Modelling the Southern Mt Lofty Ranges and KI Multiple Impact via a Digital Elevation Model and Informed by Indigenous Knowledge

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Introduction: A Southern Mt Lofty Ranges and Kangaroo Island multiple impact in South Australia was previously proposed [1][2] and stratigraphy of an indirect line of evidence indicated a mid to late Eocene event. Multiple impacts orthogonal or near-orthogonal to the earth's surface may often be difficult to study, but multiple impacts can be analysed well if the angle of approach of the meteorite/s is signifcantly oblique. New fieldwork has begun on the candidate impact sites and a growing number of newly proposed sites. The ongoing fieldwork is being informed by a topographic map investigation using a Digital Elevation Model (DEM) [3] and local indigenous knowledge. This current report concerns mainly the DEM work, and drills down into the impact approach azimuth and direction of impact known to indigenous peoples of the area. Modelling available in the public domain has resolved well the expected shapes of such oblique impact craters [4][5], and is supported by observations of oblique impact craters on Mars [6]. Extremely low angle approaches (under ten degrees from horizontal) may result in butterfly ejecta patterns [6], and the proposed impacts studied here may be in this category. As previously proposed [2], the direction of approach of the impactors in the Southern Mt Lofty Ranges and Kangaroo Island multiple impact was from the S-SW even though this direction was recently questioned [7]. The model [7] is that a rubble pile asteroid [8] dissociated.

Methods: A publicly available DEM was used [3]. Focussing investigations toward particular candidate sites was warranted by clear evidence of proposed target-rock melt in an area that has no history of volcanism. The melt is at Echunga and begins near the northwest edge of the town, extending further northwest. Energies required to produce melt are arguably beyond what a small meteorite of 50-100 metres could produce hence the study analysed candidate larger craters near Echunga. Other sites were studied as independent clear indicators of a potential multiple impact, including: an established impact site east of Mt Crawford, the nearby Saunders Creek, Kurianda in the Barossa Range, and two Kangaroo Island sites. Second tier candidate sites are Kersbook Nth and sites on the flats towards Murray River. Assistance in hypothesis-building comes via cultural records held by the indigenous Peramangk custodians.

Results and Discussion: The current study supports the original proposition by Haines of a S-SW approach, and additionally establishes a consistent shape for the proposed resulting craters - highly elliptical craters which may even be described as trench craters. Two small craters of this type, each of around 3 km length, Kurianda and Saunders Creek, lie in a roughly south to north orientation, pointing about 6 degrees east of north. These two examples established the shape and direction of the impact signatures, aided by indigenous cultural markings (corroboree geoglyphs), and indigenous camp locations. Modelling of the shape, size and direction of the 5 km Mt Crawford-to-Pewsey Vale crater emerged from DEM analysis and tallies well with an indigenous sculpture of the crater. Additionally, three more large craters are proposed, lying adjacent to each other, and occurring south of Echunga and Mt Barker namely: in the Ashbourne, Macclesfield, and Doctor's Creek localities. Of these, Ashbourne is the largest candidate at potentially some 10-15 km long, followed by Macclesfield at 6 km long, with Doctor's Creek being the smallest of the three at only <3 km long. Both the Echunga melt and the Echunga diamonds may potentially be attributable to either or both of the larger pair of these three impacts. Most likely, melt at Echunga may derive from the forward aspect of the butterfly ejecta of the Ashbourne impact, with the direction of this ejecta perhaps also influenced by the ejecta wind from the impact at Macclesfield, given that both impacts occurred within same few seconds. In this model, target rock type has affected the propagation and reflection of seismic energy following impact. In turn the modelled seismic profiles have affected the weathering profiles of Ashbourne and Macclesfield since impact, leaving concentric arcs of low hills and shallow valleys. The pound between Pound Road and Schmidt Road at the northern centre of the proposed Macclesfield crater has a current peak to trough height of 80 metres, representing a clear banking or furrow that is reproduced at Signal Flat, being in turn the northern centre of the proposed Ashbourne crater. Other sites investigated include the previously proposed Pelican crater of about 3 km length on Kangaroo Island, plus another proposed 6 km long crater just west of Pelican at Rush Lagoon, and a northerly candidate of around 3 km length in Redcliffe SA. However only the Macclesfield and Ashbourne sites record clear evidence of direction of approach in the crater shapes themselves when coupled with arcuate weathering profiles. Investigation of the physico-chemical nature of ejecta is being planned, using material from all of these sites. The spread of sites indicates that a rubble pile meteorite may have dissociated on a previous interaction with any body in the solar system before it's parts impacted earth.

[1] Haines P. W. et al. (1999). *MPS LXIII* p. A49. [2] Haines P. W. (2000). *Catastrophic Events and Mass extinctions: Impacts and Beyond*. Vienna Austria Geozentrum, Univ Vienna, Abstract #3093. [3] Yamazaki D. et al. (2017). *Geophysical Research Letters*, 44:5844-5853. [4] Pierazzo E. and Melosh H. J. (2000). *Meteoritics & Planetary Science* 35:117-130. [5] Elbeshausen D. (2013) *LPS XLIV* Abstract #1916. [6] Herrick R. R. and Hessen K. K. (2006) *Meteoritics & Planetary Science* 41:1483–1495. [7] Moore R. B. (2021) *AGU Fall Meeting* http://dx.doi.org/10.1002/essoar.10509101.1. [8] Richardson D. C. et al. (2002). In *Asteroids III*, Bottke, W.F., et al. Eds, p501-515.