REDUCED MACROMOLECULAR CARBON AND ELEMENTAL SULFUR IN NORTHWEST AFRICA 8159: IMPLICATIONS FOR OXYGEN FUGACITY OF THE MARTIAN MANTLE. A. C. O'Brien[1], L. Hallis[1], A. Steele[2] and M. R. Lee[1] [1]School of Geographical and Earth Sciences, University of Glasgow, Glasgow, UK, a.obrien.1@research.gla.ac.uk, [2]Geophysical Laboratory, Carnegie Instute, Washington DC.

Introduction: Macromolecular carbon (MMC) inclusions have been found within magmatic minerals, such as pyroxene and olivine, in numerous martian meteorites [e.g. 1-3]. MMC is identified by its characteristic Raman D (disordered carbon) and G (graphite) peaks at ~1350 and ~1580 cm^{-1}, respectively [1]. These inclusions consist of reduced polycyclic aromatic hydocarbons as well as abiotic MMC, and are of astrobiological interest because such molecules are the building blocks of terrestrial organic life. Future Mars rover instrumentation, such as the Mars Organic Molecule Analyser (MOMA) onboard ESA's ExoMars rover, will search for organic material [4]. Determining the structure of organics found in martian meteorites will aid the interpretation of such martian surface data.

MMC has been found within a variety of martian meteorite falls and finds, and there are two main hypotheses for its origin. The MMC could have been deposited on Mars by carbonaceous chondrite meteorites, because reduced carbon can survive impact events and can then be incorporated into planetary magmatic processes [5]. The other hypothesis is that the MMC is indigenous to Mars and was synthesized through basaltic volcanic processes [1]. Steele et al. (2012) argue that the latter process is a better explanation for the origin of MMC, but the martian mantle must have had a low oxygen fugacity for such reduced organic materials to form [1]. Confirming whether or not MMC is martian in origin will allow us to further characterize the planet's carbon cycle, continuing the work of [6] in constraining martian magmatic-carbon reservoir interactions.

The augite-dominated basaltic meteorite Northwest Africa 8159 (NWA 8159) is a unique, recently discovered shergottite with an early Amazonian crystallization age. The meteorite's isotopic composition, high oxygen fugacity and low-La/Yb ratio suggest a unique mantle source [7].

Herd et al. (2017) suggest that the oxygen fugacity of NWA 8159 increased during its crystallization history, perhaps through introduction of an oxidizing fluid, whereby the initial fO_2 was <QFM (quartz-fayalite-magnetite buffer) in order for olivine to remain stable. The fO_2 of the melt then increased to QFM ~ +2 such that olivine phenocryst rims were replaced by orthopyroxene and near end-member magnetite as a result of the subsolidus reaction outlined in equation 1:

$$6Fe_2SiO_4 + O_2 = 2Fe_3O_4 + 6FeSiO_3 \quad (1)$$ [7].

Modelling by Bell et al. (2015) suggests that this subsolidus reaction can occur between QMF -1.9 at 700 ºC and QMF -1 at 1000 ºC [8].

Here we present new Raman data from MMC inclusions within NWA 8159, which include the discovery of elemental sulfur, and we discuss the implications of these obervations for understanding the redox characteristics of NWA 8159.

Sample Preparation: In order to limit the risk of contamination by epoxy resin the meteorite chip was coated in gold-palladium prior to being set in epoxy. It was then ground to ~ 30 µm thickness, polished and mounted upon a glass slide. Epoxy resin has distinctive Raman peaks in the 2900-3100 cm^{-1} region [9]. Figures 1 and 3 are examples of the spectra taken, which lack any such epoxy peaks, thus demonstrating that this method has successfully inhibited ingress of the resin. The MMC inclusions selected for analysis were < 20µm in size, fully enclosed in mineral grains below the thin-section surface, and located away from fractures, thus significantly reducing the likelihood of terrestrial contamination [1].

Methods: Optical Microscopy was carried out at the University of Glasgow to locate potential regions of MMC within primary magmatic minerals. We analysed the sample using an α-scanning near field optical microscope, adapted to incorporate confocal raman spectroscopy, at the Carnegie Institute's Geophysical Laboratory, Washington DC. The presence of MMC was verified in one region of interest and elemental sulfur in another. Feldspar was also studied in order to constrain the intensity of shock metamorphism.

Results and Discussion: Our results support the hypothesis of Herd et al. (2012) [7], that during the initial period of NWA 8159 crystallization conditions were reducing (Figures 1-5). MMC species require a low oxygen fugacity to be maintained, as does elemental sulfur, perhaps constraining the initial melt conditions to be more reducing than those suggested by [7].

The presence of plagioclase feldspar (labradorite) is consistent with the conclusion by [7] that this meteorite was shocked to no more than 15-23 GPa, since feldspars amorphize at higher shock pressures [7].

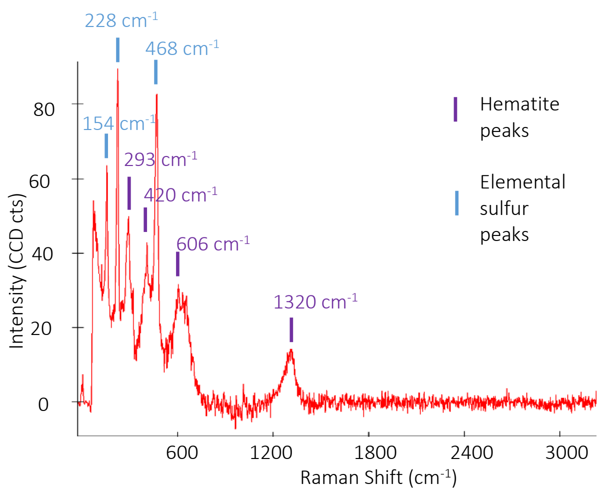

Figure 1. Raman spectrum of the elemental sulfur inclusion, located 1.4 μm below the surface of the NWA 8159 thin section. Hematite (violet) and elemental sulfur (blue) peaks are clearly identified, indicating clear association of these minerals, as displayed in Figs 2A and B.

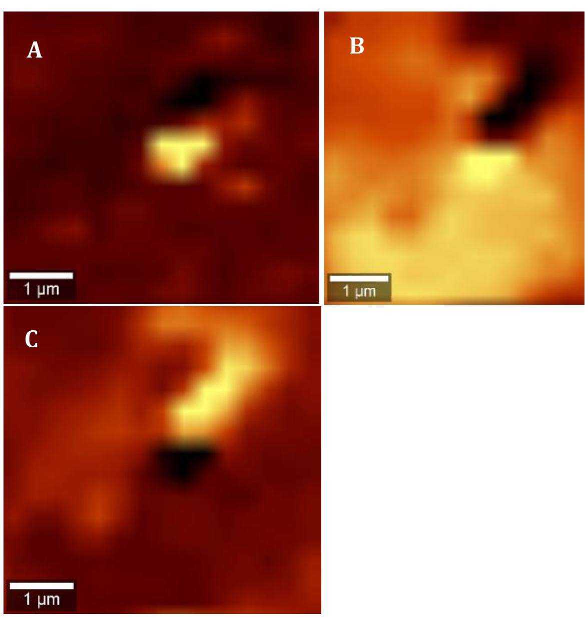

Figure 2. Raman maps of the peak intensities of elemental sulfur (A), hematite (B), and augite (C). Brighter regions indicate greater peak intensities.

Future Work: We plan to extract MMC and elemental sulfur inclusions from the thin-section using the focused ion beam (FIB) technique at the University of Glasgow, and subsequently determine the molecular structure of the MMC and find any possible nitrogen present using X-ray absorption spectroscopy (XANES) at Diamond Light Source, UK. The MMC structure will be compared to the structure of organic materials found in carbonaceous chondrites, in order to determine whether or not they are a likely source of the substance.

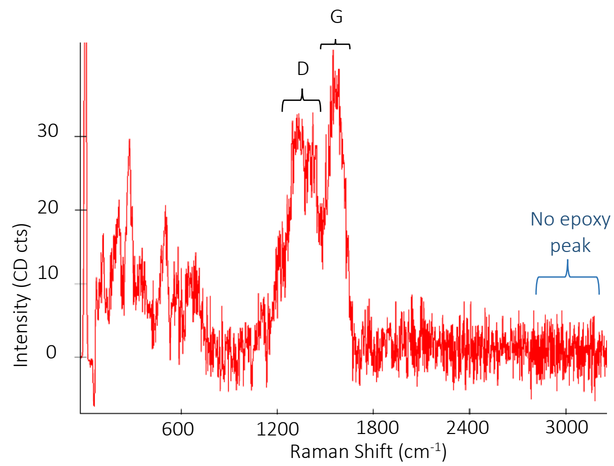

Figure 3. Raman spectrum of the MMC inclusion found 1.06 μm below the surface of the NWA 8159 thin section. MMC's D and G peaks are indicated whereas no peaks are present in the characteristic epoxy region (2900 cm^{-1} – 3100 cm^{-1}).

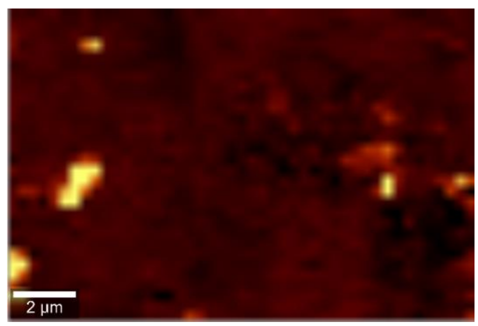

Figure 4. Map of the intensity of MMC Raman signal. Brightest regions represent areas of highest peak intensity.

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