THE IMPACT AND RECOVERY OF ASTEROID 2018.

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Introduction: Most Howardite-Eucrite-Diogenite meteorites recovered on Earth likely had their origin at asteroid 4 Vesta during an asteroid collision in the past 100 million years [1]. They either originated in a cratering event on Vesta itself or were the product of collisions with one of its Vestoids, an asteroid family created when the Veneneia and Rheasilvia impact basins were formed 1.0–4.5 Ga ago. Their cosmic ray exposure (CRE) age distribution has a significant peak, with about 1/3 of all HED having originated about 22 Ma ago in one or more significant collision events [2]. To generate the observed impact rate of dm to meter-sized HED on Earth from this CRE age event requires a crater ~10 km or larger in size, or the complete disruption of a Vestoid larger than ~1 km in diameter [3]. Known Vestoids are only up to 8 km in diameter and the combined cross section of all Vestoids ≥ 300 m is 5 times smaller than that of Vesta itself. Hence, Vesta itself was the likely target. However, the idea that a crater on Vesta itself is the direct source of most HED is not the consensus position of the community currently.

Asteroid 2018 LA: On June 2, 2018, asteroid 2018 LA was detected in space and impacted over Botswana's Central Kalahari Game Reserve 8 hours later [4]. This was only the second time that an asteroid was spotted in space before impacting over land. The asteroid was discovered by the Steward Observatory's Catalina Sky Survey and follow-up observations were made. The ATLAS survey added two more detections. We recovered four additional detections in SkyMapper Southern Sky Survey archival data that helped refine the orbital elements and determine the asteroid spin period and ellipsoidal shape axis ratio. The orbit of 2018 LA is 700 times better determined than a previous HED fall, the meteorite Sariçiçek in Turkey in 2015, which was based only on video observations of the bolide [3]. Both orbits point to an origin in the inner main belt, where Vesta is located, delived to Earth via th ν_6 resonance.

The recovery: Governement satellites detected the impact from space and provided an impact time of 16:44:12 UTC. The bolide was also recorded on video from distant locations in Maun, Rakops, Gaborone, and Ghanzi in Botswana and Ottosdal in South Africa. This data was triangulated and combined with the astronomical observations to determine the location and altitude of the disruption event [4]. From that, a strewn field was calculated in a remote area in the Central Kalahari Game Reserve, 8–12 km from the nearest road and frequented by large animals. With support of several Botswana institutes, a concerted effort was made to recover meteorites. After an initial find on June 23, 2018, 22 additional meteorites were found during a follow-up expedition in October 2018.

Meteorites Identification: Six of the meteorites, now called Motopi Pan after a nearby watering hole, were sampled at NASA JSC and material was distributed in an international 2018 LA meteorite consortium [4]. The meteorite was classified as a polymict breccia composed of diogenites, cummulate and basaltic eucrites, and howardites. Various studies found some similarities and some differences with the howardite Sariçiçek. The CRE age is 23 +/- 4 Ma, similar to Sariçiçek. Unlike Sariçiçek, Motopi Pan was heated by a significant heating event 4.2 Ga ago that melted its phosphate grains. That may also have created the record thermoluminescence signature measured in one of the Motopi Pan meteorites. Motopi Pan did not contain solar wind implanted noble gasses, while Sariçiçek did [4].

The source crater: Vesta was visited by NASA's Dawn mission in 2011–2012. Dawn imaged a number of fresh-looking craters with ejecta blankets. To derive an age from the cratering count on those blankets, an assumption has to be made regarding the unobserved population of small meter to 10-meter sized impactors in the asteroid belt. The calculated distribution of impactors from asteroid breakup models is too low and results in crater ages (the asteroid chronology scheme) that are too high to explain the observed HED CRE ages by a factor of 3–5 [4]. The young crater Arruntia has olivine in its debris, not seen in HED. On the other hand, the lunar chronology scheme provides ages for a number of craters that match the CRE distribution diagram [3]. Two craters have ages about 22 Ma: Antonia on the slopes of the Rheasilvia impact basin and Rubria on a topographic high on the Divalia Fossae Formation ridges that are covered in Rheasilvia impact ejecta. The Antonia site is prone to landslides and is thought to have originated the Sariçiçek meteorite [3]. Rubria is a good candidate for the origin crater of Motopi Pan [4]. Motopi Pan adds one more ~4.2 Ga Pb-Pb age to a discrete population of such ages measured for several other HED. Ar-Ar ages tend to scatter around ages of 3.7 Ga ago. This further strenghtens the hypothesis that Veneneia was formed ~4.2 Ga ago, while the Rheasilvia impact event scattered the material heated during the Veneneia impact around Vesta ~3.7 Ga ago [4].

Acknowledgements: A full list of acknowledgements is provided in [4].

References: [1] McSween H. Y., et al. (2013) *Meteoritics and Planetary Science* 48:2073. [2] Eugster O., et al. (2006) In: *Meteorites and the early solar system II.* D. S. Lauretta, McSween H. Y. Jr (eds), Tucson Arizona: The University of Arizona Press, p. 829, [3] Unsalan O., et al. (2019) *Meteoritics and Planetary Science* 54:953. [4] Jenniskens P., et al. (2021) *Meteoritics and Planetary Science* 56:doi 10.1111/maps.13653.