THE ALLENDE METEORITE: A CASE STUDY FOR ALL THE FAMILY? H. E. A. Brand and D. Martin, Australian Synchrotron, 800 Blackburn Rd., Clayton, VIC3168, Australia. helen.brand@synchrotron.org.au.

Introduction: The Allende meteorite is the most studied meteorite, possibly the most studied rock assemblage, in the world. The meteorite has an extremely well documented history and relatively large, gram-sized samples can be obtained easily for relatively low cost. The heterogeneity of the meteorite lends itself to study by many different techniques as is evidenced by the wealth of high-quality publications produced on a range of topics. Indeed, the Allende meteorite has an enviable *h*-index of 124, with more than 68,240 citations*.

The broad reach of this sample, together with pre-existing data from many documented studies, makes the Allende meteorite an excellent example sample with which to showcase the capabilities of a suite of complementary instruments such as those found at a large central facility; in this case the Australian Synchrotron. It also provides opportunity for the development of a number of outreach tools targeted at particular stakeholder groups at different technical skill levels. These can be integrated with online platforms and social media tools to find a wider audience and become an educational resource for the broader community.

At present the resources are under development specifically with respect to the Australian Synchrotron and this contribution is aimed at raising awareness and garnering support, suggestions and expertise from the planetary science community to help this project grow beyond the facility.

The Allende Meteorite: The Allende meteorite is a "fall", a meteorite seen entering the atmosphere, and tracked to impact. It fell over the Mexican state of Chihuahua in February 1969 and to date over 2 tonnes of material have been recovered. This makes it the largest of its type ever found, collected from one of the largest recorded strewnfields. The fall occurred at a fortuitous time, with the world enthused to planetary exploration and research thanks to NASA's efforts to land on the moon. Thus, much effort has been afforded to studies of this meteorite.

The Allende meteorite is a CV3 type carbonaceous chondrite; a stony meteorite. Lithologically, Allende is a breccia. It is composed of abundant mafic chondrules and calcium-aluminium inclusions (CAIs), within a dark matrix. Unusually, for a chondrite, there is almost no iron-nickel metal present. CAIs are thought to be the earliest solids in the solar system [1], while chondrules are thought to be the earliest reworked materials, representative of dust and earlier chondrule generations [2]. Almost every diagnostic geochemical test has been performed on this rock, with it becoming a standard material for several.

Australian Synchrotron (AS): The AS is a powerful source of electromagnetic radiation that produces photon energies up to 3 GeV. A user facility, the AS supports 4800 users to carry out 1000 experiments a year on 10 beamlines, producing >500 publications per year.

The suite of beamlines at the AS covers a range of techniques from spectroscopy to diffraction and a broad range of the electromagnetic spectrum from high energy (~100 keV) X-rays to the infrared region. This allows flexibility in the experiments carried out on different beamlines, and each beamline is optimised to fulfill a particular demand in the scientific community.

Access to the facility is largely via peer reviewed merit application with a small proportion (~10%) paid industry work. Users are typically academics or from universities or government research institutes based in Australia, New Zealand and throughout the Asia-Oceania region.

Stakeholder groups:

General Public and Education: Planetary sciences are popular with the general public as a research tool. They represent an easy way to enthuse the public interest in a facility with which they generally do not directly interact. Integration of this program with existing tools such as websites and open day self-guided tours will allow explanations of the technology and techniques using concepts that the public are already invested in and familiar with.

Scientists – Users, New and Old: Pitched at a more scientifically literate audience, potential and existing users of the facility can be educated on applications of synchrotron techniques to answer their scientific questions. It can also be used to aid preparation for experiments, e.g. by providing sample preparation instructions for each beamline. Existing users can learn about complimentary techniques, and datasets with well-documented outcomes could be provided as tutorial material aimed at teaching users how to approach data analysis.

Industry: Engaging with industry is a growing remit for facilities everywhere as more funding becomes linked to industry integration. This sector can be treated as having a similar skill level to the user community.

Government: Securing funding for operational and capital growth is an ongoing challenge for major facilities. Demonstrating an ability to engage a diverse range of stakeholder groups is of great importance when lobbying government, and this case study would also provides an opportunity to educate government departments about outcomes from the facility.

Tools: A variety of collateral will be developed to engage the various groups. As much as possible, existing platforms will be leveraged in order to avoid the need to develop tools at a cost. Such existing platform would likely include social media websites(e.g. *Facebook*, *Twitter*, *Wordpress)* and the existing facility website, for factsheets and turorials. Information sheets and posters in the facility could then include content linked to the online tools mentioned above, through QR codes, or similar.

Exemplar Data: This section will briefly introduce 3 of the beamlines and give examples of the data produced. Only 3 are presented here in the interests of brevity. These and other exemplar data will be presented in more detail in the poster submission.

Powder Diffraction (PD): The PD beamline at the Australian Synchrotron has been designed to be ideal for time-resolved, *in situ* X-ray PD experiments requiring high resolution data collection under a variety of conditions replicating industrial and environmental conditions throughout the solar system.

In this case, the beamline has been used to determine the mineral phases present in the matrix of the Allende meteorite on heating from room temperature to 900°C. Figure 1 shows stack of diffraction patterns showing the evolution of the mineral phases with time.

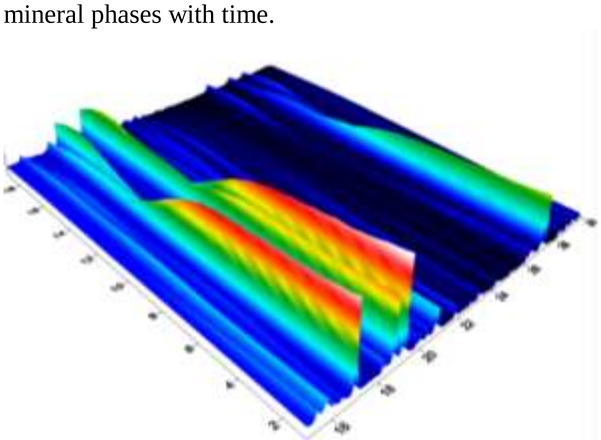

Figure 1. 2D representation of time resolved diffraction data. X-axis is 2Theta, Y is time. Each increment is 50°C, and Z is intensity (arb. units).

The X-ray Fluorescence Microscopy beamline (XFM): XFM is able to non-destructively map elemental abundance over a large (mm – cm sized) sample (such as a thin section) at sub-micron resolution, as well as providing tomographic information at a larger spacial resolution. Figure 2 shows a slice of the Allende meteorite, approximately 3 mm in length, mapped to ~5 µm resolution showing the abundances of Ca, Fe & Cr.

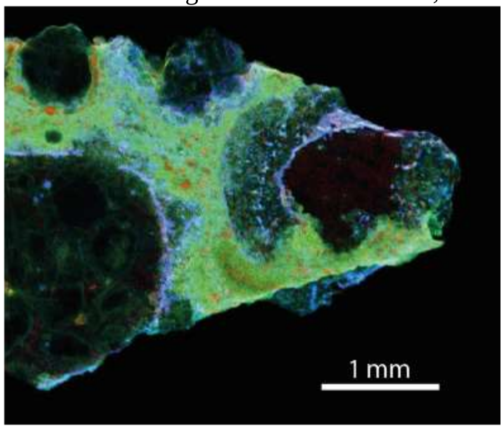

Figure 2. A false colour image of fluorescence from a small piece of the Allende meteorite. Red indicates calcium, green, iron, and blue, chromium.

The Imaging and Medical Beamline (IMBL): IMBL is one of only a few beamlines of its type, and delivers the world's widest synchrotron X-ray beam for imaging and radiotherapy applications. Key techniques at IMBL include: phase-contrast X-ray imaging and 2- and 3D imaging at high resolution (10 µm voxels) on large (handspecimen sized), samples. Figure 3 shows a raw contrast slice through an ~1 cm long piece of Allende at ~10 µm resolution.

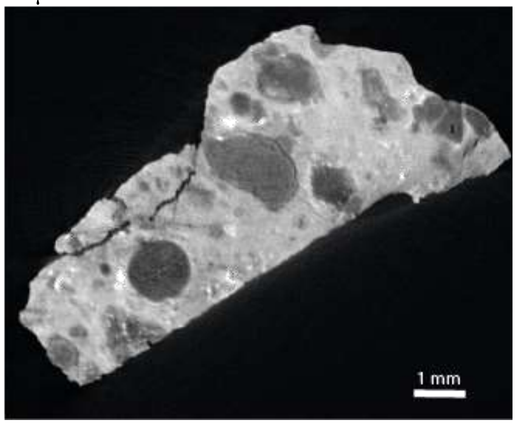

Figure 3. Raw image slice of a portion of the Allende meteorite. Greyscale variations indicate different X-ray scattering contrast.

References: [1] Jones R. H., *et al*. 2005. In *Chondrites and the protoplanetary disk,* 251–286. [2] Russell S. S., *et al.* 2006. *In Meteorites and the early solar system II,* 233–253. [3] Amelin and Krot (2007) *Meteorit. Planet. Sci. 7/8* 1321 – 1335 *taken from the first 1000 hits on google scholar.