PETROGRAPHY AND PROVENANCE OF TRIASSIC IMPACT EJECTA FROM SW ENGLAND, UNITED KINGDOM. S. J. Jaret[1] S. P. Hesselbo[2], E. T. Rasbury[3], and D. S. Ebel[1]. [1]Department of Earth and Planetary Sciences, American Museum of Natural History, NY, NY, 10024. [2]Camborne School of Mines, University of Exeter, Penryn, Cornwall, United Kingdom. [3]Department of Geosciences, Stony Brook University, Stony Brook, NY 11794. Sjaret@amnh.org

Introduction: The late Triassic to Early Jurassic is an important period in Earth's climatic and paleoevolutionary history both leading up to and after the end-Triassic mass extinction. This time period has been extensively studied in well-exposed and preserved sedimentary settings such as the Newark Supergroup in Eastern North America, the Junggar Basin in China and Mongolia, and in the Basin and Range of the Colorado Plateau [1-2].

One challenge in reconstructing the global climate record is the apparent lack of widespread volcanic marker units and therefore connecting these basins in time remains challenging. Impact ejecta deposits, however, may be extremely useful as a correlating marker because they are instantaneous deposits that can have near global coverage.

The Triassic is a known period of elevated impact events, with at least two large impacts over the span of 14 million years. These include the 85 km diameter Manicouagan impact structure, Canada, at 215.4 +/- 0.2 Ma [3] and the 45 km diameter Rochechouart impact structure, France, at 206.92 +/- 0.2 Ma [4]. Identifying and sourcing impact ejecta deposits in the late Triassic will thus be important for precise correlating during this critical time in Earth's history.

Methods: Optical microscopy was conducted on a standard polarized light microscope. Additional measurement of shock lamellae were conducted with a Leitz 5-axis universal stage mounted on a Nikon BH2 microscope. Electron microprobe X-ray elemental mapping was conducted on an SXFive-TACTIS at the American Museum of Natural History using an accelerating voltage of 15 kEv and 88 nA.

Samples (70 mg) for Nd isotope analyses were dissolved in nitric + HF followed by nitric + HCl. After dissolution, we followed a 2-step column chemistry: TRUSpec to isolate REE elements, followed by LNSpec for Nd separation. The Nd cut was diluted to 100 ppb and analyzed on a Nu II mulit-collector Inductively coupled plasma mass spectrometer (MC-ICP-MS) at Stony Brook University. Samples were bracketed by an internal 100 ppb Nd solution and standardized with 100 ppb jNdi solution.

Samples: Samples studied here are from the same suite as reported by Walkden et al. [5- 6] and lie within the Mercia Mudstone Group playa lake sediments, and sit at the base of a palaeo-escarpment formed of Carboniferous limestone [7]. The deposit is interpreted to have formed an unusually thick deposit by washing down the hill in mudslides, therefore likely containing some detrital material during deposition.

Petrography: In hand sample, the impactite bed occurs as a 7 cm green layer with a sharp erosion surface at its base. Green spherules 1 mm in diameter are visible in hand sample and occur within laminated layers. In thin section, the spherule bed appears laminated with both blocky calcite as well as fine-grained micrite lenses. Spherules occur in both the blocky calcite and micrite layers, with no apparent sorting.

In thin section, spherules are marked bythin yellowish rims which are translucent in plane polarized light. The interiors of the spherules have been replaced by calcite, with occasional spherules replaced by phosphate (Fig. 1). Spherules within spherules are common, and frequently occur with concentric rings (or parts of concentric rings). In cross-polarized light the outer rims of the spherules are nearly isotropic. Elemental X-ray mapping shows (Fig. 2) that the rim of the spherules are enriched in K, Al, Si, Mg, and Fe, consistent with slight alteration of the silicate glass.

Shock Petrography: Shocked quartz has been identified using standard petrographic techniques. Planar Deformation Features (PDFs) occurs as 1-2 micron parallel planes occurring with spacing between the planes of 3-4 microns (Fig. 3). Shocked quartz occur as 23 of 1260 total quartz grains (1.8%). They occur within the

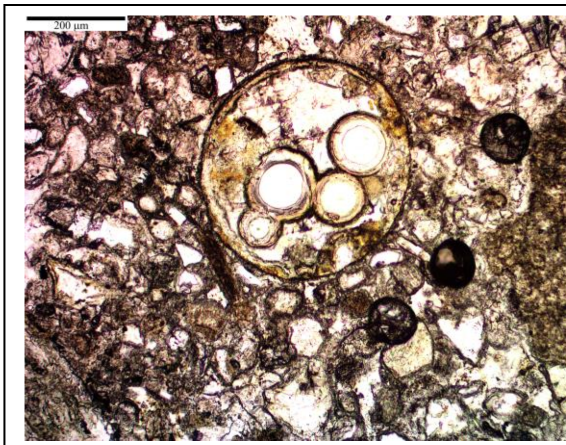

Figure 1: Plane polarized light image of the impact spherules, showing multiple spheres within a larger spherule.

matrix; no shocked quartz grains have been found within spherules.

With the exception of one grain, shocked quartz in these samples is dominated by a single deformation plane per grain. Even upon rotation with the universal stage, all shocked grains are nearly exclusively single-plane grains. One grain did appear to have multiple planes, but this grain was at the edge of the thin section and was not measurable under the universal stage. No other shocked phases were identified optically.

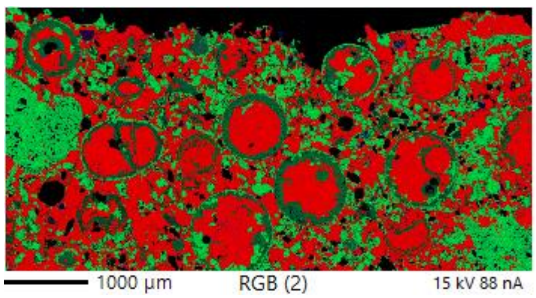

Figure 2: X-ray elemental map. Red= Ca, Green=K, Blue=Al. Spherules have a rim of slightly altered silicate glass, with interiors that have been replaced by calcite.

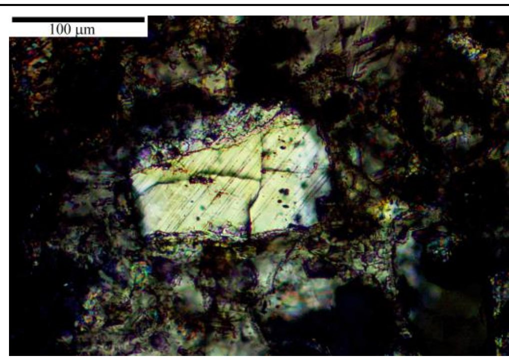

Figure 3: Shocked quartz grain showing 1 plane of PDFs.

Results and Discussion: This impact ejecta horizon has been previously described from the Triassic in SW England [5-7] The impact origin of the spherules was questioned [8-9], citing low numbers of shocked grains and lack of petrographic description of shock indicators. Here we have found more than 2 dozen shocked grains, of appropriate petrographic characteristics (see [10]) and therefore support the impact origin of the spherules and this deposit. Interestingly, the shocked quartz grains are overwhelmingly dominated by grains with only one set of PDFs. It is not uncommon for distal ejecta to be dominated by grains with only one set of PDFs particularly among distal ejecta (e.g., Western US K/Pg ejecta deposits from Colorado [11]), although usually a few more highly shocked grains are found. Our ongoing work includes additional searces for highly shocked quartz grains.

Nd Isotopes: Previous workers, particularly [5-6] have linked the ejecta in the UK to the Manicouagan impact, based on stratigraphy, argon geochronology, and heavy mineral (garnet) geochemistry. Given the large number of potential impacts during this time, age may not be a unique fingerprint for ejecta provenance in the later Triassic. Therefore we supplement previously used techniques with Nd isotope analyses.

Previous Nd studies of the Carboniferous and Triassic basins in the UK suggest the source of sediments is largely Variscan with εNd between -6 and -12. [12] On the other hand, Manicouagan target rocks have εNd values that range from -26 to -34. Impact melt rocks from Manicouagan have εNd values of -18 [13].

The ^{143}Nd/^{144}Nd ratio of this deposit is 0.511664. The εNd value for the sample is -19 relative to CHUR. The εNd values of this ejecta deposit are consistent with the Manicouagan melt sheet, and not consistent with the other Triassic impacts [14].

Nd isotopic studies are ideal for tracing ejecta deposits, particularly in the case where there are multiple impacts closely spaced in time, but into drastically different lithologies. Similar work has been done for the Eocene [14] but this is the first attempt to source ejecta using this method in the Triassic.

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References: [1] Kent and Olsen, (1999). JGR 104, 12,831-12,841. [2] Sha et al. (2015). PNAS 112, 3624-3629. [3] Jaret et al. (2018). EPSL 501, 78-89. [4] Cohen et al. (2017). 52, 1600-1611. [5] Walkden et al. (2002). Science 298, 2185-2188. [6] Thackrey et al. (2009). EPSL 285, 163-172. [7] Kirkham, A. (2003). Proc. of the Geologists' Assoc. 114, 11-21. [8] Glass (2003). Proc. of the Geologists' Assoc. 114, 175–179. [9] Koeberl (2003). Proceedings of the Geologists' Association 114, 175–179. [10] Ferrière et al. (2009) MAPS 44, 925–940. [11] Izett (1990). GSA Special Paper 249. [12] Leng et al. (1999). Petroleum Geoscience 5, 293-301. [13] O'Connell-Cooper et al. (2012), EPSL 335, 48-58. [15] Reimold et al. (1983). LPS XIV, pp. 636-639 [15] Liu et al., (2006). MAPS 41, 705-714.