TSUNAMI(?) DEPOSIT OF TERMINAL EOCENE AGE, SOUTH AUSTRALIA: THE INFERRED EFFECTS OF A LOW-ANGLE MULTIPLE IMPACT EVENT. P. W. Haines, School of Earth Sciences, University of Tasmania, GPO Box 252-79 Hobart, Tasmania 7001, Australia (e-mail: Peter.Haines@utas.edu.au).

Introduction: The author has recently reported the discovery of two new impact structures near Adelaide in South Australia [1]. Both sites exhibit shock metamorphism and include an 8.5km long elongate crater (Crawford), interpreted as the product of a very low-angle NNE-directed grazing impact, and a nearby structure considered to be of secondary origin (Flaxman), resulting from down-range ricochet of part of the projectile. These sites form part of an extensive (230x30km) NNE-trending corridor of similar elongate features and breccia zones (Fig. 1). The corridor cuts obliquely across regional structural, stratigraphic and geophysical trends and defies conventional geological explanations. Although definitive shock metamorphism has yet to be discovered at the other structures, it has been hypothesised that the corridor is the consequence of a multiple low-angle impact event of substantial magnitude [1], resembling a scaled-up version of the Rio Cuarto crater field in Argentina [2]. The southern limit of the exposed corridor coincides with the shore of the Southern Ocean (on Kangaroo Island) and it is speculated here that the entire putative crater field may comprise secondaries from a single large grazing impact into the Southern Ocean south of Australia.

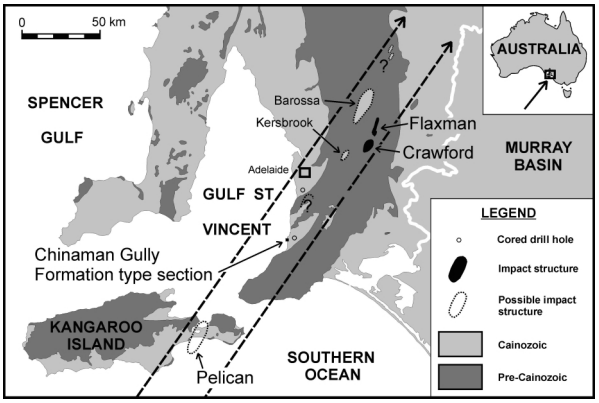

Fig. 1: Locality diagram.

Pelican: The southern-most candidate impact structure, here named Pelican (after Pelican Lagoon), is a mainly covered feature marked at surface by an anomalous gap in Cambrian outcrop on Kangaroo Island (Fig. 1). This gap is coincident with a significant gravity low, which has been modelled as an elongate NNE-trending sediment-filled basin. The basin extends from the near shore continental shelf of the Southern Ocean, across Kangaroo Island, to the southern margin of Gulf St Vincent. The shape, dimensions (ca. 18x8km), orientation, and alignment are analogous to the craters and inferred craters further north, and in similar fashion the Pelican structure cuts at a high angle across structural, stratigraphic and geophysical trends in the surrounding area. The age of the infilling succession is unknown. From the only deep drill hole into the basin, Wade [3] infers a Tertiary age for the boulder-free, clay-rich fill. However, the cuttings were not examined palaeontologically and unfortunately were not archived. Gulf St Vincent is underlain by the St Vincent Basin, which has been undergoing almost continuous marine sedimentation since at least the Middle Eocene. Basin margin areas, now uplifted onshore, probably preserve a relatively complete shallow marine sequence from the Middle Eocene to the Middle Miocene [4]. Thus, if Pelican does represent an impact structure younger than Middle Eocene, its position straddling the margin of St Vincent Basin suggests that an impact tsunami/ejecta horizon should be preserved within the basin succession. This provides one test of the multiple impact hypothesis and could provide independent timing constraints. As most of the succession is comprised of low-energy muddy sediments, the preservation potential of a significant regional event horizon should be high.

Impact tsunami horizon?: The accessible basin stratigraphy was searched in outcrop and in the two available diamond drill cores. A unique and obvious candidate for a tsunami deposit was quickly located: namely the thin Chinaman Gully Formation (CGF), which has long been recognised as an important marker horizon within the basin stratigraphy. The CGF lies sharply above fossiliferous grey mudstones of the Blanche Point Formation. The sedimentary facies and microfauna of the Blanche Point Formation indicate a low energy marine environment with poor circulation and poor ventilation [5,6]. It has been considered that during Blanche Point time the link between the Southern Ocean and St Vincent Basin was significantly more tenuous than it is today [7]. At the 2 m thick type section (60 km N of Pelican), the CGF consists of a series of graded sand beds interbedded with mudstones in the upper part. Most of the sand, although often intermixed with mud, has the texture of beach and dune sand and contains scattered terrestrial plant remains. The unit is bioturbated in its upper part with burrows concentrated at, and extending down from a single horizon consistent with the entire unit below representing a single (although pulsed) event deposit. In weathered surface outcrop the formation is leached and heavily iron stained. In drill core the CGF is dark coloured, carbo-

naceous and pyritic, containing abundant terrestrial plant matter in some horizons. Micropalaeontological investigations reveal a mixture of marine (foraminifera, dinoflagellate cysts, acritarchs) and terrestrial (pollen, spores) indicators [8]. Based on sub-surface information, the CGF is thickest (up to 10m) and best developed close to the palaeo-shoreline, but is thinner, finer and sometimes difficult to recognise (from drill cuttings) in distal settings [4,8]. The CGF has long been interpreted as the result of a brief marine regression and most workers assume it to be largely of terrestrial origin [4,5,6,8]. The CGF is overlain sharply but conformably by the Aldinga Member of the Port Willunga Formation. This unit displays a more open marine fauna than the Blanche Point Formation and its basal part shows evidence of significant current activity, which decreases up section.

Microspherules: In both of the examined drill cores the upper parts of the CGF contain horizons of palagonitic microspherules (ca. 0.1-1 mm). These are most abundant and best preserved right at the top of the formation in both holes, but are not found above. Shapes vary from spheres to ovoids and more rarely dumbbells, although those in contact with detrital sand grains are commonly deformed by compaction suggesting that palagonitisation was an early phenomenon. The microspherules display a thin whitish fragile shell and are hollow except for a 'loose' core of brown waxy palagonite of varying size. No relic glass has been observed. The microspherules appear to be similar to palagonitic K-T boundary spherules such as those reported from Haiti [9]. The microspherule-rich horizons are an obvious candidate for searching for shocked debris, as well as siderophile and isotopic anomalies associated with the putative projectile. Such studies are in progress.

Age: The exact position of the Eocene-Oligocene boundary in southern Australian Tertiary sections in general, and in the St Vincent Basin in particular, has long been a matter of speculation. A particular problem for the St Vincent Basin is that its restricted nature has precluded many of the open marine planktonic foraminifera on which the boundary is based elsewhere [10]. Traditionally the boundary has been placed a short distance above the top of the CGF near the top of the Aldinga Member of the overlying Port Willunga Formation [10]. Recently it has been argued that the boundary should be lowered to the base of the CGF [5]. This reasoning is based mainly on the assumption that the CGF represents a brief marine regression, which, if it were eustatically controlled, might be correlated with a brief regressive event placed at the boundary on global sea level curves. Of course this argument looses its strength if one accepts the tsunami hypothesis presented here. Pending further information the CGF is here considered to be of approximately 'terminal Eocene' age.

Discussion: Any major impact generated tsunami within shallow, confined Gulf St Vincent would be catastrophic on a local scale. It could be expected that a significant volume of water would be displaced onshore, the return of which would transport large volumes of marginal marine and terrestrial sediment and associated flora into the near shore marine zone. Giant waves would no doubt be reflected across the Gulf multiple times inducing a pulsed character on the resulting deposit. The rain of impact ejecta would be ongoing during tsunami activity and such material would thus be substantially dispersed, except that finer material such as microspherules should arrive last and be concentrated at the top of the deposit. Subsequent bioturbation by recolonising organisms seeking trapped organic matter would extend down from a single horizon at the top. It is considered that the sedimentological and other characteristics of the CFG are in much better agreement with these expectations than any predictions that could be based on the marine regression hypothesis. Any genetic association with the Pelican structure still remains highly speculative, and another unidentified impact site(s) could exist. However, the unique position of this feature, straddling the divide between Gulf St Vincent and the Southern Ocean, potentially explains another observation, ie. the more open marine and higher energy character of the basal Port Willunga Formation. It is speculated that the inferred impact event may have created a new and more direct pathway to the open ocean, temporarily establishing a new wave and tidal regime in the Gulf, until the connection silted up. The apparent transgressive character of the Aldinga Member may not be real, are there is thus no necessity for a significant changes in water depth across the CGF. Other workers have also speculated on the existence of a temporary marine connection in the same locality during the Tertiary [11].

References: [1] Haines P. W. et al. (1999) *Meteoritics & Planet. Sci., 34*, A49-A50. [2] Schultz P. H. and Lianza R. E. (1992) *Nature, 355*, 234-237. [3] Wade L. K. (1944) *Geol. Surv. S. Austral. Bull. 22*. [4] Alley N. F. et al. (1995) *Geol. Surv. S. Austral. Bull. 54*, 151-217. [5] McGowran et al. (1992) Eocene-Oligocene climatic and biotic evolution. Princeton Uni Press. [6] McGowran B. and Beecroft A. (1986) *Palaeogeog., Palaeoclim., Palaeoecol. 55*, 23-34. [7] Glaessner M. F. and Wade M. (1958) *J. Geol. Soc. Austral. 5*, 115-126. [8] Cooper B. J. 1979. *Geol. Surv. S. Austral. Rept. Invest. 50*. [9] Bohor B. F. and Glass B. P. (1995) *Meteoritics 30*, 182-198. [10] Lindsay J. M. and McGowran B. (1986) Terminal Eocene events. Elsevier. [11] Cooper B. J. and Lindsay J. M. (1978) *Q. Geol. Notes, Geol. Surv. S. Austral. 67*, 4-5.