TURNING TISSINT INSIDE OUT; SEARCHING FOR ITS LAUNCH PAIR(S) FROM MARS N. R. Stephen[1, 2], M. J. Genge[2], S. S. Russell[1] and P. F. Schofield[1], [1] Department of Earth Sciences, The Natural History Museum, Cromwell Road, London, SW7 5BD, UK (*Email*: n.stephen@nhm.ac.uk) [2] Department of Earth Science & Engineering, Imperial College London, South Kensington, London, SW7 2AZ, UK.

Introduction: DaG476 (BM2000, M7), EET79001 *(loan)* and SaU005 (BM2000, M40) are all shergottites suggested to be the result of the same lauch event as Tissint (BM2012, M3) [1]. Our previous study [2] revealed both mineral and melt inclusions within the available sections of Tissint, predominantly composed of feldspathic glass and maskelynite alongside both clinopyroxenes, pigeonite and augite, with minor sulphides and phosphates. Melt inclusions have been reported previously in Shergottite meteorites although their occurrence is not common [e.g. 3, 4]. Also noted in previous studies [1, 2] is the lack of twinning and exsolution lamellae in Tissint when compared to DaG476, EET79001 and SaU005.

In this study, we aim to analyse the individual silicate minerals within the Tissint meteorite; characterising them in terms of their mineralogy and varying crystallographic orientations, as well as the overall petrology. Fully characterising the mineralogy should allow for further discussion regarding the magmatic history of the particular source region on Mars from which Tissint and the other suggested launch-paired shergottites are thought to have originated. We expect that these detailed analyses, alongside their extracted mineral spectra [2, 5], will eventually aid in the spectral unmixing (or "*deconvolution*") of spacecraft data by providing a more accurately characterised spectrum for each Martian-specific mineral phase.

Samples & Analytical Techniques: 4 polished, resin mounted sections were produced in-house from the Tissint meteorite held at the Natural History Museum (NHM) in London, UK. X-ray element and back-scattered electron maps were obtained using both the Zeiss™ EVO 15LS and LEO 1400VP variable pressure SEMs and quantitative geochemical data from the Cameca™ SX-100 microprobe, both housed within the NHM. Element maps of these sections were extracted using the Oxford Instruments INCA® software.

We have determined the relative modal abundance of each phase in a powdered bulk sample of the Tissint meteorite using Position Sensitive Detector X-Ray Diffraction (PSD-XRD) and a pattern stripping technique [6, 7] at the NHM in London. Quantitative assessment of maskelynite is achieved by difference due to the lack of a suitable maskelynite standard [8]. Whilst previous work has confirmed the accuracy of this method when compared to point-counting techniques [8], we are still attempting to source a suitable maskelynite standard to further constrain these data.

Electron-backscatter diffraction (EBSD) was conducted using the CamScan™ SEM setup at the University of Liverpool, UK using the HKL and American Mineralogist phase databases for band-matching. Further processing of the acquired data was completed using the Oxford Instruments HKL Channel 5® software.

Results & Discussion: Modal heterogeneity within the Tissint meteorite is comparable to other olivine-phyric, or picritic, shergottites; traditional point-counting techniques along with more modern pixel-counting techniques [9] are hampered by thin section bias whereas XRD provides a more representative bulk analysis [8]. Table 1 illustrates how our new modal analysis of Tissint compares to prior studies [10] of the shergottites with which it was reportedly launch-paired. Whilst mineral assemblages are similar, Tissint contains a noticeably larger proportion of Ca-rich augite than its counterparts; a low augite percentage being a defining property of this picritic group [3]. The larger proportion of phosphates (namely merrillite) also seen in Tissint possibly suggests a different magmatic history to that of the DaG476, EET79001 and SaU005 meteorites, where fewer late-stage crystallization products are observed.

	Tissint	DaG476	SaU005	EET79001
Pigeonite	25.7	42	36.4	38
Augite	29.2	13	16	16
Olivine	21.9	28	24.8	14
Maskelynite	17.2	12	18.2	29
Opaques	3.7	0.6	2.4	2
Phosphate	2.4	0.4	0.6	1
Calcite	0	4	1.6	0

Table 1: Modal proportions of each phase within the Tissint meteorite and its suggested launch-pairs; data presented are averaged modes taken from various techniques including both PSD-XRD and pixel-counting in this study.

Melt Inclusions within Tissint: Detailed descriptions of melt inclusions within SaU005 and EET79001 can be found in [3] and as in Tissint, are predominantly composed of plagioclase glass/maskelynite and clinopyroxene, both augite and pigeonite. The inclusions within Tissint, however, are more variable in size. Unlike in SaU005 and EET79001 chromite-hosted inclusions are not seen; instead sulphides are hosted within the large olivine macrocrysts.

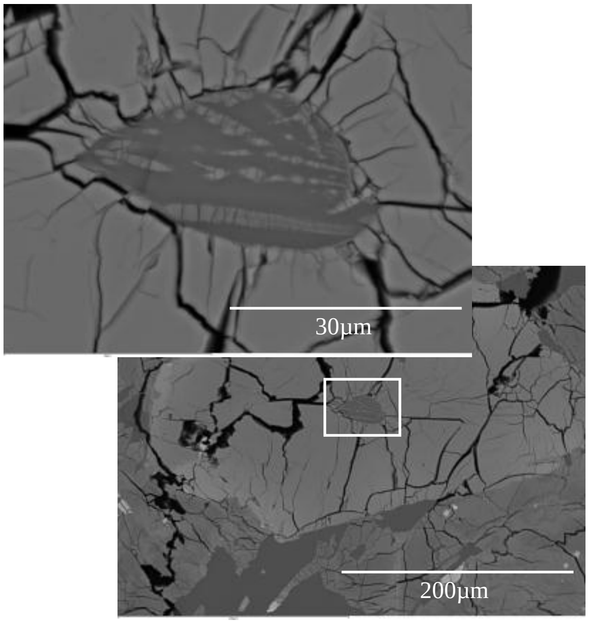

Figure 2: An olivine-hosted melt inclusion in Tissint. The macrocrystic olivine hosts a range of inclusions varying in shape, composition and size. Inclusions are most commonly plagioclase glass or maskelynite with skeletal pyroxene crystals (largely augite) contained within.

EBSD orientation analysis suggests magmatic history: Whilst our studies of olivine-phyric shergottites indicated no definitive preferred orientation of the silicate phases, EBSD analyses on Tissint reveals a positive alignment of the constituent pyroxenes, in particular, Ca-rich augite. The alignment can be seen along the long (100) axis; more typically indicative of settling deeper within a magma chamber rather than near-surface or surficial flow, where clustering would be around one of the shorter (010) or (001) axes.

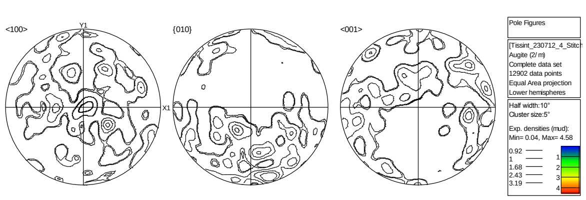

Figure 3: Equal area, lower hemisphere pole figures for augite within Tissint. Clustering around the {010} plane can be seen with a potential alignment at the (100) axis, illustrated here by the pole-to-plane illustration, <100> and <001>.

CT imaging of Tissint: Small chips of Tissint were scanned using CT to reveal the internal structure of Tissint without sectioning and, therefore, without producing a bias. As in previous studies [12] potential pore spaces were present within Tissint as well as large areas of maskelynite and the 'black glass' [1]. CT scans also revealed melt pockets and mineral inclusions within the large (<3mm) olivine macrocrysts. In some regions, olivine macrocrysts looked to be filling the pore or void spaces within the meteorite. A significant proportion of the larger macrocrysts appear to be fully euhedral within Tissint unlike their counterparts in DaG476, EET79001 and SaU005.

Conclusions: Whilst secondary crystallization of fluids occurring after initial crystallization at or near the Martian surface *could* account for the mineralization in the meteorite as suggested by [1], this new work alongside our previous study [2] suggests that the magma was potentially emplaced deeper below the Martian surface within the magma chamber and as a result, Tissint has a cumulate texture. Tissint is probably not a launch pair for EET79001, DaG476 or SaU005 as previously suggested.

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