APPENDIX 55: OPTICAL MICROSCOPY OF IRON SLAG, LEAD SLAG AND GLASS PRODUCTION RESIDUE SAMPLES

This appendix summarises the results of the optical microscopic examination of selected mounted sub-samples, subsequent to the laboratory measurement of mass specific magnetic susceptibility of a series of samples obtained from the following locations:

Iron smelting slag	Myers Wood, W. Yorkshire
	Stingamires, N. Yorkshire
Blast furnace slag	Bretton, W. Yorkshire
	Rievaulx, N. Yorkshire
	Sowerby Bridge, W. Yorkshire
Lead smelting slag	Botchergate, Carlisle
	Grinton Smeltings, N. Yorkshire
	Pentre Farm, Flint
Glass production residues	Hutton Common, N. Yorkshire
	Knightons, Surrey
	St. Aidan's, W. Yorkshire
Glass production crucibles	Knightons, Surrey
	St. Aidan's, W. Yorkshire

The sub-samples were selected on the basis of the minimum, mean and maximum values in the measured range of magnetic susceptibility for each sample group; thus each site is represented by a set of three data sheets. These sheets are arranged in site

order as listed above, and minimum, mean and maximum susceptibility within each site data.

Each data sheet gives a description of the sub-sample's morphology and microscopy, and shows reflected light images of areas of interest; where only one image is produced, this is due to the sample being virtually featureless and a second image was considered superfluous.

OPTICAL MICROSCOPY

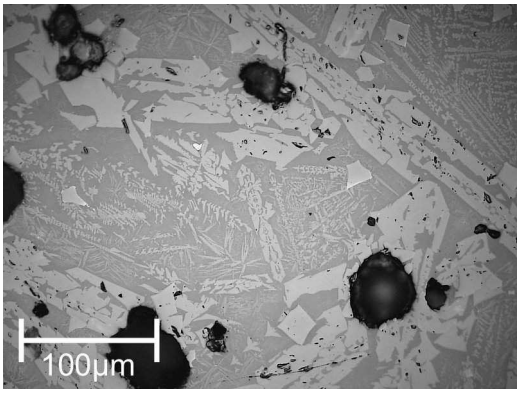
Sample: Iron smelting slag – Myers Wood SH1s-C

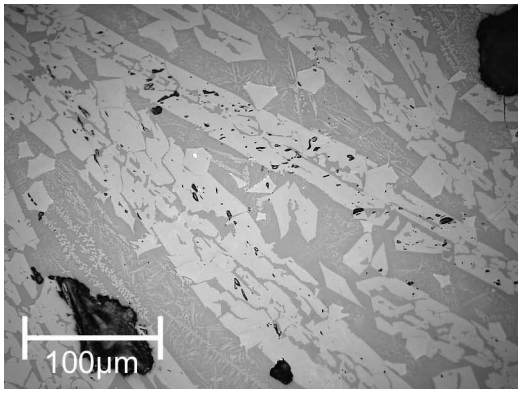
Morphology:

Dense, grey/black slag material with pitted surfaces. A considerable number of visible vesicles, ranging in diameter from <1mm to 4mm. Some surface discoloration caused by oxidation of iron content.

Microscopy:

Little evidence of iron oxide dendritic structure even at high magnification. Fayalitic laths (light grey) contained in a glassy phase (darker grey). A few small iron prills observed and some evidence of blocky/angular phases (mid grey). Minor cracking in the sample structure noted.





OPTICAL MICROSCOPY

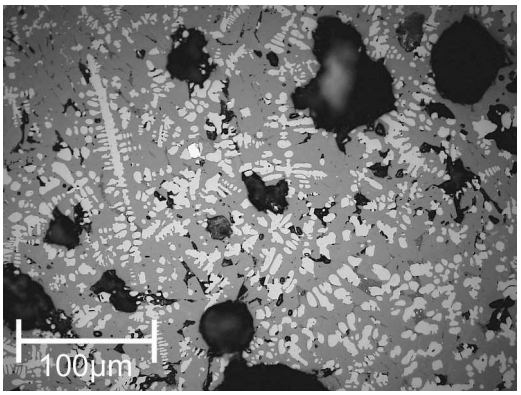
Sample: Iron smelting slag – Myers Wood D414s-D

Morphology:

Dense, dark grey/black slag material. Some visible vesicles, ranging in diameter from *c*.1mm to 5mm. Surfaces vary: one side smooth, no sign of ropey flow, whilst the opposite side is very uneven, possibly reflecting the surface over which the slag flowed.

Microscopy:

An iron oxide dendritic structure, mainly skeletal but some blocky features. Blocky fayalitic material (light grey) contained in a glassy phase (darker grey). A few very small iron prills observed and some evidence of blocky/angular phases (mid grey). No cracking in the sample structure noted.



OPTICAL MICROSCOPY

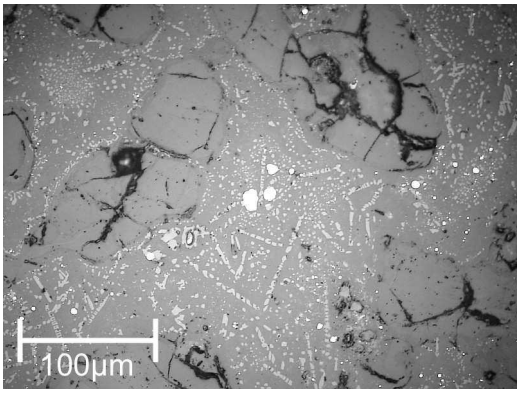
Sample: Iron smelting slag – Myers Wood B210s-I

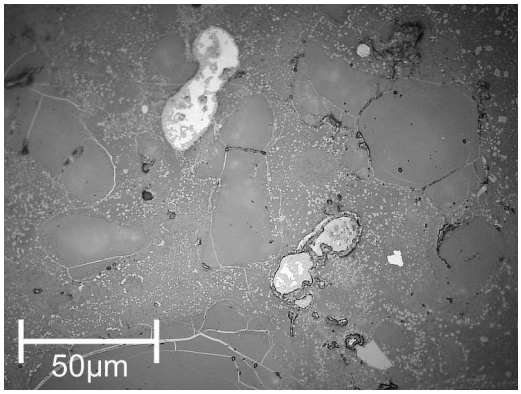
Morphology:

Dense, grey/brown slag material with a glassy appearance. Some visible vesicles, ranging in diameter from <1mm to *c*.5mm. Yellow/brown surface discoloration due to oxidation of iron content.

Microscopy:

Very few iron oxide dendrites. Small amount of fayalitic laths (light grey) contained in a glassy phase (darker grey). Iron prills observed of varying sizes and some evidence of blocky/angular phases (mid grey), boundaries highlighted by iron oxide or fayalite. Some cracking in the sample structure noted.





OPTICAL MICROSCOPY

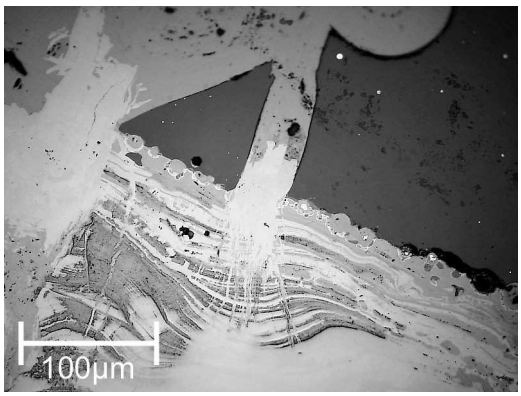
Sample: Iron smelting slag – Myers Wood SH4-501s-D

Morphology:

Porous and lightweight, dark grey/black magnetic slag material. Few visible vesicles, all *c*.1mm diameter. Excessive dark brown to yellow brown surface discoloration caused by oxidation of high iron content. A piece of burnt stone is attached.

Microscopy:

No dendritic structure. A small amount of fayalitic laths and a few very small iron prills observed. Laminar flow features of lighter and dark grey phases, containing some large blocky phases. Very few voids in the sample structure noted, with some cracking.



OPTICAL MICROSCOPY

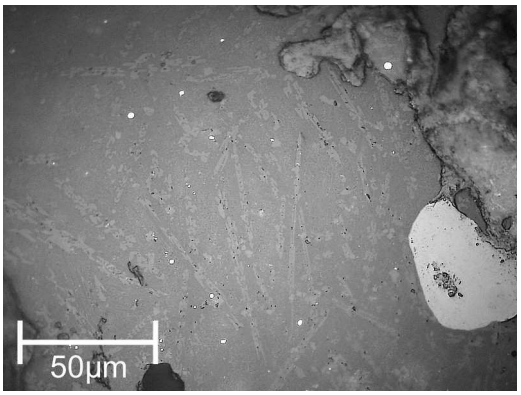
Sample: Iron smelting slag – Myers Wood SH3s-G

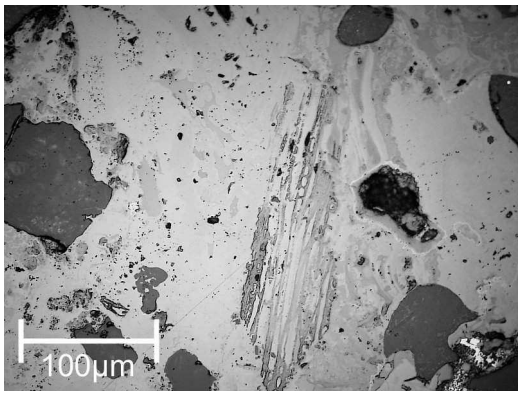
Morphology:

Dense, dark grey/black slag material. Few visible vesicles, all *c.*1mm diameter. Yellow brown surface discoloration caused by oxidation of high iron content.

Microscopy:

No dendritic structure. Very thin laths of fayalitic material (light grey) within a glassy phase (dark grey). Iron prills observed of varying sizes and some indication of laminar flow features and a large blocky phase. A considerable number of voids in the sample structure noted, of a range of sizes and associated cracking.





OPTICAL MICROSCOPY

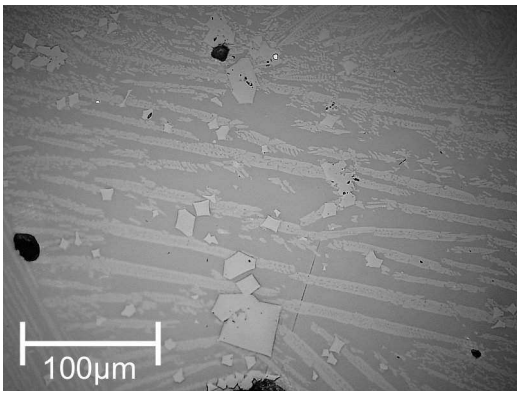
Sample: Iron smelting slag – Stingamires 401-H

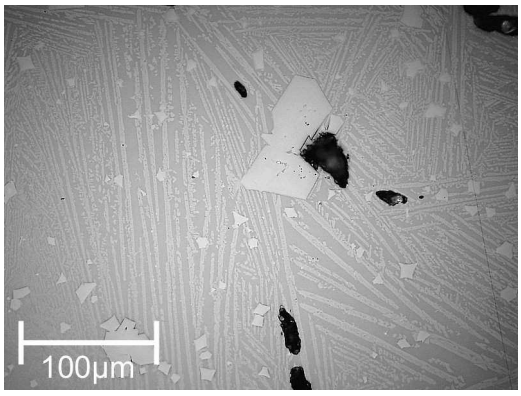
Morphology:

Dense, dark brown/black glassy material with a lighter brown surface discoloration. Very few visible vesicles, all <1mm in diameter. One surface has signs of flow marks whilst the opposite one is very uneven, possibly caused by flow over rough ground surface.

Microscopy:

No dendritic structure. Laths of fayalitic material (light grey) within a glassy phase (dark grey). Very few iron prills observed and evidence of small blocky/angular phases (mid grey). Voids of varying sizes in the sample structure noted, but no associated cracking.





OPTICAL MICROSCOPY

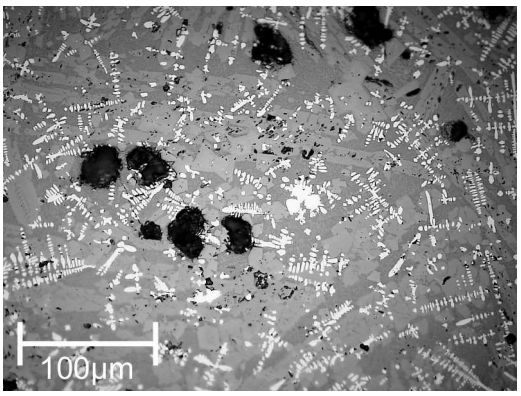
Sample: Iron smelting slag – Stingamires 223-B

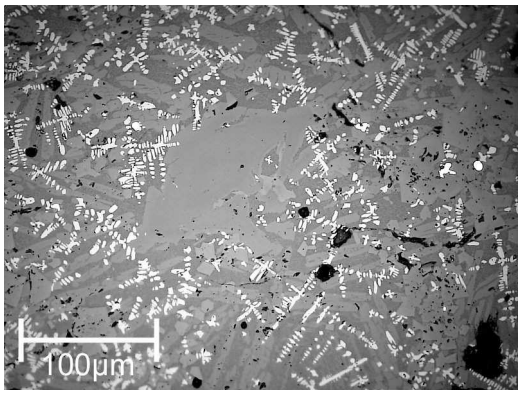
Morphology:

Dense, dark brown/black material with a lighter brown pitted surface. A few large visible vesicles, ranging in size from *c*.2mm diameter to 10mm x 6mm. Signs of surface flow. Surface discoloration possibly caused by the burial environment reacting with the iron oxide content in the sample.

Microscopy:

A skeletal iron oxide dendritic structure. Fayalitic laths (light grey) contained in a small amount of glassy phase (dark grey). Some small sized prills noted and a few blocky/angular phases (mid grey) observed. Considerable number of voids in the sample structure noted, of a range of sizes and associated cracking.





OPTICAL MICROSCOPY

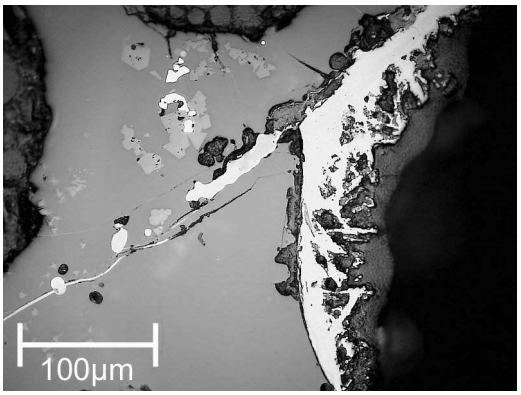
Sample: Iron smelting slag – Stingamires 201-C

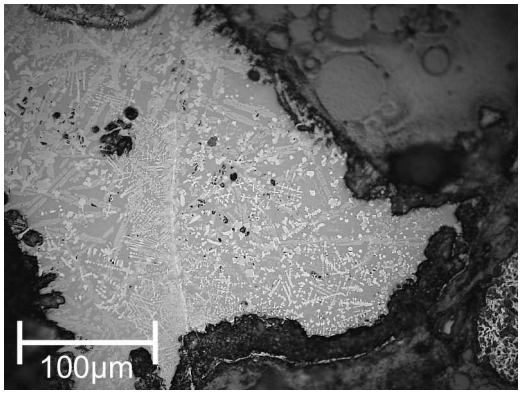
Morphology:

Very porous, dark brown/black cinder-like material with a lighter brown pitted surface. Visible vesicles *c.*1mm in diameter. Signs of surface flow. Surface discoloration possibly caused by the burial environment reacting with the iron oxide content in the sample.

Microscopy:

Very few dendrites, only over a small area. Some fayalitic laths (light grey) contained in a featureless glassy phase (dark grey). A very few large sized prills noted. An extensive amount of a blocky/angular phase (mid grey) observed. A substantial number of large voids in the sample structure noted, with some associated cracking. Evidence of iron oxide at the edges of voids and along the cracks.





OPTICAL MICROSCOPY

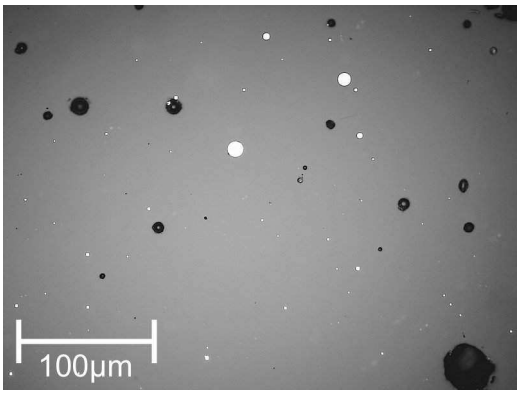
Sample: Blast furnace slag – Bretton BRE-F

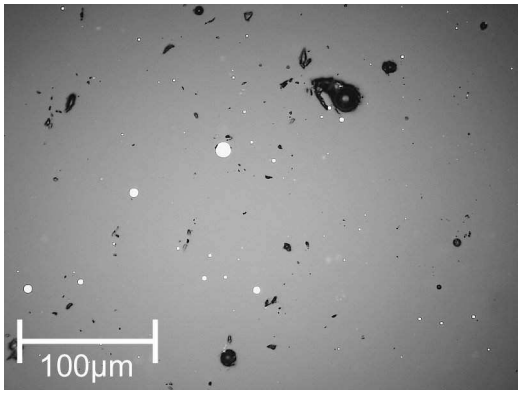
Morphology:

Dense, olive green opaque glassy material. Few visible vesicles, ranging in diameter from <1mm to 3mm. Some surface degradation.

Microscopy:

No dendritic structure. An almost featureless glassy phase containing no laths nor blocky/angular phases. A large number of prills observed, of varying sizes but mainly very small. A considerable quantity of voids, of varying sizes but with no associated cracking.





OPTICAL MICROSCOPY

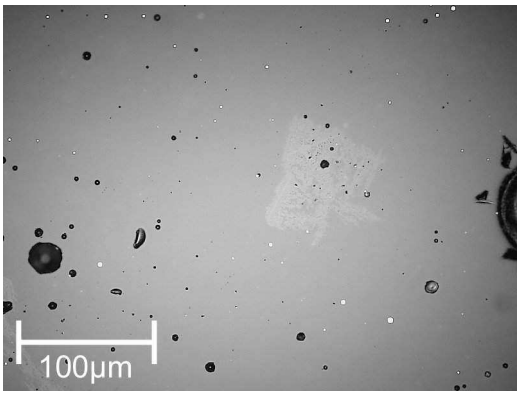
Sample: Blast furnace slag – Bretton BRE-D

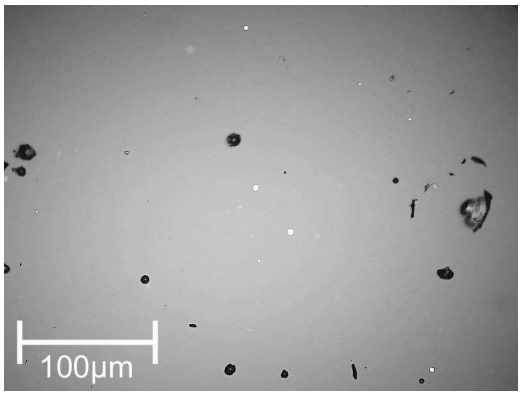
Morphology:

Dense, black opaque glassy material. Some visible vesicles, ranging in diameter from *c*.1mm to 3mm. Signs of surface flow and degradation.

Microscopy:

No dendritic structure. An almost featureless glassy phase (mid grey). Some blocky/angular phases containing lathe-like phases (light grey). A smaller number of prills observed compared to sample BRE-F. A considerable quantity of voids, of varying sizes but with no associated cracking noted.





OPTICAL MICROSCOPY

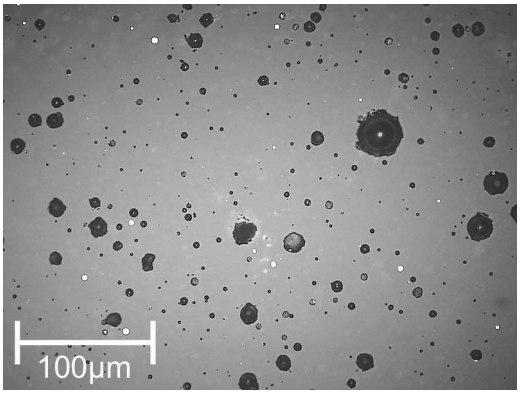
Sample: Blast furnace slag – Bretton BRE-I

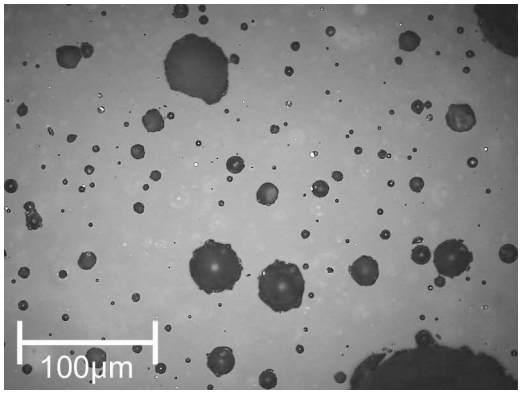
Morphology:

Very dense, grey/green opaque material. Numerous visible vesicles, ranging in diameter from <1mm to 10mm. Larger vesicles are located close to a boundary layer. Some surface degradation from attached non-glassy material.

Microscopy:

No dendritic structure. An almost featureless glassy phase containing no laths nor blocky/angular phases. A large number of prills observed, of varying sizes but mainly very small. Very porous material having voids of varying sizes but with no associated cracking.





OPTICAL MICROSCOPY

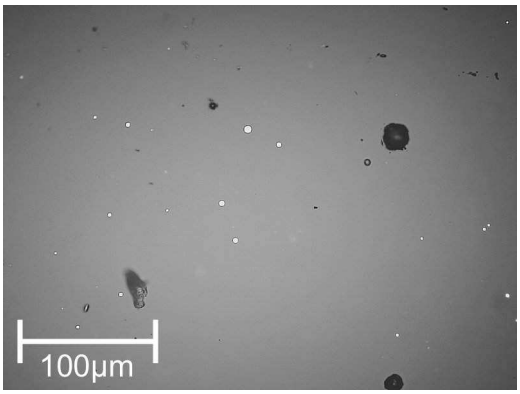
Sample: Blast furnace slag – Rievaulx 111/68-A

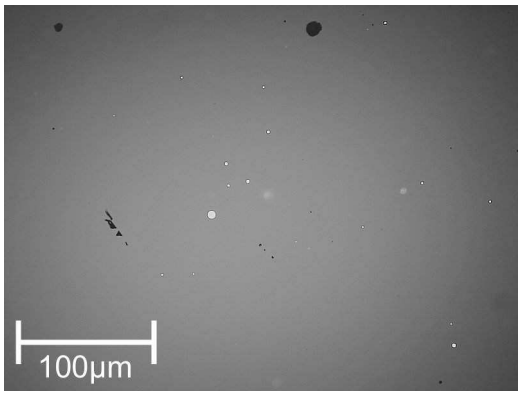
Morphology:

Very porous and lightweight, grey/green opaque material. Few visible vesicles, maximum diameter *c.*1mm. Smooth surface.

Microscopy:

No dendritic structure. An almost featureless glassy phase (mid grey) containing no fayalitic structures or blocky/angular phases. A substantial number of small prills observed. A considerable quantity of voids in the sample structure noted, of varying sizes but with no associated cracking.





OPTICAL MICROSCOPY

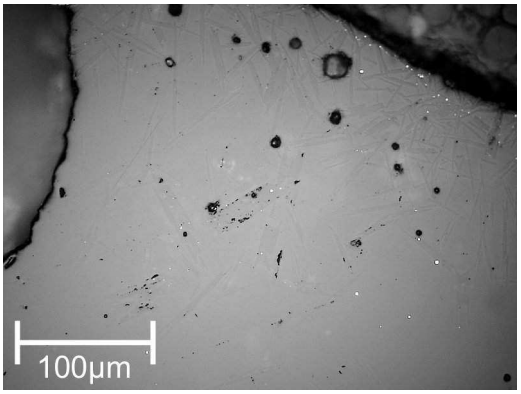
Sample: Blast furnace slag – Rievaulx RIV 105/63-C

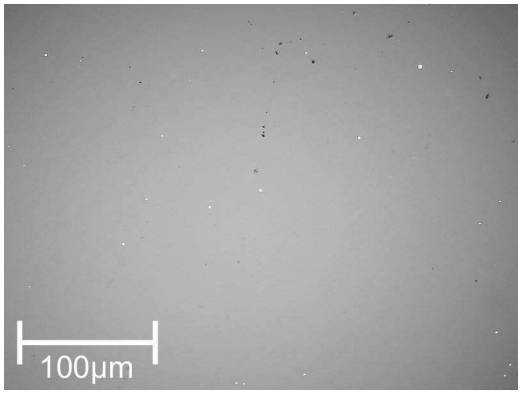
Morphology:

Very porous and lightweight, grey/green opaque material, lighter than RIV 111/68-A. Visible vesicles, either round (*c.*5mm in diameter) or rectangular (up to 6mm x 2mm). Signs of surface flow.

Microscopy:

No dendritic structure. An almost featureless glassy phase (mid grey) containing laths of darker grey material but no blocky/angular phases. A substantial number of small prills observed. A considerable quantity of voids in the sample structure noted, of varying sizes but with no associated cracking.





OPTICAL MICROSCOPY

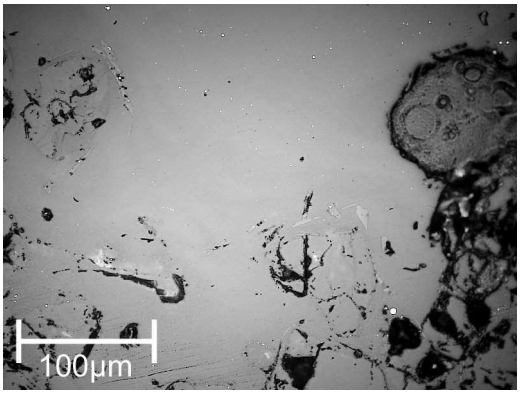
Sample: Blast furnace slag – Rievaulx RIV 117/90-C

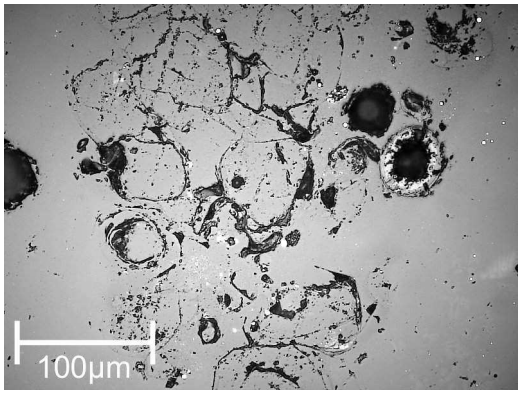
Morphology:

Porous and lightweight, dark grey material similar to iron smelting tap slag. Visible vesicles ranging in diameter from *c.*1mm to 10mm.

Microscopy:

No dendritic structure. An almost featureless glassy phase (mid grey) containing laths and small blocks of light grey material. A substantial number of small prills observed. A considerable quantity of voids in the sample structure noted, of varying sizes and with associated cracking.





OPTICAL MICROSCOPY

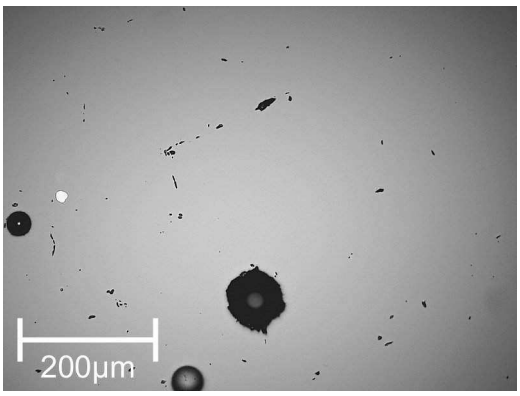
Sample: Blast furnace slag – Sowerby Bridge SOW-K

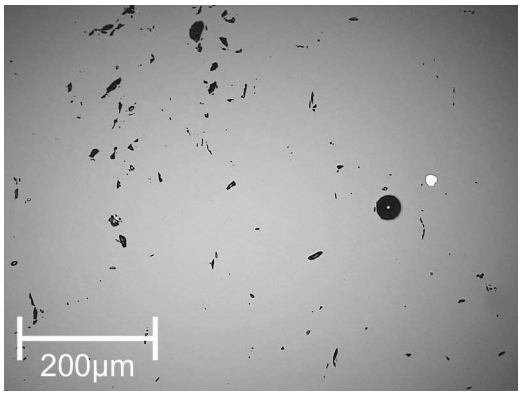
Morphology:

Dense, black opaque glassy material. Very few visible vesicles, all <1mm in diameter. Some surface degradation.

Microscopy:

No dendritic structure. An almost featureless glassy phase containing no laths nor blocky/angular phases. A small number of small-sized prills observed and a considerable quantity of voids, of varying sizes but with no associated cracking.





OPTICAL MICROSCOPY

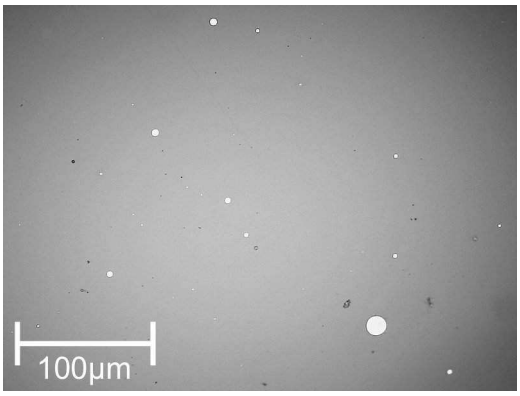
Sample: Blast furnace slag – Sowerby Bridge SOW-J

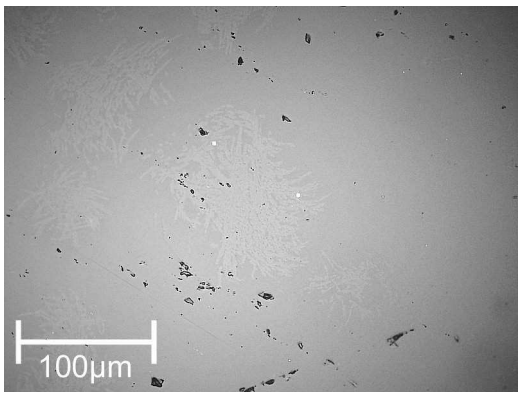
Morphology:

Dense, grey/yellow green opaque material, with dark grey flow patterns throughout. No visible vesicles.

Microscopy:

No dendritic structure. An almost featureless glassy phase (mid grey) containing laths and small blocks of lighter grey material. A small number of small-sized prills observed and some voids, of varying sizes but with no associated cracking.





OPTICAL MICROSCOPY

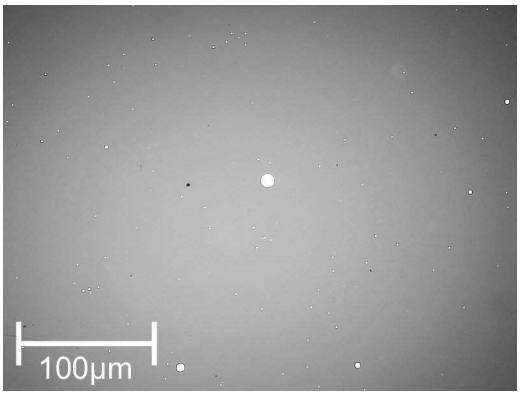
Sample: Blast furnace slag – Sowerby Bridge SOW-C

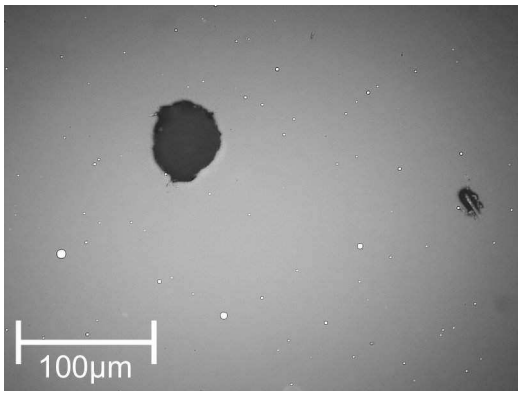
Morphology:

Dense, black opaque glassy material. Very few visible vesicles, ranging in diameter from <1mm to 2mm. Some surface degradation.

Microscopy:

No dendritic structure. An almost featureless glassy phase containing no laths nor blocky/angular phases. A large number of small-sized prills observed and some voids, of varying sizes but with no associated cracking.





OPTICAL MICROSCOPY

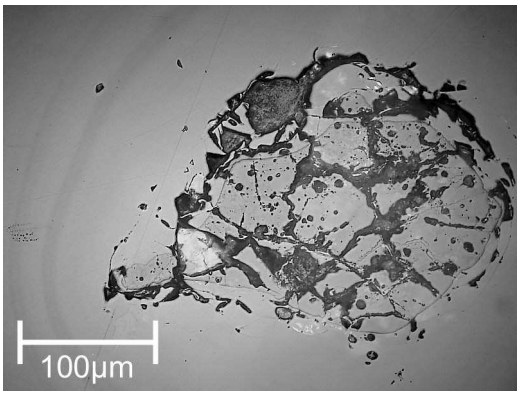
Sample: Lead smelting slag – Botchergate 337B

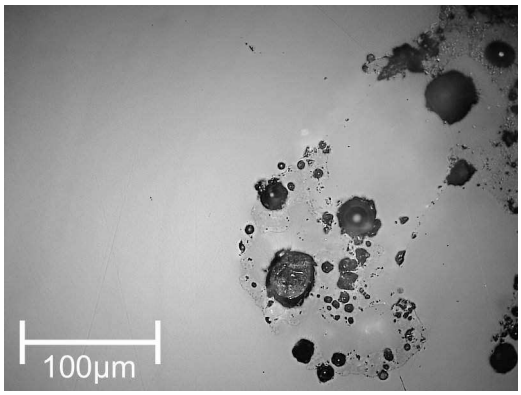
Morphology:

Dense, dark grey/black glassy material. Very few visible vesicles, all <1mm. Some surface degradation with a white coloured material observed, possibly lead carbonate. Indications of high temperature flow.

Microscopy:

A small amount of blocky/angular phase (dark grey) contained in an otherwise featureless glassy phase. Some very small prills observed and a quantity of voids, of varying sizes with some associated cracking.





OPTICAL MICROSCOPY

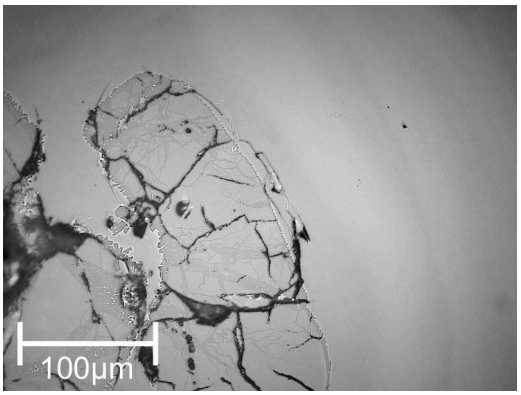
Sample: Lead smelting slag – Botchergate 155A

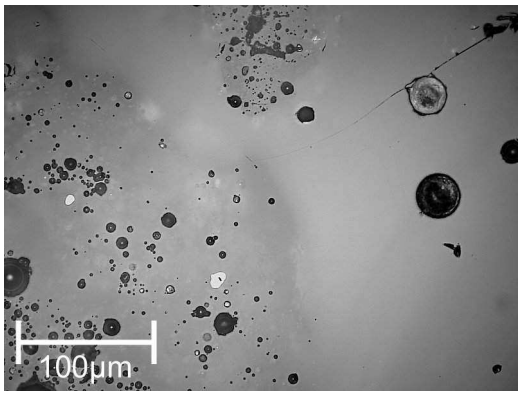
Morphology:

Dense, dark grey/black glassy material. Few visible vesicles, ranging in diameter from <1mm to *c.*2mm. A substantial amount of surface degradation with a white coloured material observed, possibly lead carbonate. Sample appears to have been "folded" at high temperature.

Microscopy:

A small amount of blocky/angular phase (dark grey) contained in an otherwise featureless glassy phase. Some small prills observed and a quantity of voids, of varying sizes with some associated cracking.





OPTICAL MICROSCOPY

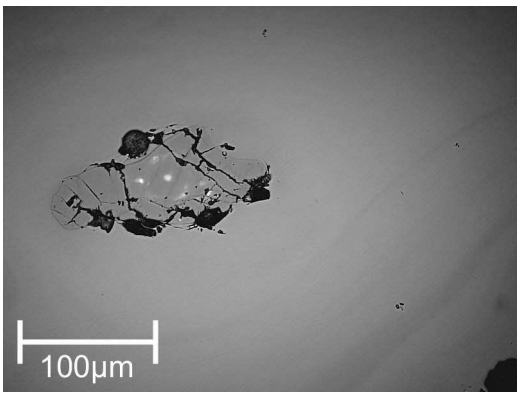
Sample: Lead smelting slag – Botchergate 160

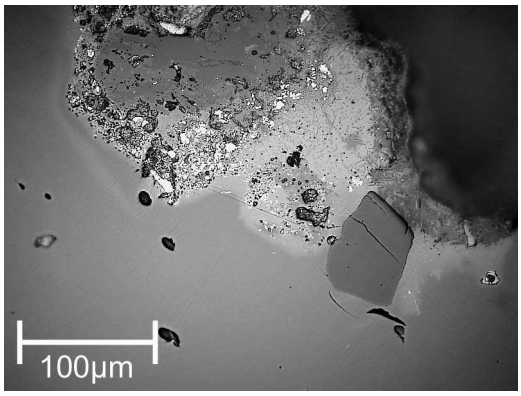
Morphology:

A porous and lightweight, black glassy material attached to some stone. Visible vesicles up to *c.*2mm in diameter. Some surface degradation with lead carbonate observed.

Microscopy:

Some blocky/angular phases (dark grey) contained in an otherwise featureless glassy phase. A few small prills observed and a quantity of voids, of varying sizes with some associated cracking.





OPTICAL MICROSCOPY

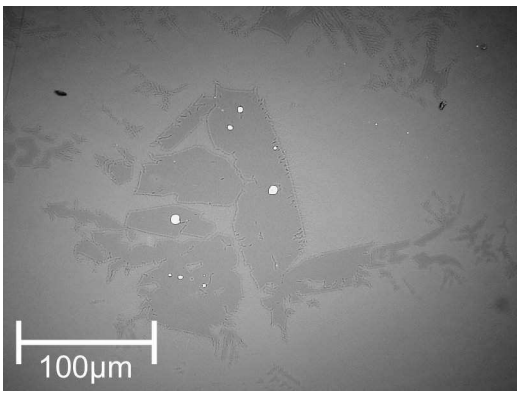
Sample: Lead smelting slag – Grinton Smeltings GS-C

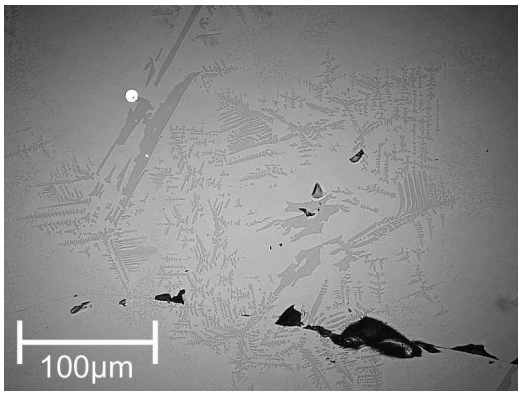
Morphology:

Dense, grey/black slag material. No surface voids. Yellow/red surface corrosion over most of the sample. No other surface degradation observed.

Microscopy:

A considerable quantity of needles, laths and dendritic features (darker grey) contained in an otherwise featureless glassy phase. Larger blocky/angular phases (darker grey) and a few small prills observed. Some small voids, with some associated cracking noted.





OPTICAL MICROSCOPY

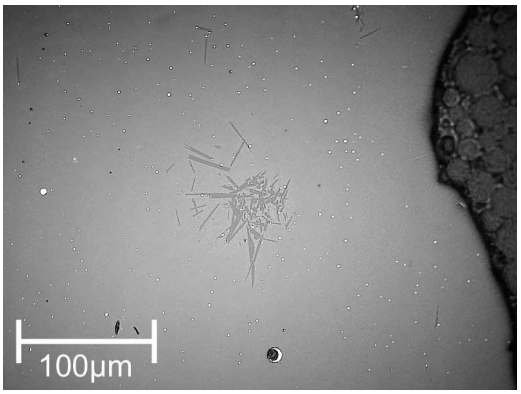
Sample: Lead smelting slag – Grinton Smeltings GS-K

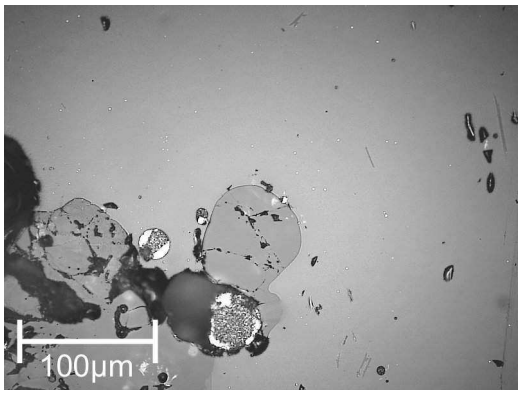
Morphology:

Dense, black slag material. No surface voids or degradation.

Microscopy:

A considerable quantity of needles and laths (darker grey) contained in an otherwise featureless glassy phase. Some blocky/angular phases (darker grey) and a large amount of small prills observed. A quantity of small voids, with no associated cracking noted.





OPTICAL MICROSCOPY

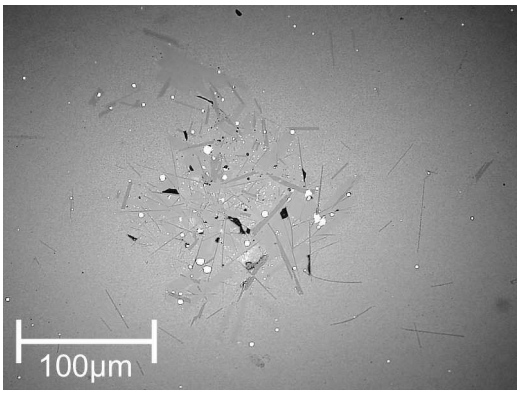
Sample: Lead smelting slag – Grinton Smeltings GS-B

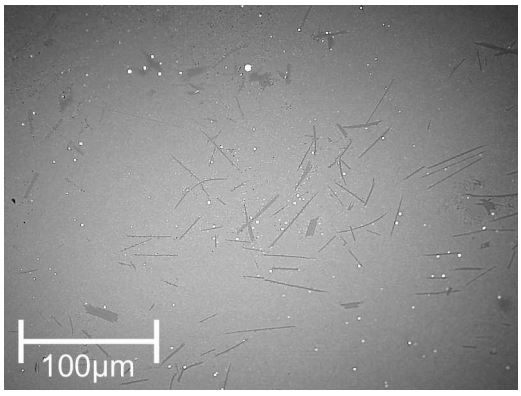
Morphology:

Dense, grey/black slag material. Very small visible vesicles (<0.5mm in diameter) throughout the body of the sample but some large voids (>5mm in diameter) on the surface. Some surface degradation with a white coloured material observed, possibly lead carbonate, and other yellow/red patches caused by iron oxide content.

Microscopy:

A considerable quantity of needles, laths and angular phases (darker grey) contained in an otherwise featureless glassy phase. Some larger blocky/angular phases (mid grey) and a large amount of small prills observed. A small quantity of voids, of varying size with some associated cracking noted.





OPTICAL MICROSCOPY

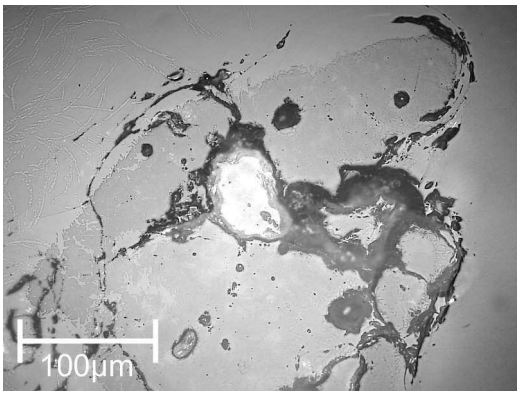
Sample: Lead smelting slag – Pentre Farm PFCT/YD-14

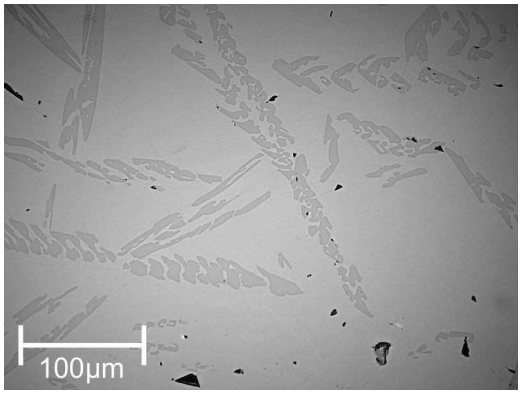
Morphology:

Lightweight, yellow/dark green glassy material, with very little porosity. Few visible vesicles, all <1mm. Sample appears to have been "folded" at high temperature.

Microscopy:

Spine-like laths (light and dark grey) and large angular phases (dark grey) contained in an otherwise featureless glassy phase. Some large voids observed, but with no associated cracking.





OPTICAL MICROSCOPY

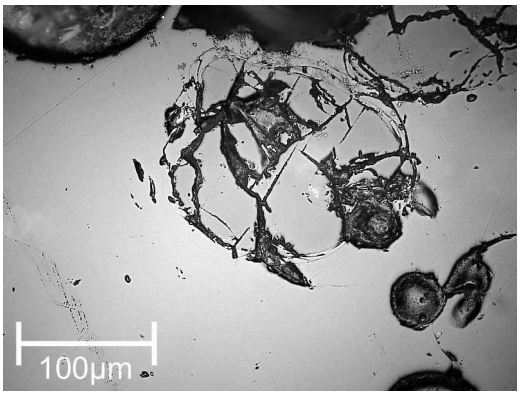
Sample: Lead smelting slag – Pentre Farm PF8-31

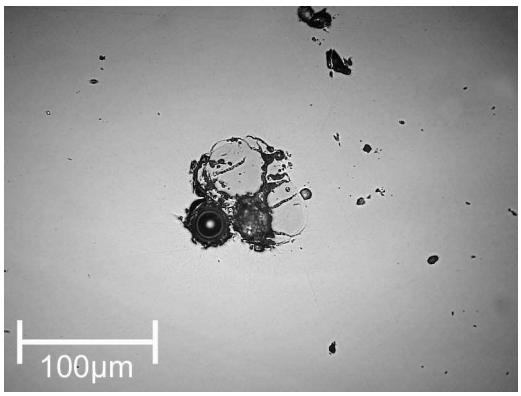
Morphology:

Lightweight, yellow/green glassy material, with some porosity. Visible vesicles ranging in diameter from *c.*1mm to 4mm. Some surface degradation with lead carbonate. Pitted and folded appearance.

Microscopy:

Large angular phases (dark grey) contained in an otherwise featureless glassy phase. Some very small prills observed and a considerable quantity of voids, of varying sizes with some associated cracking.





OPTICAL MICROSCOPY

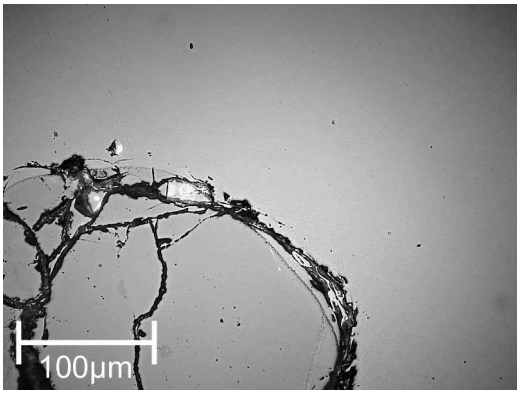
Sample: Lead smelting slag – Pentre Farm PF7-46

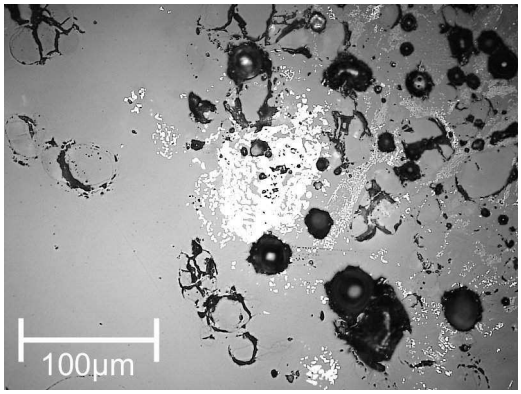
Morphology:

Olive green glassy material attached to stone, with some porosity. Visible vesicles all <1mm in diameter. A minor amount of surface degradation from lead carbonate observed.

Microscopy:

Large angular phases (dark grey) contained in an otherwise featureless glassy phase. Some small prills observed and a considerable quantity of voids, of varying sizes with some associated cracking.





OPTICAL MICROSCOPY

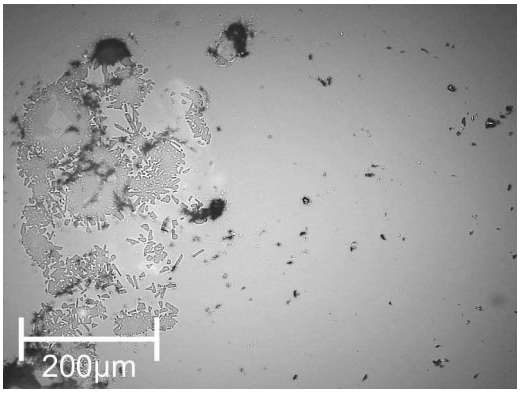
Sample: Glass production residues – Hutton H4E

Morphology:

Dense, light green translucent glassy material. Some surface degradation observed.

Microscopy:

An almost featureless glassy phase containing some blocky/angular phases (darker grey). Some voids, of varying sizes but with no associated cracking noted.



OPTICAL MICROSCOPY

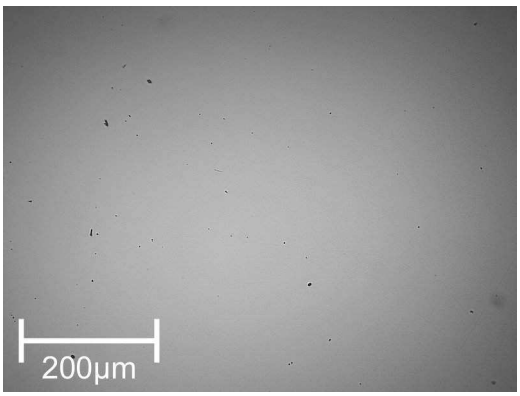
Sample: Glass production residues – Hutton H4G

Morphology:

Dense, dark green translucent glassy material. Some surface degradation observed.

Microscopy:

An almost featureless glassy phase. Some voids noted, of varying sizes but with no associated cracking.



OPTICAL MICROSCOPY

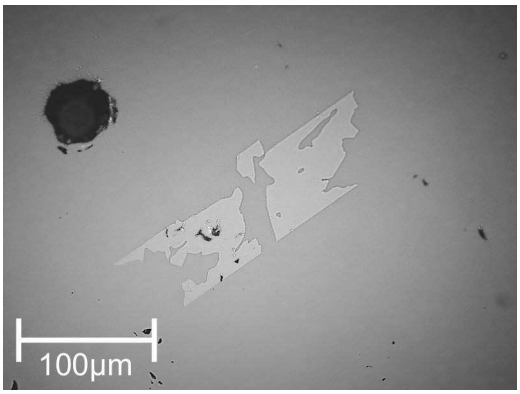
Sample: Glass production residues – Hutton H4A

Morphology:

Dense, light green translucent glassy material. Some surface degradation of flaky pearlescent appearance observed.

Microscopy:

An almost featureless glassy phase containing some blocky/angular phases (light grey). Some voids, of varying sizes but with no associated cracking noted.



OPTICAL MICROSCOPY

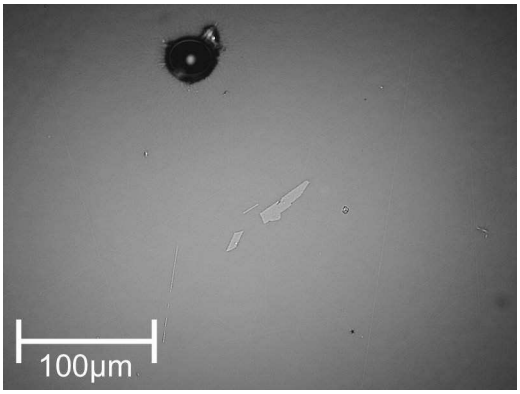
Sample: Glass production residues – Hutton H4C

Morphology:

Dense, dark green translucent glassy material. A few visible vesicles, ranging in diameter from *c.*1mm to 2mm. Some surface degradation or oxidation observed.

Microscopy:

An almost featureless glassy phase containing a few blocky/angular phases (light grey). Some small voids, with no associated cracking noted.



OPTICAL MICROSCOPY

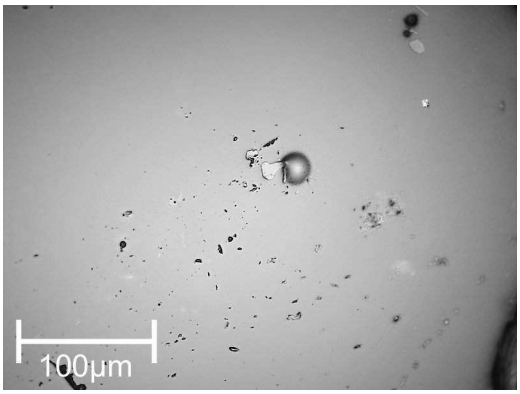
Sample: Glass production residues – Knightons K2A

Morphology:

Dense, dark grey/green opaque glassy material. Few visible vesicles, all <<1mm in diameter. Some surface degradation observed.

Microscopy:

An almost featureless glassy phase containing some blocky/angular phases (light grey). Very few small voids, with some associated cracking noted.



OPTICAL MICROSCOPY

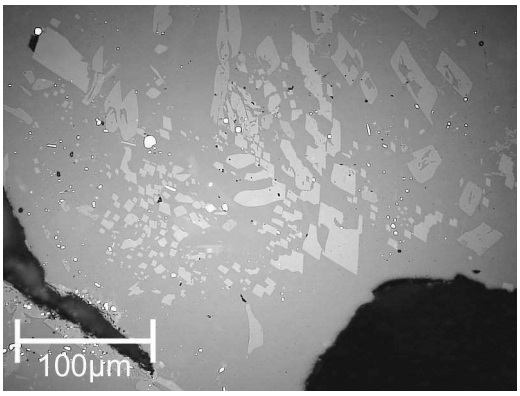
Sample: Glass production residues – Knightons K1

Morphology:

Very porous and lightweight, dark grey/green slag material. Large visible voids up to *c.*10mm in diameter. Some surface degradation or oxidation observed.

Microscopy:

An almost featureless glassy phase containing some blocky/angular phases (light grey). Some prill-like inclusions (white) and a small quantity of voids, of varying sizes with some associated cracking noted.



OPTICAL MICROSCOPY

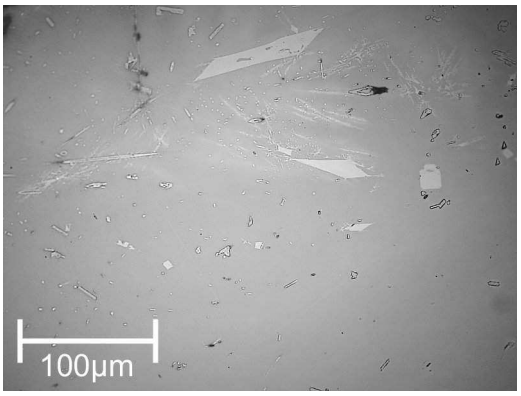
Sample: Glass production residues – Knightons K5

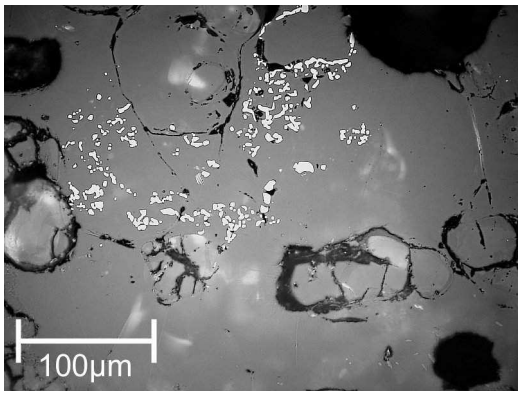
Morphology:

Lightweight, light grey/green material. A few visible vesicles, ranging in diameter from <1mm to *c.*2mm. Some surface degradation observed.

Microscopy:

An almost featureless glassy phase containing some blocky/angular phases (light grey). Some prill-like inclusions (white) and a large quantity of voids, of varying sizes and associated cracking noted.





OPTICAL MICROSCOPY

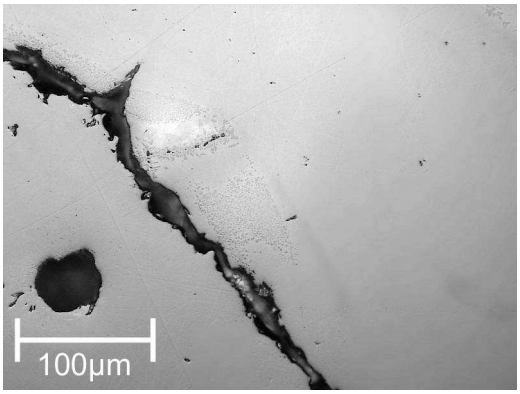
Sample: Glass production residues – St. Aidan's STA 2110-A

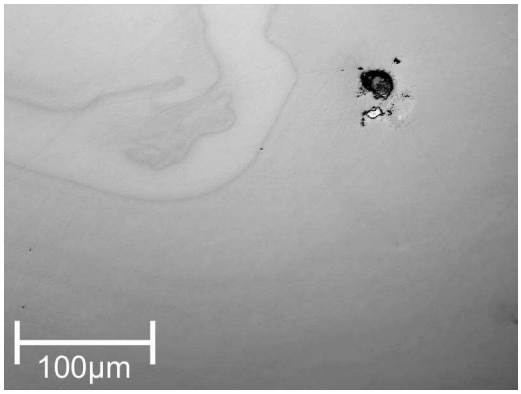
Morphology:

Dense, light grey/white semi-transparent glassy material with a light grey slag-like surface at one end. Few visible voids. Some surface degradation on the slag-like material observed.

Microscopy:

An almost featureless glassy phase containing some very small blocky phases (darker grey). A large quantity of voids, some large but mainly small sized, with some cracking between the large voids noted.





OPTICAL MICROSCOPY

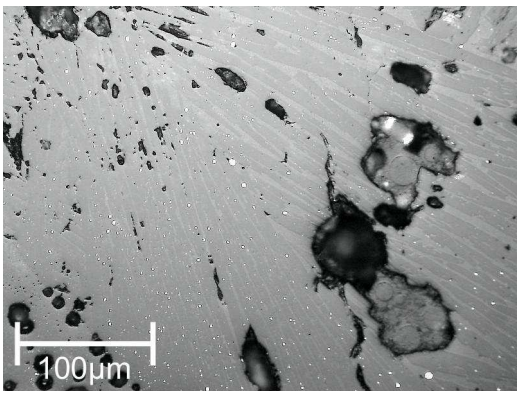
Sample: Glass production residues – St. Aidan's STA 2110-D

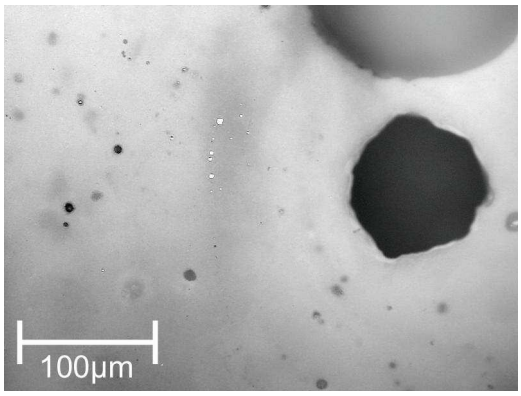
Morphology:

Porous and lightweight, light grey/green slag material. A substantial number of visible vesicles, up to *c.*3mm in diameter but mostly *c.*1mm in diameter.

Microscopy:

An almost featureless glassy phase containing some needle-like laths (darker grey). Some prill-like inclusions (white) and a quantity of voids, of varying sizes and associated cracking noted.





OPTICAL MICROSCOPY

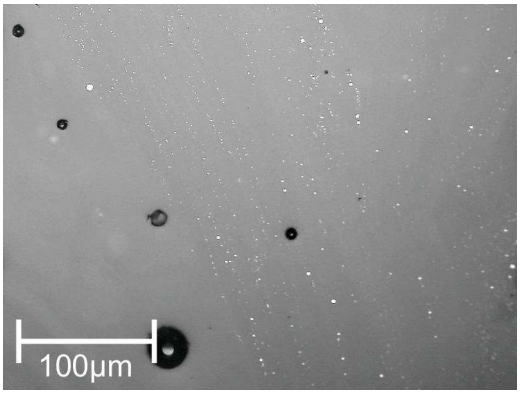
Sample: Glass production residues – St. Aidan's STA 2110-C

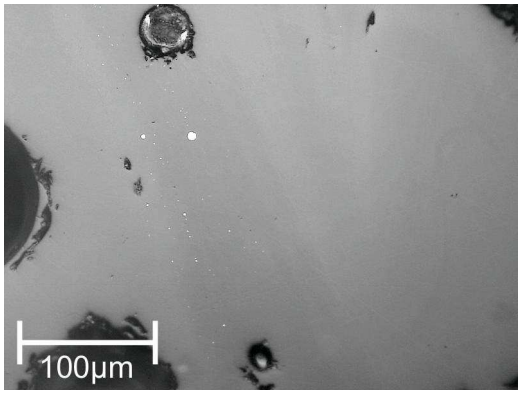
Morphology:

Porous and lightweight, dark blue/grey/black slag material. A large number of visible vesicles, up to *c.*1mm in diameter. Some surface degradation observed.

Microscopy:

An almost featureless glassy phase containing some very small prill-like inclusions (white). A quantity of voids, of varying sizes with no associated cracking noted.





OPTICAL MICROSCOPY

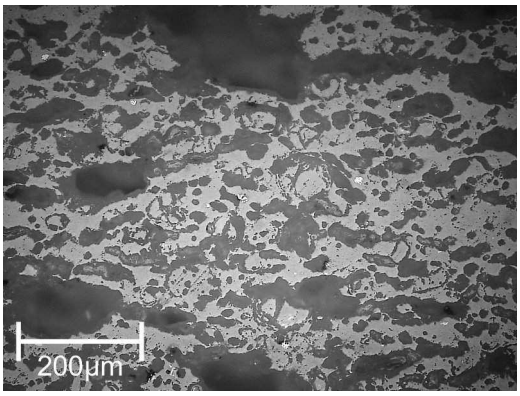
Sample: Glass production crucibles – Knightons KC5

Morphology:

Dense, yellow/grey material, coarse with no sign of temper. Some visible minor cracks and voids, all <<1mm in diameter. Sample surface has a thin layer (<1mm) of pitted light grey coloration.

Microscopy:

A porous fabric consisting of an even distribution of large grained material (light grey) interspersed with small voids (mid grey). Some prill-like inclusions (white) noted.



OPTICAL MICROSCOPY

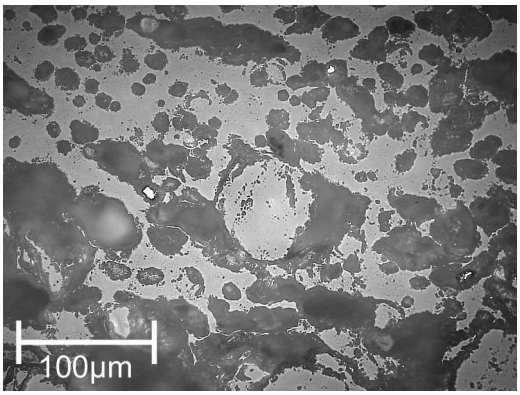
Sample: Glass production crucibles – Knightons KC1

Morphology:

Dense yellow/grey material, coarse with no sign of temper. Very small elongated voids visible, *c.*2mm long and <<1mm wide. Sample surface has a thin layer (<1mm) of white/light grey matt "glaze".

Microscopy:

A very porous fabric consisting of an even distribution of large grained material (light grey) interspersed with voids larger than KC5 (mid grey). Some very small prill-like inclusions (white) noted.



OPTICAL MICROSCOPY

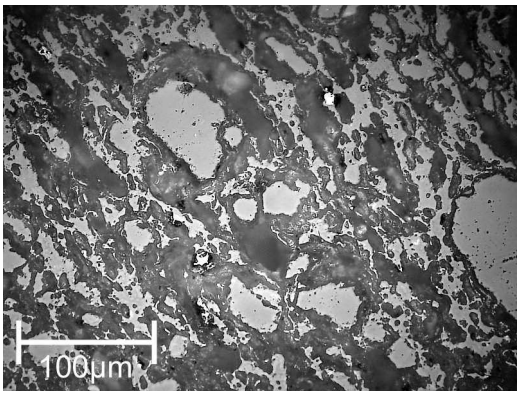
Sample: Glass production crucibles – Knightons KC3

Morphology:

Dense, dark yellow/grey/blue-grey material, coarse with no sign of temper but evidence of layering. Very small visible voids, all <<1mm in diameter. Sample surface has a dark yellow/black coloration.

Microscopy:

A very porous fabric consisting of an even distribution of large grained material (light grey) interspersed with large voids (mid grey). Some very small prill-like inclusions (white) noted.



OPTICAL MICROSCOPY

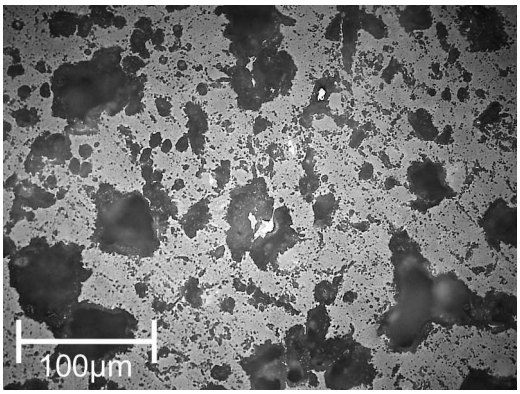
Sample: Glass production crucibles – St. Aidan's STA 2180

Morphology:

Dense, light grey material, with no sign of temper. Some visible voids, *c.*1mm in diameter. Sample surface has a thin layer (<1mm) of whitish yellow "glaze".

Microscopy:

A porous fabric consisting of an even distribution of large grained material (light grey) interspersed with large voids. A few very small prill-like inclusions (white) noted.



OPTICAL MICROSCOPY

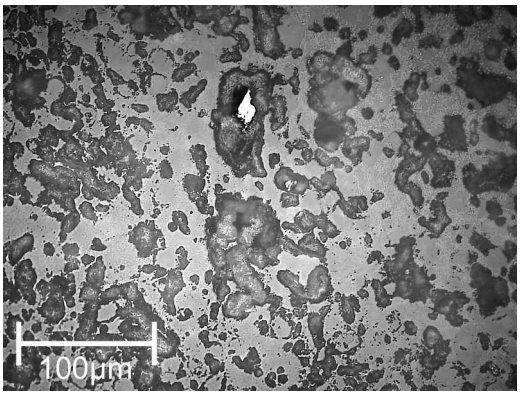
Sample: Glass production crucibles – St. Aidan's STA 2104-D

Morphology:

Dense, yellow/grey material with some porosity. A few very small visible vesicles, <<1mm in diameter. Sample surface has a thin layer (<1mm) of white glazing.

Microscopy:

A porous fabric consisting of an even distribution of two types of large grained material (light and mid grey), interspersed with large voids. A few very small prill-like inclusions (white) noted. No obvious difference between the bulk material and a very thin glaze layer on the edge of the sample.



OPTICAL MICROSCOPY

Sample: Glass production crucibles – St. Aidan's STA 2104-E

Morphology:

Dense, yellow/grey material with some porosity. A few very small visible vesicles, <<1mm in diameter. Sample surface has a thin layer (<1mm) of white glazing.

Microscopy:

A porous fabric consisting of an even distribution of two types of large grained material (light and mid grey), interspersed with larger voids. No prill-like inclusions observed.