RECONNAISSANCE MICRO-XRD STUDIES OF METEORITES: RAPID *IN SITU* MINERAL IDENTIFICATION AND TEXTURAL INFORMATION.

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Micro X-ray Diffraction (µXRD) is a versatile technique in geoscience[1]. In meteoritics, it is particularly useful for non-destructive mineralogical analysis at 500 to 50 µm scale. It is also ideal for *in situ* studies of whole-rock specimens, cut surfaces and thin sections, providing mineral identification using crystal structural parameters.

Our µXRD data were collected with the Bruker D8 Discover diffractometer at the University of Western Ontario (UWO), operating with Cu Kα radiation (λ = 1.5418 Å) at 40 kV and 40 mA. A two-dimensional (2D) General Area Detector Diffraction System (GADDS) also enables detection of textural features such as crystallite size, alignment, and strain-related mosaicity. Large crystals give single X-ray diffraction spots, whereas randomly-oriented microcrystallites give complete and homogeneous Debye rings. Most natural textures lie somewhere between these two extremes. Minerals which have undergone inhomogeneous strain, such as induced by a shock event, give X-ray patterns in the form of partial diffraction lines, or streaks.

Previous workers have observed strain-related mosaicity or asterism in meteorites using Debye Scherrer X-ray cameras[2,3]. This has been experimentally related to shock state[3,4]. Horz et al.[4] observed the Debye Scherrer XRD patterns of experimentally shocked minerals to proceed from spots in unstrained single crystals to streaks, after applying moderate shock pressure, to virtually-continuous (polycrystalline) rings with increasing shock pressure. Eventually some minerals gave no coherent pattern at all, indicating complete amorphization.

Previous X-ray techniques have required disaggregation of the meteorites and removal of selected minerals. Micro X-ray diffraction enables *in situ* reconnaissance study of individual mineral grains with their natural context preserved, with a spot size of 500 µm to 50 µm. The examples shown herein demonstrate the breadth of information that can be obtained by reconnaisance µXRD of planetary materials.

Rapid mineral ID - Toluca Iron Meteorite: The Toluca (Mexico) iron meteorite exhibits a Widmanstätten pattern caused by the exsolution of kamacite from taenite upon very slow cooling. The unit cell dimensions of kamacite are different than taenite, making their d-spacings distinguishable on the GADDS image as distinct arcs with different 2θ values (Fig 1). Using µXRD, the presence of these two minerals – an indicator of extraterrestrial origin - can be tested rapidly *in situ*. Furthermore, the Widmanstätten pattern can be reproduced by 2D mineral mapping of the meteorite's surface without etching the sample.

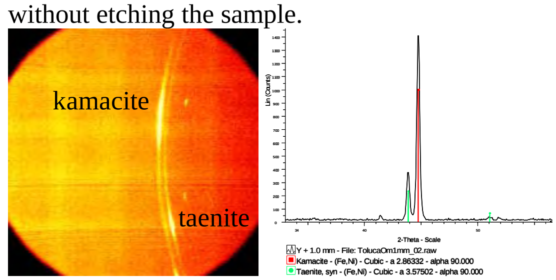

Fig 1. GADDS image and resulting XRD pattern of a 500 µm location on the Toluca iron.

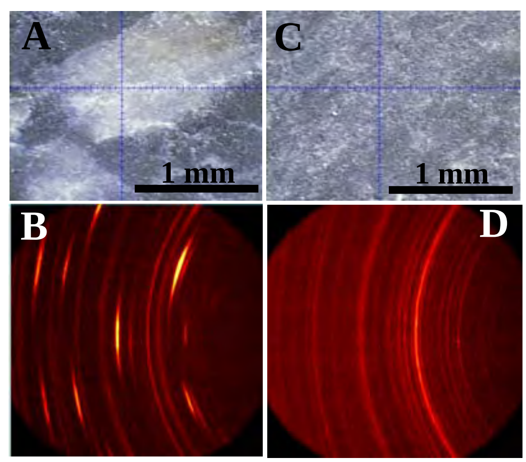

Fig 2. Paired context video image and GADDS image of 500 µm locations on a cut surface of lunar melt breccia DaG 400, showing (A,B) an anorthite xenocryst with mosaicity, and (C,D) dominantly anorthitic polycrystalline matrix.

Mineral ID and textural information – DaG 400: DaG 400 is a Lunar melt breccia[5] consisting dominantly white relict anorthite grains (Fig 2a) set in a fine grained gray matrix (Fig 2c). The GADDS images from the relict grains (Fig 2b) showed partial diffraction lines, or streaks, indicating a high mosaicity of the anorthite lattice. The gray matrix consists mostly of microcrystalline anorthite Debye rings (Fig 2d), along with minor pyroxene.

Shock-related mosaicity - Martian shergottite NWA 3171: µXRD confirmed the major crystalline components in NWA 3171 to be two pyroxenes - augite and pigeonite. Mineralogy of shergottites is typified by the amorphization of plagioclase to maskelynite, due to the low tensile strength of plagioclase. Pyroxene, on the other hand, has high tensile strength[3] and has retained its crystal structure with some mosaicity (Fig 3b). Pyroxene from glassy areas in NWA 3171 showed polycrystalline rings of augite only (Fig 3d), which likely crystallized from a shock-related partial melt associated with the ejection event.

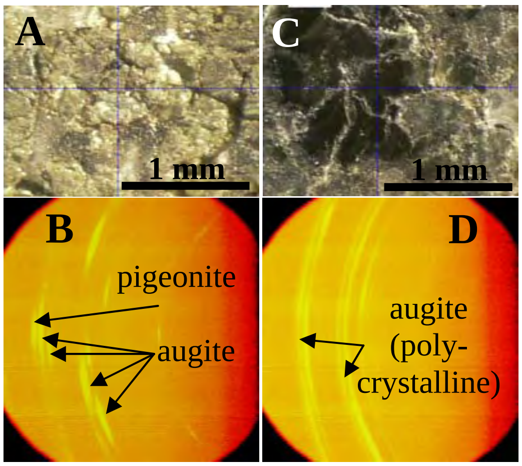

Fig 3. Paired context video image and GADDS image of 500 µm locations on a cut surface of shergottite NWA 3171, showing (A,B) two pyroxenes with some mosaicity, and (C,D) a melt pocket exhibiting the two pyroxenes as a polycrystalline texture.

Comparison of relative strain in Diogenites: Diogenites Dhofar 700 and NWA 2038 are both enstatite cumulates; the µXRD confirmed ferroan enstatite to be the dominant mineral present. Dhofar 700 exhibited relatively minor mosaicity (Fig. 4), likely reflecting a low shock stage whereas NWA 2038 showed partial diffraction rings suggestive of greater shock deformation (Fig. 5).

Additional information available from µXRD: µXRD data can be used to determine unit cell parameters as potentially sensitive indicators of chemical composition. Reconnaissance µXRD data can also provide contextual information to aid Rietveld refinement of the modal mineralogy for complex natural samples (see Izawa et al., this meeting).

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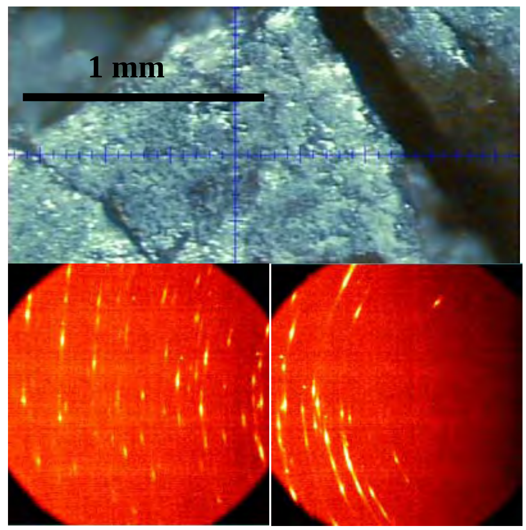

Fig 4. Context image and GADDS images of a 500 µm location on Dhofar 700.

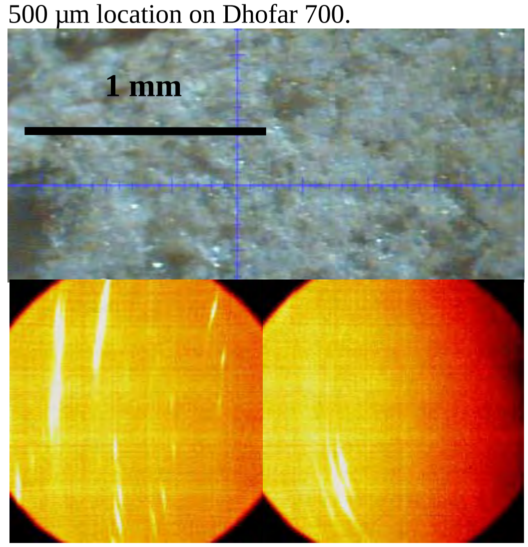

Fig 5. Context image and GADDS images of a 500 µm location on NWA 2038.