1
0.2
0.8
Two Liquids
0.4
0.6
Cristobalite
α CaSiO3
Tridymite
β CaSiO3
0.6
0.4
Olivines
Ca2SiO4
0.8
0.2
Wustite
Lime
1
0
CaO
FeO
0
0.2
0.4
0.6
0.8
1

Plate 1

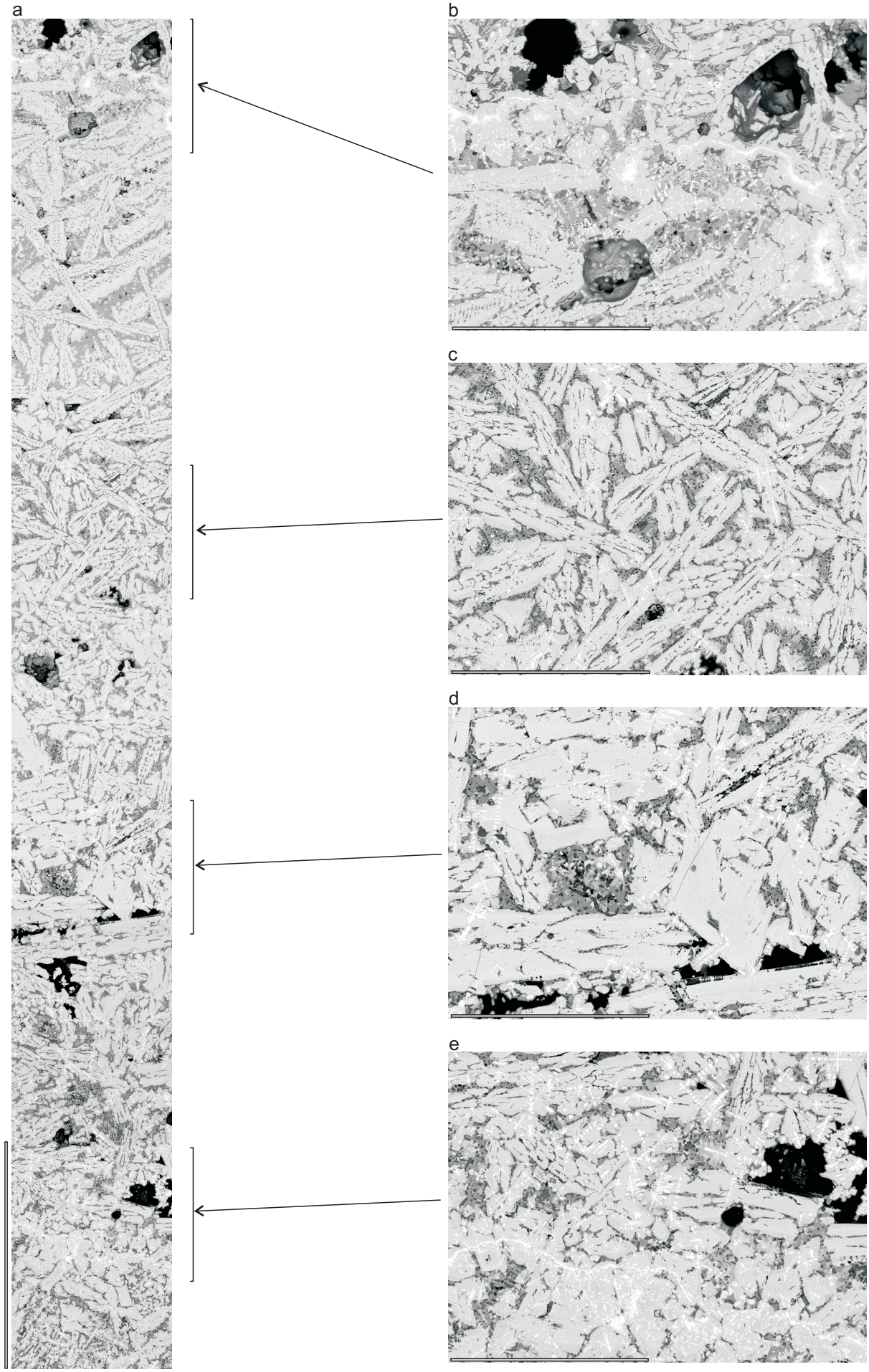
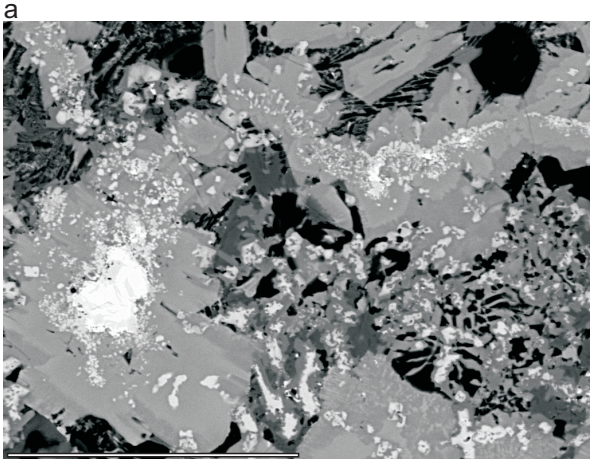


Plate 2

a



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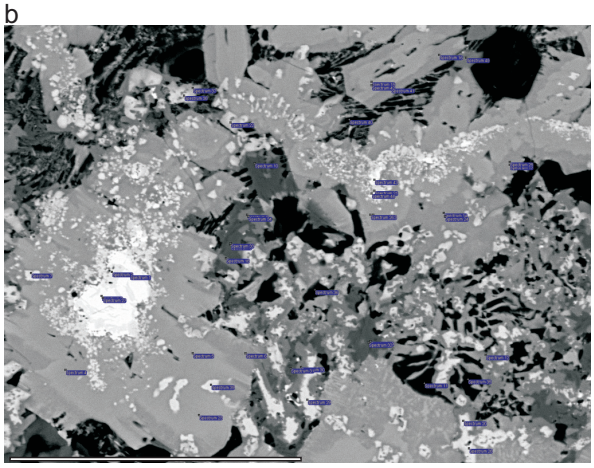
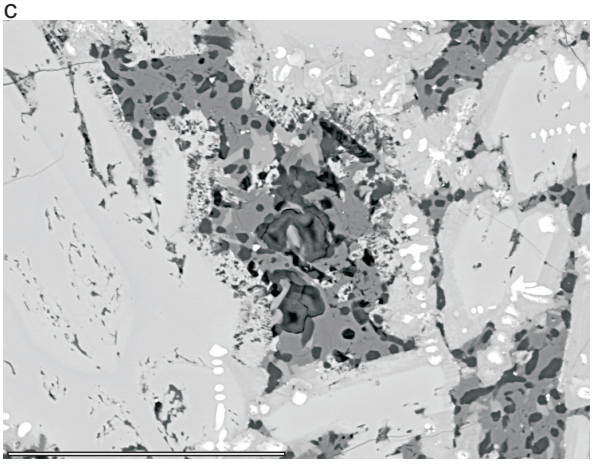


c



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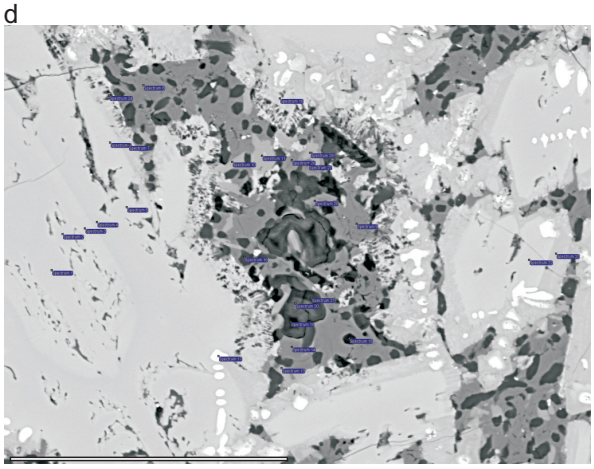

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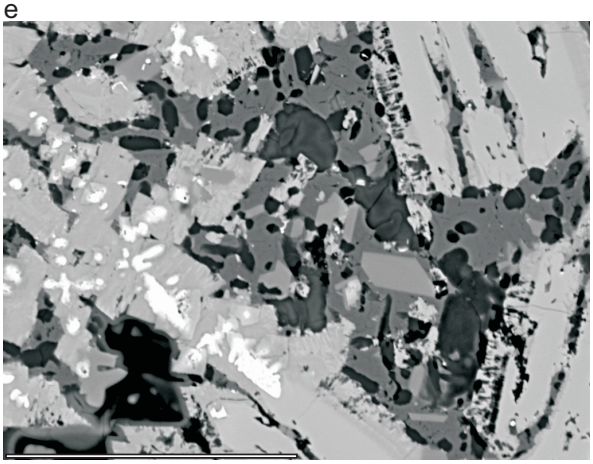

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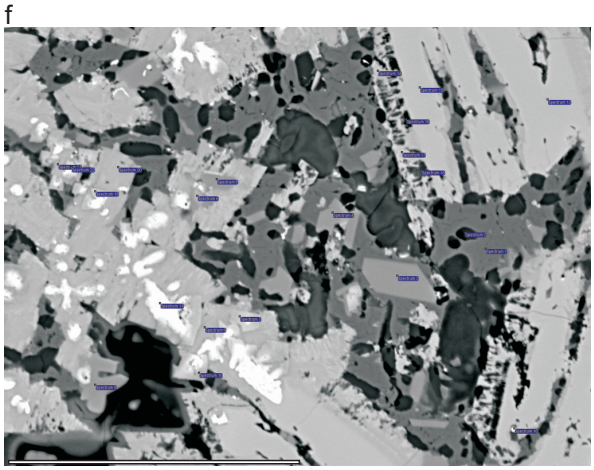

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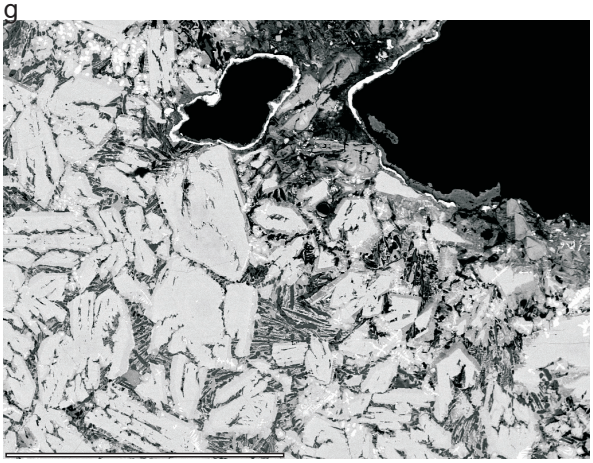
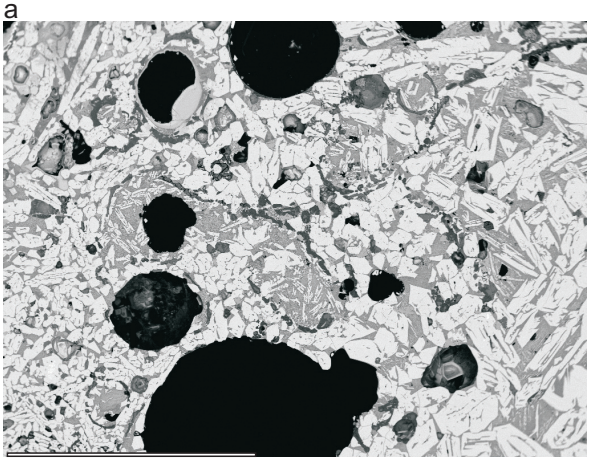


Plate 3

a



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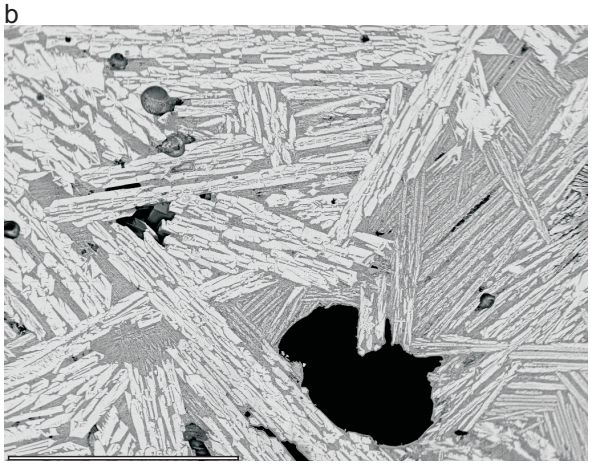

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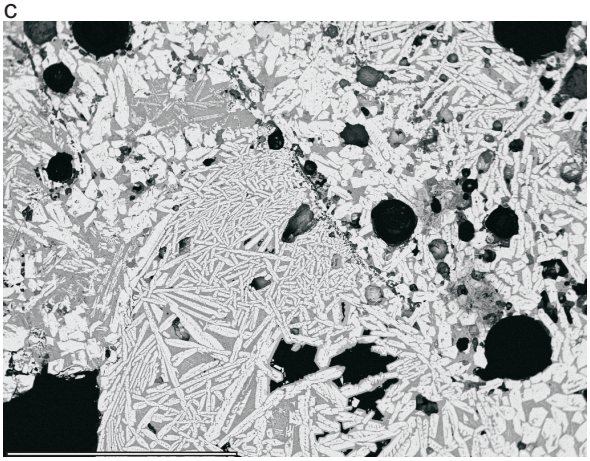

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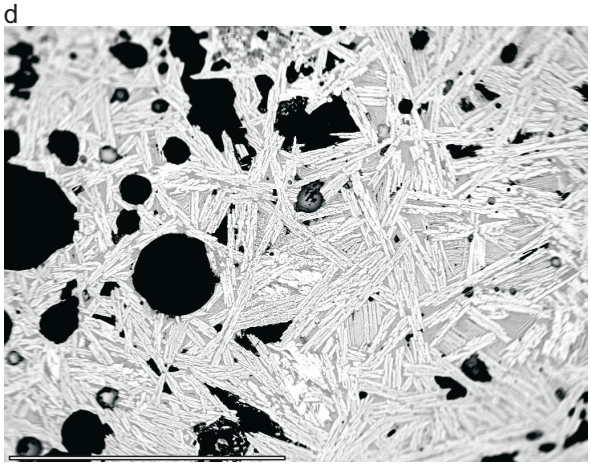

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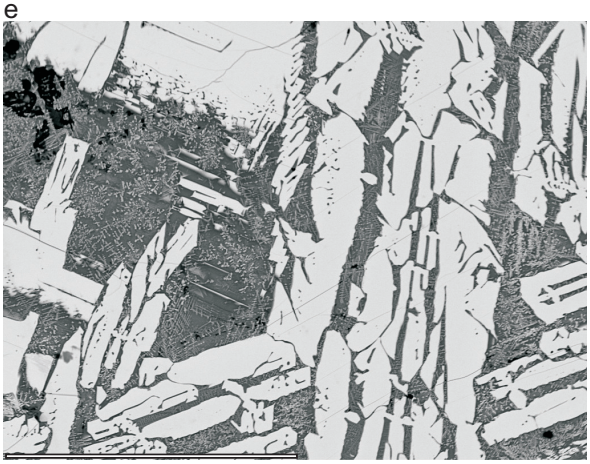

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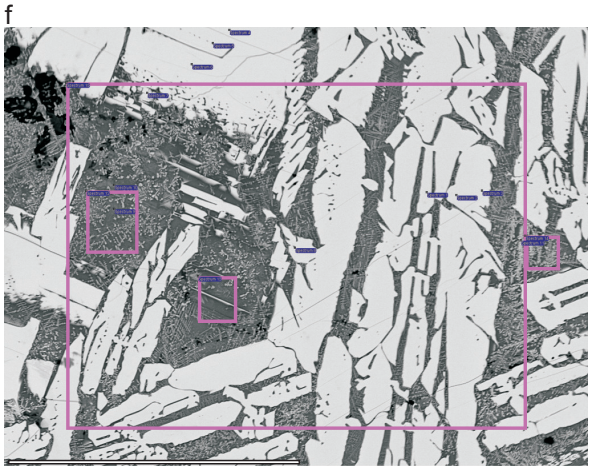

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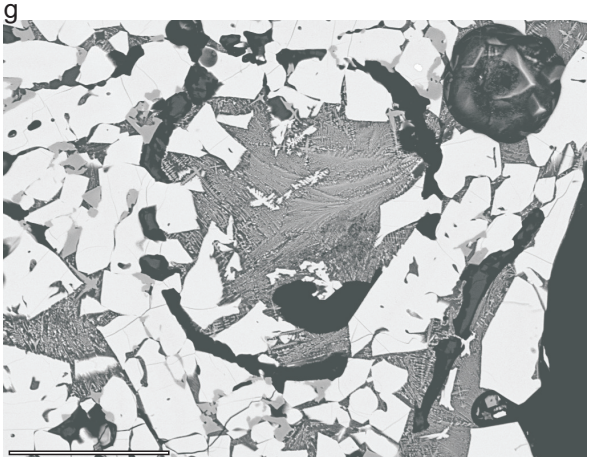

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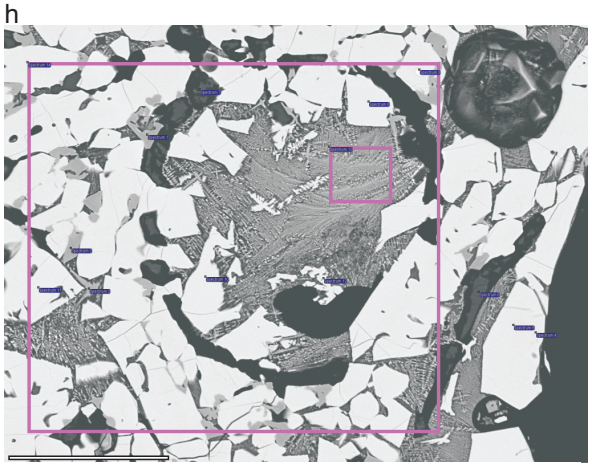

Plate 4

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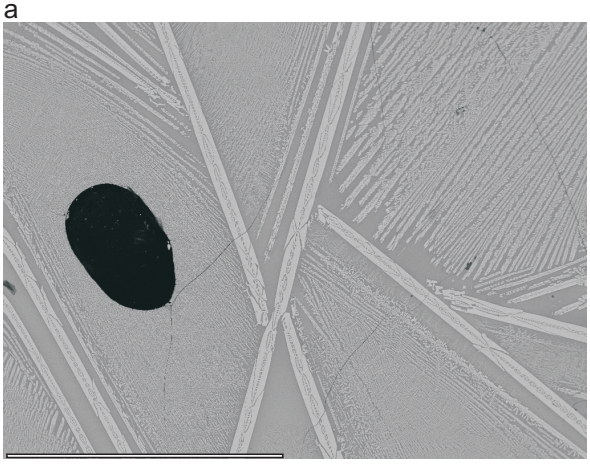

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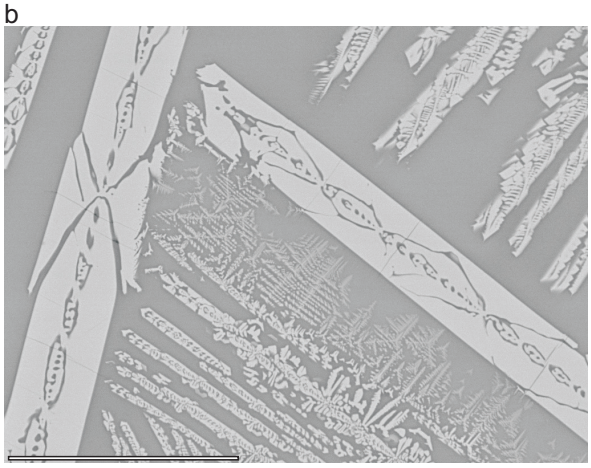

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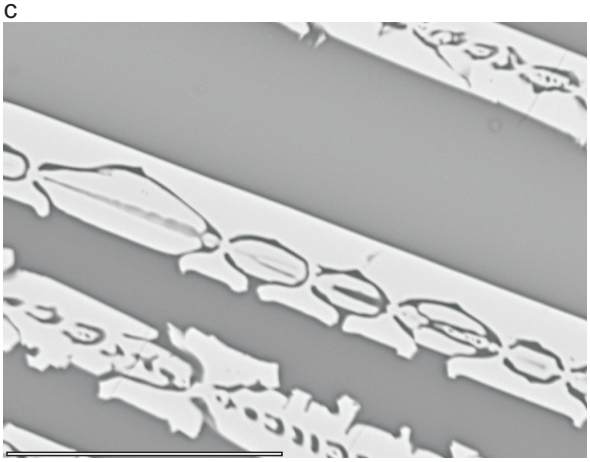

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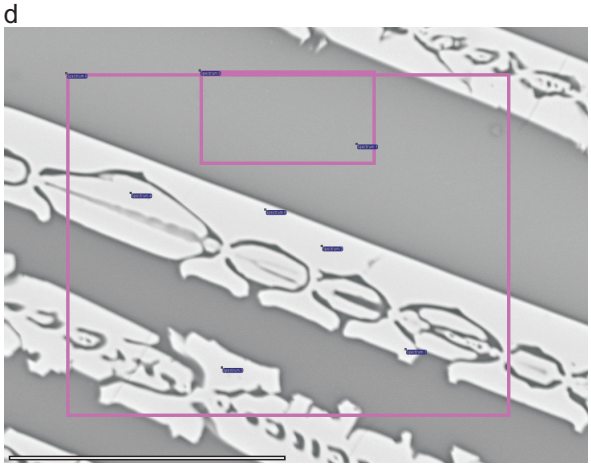

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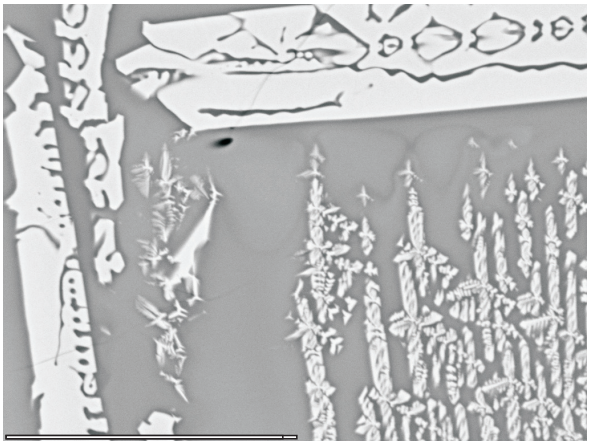

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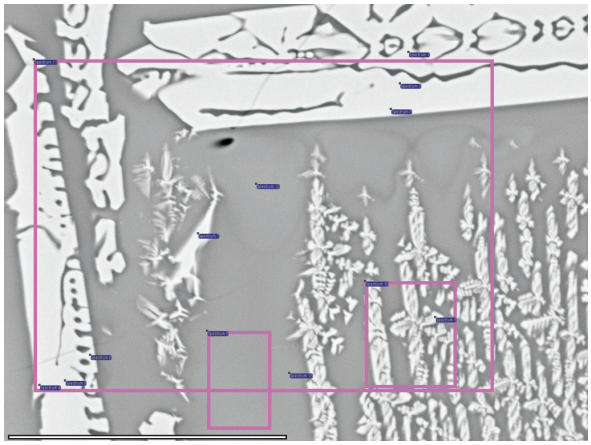

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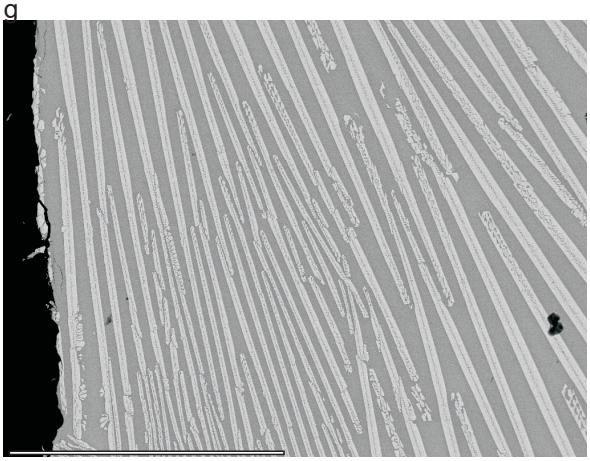

Plate 5

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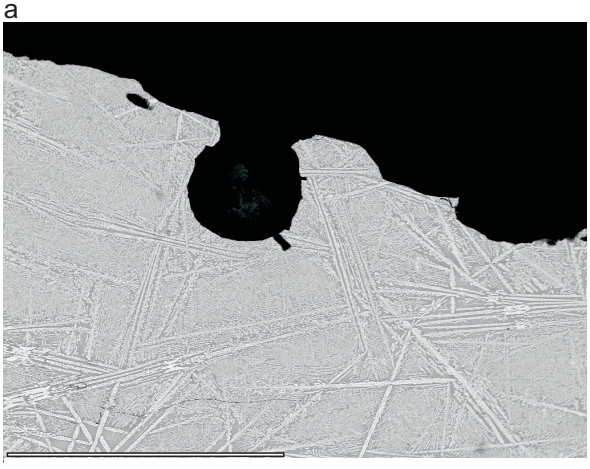

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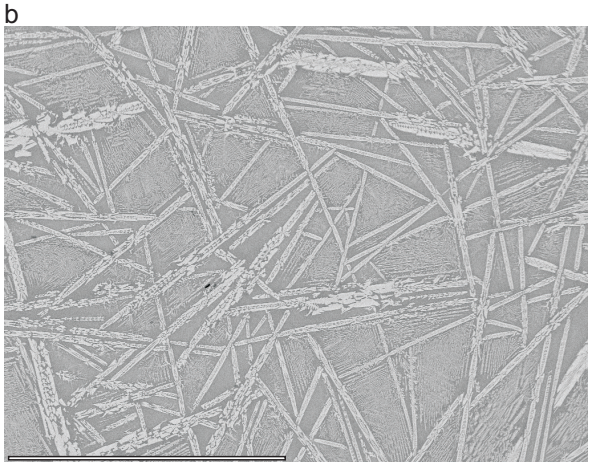

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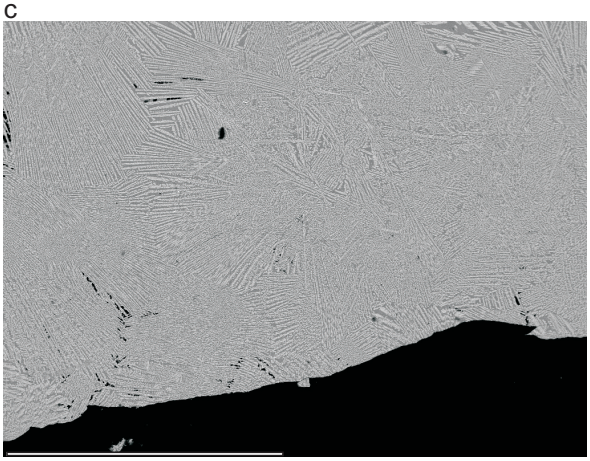

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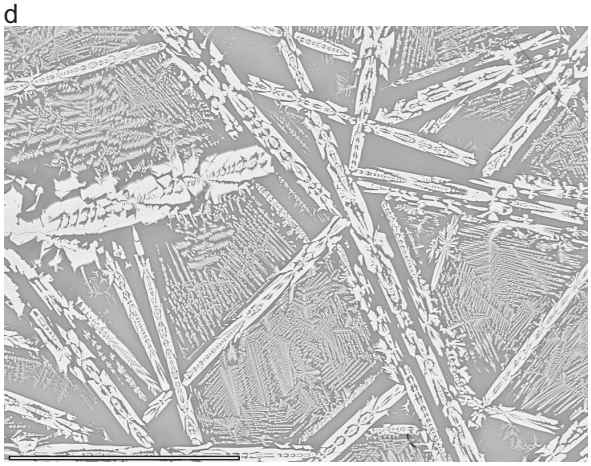

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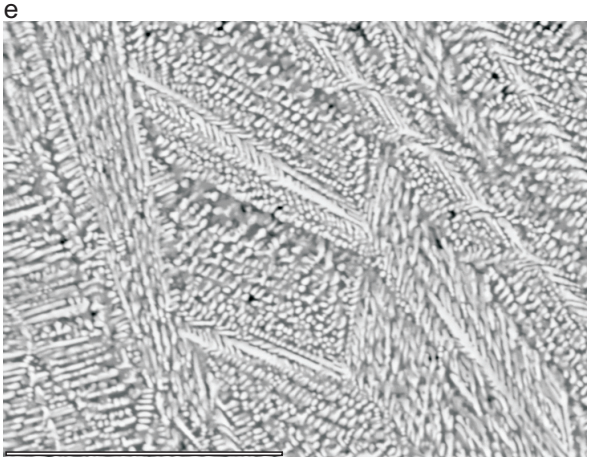

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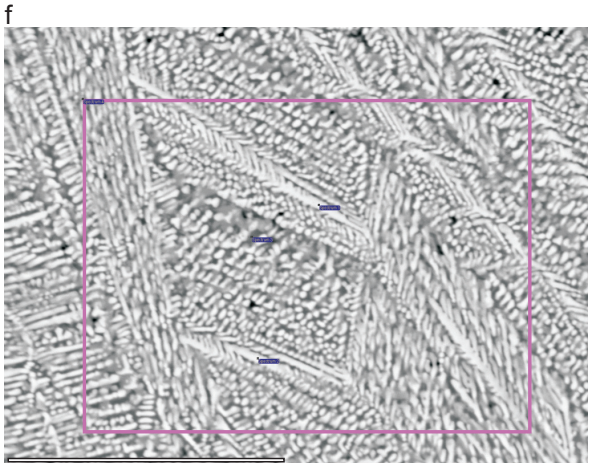

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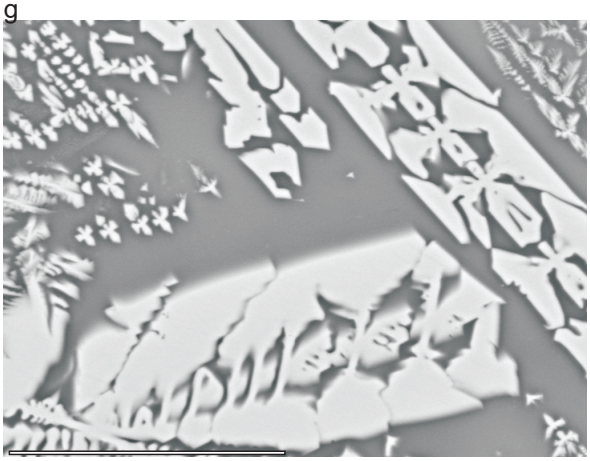

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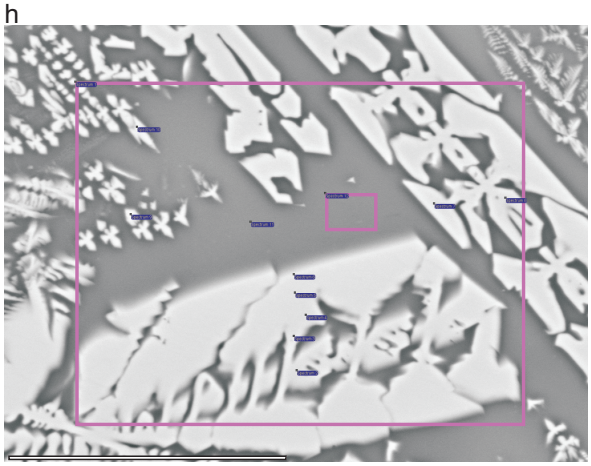

Plate 6

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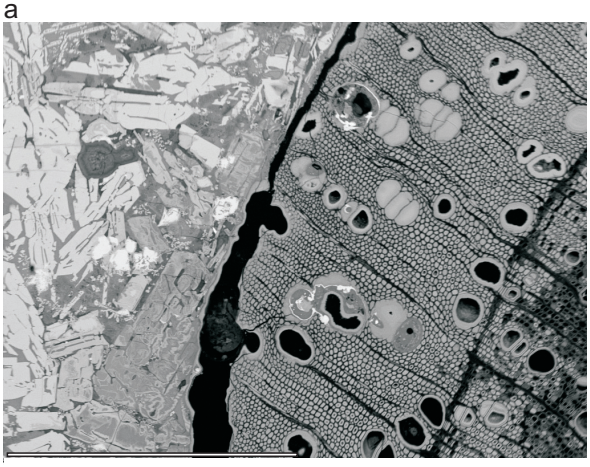

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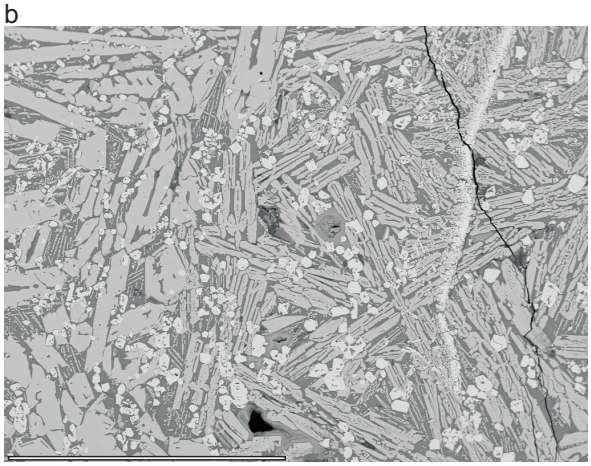

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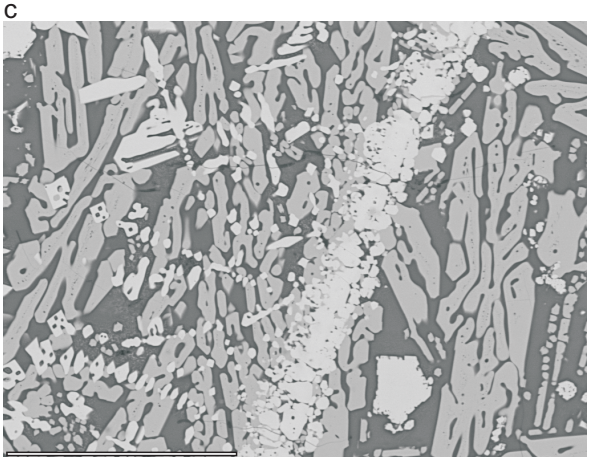

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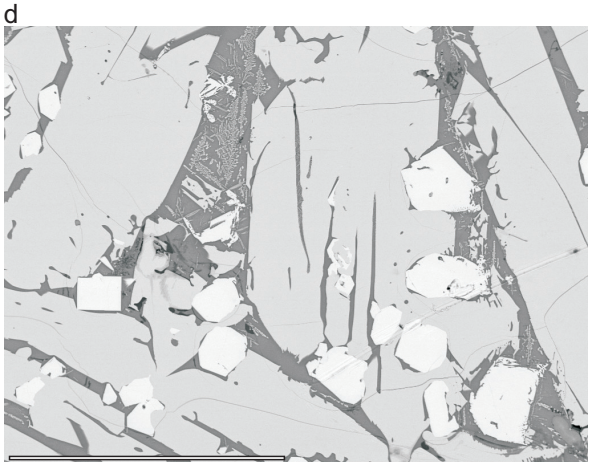

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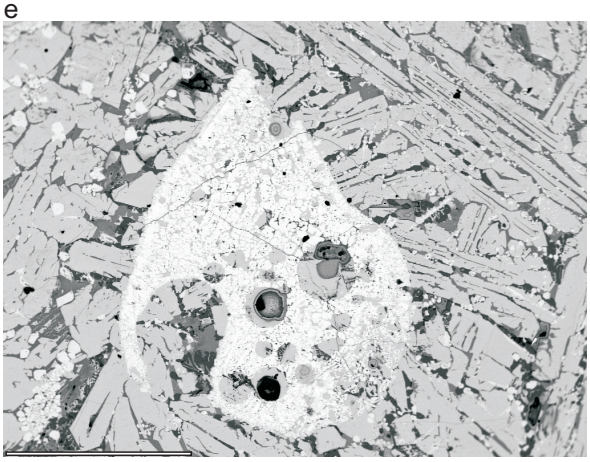

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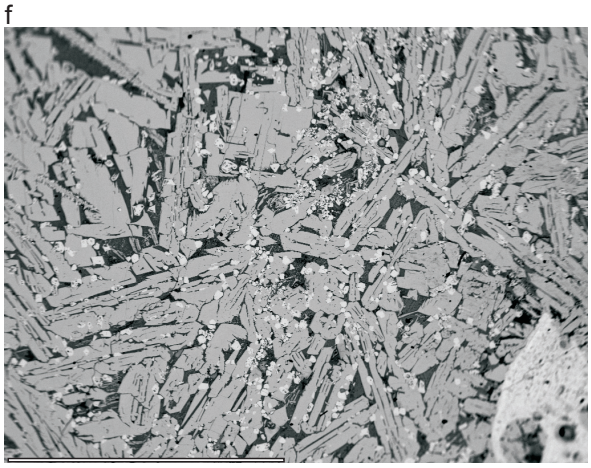

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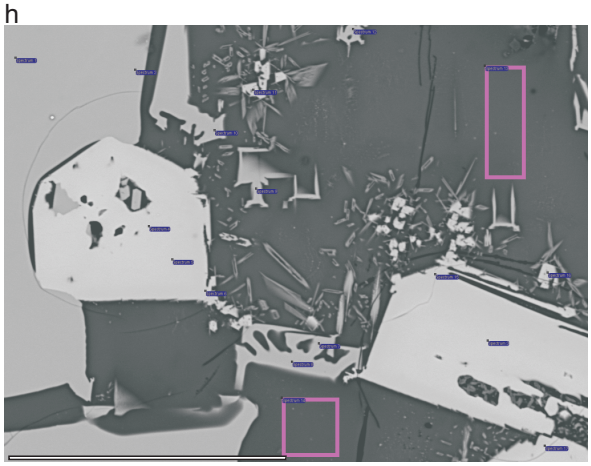

Plate 7

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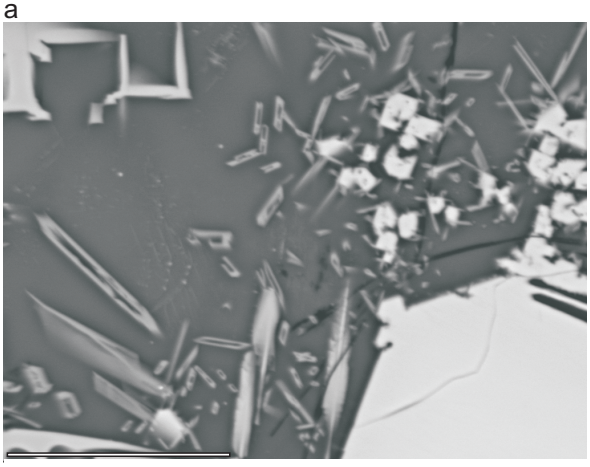

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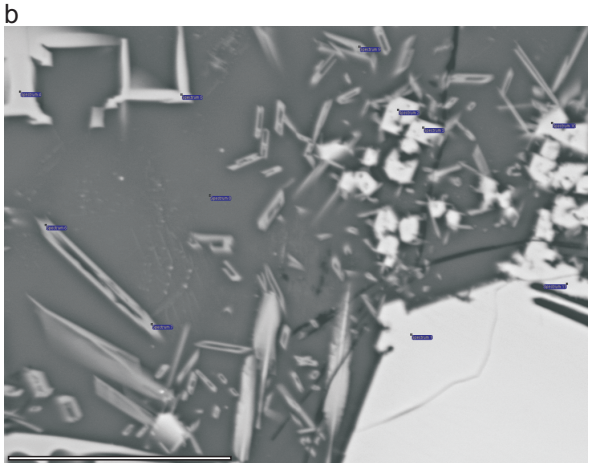

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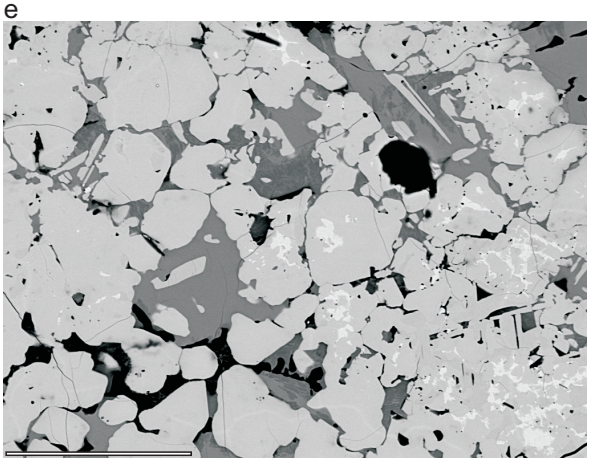

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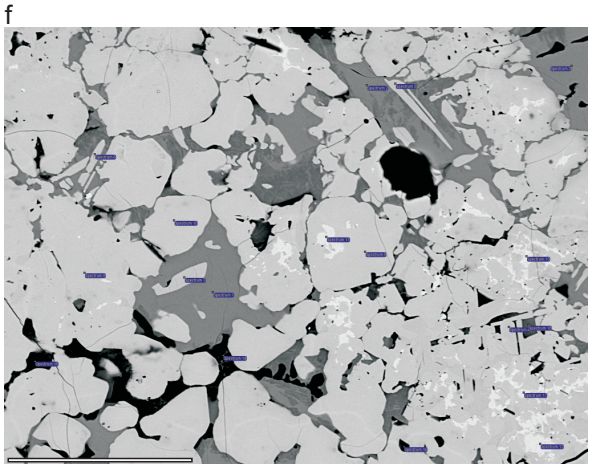

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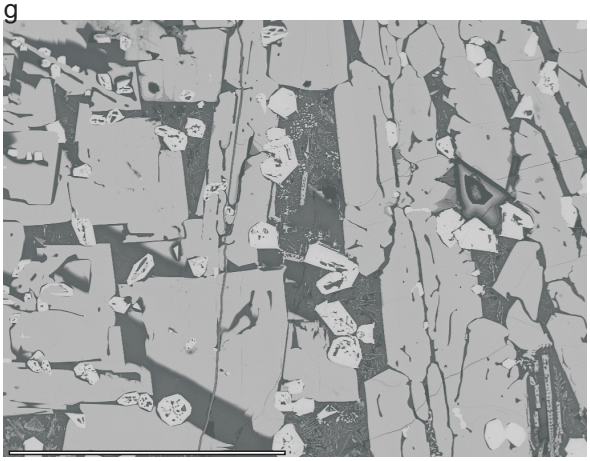

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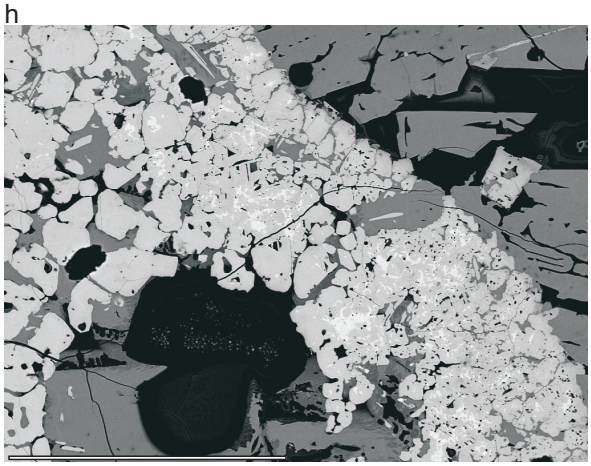

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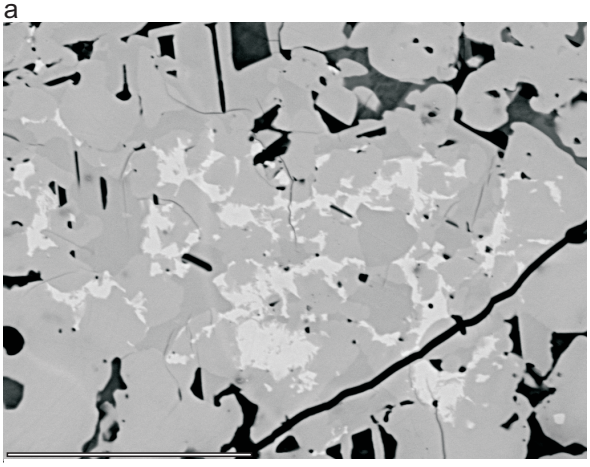

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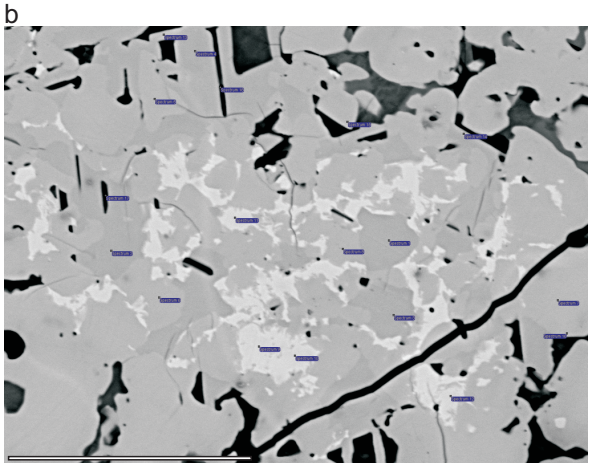

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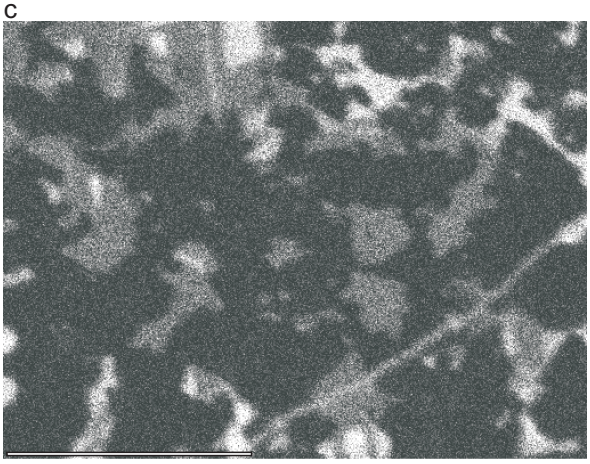

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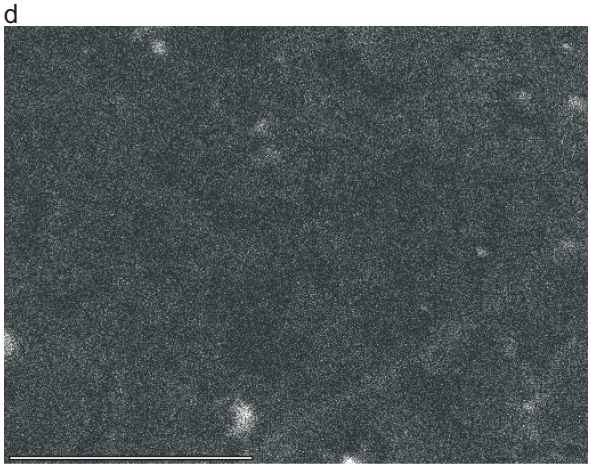

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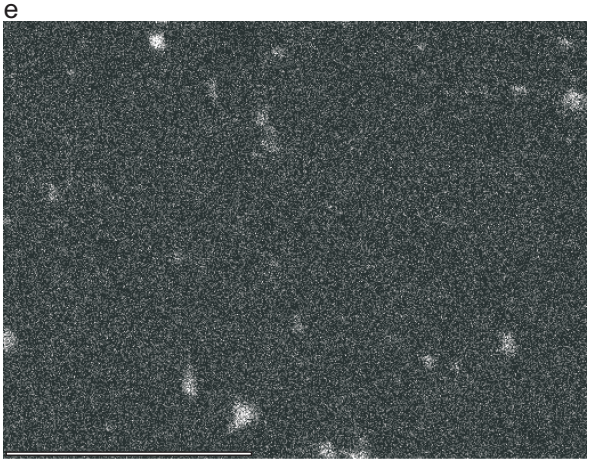

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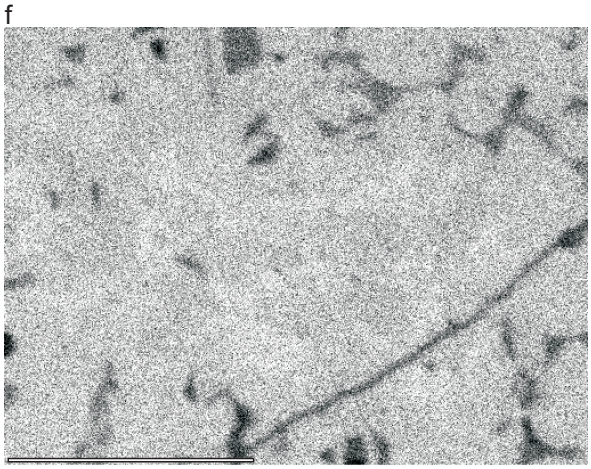

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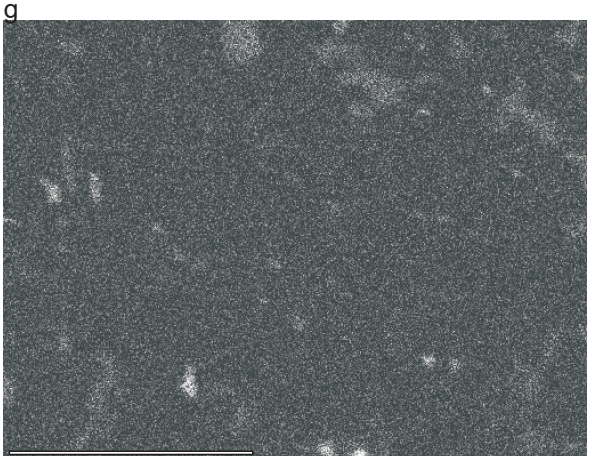

Plate 9

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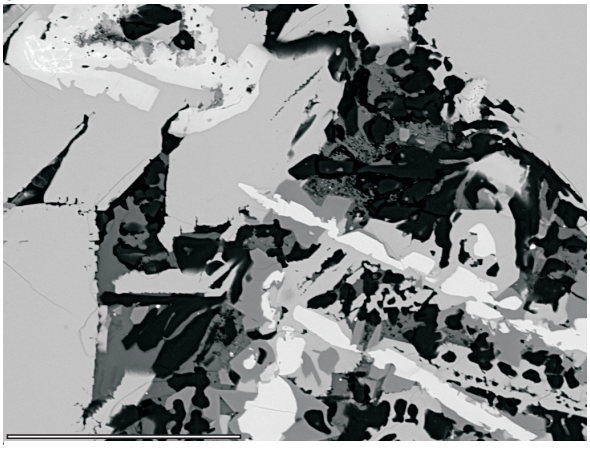

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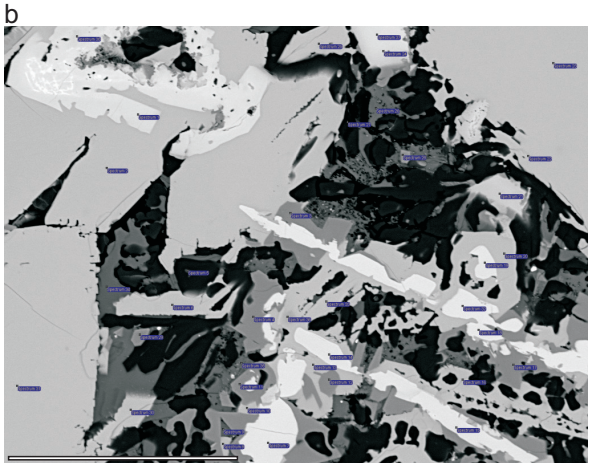

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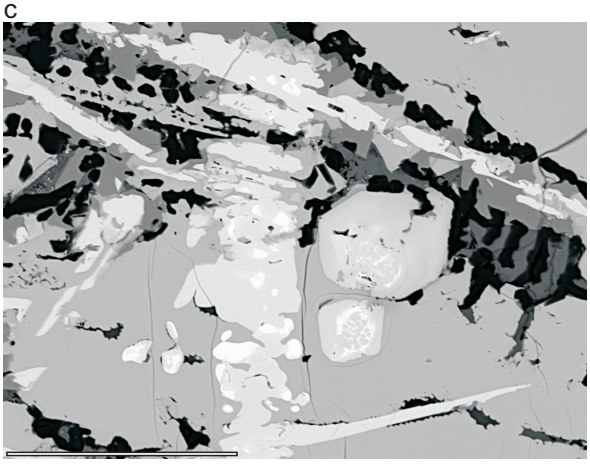

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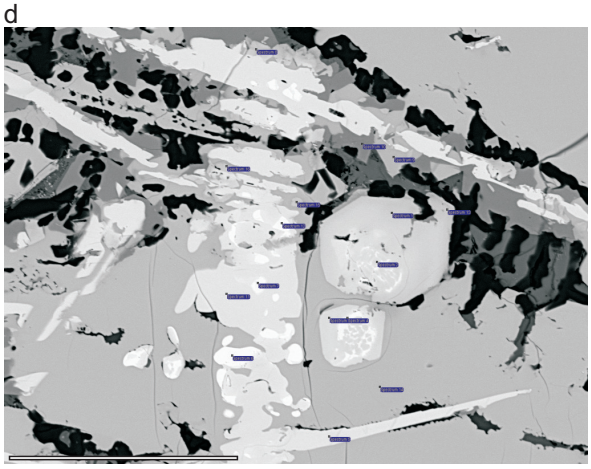

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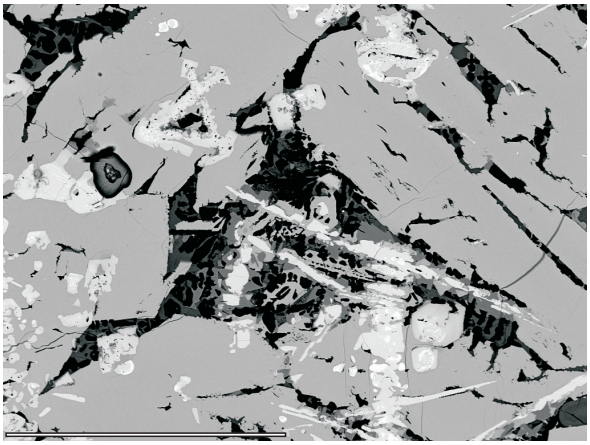

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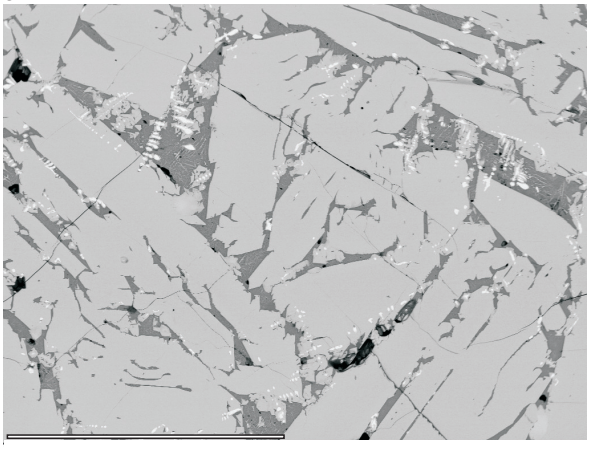

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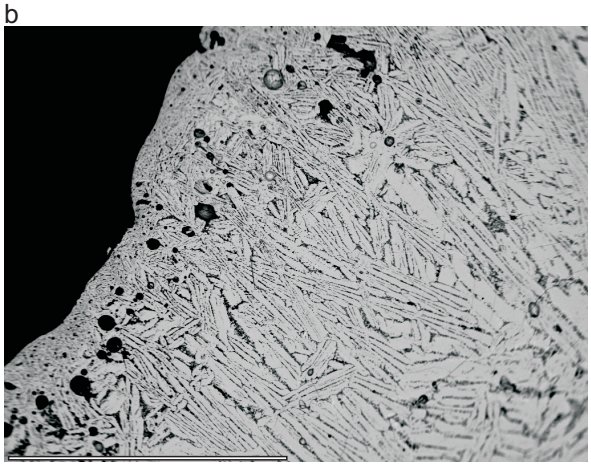

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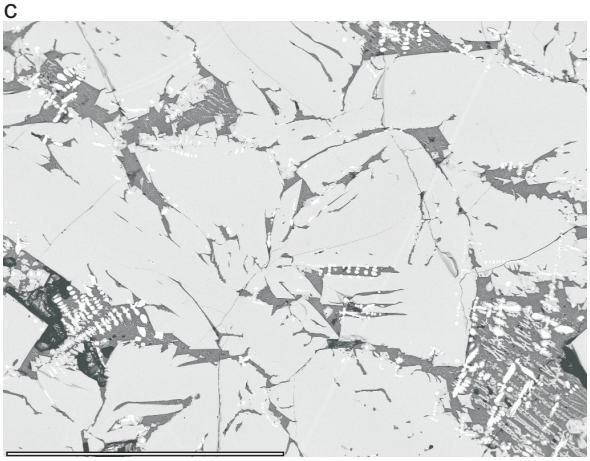

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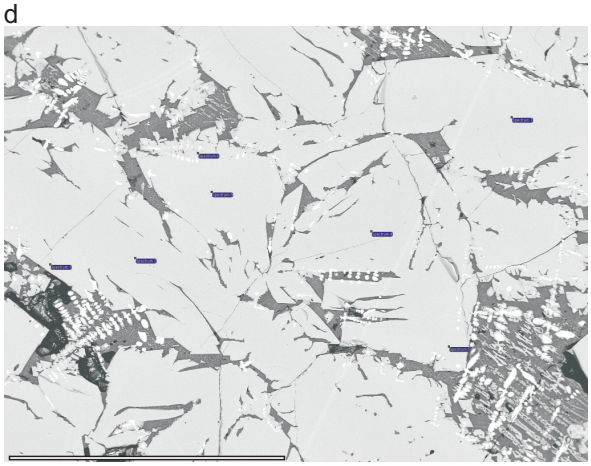

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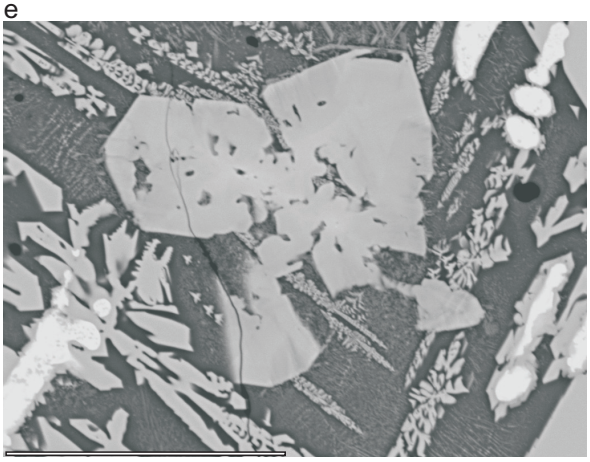

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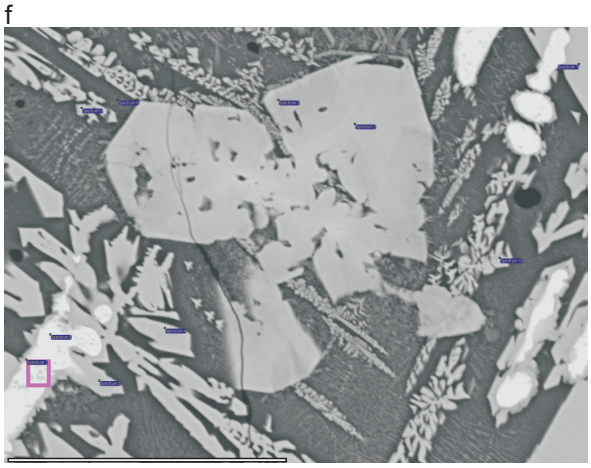

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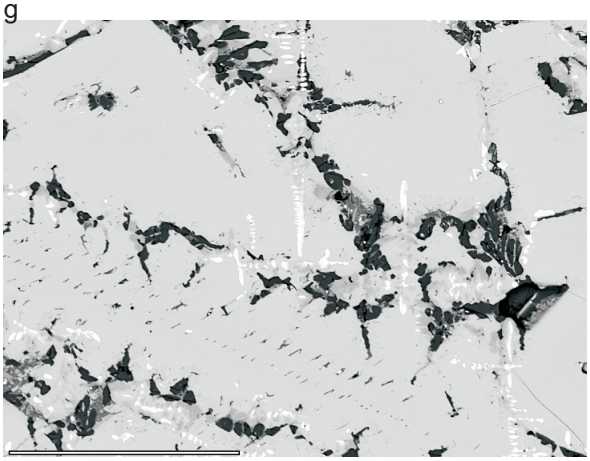

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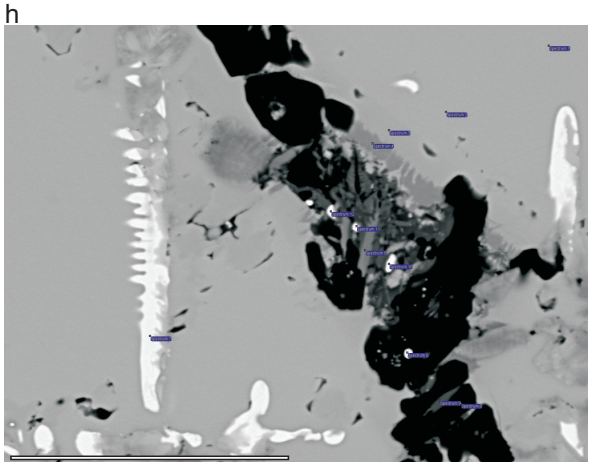
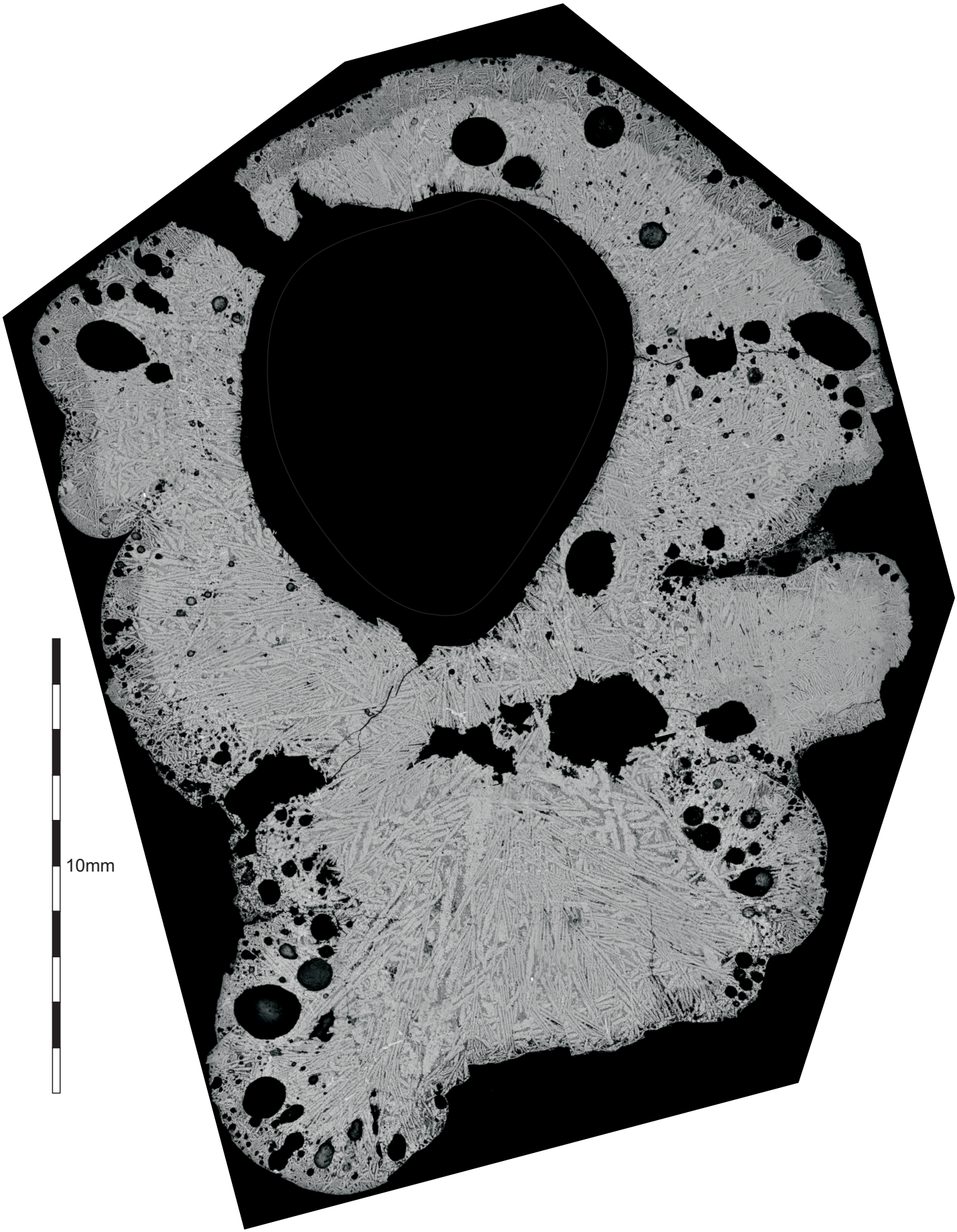


Plate 11



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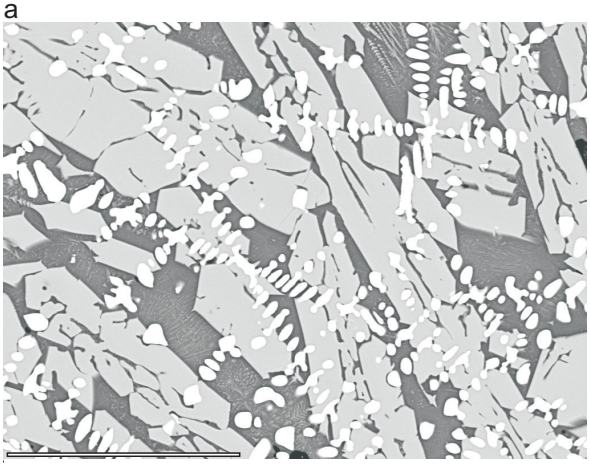

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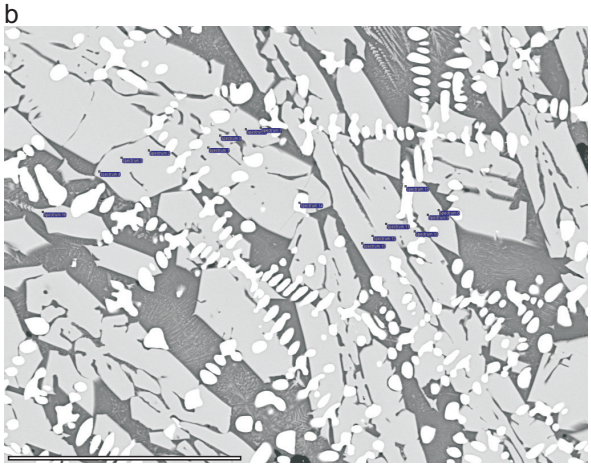

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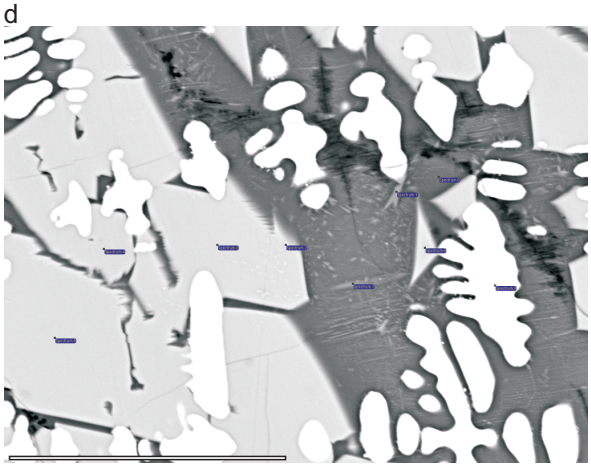

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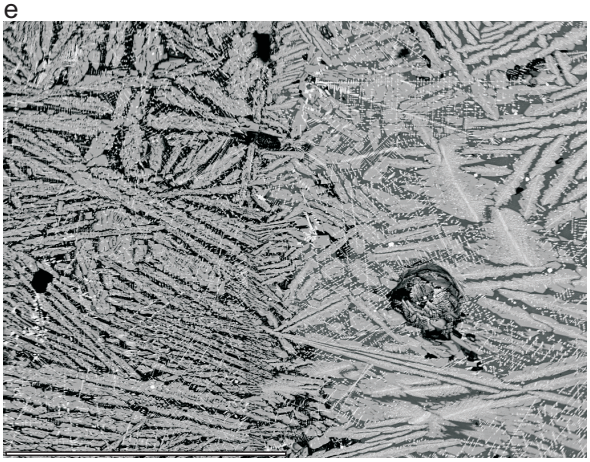

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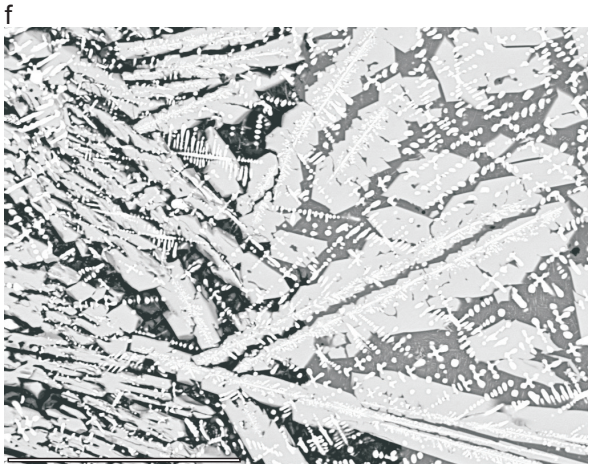

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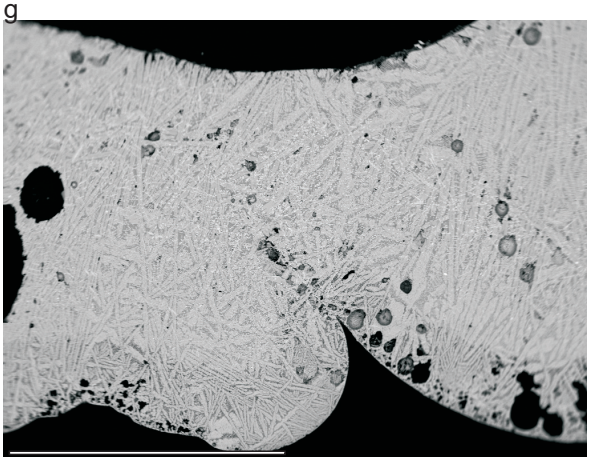

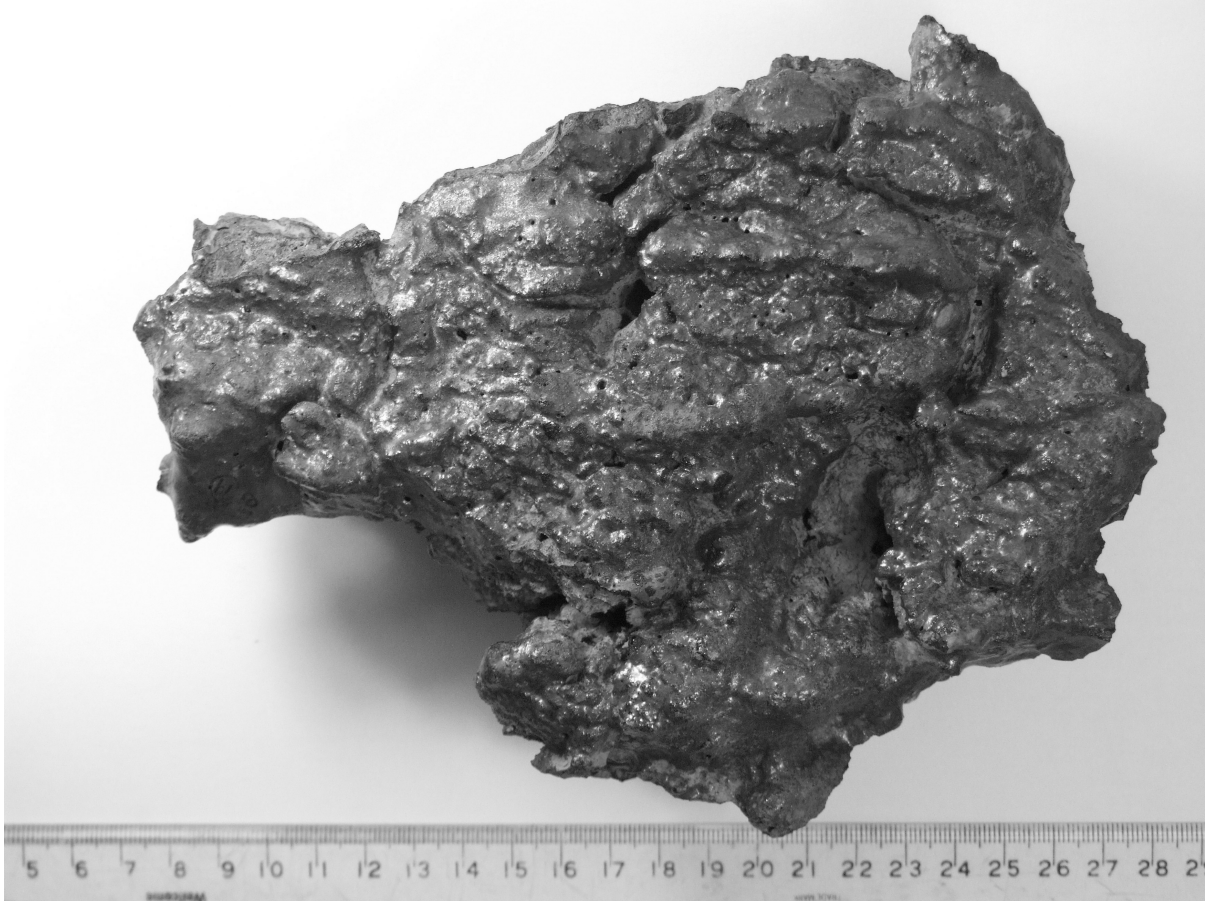

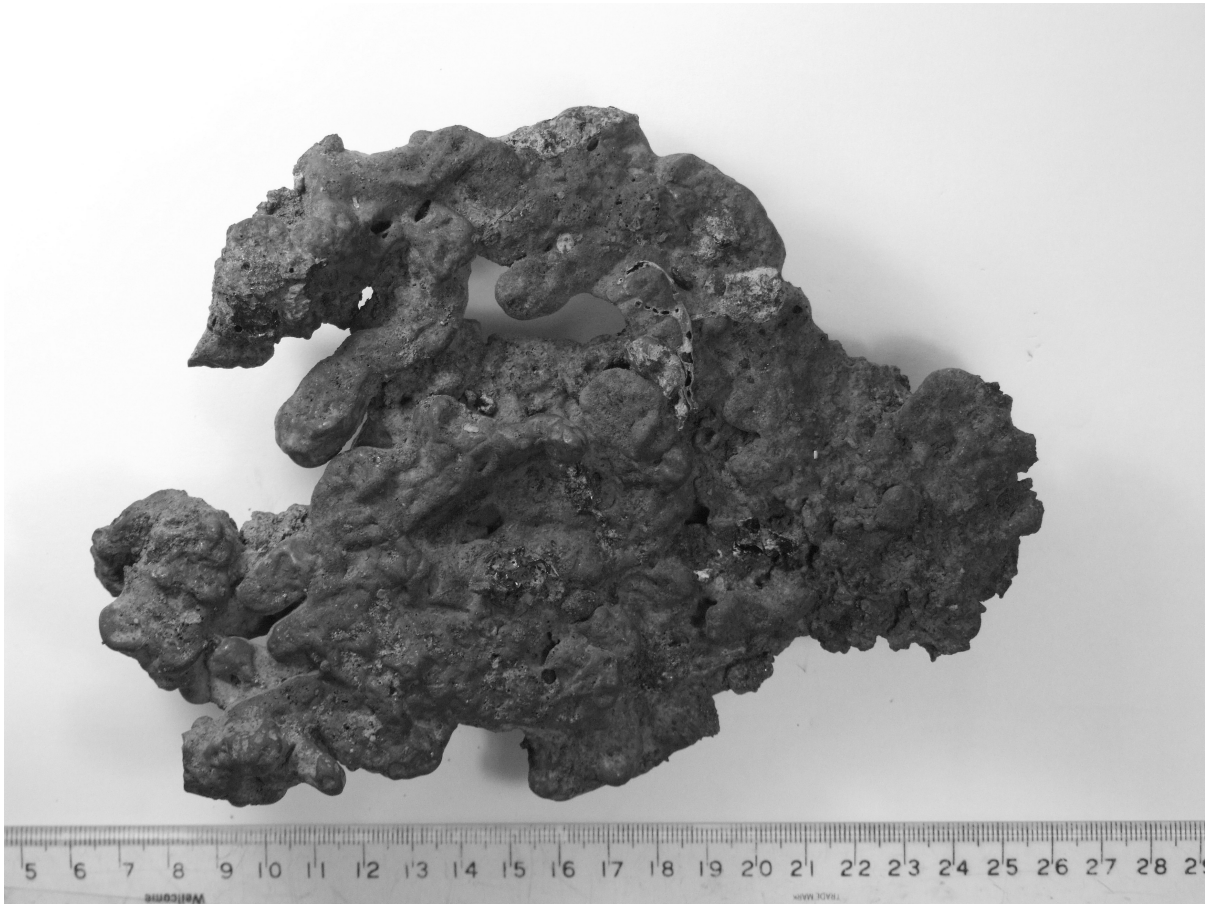

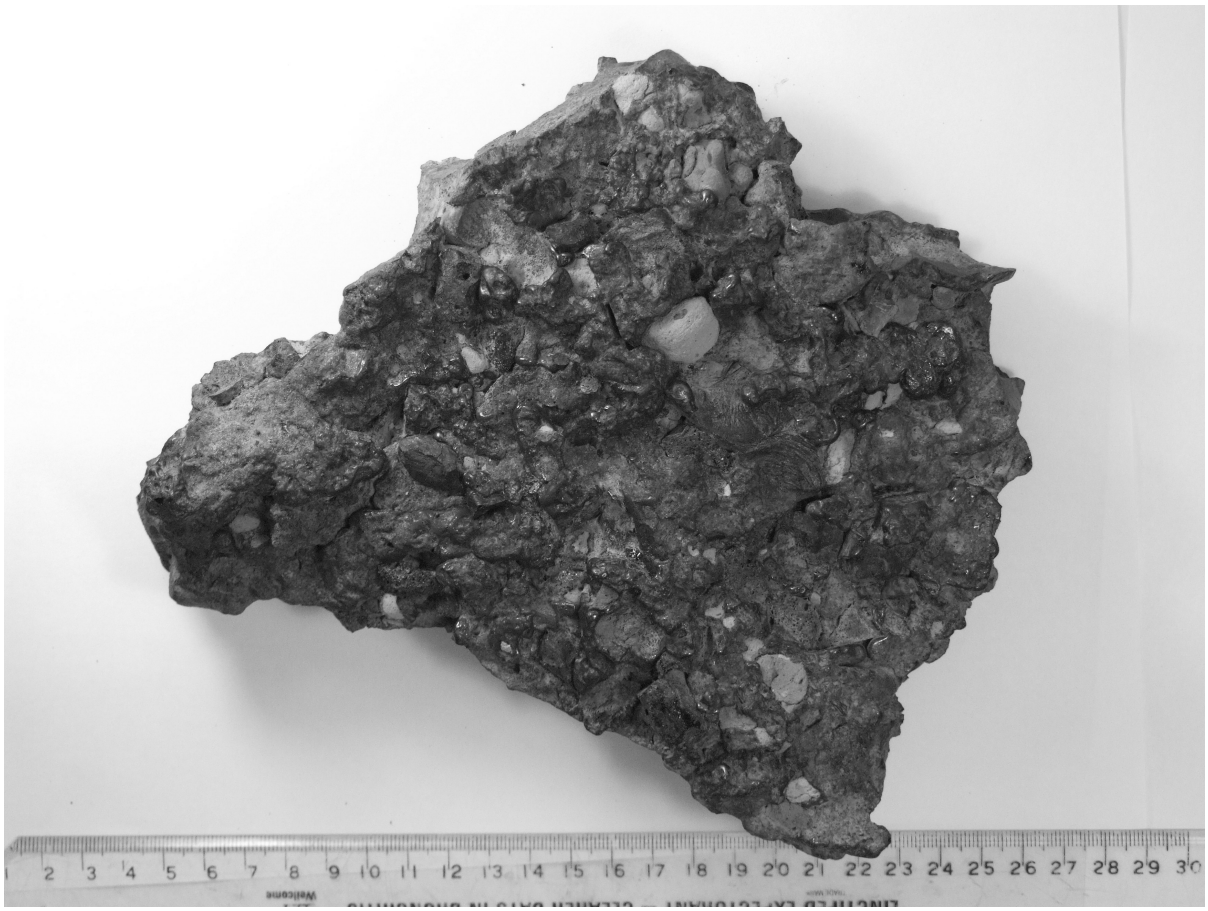

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