BULK AND THERMAL PROPERTIES OF PLANETARY ANALOGUE SIMULANTS AND MARTIAN METEORITES.

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Introduction: Planetary analogue materials and meteorites are windows into solar system evolution. They provide invaluable insights into the composition and geological processes that formed, and continue to shape, our solar system. Previous investigations into planetary materials such as these have involved microscopic and spectroscopic techniques [e.g. 1, 2]. However, there is an emerging research area using scattering techniques to investigate the bulk properties of these extra-terrestrial materials [3]. In this study we will concentrate on Martian materials, simulants and meteorite samples, and their comparison to both primitive early solar system material and lunar surface.

Both ESA and NASA produce and curate simulant materials for various planetary bodies [4,5]. There are a number of active sample return missions, with further missions scheduled to Mars within the next few decades. Interest in benchmarking simulant materials and their properties relative to “real” extra-terrestrial samples is growing.

Martian meteorites: There are 224 identified Martian meteorites on Earth [6]. The chemical compositions and textures of Martian meteorites record a large variability in Martian crustal processes over billions of years, as well as the violent events that removed them from the surface of the planet itself.

Asteroidal Meteorites: Chondritic meteorites are taken to represent the bulk composition of the proto solar nebula. As such, they contain the building blocks from which the solar system evolved.

Phase one of this project produced room temperature high resolution diffraction patterns of a suite of meteorites, both asteroidal and Martian in origin, as well as for analogue simulants designed to simulate a range of planetary bodies. Synchrotron XRD represents a fast way to gain detailed bulk mineralogy of these samples to complement and add to the existing data.

Phase two of the project will investigate the thermal behaviour of these materials, both the meteorites and the analogue simulants, upon heating, melting and re-crystallisation and cooling. This will simulate metamorphic processes on the planetary bodies (heating) and formation processes (cooling).

Comparison of the behaviour of the bulk compositions of the Mars simulant material with the more variable Martian meteorites will give insights into not only early Martian processes, but will allow us to test the validity of the simulants as an analogue. These will also be compared to asteroidal meteorite samples as a base line for the original bulk solar system composition. The cooling rates available in this experiment are much faster than those of the early solar system. However, this study will provide insight into the crystallisation sequence and compositional variations with cooling in these systems. It forms a preliminary study for a long duration experiment where much more precise temperature control and slower cooling rates can be achieved through an experiment lasting months rather than hours.

Samples:

Simulants:	Martian meteorites:	Asteroidal meteorites:
NASA JSC1A – Mars regolith	Zagami – basaltic shergottite	Ordinary Chondrite: Chelyabinsk
UCF MGS-1 Mars	Tissint – basaltic shergottite	Carbonaceous chondrite: Allende
UCF JEZ-1 Mars	NWA 7034 “Black beauty” – basaltic breccia	Pallasite: NWA 5693
NASA JSC1A – Lunar regolith	NWA 10441 - gabbroic shergottite	
ESA EAC-1 Lunar regolith	NWA 10645 - Nahklite	
ESA 16NO01 Lunar highland	NWA 2737 Chassignite	

Experimental Method: Samples are micronized and then hand ground before being loaded into 0.7 mm quartz or sapphire glass capillaries. Capillaries were loaded onto the Powder Diffraction beamline at the Australian synchrotron [7]. Datasets were collected at a wavelength of 0.774802(1) Å as determined using NIST SRM LaB_6 660b.

Data were collected using the Mythen microstrip detector [8], from 3.5 – 78.5° 2Theta. To cover the gaps between detector modules, 2 datasets were collected with the detector set 5° apart and then merged to a single dataset. Collection time for each detector position was 300 seconds for room temperature datasets and 60 seconds for variable temperature datasets. Synchrotron datasets were merged using in-house data processing software, PDViPeR, available at the Australian synchrotron powder diffraction beamline.

Samples were heated using either a Cyberstar hot air blower (preliminary experiments to 920 °C) or Stoe capillary furnace (to 1100 °C). Capillaries were heated at 5° C per minute from 30 °C – final temperature, held for 1 hour and then cooled at 1°C per minute and rotated at c. 1Hz while datasets were contiguously collected.

Preliminary results: This work is ongoing. Exemplar room temperature data is shown in Figure 1 for a) ESA Lunar Analogue 16NO01 b) Tissint, c) Pallasite NWA5693. Descriptions of the variation in mineralogy, compositions and discussion about relative crystallinity/amorphous content will appear in the full contribution.

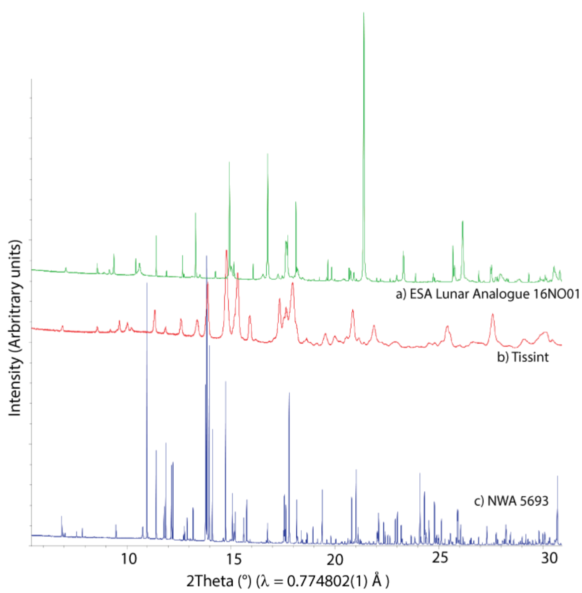

Figure 1. Room temperature diffraction patterns for a) ESA Lunar Analogue 16NO01 (green), b) Tissint (Red), and c) NWA 5693 (Blue).

Variable Temperature: Initial results are presented from the heating of the Martian meteorite Tissint. Figure 2 shows a section of a stack of diffraction patterns showing the evolution of the mineral phases with time as the Tissint sample was heated. It shows both the development of new phases (e.g. Ilmentite), as well as changes in the intensity and position of persistent phases. This hints at changes in the composition of these phases with time and temperature. This will be discussed in depth and with relation to the other samples in the full contribution.

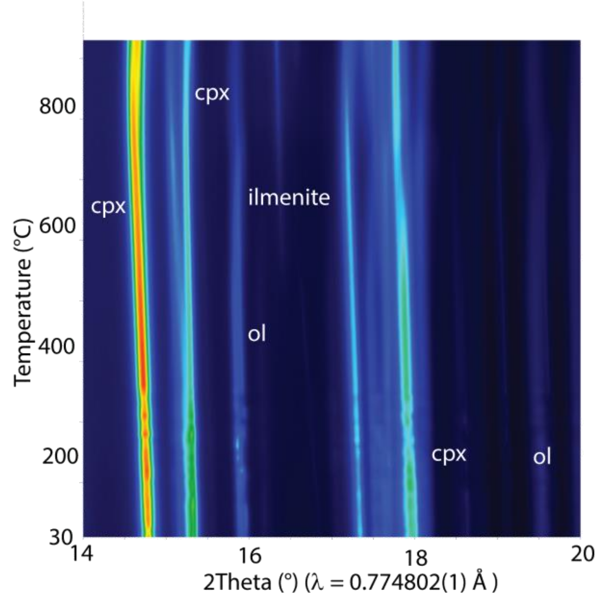

Figure 2. 2D representation of time resolved diffraction data as viewed down the intensity axis of stacked patterns upon heating of Tissint from room temperature to 920 °C.

Acknowledgments: This research was carried out on the powder diffraction beamline at the Australian synchrotron.

References:

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