ADDRESSING THE CHALLENGES TO PROGRESS ON A PREVIOUSLY PROPOSED SOUTHERN MT LOFTY RANGES MULTIPLE IMPACT. R. B. Moore, Member of the Royal Society of Victoria (Australia), science@academicmail.org

Background: Certain iron-rich conglomerates investigated in the field are potential impact-melt breccia. These potential impact-melt breccia are present across the Southern Mt Lofty Ranges (South Australia) including at many candidate sites of oblique multiple-impact. Two candidate sites of oblique impact were documented by Haines et al. in 1999 [1], using planar deformation features in quartz, namely: the Mt Crawford Forestry area, and a quarry in Flaxman Valley.

In a subsequent study as broadened by Haines et al. in 2000 [2], no evidence was presented for the suggestion of additional candidate sites, including Happy Valley and Kersbrook, yet iron-rich breccia are present north of those sites. The hypothesized impacts, as a set, were proposed by Haines et al. in 2000 [2] to have occurred from the south, and a digital elevation model study by Moore [3] was recently undertaken to search for candidate primary impact site/s.

Haines also proposed that the impact/s were at an extremely low angle of 0 to 5 degrees from horizontal, and Moore [4] has suggested that the impactors may have been in orbit prior to impact. Such impacts may leave a significant percentage of the bolide unvaporized, if a principle that was first posited by Pierazzo and Melosh [5,6] is taken to its logical conclusion. Subsequent follow-up of that modelling has not been done, that might otherwise have taken into account the suggestion of those authors on the fate of the projectile. Lower impact angles than the ~30 degrees investigated by Pierazzo and Melosh have been modelled over the past two decades but not with this question of survivability in mind.

Challenges to progress on this author obtaining further hard data that might support the finding by Haines et al. [1] of planar deformation features at Crawford Forest, include a) the funding type (private, limited), b) the lack of modelling since Pierazzo and Melosh [5,6] on fate of the projectile, with possible inertia of willingness setting in amongst the meteoritic community, and c) the lack of an established precedent event/site on Earth, although many similar events have left scars on Mars [4,7].

By contrast to these challenges, benefits also exist in the study, namely a) the accessibility of the Southern Mt Lofty Ranges study sites is obviously better than that on Mars; b) stratigraphy and/or nuclear-geochronology ought to be a useful basis for dating the proposed breccia; and c) the presence of an atmosphere on Earth at every date (versus comparatively rapid loss of atmosphere on early Mars) may mean Earth-orbiting bolides may develop greater fusion crust [8] than non-orbiting on non-oblique ones. Also, the velocities of the orbiting bodies may slow down via atmospheric interaction, compared to non-orbiting impactors, so further opposing the default occurrence of complete vaporization on impact. It was already established [5,6] that low impact angle prevents total vaporization.

Earth interactions of the majority of meteorites that are generally studied by the meteoritics community, and in which material survives, generally involve aerial explosion and raining down of fragments onto earth. Perhaps it can be posited by contrast that if a projectile is sufficiently large and in a low orbit, then an actual impact and a degree of survival are possible, even without aerial explosion, although such a case has not been demonstrated on Earth by any previous studies. In comparison, while such oblique impacts (e.g. from low orbit) are evident on Mars and abundant there, the aspect of partial survival has also not been studied there.

Methods: Hand specimens and some boulders of marble splashed with melted iron are commonly observed across the Adelaide Hills, well distant by many tens of kms from any kiln and in near virgin bush settings. Selected complex conglomerates of shattered marble fragments that are bound within iron-rich matrices were photographically documented at 1. Mt Crawford Forest, 2. Flagstaff Hill (North of Happy Valley), 3. Parra Wirra (North of Kersbrook), 4. Bullock Hill (North of Goolwa) and these were also sampled. Recording of GPS co-ordinates was routinely done. Advice from fellow amateurs in SA is that sampling on public land is not necessarily subject to permission being obtained, and if so then the same would apply to geochemical analyses, given that no commercial gain is sought in the project. Care was taken to avoid any conglomerates that have only rounded inclusions, and also to avoid any conglomerates of obvious sedimentary nature (for instance Sturtian Tillite). As an example, the Flagstaff Hill samples occur at a stratigraphic level some 20 meters above the tillite zone. [The Adelaide Hills are known to have significant unconformities, as missing strata of certain eons, indicating these hills (broadly speaking) have been at raised elevations potentially since the Delamerian inclusive, hence a lack of continuous and useful sedimentary records/indicators for some eras, in many of the central sections.]

Figure 1. (1) Large jagged marble inclusions in an iron -rich matrix found at -34.70325, 139.01815, Crawford Forest, a km or so from the site listed in Haines et al. 1999 as the source of quartz pdfs; (2) Smaller jagged marble inclusions in a rich red matrix found at -35.04872, 138.59045, Flagstaff Hill with a possible origin somewhat south of that spot; (3) Medium sized marble inclusions, mostly jagged, in iron-enriched conglomerate found at -34.67361, 138.85055 Parra Wirra; (4) Fine grained conglomerate of unknown materials, of around 1 inch thickness overlying Permian sedimentary strata, found at -35.31210, 138.79475 Bullock Hill.

Field samples: In Figure 1 the collected samples are compared as regards fragment size and jaggedness, and visual characteristics of the matrix.

Discussion: In the background setup it was proposed that orbiting asteroids that impact earth may have a decreased velocity. This is posited here by reference to the finding of a presumptive meteorite fragment at Angaston bearing a 5 mm fusion crust [8]. If it were so that such slowing occurs, then less energy may be available for vaporization than in the case of orthogonally or near orthogonally impacting hyper-velocity meteorites. Further, some of the sites examined in this study and previous studies [1,2,8,3] may be secondary impact sites and a primary impact site may lie further south. Partial survival of the projectile as proposed in unrelated modelling done by Pierazzo and Melosh [5,6] implies secondary impacts, each also of a relatively low energy, occur in oblique scenarios. Current attention might best be placed on the Goolwa area as a candidate primary impact zone, and/or south of there on the continental shelf. Until the impact site is ascertained it is not timely to widen the search to other parts of the continent or other parts of the world, required if the causative asteroid was of the rubble pile type and reached the Roche Limit before its parts impacted Earth. A motivation for the study is that its proposed recent nature (Haines 2000 estimated $\geq$35 mya) could involve at least subtle effects on the evolution of extant classes, orders, and families in many super phyla, if indeed the widening of the study were to find additional and larger impacts occurred at the same time. The lower tertiary nature of the Parra Wirra conglomerate [9] if related, could indicate a Paleogene timing. These matrices 1-4 (Fig 1) and others could prove suitable for U-Pb analyses of zircon crystals if present.

Acknowledgments: First Nations records were extensively consulted alongside SA state publications of surface-geology mapping in the modern day.

Peramangk, Ngarrindjeri and Kaurna records that were consulted consisted of dreamtime stories invoking falling objects, their timing and sites of impact.

References: [1] Haines P.W., et al. (1999) *MetSoc LXII Meteoritics & Planet. Sci., 34*, A49. [2] Haines P.W. (2000) In: Catastrophic Events and Mass extinctions: Impacts and Beyond. Vienna Austria Geozentrum, Abstract # 3093. [3] Moore R.B. (2022a) *MetSoc LXXXV* Abstract # 6133 [4] Moore R.B. (2022b) Planetary Crater Consortium *XIII* Abstract # 2011. [5] Pierazzo E. and Melosh H.J. (1998) LPI Contribution 957 p. 33. [6] Pierazzo E. and Melosh H.J. (2000) *Meteoritics & Planet. Sci., 35, 117-130*. [7] Sefton-Nash E, et al. (2019) *LPSC L* Abstract # 3252. [8] Moore R.B. (2021) *AGU Fall Meeting*, https://www.essoar.org/doi/10.1002/essoar.10509101.1 [9] Thomson B.P. (1969). SA Geol. Atlas Series Sheet S1 54-9. Geol. Survey of South Aust., Dept of Mines, Adelaide.