MetPrep Application Notes – Application Note – 001

# The Sectioning, Preparation and Analysis of Meteorites using the Brillant 220 cutter & accessories

Kevin Smith - January 2020

Introduction

Meteorites regularly land on our planet having spent billions of years travelling in space. They often represent some of the earliest rocks known and are clues to the origin of our Solar System, and possibly life itself. Recovering such meteorites is a great way to investigate the properties of the Solar Systems earliest beginnings.

Collecting these visitors from space is both demanding and often expensive, therefore we have to look after them as they are valuable in many ways. Often such meteorites are bought by a collection of institutions, and thus have to be divided by sectioning. Even if held by a single institution these items still need sectioning carefully, as mistakes on sectioning can ruin a unique sample forever.

Large meteorites can be sectioned using large abrasive cut off machines or wire saws, but the smaller items require careful holding and precise steady cutting. The machine well suited for such an application is the MetPrep Brillant 220 Precision Cutter.

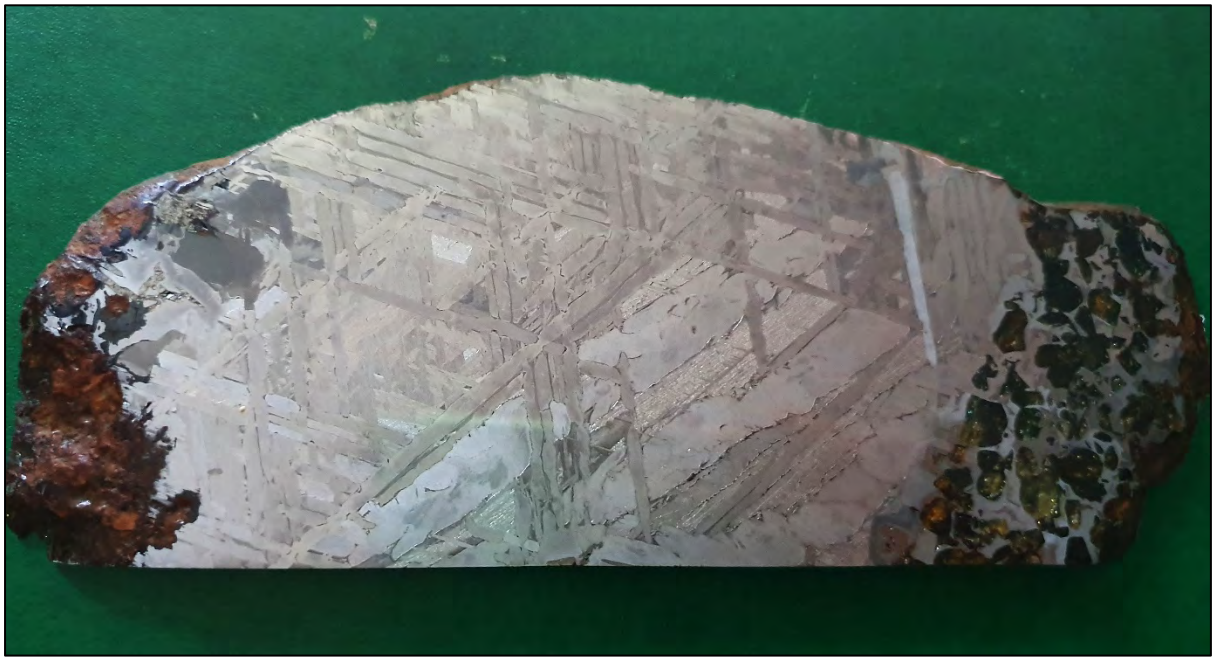


Fig 1 - Large slice of Seymchan Meteorite – Sample width 200mm

The cutter

The Brillant 220 is precision cut off machine allowing controlled sectioning using three automatic axes. (X, Y, Z). X – 210 mm inward horizontal feed, Y - 80 mm chop cut, and a Z movement right to left of 80 mm. With such a wide range of movement most ‘smaller’ meteorites can be accommodated in such a machine. With an auto Z axis option, it is possible to remove several sections automatically. With an accuracy of 1 micrometer in table movement and the option of including the blade thickness in the calculation samples can but cut safely, accurately and with minimal operator attendance. Coolant is supplied using an external tank holding 15 litres of coolant. If using various coolants e.g. oil based for water soluble samples, etc it is possible to swap these over with little inconvenience.


Fig 2 - Brillant 220 precision cutter

Blade rotation speeds cover 300 – 5000 rpm and a blade up to 203 mm can be used. Feed speed & rotational speed can be controlled to the supplier recommendations. In general, it is better to use a smaller blade as they are thinner this resulting in more material retained and less damage. A typical continuous rim blade of Diamond or CBN of 175 mm has a thickness of 600um whereas an equivalent blade of only 75 mm diameter is only 150um. The type of blade to use for each meteorite is dependent on its type. The 'Irons' usually of iron – nickel are best cut using a CBN as they benefit from the sharper abrasive type and can still cover a significant hardness. The 'Stony' meteorites and the 'Stony Iron' meteorites will usually benefit from the use of a High Concentration diamond blade instead.

Securing the samples

As with any sectioning, you need to be able to hold the sample securely. With meteorites it is expected your sample will be irregular in shape and thus difficult to hold. It is therefore crucial not to have the sample move during sectioning. Not only can you damage your sample but you can also destroy the blade. Therefore, securing the sample is of vital importance. You also require a means to clamp which will hold the sample securely whilst not crushing it and also to enable the correct orientation to get the cut in the right location. For this the Brillant 220 has a wide range of accessories to aid in helping you get the best possible solution.

The samples to be prepared

1) A 1 cm round sample of the Chelyabinsk meteorite - Block & Thin Section required.
2) Broken off cuts of unclassified impact melt - Block & Thin Section required.
3) A broken off cut from the Seymcham Pallasite - Block only, no sectioning required.
4) A NWA sample from Niger a 40 mm sized solid item - Block & Thin Section required.


Fig 3 - Meteorites requiring preparation


Fig 4 - Larger meteorite requiring sectioning

Obviously with different shapes, sizes and requirements different approaches will be needed.

Methodology

Sample 1 – Chelyabinsk - Single sample covered in fusion crust and difficult to hold

Solution

Cold mount complete. This ensures that the sample can be kept intact regardless of its shape and fragility. With the distinct possibility of cracking due to its journey through the atmosphere the sample could already be cracked and the fusion crust created by entry could be very delicate. To give additional support and to give as good adhesion as possible the sample was mounted in a low viscosity Epoxy resin e.g. Epo-Flo, using vacuum impregnation to aid the resin to travel into any cracks that may exist. The sample was mounted in a 25 mm mount.

Sample 2a & 2b – Unclassified impact Melt - Already cut

Solution

One sample retained for a block; one sample retained for a thin section. The sample for block preparation was vacuum impregnated in Epoxy, the other section was smeared in warm epoxy resin to give some support and then fixed to a glass slide using a UV curing resin. The section was then set aside for further processing. Mounted in 32 mm mould.

Sample 3 – Seymchan Pallasite

Solution

The sample of Seymchan Pallasite did not need any sectioning and was vacuum impregnated in a low viscosity resin with the others even though the vacuum process was not necessarily needed. No thin section required therefore just mount for one sample. Mounted in 25 mm mould

Sample 4 – NWA Stony Iron meteorite

Solution

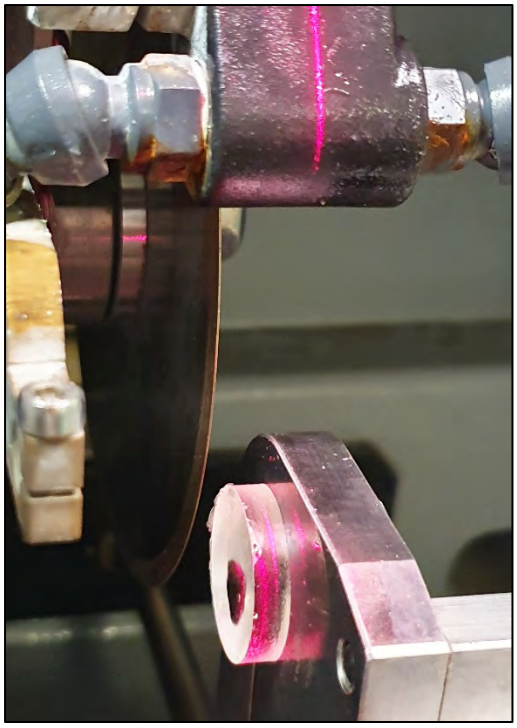
The NWA meteorite is a substantial piece about 40 mm x 35 mm and again difficult to hold. It seems quite heavy & appears well held together suggesting that sectioning can be carried out without requiring the meteorite to be mounted in advance. All that is needed is a good clamping. Having taken the section as required again mounting in a low viscosity will be required. Vacuum impregnation will be used again as it will help in the event of any small unseen cracks. A 40 mm mould was used due to the larger size required.

Sectioning

Sample 1 – Chelyabinsk

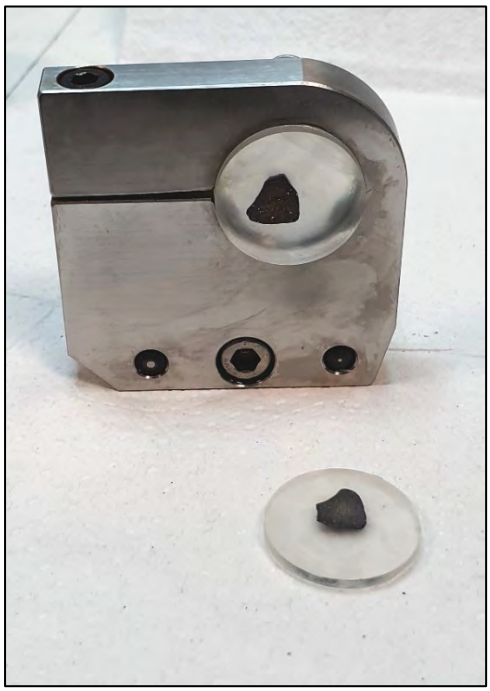
Sectioning of a mounted sample that is round in a standard vice arrangement is both awkward and unsafe. To aid in holding the sample and keeping it orientated correctly a special accessory is used.

Designed specifically to hold round mounted samples of the standard sizes it sits in the standard Vice clamp 50 and holds the sample firmly parallel to the blade. To line up the section to the correct positioning a laser is used to make things quicker and easier. One sample to be used as a block the offcut to be used for a thin section.



Set for cutting using the laser alignment

The completed cut



Section in the MetPrep special 25 mm sample holder

Fig 5 - Securing the Chelyabinsk sample for sectioning

Sample 4 - NWA Stony Iron Meteorite

An irregular shape and being a substantial piece, this meteorite will need a firm but flexible clamp. A standard camlock vice is hardly ideal even if packed to take up some of the irregular shape it might not hold the sample causing it to move during sectioning and possibly causing damage both to the meteorite and the blade. Again, we have a special clamp, the X-Clamp. With a selection of independent pins, the sample can be firmly secured in many locations without exerting excessive force on a small area. With a clamp of this design the sample is not going to move.


The X- Clamp – Secure clamping of irregular samples without the use of excessive force

Alignment using the laser & setting up for a second cut

Sectioning completed multiple sections and the sample is not damaged & still held secure.

Fig 6 – Securing the meteorite with the X-Clamp

With sectioning completed & all the samples mounted, the completed blocks can now be processed using standard metallographic techniques for optical & electron microscopical analysis.

Fig 7 - Mounted sections for block samples

Brillant 220 in the grinding mode

Sample 2 requiring only a thin section does not need any sectioning but will need supporting, mounting and grinding to produce a standard 30um thin section. Initially the sample is smeared in warm epoxy resin then fixed to a glass slide using a UV curing resin.

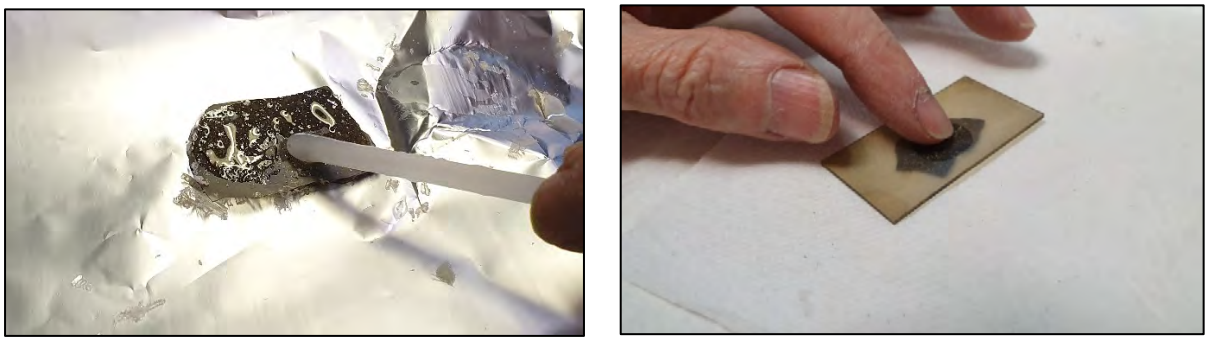


Fig 8 – Fixing to the slide for support

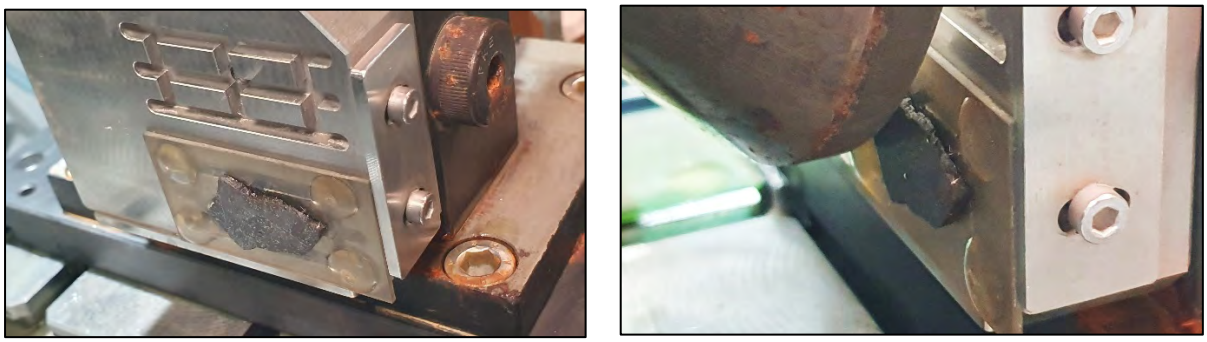


Fig 9 - Surface preparation using a Cup grinding Wheel on the Brillant 220

The supported material is then returned to the Brillant 220 and held with the Vacuum chuck. The chuck offers the opportunity to hold 2 x 76 x 26 mm slides or a single 75 x 50 mm slide. Smaller 48 x 26 mm & similar can also be accommodated in singles or pairs. The surface to be attached to the glass for thin section is then ground with a Diamond Cup Grinding Wheel to create a damage free surface which can be further prepared if required.

The sample has the glass scribed and snapped to remove the excess and is then ready for further preparation.

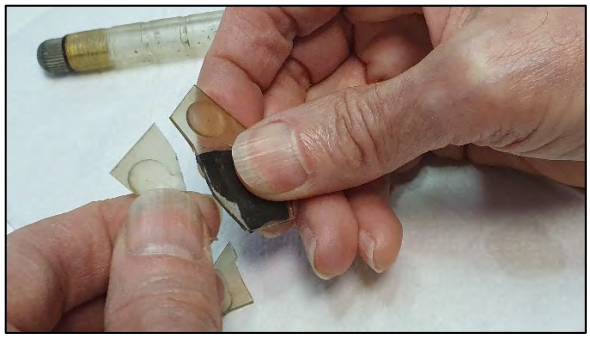



Fig 10 - Removal for final thin section bonding & preparation

Samples 1 & 4 requiring both block & thin sections have their separate mounts impregnated when required and sized to fit the 48 x 26 mm slides. Excess resin has been removed from Sample 4 & will also be removed from Sample 1. Samples are then ready for bonding to glass slides using a suitable resin; In this case a UV curing option is used.



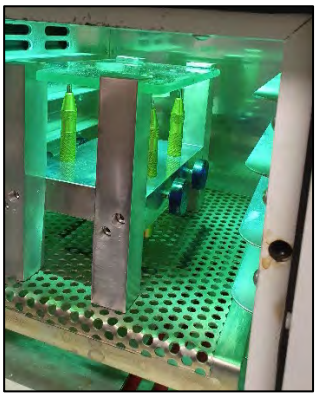



Fig 11 - Ready for mounting, adhering to the glass slides, jigging & UV cure

Fully adhered, the mounted slides require grinding from their current 1 – 2 mm thickness to a nominal thickness of 100 um prior to final grinding and polishing to 30 um.

The use of a Diamond Cup Grinding wheel with the Brillant 220 Vacuum system enables this to be done efficiently and automatically. Just select the start position & the amount of material to be removed and the Brillant 220 can accurately and careful reduce the sample to the correct thickness leaving minimal damage for the final stages of preparation.

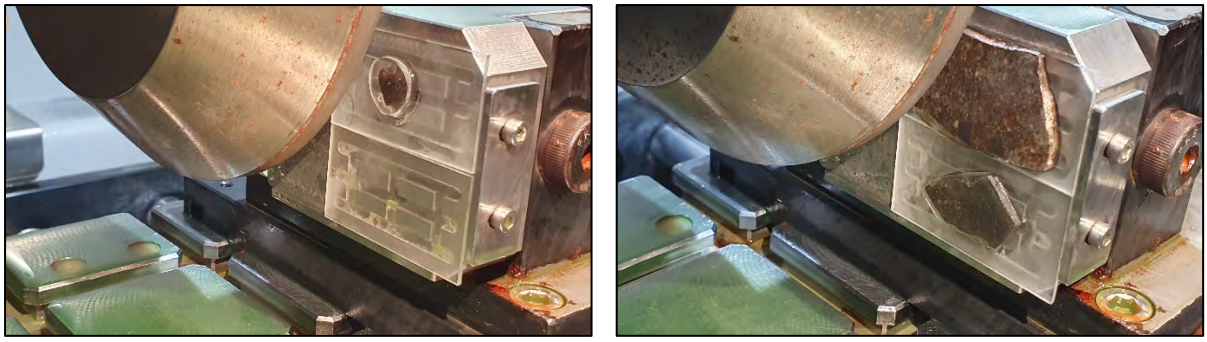


Fig 12 - Single & multiple slides ready for their final precision grind

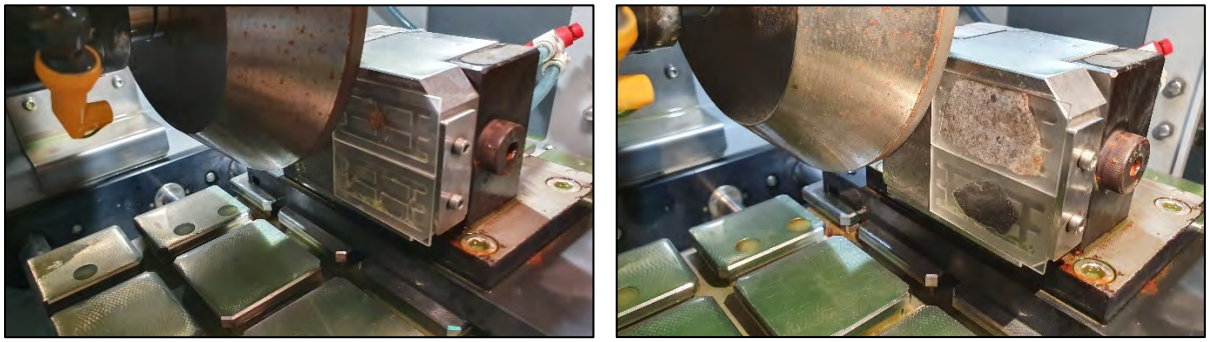


Fig 13 - Fully thinned sections ready for final preparation

Grinding & Polishing

Grinding either by fixed diamond Cameo discs or Silicon Carbide followed by Alumina or Colloidal Silica as a polishing stage is all that is needed to create suitable polished blocks for analysis. This can be done manually or semi automatically. Polishing is typically by a chemotextile cloth such as Planocloth with 0.3um Alumina. Similar for thin sections too. These samples were prepared by the traditional method.

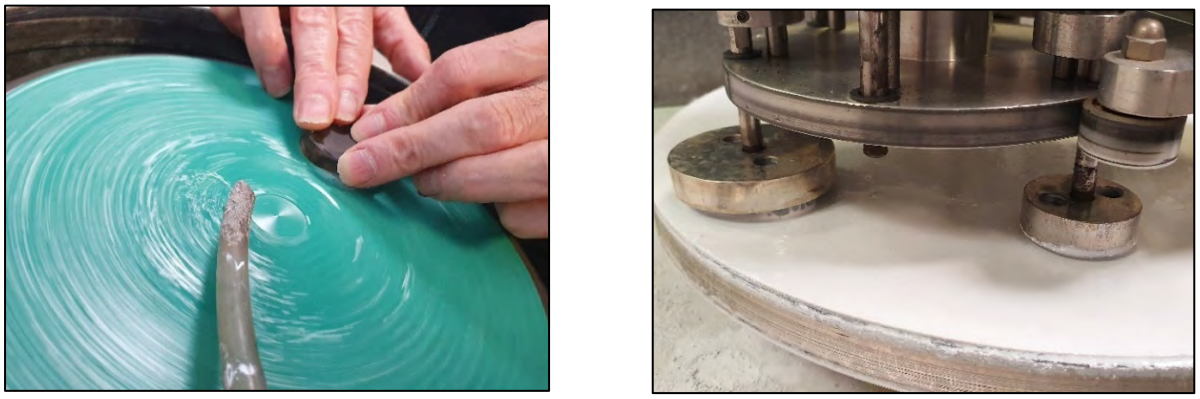
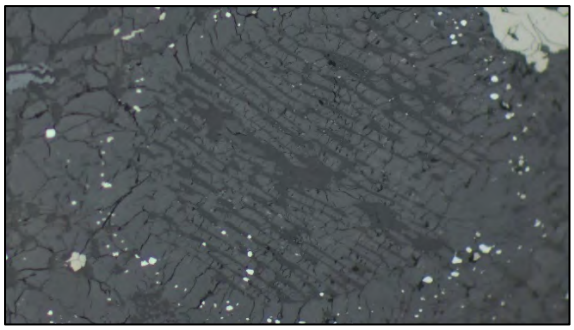


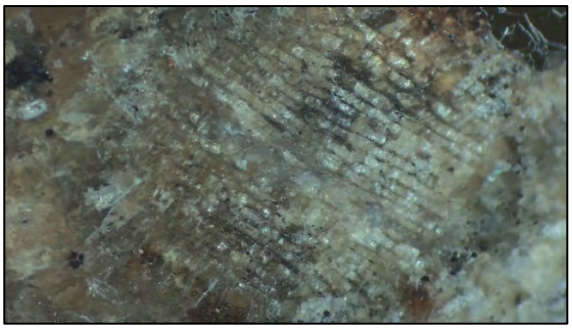
Fig 14 - Grinding & Polishing

Microscopy of resultant samples – Assorted contrast techniques

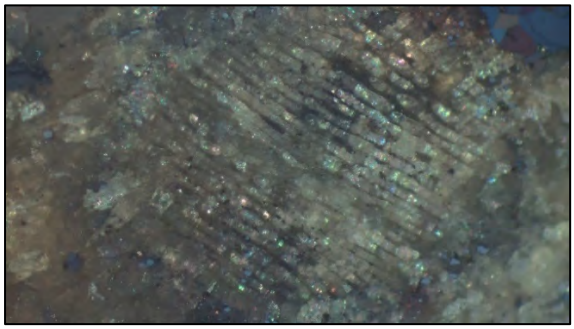
Region 1 - FOV 1.2 mm wide



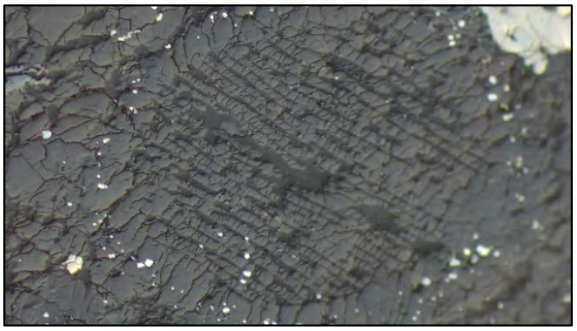
Typical Chondrule – Brightfield Illumination



Typical Chondrule – Darkfield field Illumination

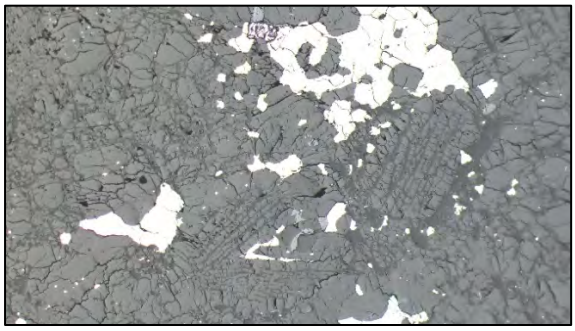


Typical Chondrule – Crossed Polars



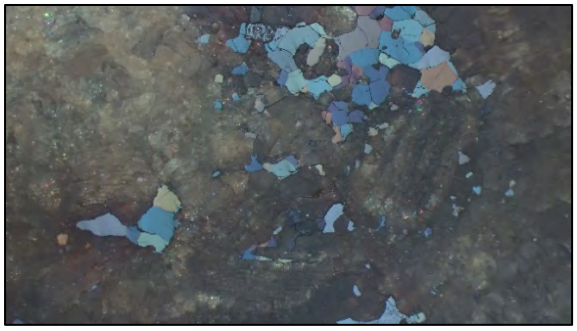
Typical Chondrule – DIC

Region 2 - FOV 2.2 mm wide

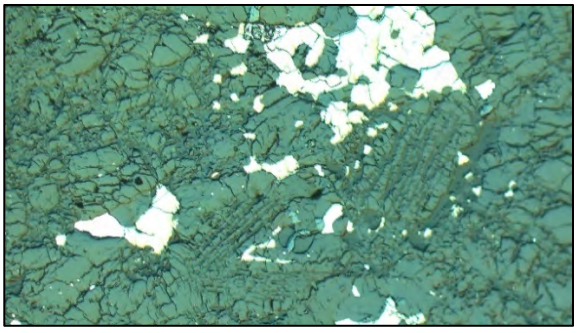


Region of high reflectivity – Brightfield

Region of high reflectivity – Darkfield



Region of high reflectivity – Crossed Polars



Region of high reflectivity – DIC

Fig 15 - Light microscopy of the Chelyabinsk block- Zeiss Axiolab 5 & Axiocam 208 reflected light

Additional to general structure micro analysis was required on the Chelyabinsk meteorite. This was carried out using the Tescan Vega 3 SEM and Aztec analysis package of the Chondrule region.

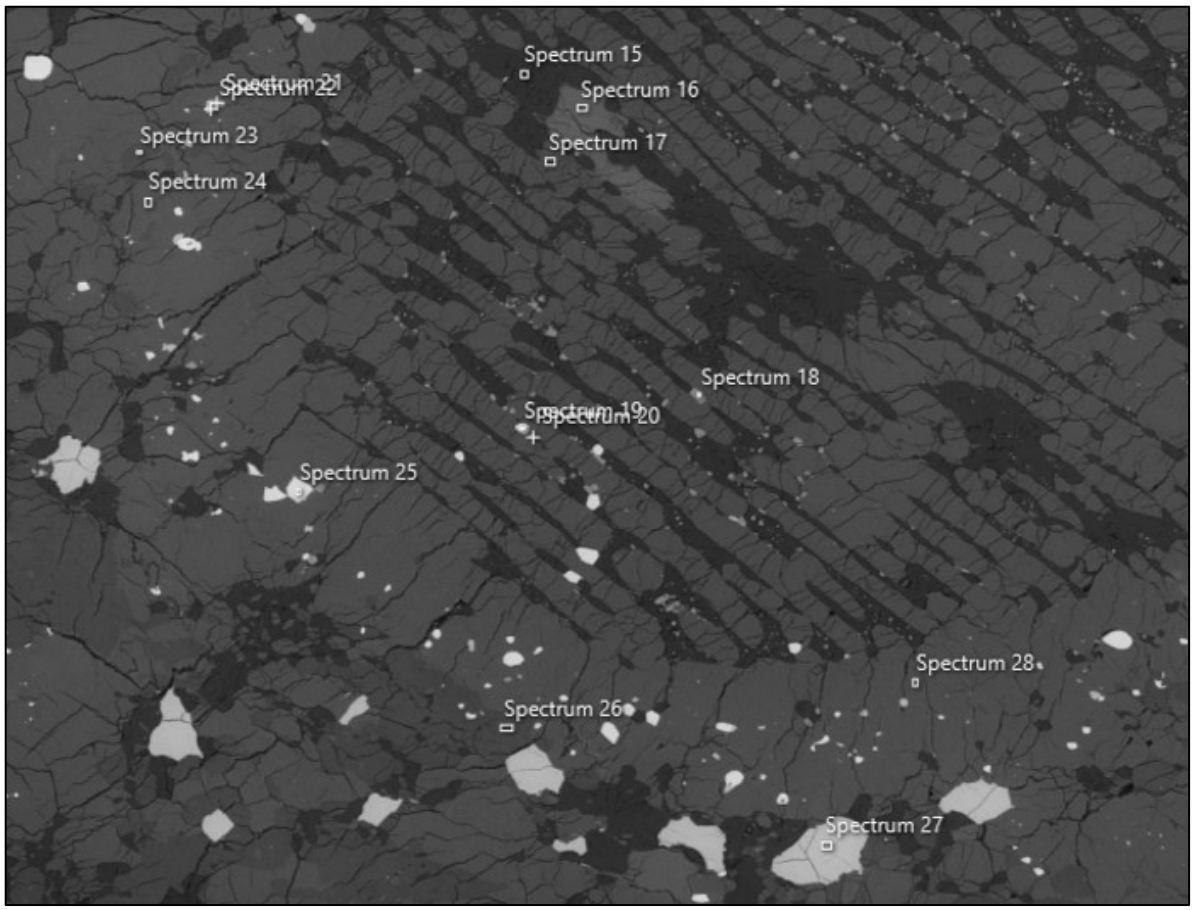



Fig 16 - Back Scattered Electron image showing points of analysis in Chondrule region.

| Spectrum Label | Spectrum 15 | Spectrum 16 | Spectrum 17 | Spectrum 18 | Spectrum 19 | Spectrum 20 | Spectrum 21 | Spectrum 22 | Spectrum 23 | Spectrum 24 | Spectrum 25 | Spectrum 26 | Spectrum 27 | Spectrum 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 5.39 | 4.21 | 4.00 | 3.63 | 5.03 | 4.01 | 6.32 | 4.29 | 3.86 | 3.33 | 3.26 | 4.03 | 5.02 | 2.73 |
| O | 48.29 | 48.20 | 46.98 | 41.65 | 24.25 | 41.04 | 29.79 | 25.69 | 47.49 | 47.23 | 23.17 | 48.34 | 24.65 | 46.22 |
| Na | 4.77 | 1.37 | 1.04 | 1.44 | 1.26 | 1.19 | 0.67 | 0.80 | 0.74 | 0.50 | 0.72 | 0.57 | 0.80 | 0.53 |
| Mg | 5.53 | 5.55 | 16.02 | 8.52 | 10.25 | 9.24 | 8.79 | 11.71 | 12.37 | 17.84 | 11.58 | 14.59 | 6.85 | 17.56 |
| Al | 6.90 | 1.64 | 1.82 | 3.44 | 1.89 | 2.97 | 0.92 | 1.27 | 1.01 | 0.90 | 1.24 | 1.03 | 1.15 | 1.09 |
| Si | 20.66 | 7.47 | 15.74 | 9.86 | 10.27 | 9.52 | 8.17 | 10.29 | 18.86 | 15.86 | 10.10 | 18.78 | 7.66 | 16.12 |
| P | 0.31 | 9.39 | 0.52 | 0.10 | 0.06 | 0.03 | 0.04 | 0.13 | 0.02 | 0.08 | 0.02 | 0.07 | 0.04 | 0.05 |
| S | 0.35 | 0.24 | 0.21 | 0.24 | 0.34 | 0.23 | 16.44 | 0.83 | 0.39 | 0.39 | 0.35 | 0.82 | 20.02 | 0.54 |
| Cl | 0.07 | 2.10 | 0.13 | 0.01 | 0.04 | 0.04 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.03 | 0.00 | 0.03 |
| K | 0.46 | 0.17 | 0.14 | 0.12 | 0.16 | 0.09 | 0.12 | 0.08 | 0.07 | 0.07 | 0.04 | 0.03 | 0.07 | 0.03 |
| Ca | 1.22 | 13.70 | 1.07 | 0.38 | 0.36 | 0.32 | 0.44 | 0.54 | 5.39 | 0.46 | 0.36 | 0.61 | 0.61 | 0.46 |
| Ti | 0.01 | 0.00 | 0.02 | 0.35 | 0.00 | 0.41 | 0.00 | 0.05 | 0.08 | 0.02 | 0.00 | 0.05 | 0.02 | 0.03 |
| V | 0.03 | 0.00 | 0.04 | 0.18 | 0.01 | 0.17 | 0.05 | 0.05 | 0.03 | 0.00 | 0.04 | 0.00 | 0.00 | 0.01 |
| Cr | 0.08 | 0.14 | 0.13 | 14.47 | 0.43 | 14.23 | 0.12 | 0.07 | 0.26 | 0.10 | 0.10 | 0.11 | 0.13 | 0.09 |
| Mn | 0.08 | 0.05 | 0.19 | 0.16 | 0.08 | 0.30 | 0.14 | 0.07 | 0.22 | 0.31 | 0.07 | 0.26 | 0.14 | 0.25 |
| Fe | 5.80 | 5.66 | 11.93 | 15.42 | 34.89 | 15.93 | 27.88 | 38.55 | 8.90 | 12.76 | 37.98 | 10.50 | 32.56 | 14.09 |
| Ni | 0.06 | 0.11 | 0.01 | 0.04 | 9.43 | 0.29 | 0.11 | 5.57 | 0.21 | 0.14 | 10.96 | 0.17 | 0.25 | 0.17 |
| Er | | | | | 1.25 | | | | | | | | | |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

Fig 17 – Individual analysis of the Chondrule region locations.

Comparing the analysis with that described in Chelyabinsk Superbolide (*ref 1*) this puts the Chelyabinsk meteorite into the ordinary Chondrite class of LL, Petrological Type 5 – An LL5 Chondrite.

Additional to point analysis of the various features on the prepared samples X-Ray mapping using EDS (Energy Dispersive Spectroscopy) has been employed to indicate variations in compositions across typical features.

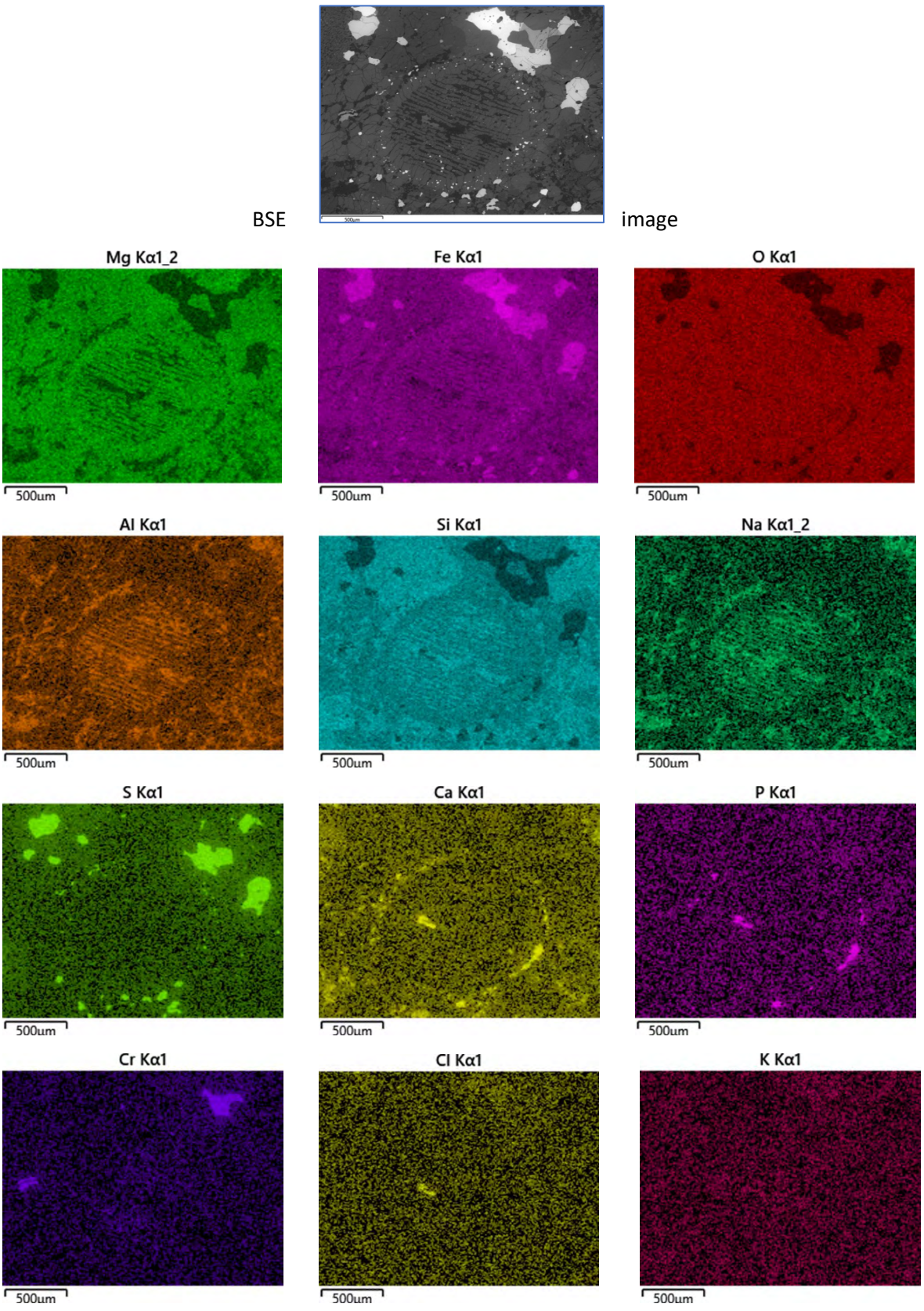
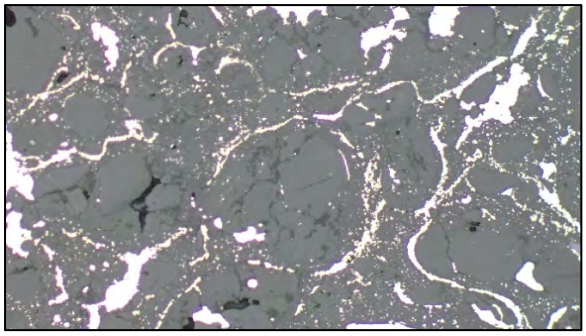
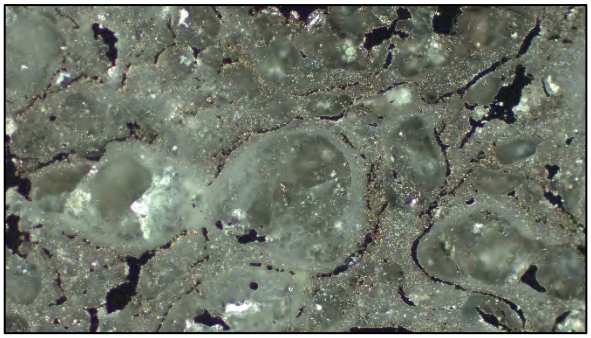


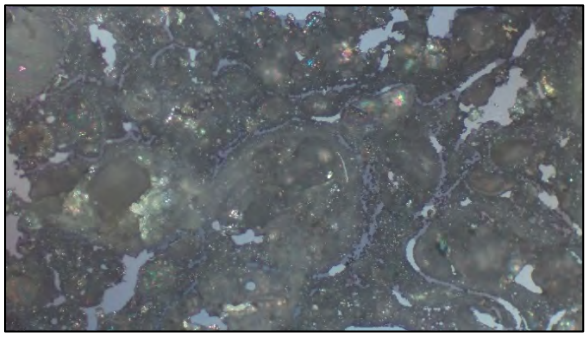

Fig 18 – X-Ray mapping of the major elements found in the sample



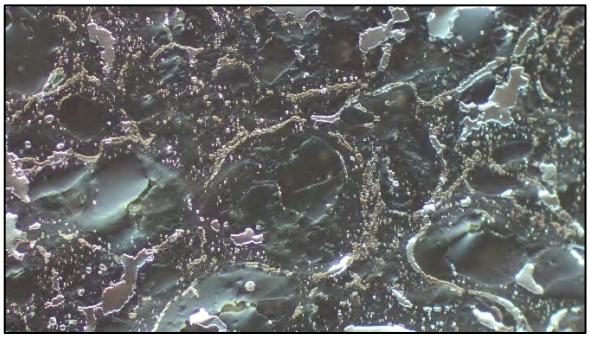
Typical Chondrule – Brightfield Illumination



Typical Chondrule – Darkfield field Illumination

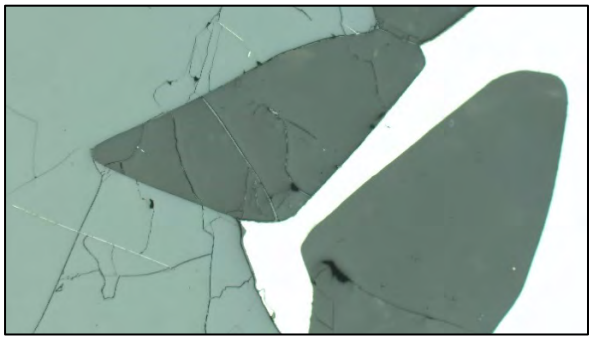


Typical Chondrule – Crossed Polars

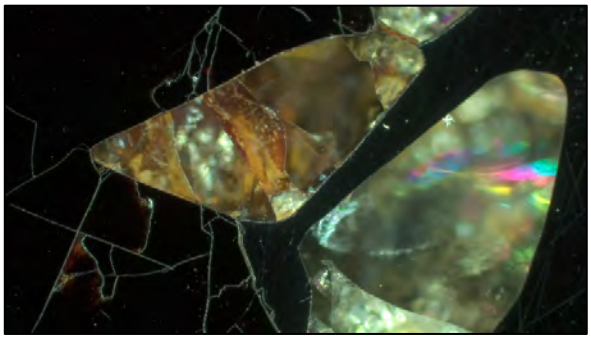


Typical Chondrule – DIC

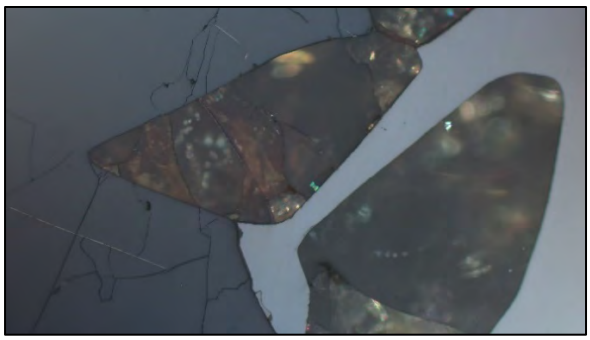
Fig 19 - Light microscopy of Sample Breccia block- Zeiss Axiolab 5 & Axiocam 208 ref light FOV 1.2mm



Typical Pallasite region – Brightfield Illumination



Typical Pallasite region – Darkfield Illumination

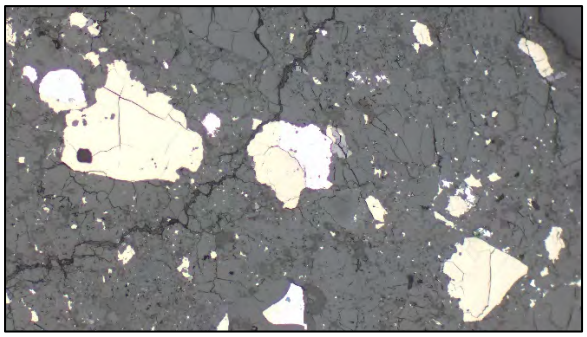


Typical Pallasite region – Crossed Polars

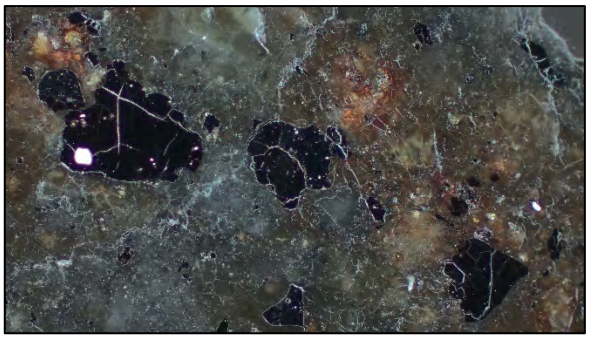
Typical Pallasite region – Darkfield DIC

Fig 20 - Light microscopy of Sample 3 Seymchan - Zeiss Axiolab 5 & Axiocam 208 ref light FOV 2.2mm

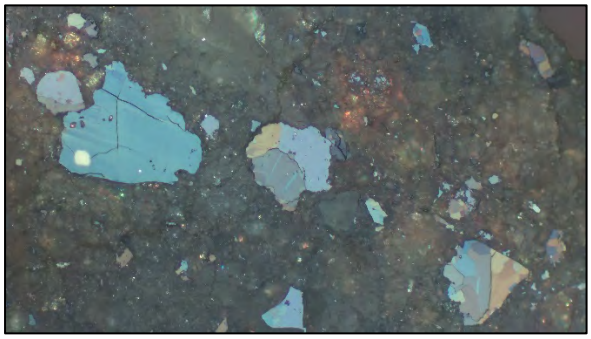
Region 8 - FOV 1.2mm wide



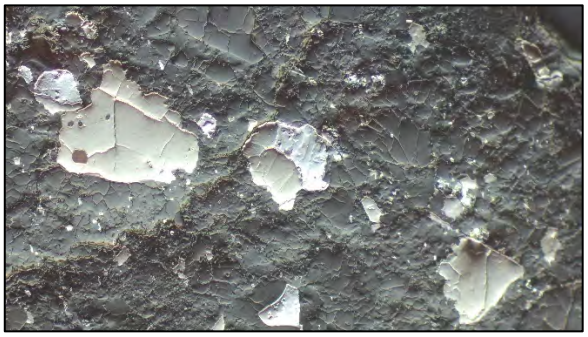
Region of high reflectivity – Brightfield



Region of high reflectivity – Darkfield



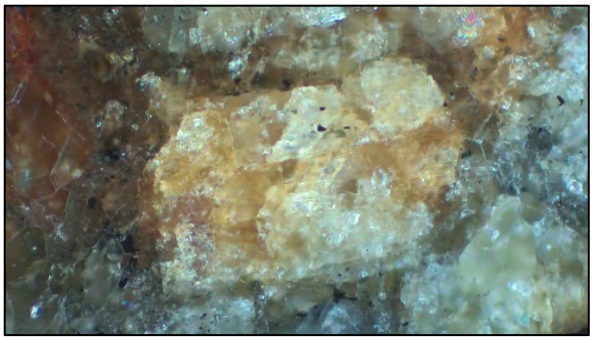
Region of high reflectivity – Crossed Polars



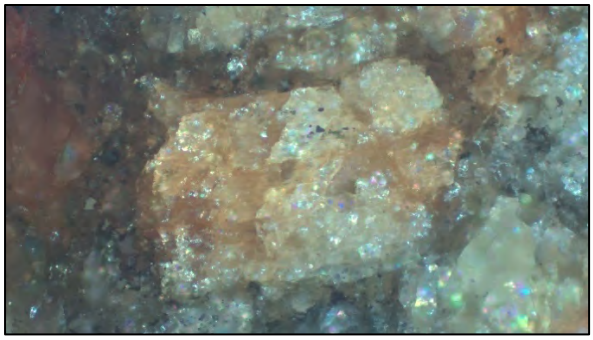
Region of high reflectivity – DIC

Region 9 - FOV 1.2mm wide

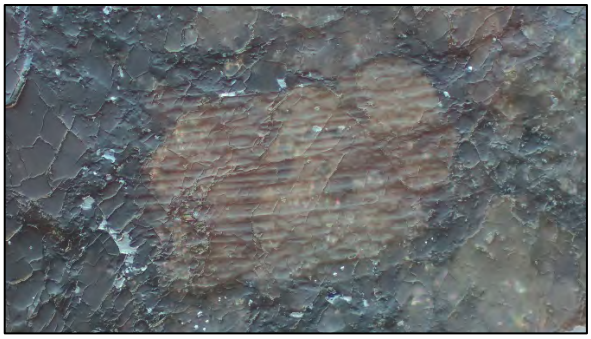
Typical Chondrule – Brightfield Illumination



Typical Chondrule – Darkfield field Illumination



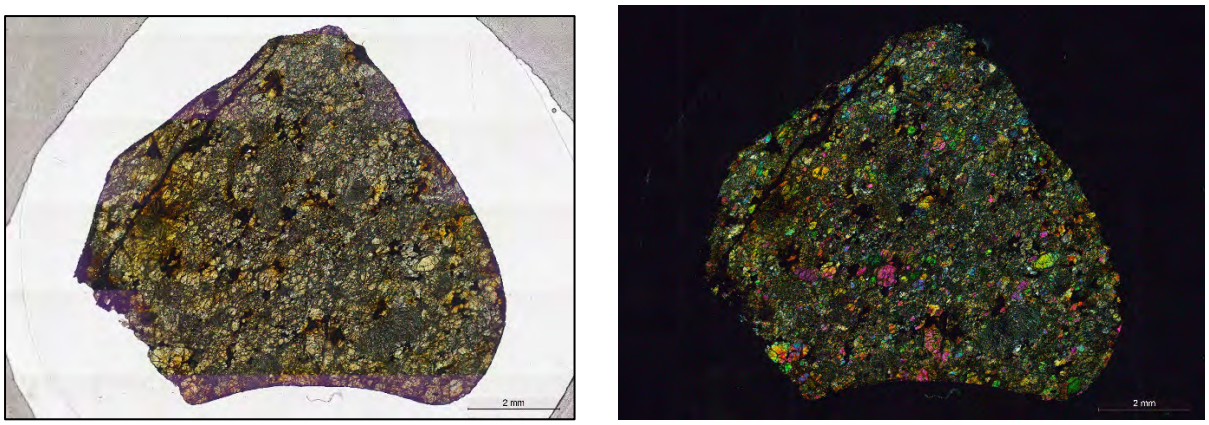
Typical Chondrule – Crossed Polars



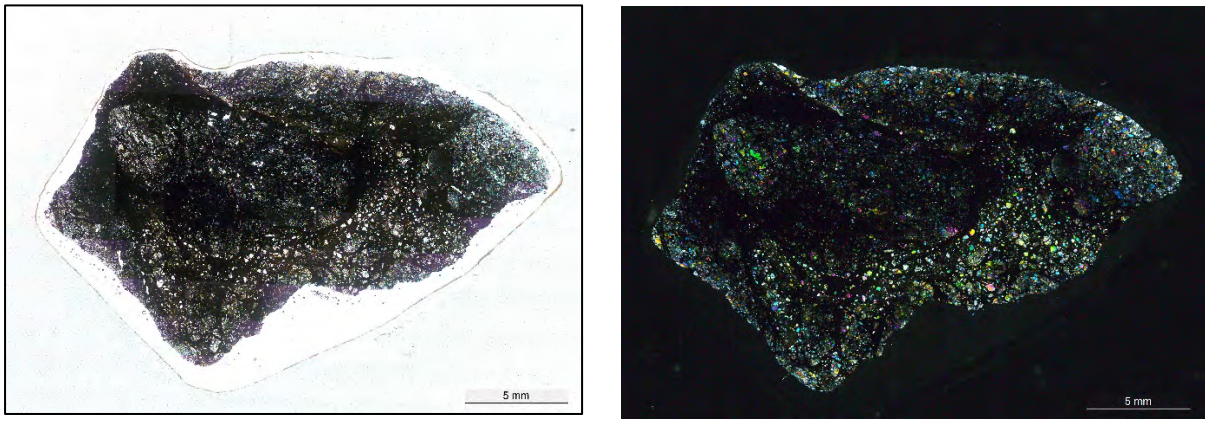
Typical Chondrule – DIC

Fig 21 - Light microscopy of the Niger NWA block- Zeiss Axiolab 5 & Axiocam 208 reflected light

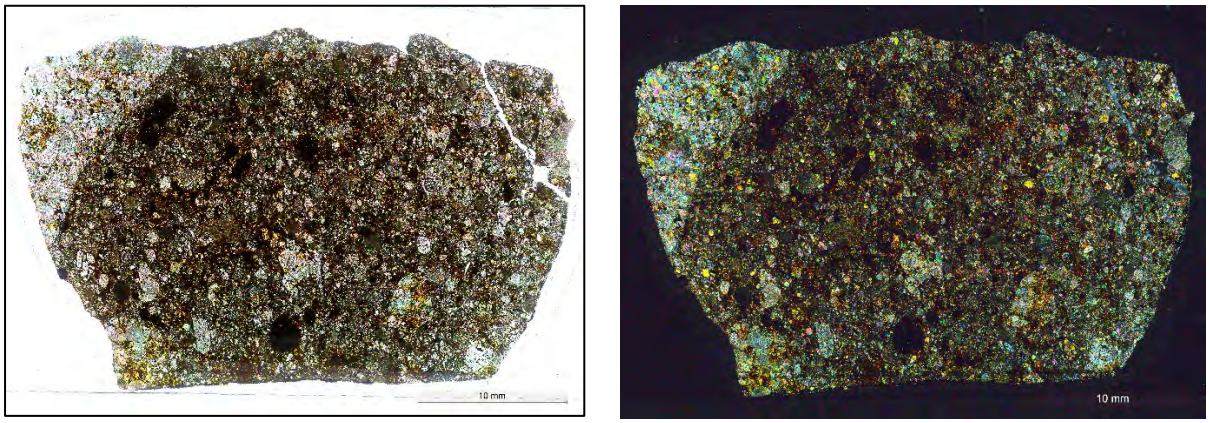
Light microscopy of the Chelyabinsk sample – Plain & Crossed Polarised light




Light microscopy of the unclassified impact melt – Plain & Crossed Polarised light




Light microscopy of the NWA Niger sample – Plain & Crossed Polarised light




Thin Section imaged using a Leica DM4000 using Power Mosaic to automatically scan the complete area of thin section.

Fig 22 - Light microscopy of the Thin sections, plain & crossed polarized light

Summary

The accuracy, flexibility & quality of the Brillant 220 and its associated accessories allows the operator a huge range of options when preparing samples such as meteorites. The wide variety of properties of such materials are easily catered for with the comprehensive range of accessories that are available both for cutting and holding these fascinating materials. Care taken at the cutting stage using the correct clamps, correct blades and followed by suitable preparation, full analysis of such materials is possible with ease and speed.

Acknowledgements

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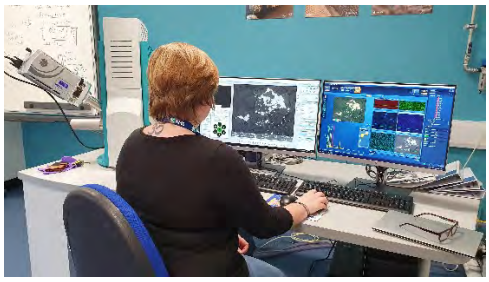
Tony preparing to section the large sample on the Brillant 220

Additional thanks to Christine & Stephanie Kimpton, Cranfield University for the SEM & Analysis services. In particular Stephanie for her hands operation as we worked our way through the samples and regions.


Steph creating elemental maps of the assorted regions

Thanks also to Michelle Higgins at the Open University – Dept of Earth Sciences for the large area thin section imaging.


Michelle preparing the large format thin section images.

References

1) Chelyabinsk Superbolide – Gorkavyi, Dudorov, Taskaev – Springer ISBN 978-3-030-22985-6

Additonal information

The MetPrep web site can be found at https://metprep.co.uk/

Further information on the Brillant 220 Precision Cutter can be found here

http://metprep.co.uk/wp-content/uploads/2016/02/brochure_cutting_brillant220_en.pdf

Assorted vices & accessories particular to the Brillant 220 can be found here

https://metprep.co.uk/equipment/cutters/brillant-220-accessories/

Information on the Diamond Cup Grinding discs

https://metprep.co.uk/product-category/consumables/grinding-stones-cup-grinders/diamond-cup-grinding-wheels/

Specialist vices for assorted cutters can be found here

http://metprep.co.uk/wp-content/uploads/2016/03/Special-solutions-brochure.pdf

Details concerning the Cameo fixed diamond grinding discs can be found here

http://metprep.co.uk/wp-content/uploads/2016/09/Cameo-Grinding-Disc-Platinum-2016-0008-B.pdf

An overview of our Zeiss microscope equipment can be found at

https://metprep.co.uk/equipment/microscopes-zeiss/

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