quent on these events is capable of resolving the volume problem that arises from comparisons between modern continental crust and the estimated sial produced by continuous two-stage mantle melting processes. The volume problem is exacerbated by projected high accretion rates under high Archaean geotherms. In accord with the model portrayed in Fig. 1, it is suggested that impact shock effects have been largely obscured by (1) outpouring of voluminous basic/ultrabasic lavas, inundating shock-deformed crust and extending beyond the perimeters of impact excavated basins; (2) gravity subsidence and downfaulting of terrestrial maria, accounting for the burial and anatexis of subgreenstone basement; and (3) extensive shearing and recrystallization at elevated temperatures of impact structures, breccias, and mineral deformation features beneath impact-excavated basins, relics of which may be retained in structural windows in high-grade metamorphic terranes. Isostatic subsidence and anatexis of thick maria-type piles and underlying impacted crust resulted in formation of intracrustal comagmatic plutonic and volcanic suites within periods in the order of 15–30 × 10^6 yr, limited by postimpact mantle convection cooling. Repeated posttectonic thermal/magmatic fluctuations reflect existence of long-term anomalous mantle regions beneath excavated impact basins, and possibly thermal perturbations related to younger distal impacts. The broad age zonation of some Archaean terranes suggests lateral accretion of the maria piles in a convection-driven plate tectonic regime.

References: [1] Grieve R. A. F (1980) *Precambrian Res., 10,* 217–248. [2] Green D. H. (1972) *EPSL, 15,* 263–270. [3] Glikson A. Y. (1976) *Geology, 4,* 202–205. [4] Glikson A. Y. (1990) *LPI Contrib. No. 746,* 13–15. [5] Goodwin A. M. (1976) In (B. F. Windley, ed.), 77–98, Wiley. [6] Weiblen P. W. and Schultz K. J. (1978) *Proc. LPSC 9th,* 2749–2773. [7] Compston W. (1990) *Third Intl. Archaean Symp.,* 5–6, Perth. [8] Lowe D. R. and Byerly G. R., *Geology, 14,* 83–86. [9] Lowe D. R. et al. (1989) *Science, 245,* 959–962.

529-46 N93-10141

475175

THE ACRAMAN IMPACT AND ITS WIDESPREAD EJECTA, SOUTH AUSTRALIA.

V. A. Gostin[1], R. R. Keays[2], and M. W. Wallace[2], [1]Department of Geology and Geophysics, University of Adelaide, GPO Box 498, Adelaide, 5001, Australia, [2]Department of Geology, University of Melbourne, Parkville, Victoria 3052, Australia.

AB830877
MS055827

Discovery of a widespread horizon of shock-deformed volcaniclastic ejecta preserved in Late Proterozoic (~600 Ma) shales in South Australia [2–4,7] and its probable link to the Acraman impact structure in the Middle Proterozoic Gawler Range Volcanics [2,8,9] provide a rare opportunity to study the effects of a major terrestrial impact, including the sedimentology and distribution of an ejecta blanket and its precious-metal signature.

The ejecta horizon occurs in the Bunyeroo Formation at many localities within the Adelaide Geosyncline [2,3], including the Wearing Hills, which are ~350 km northeast of the Acraman impact site. Following a search at the same stratigraphic level in other basins in South Australia, the ejecta has been located within the Lower Rodda beds of the Officer Basin, extending the limits of the ejecta to ~470 km northwest of the Acraman impact structure [4,7]. The ejecta is therefore widely dispersed, and provides an important chronostratigraphic marker enabling precise correlation of Late Proterozoic sequences in southern Australia.

The ~600-Ma Bunyeroo Formation consists of maroon and green shales, with minor concretionary carbonates, deposited in an outer marine-shelf setting. The ejecta horizon comprises mainly angular clasts of acid volcanics ranging from boulder (up to 30 cm diameter) to fine sand size. All large fragments and most sand-grade material were derived from a pink to red porphyritic volcanic rock like that at the Acraman impact site. The ejecta sequence varies in thickness from 0 to 40 cm, and is commonly (from base upward) breccia, sandy mudstone, and graded sand. Such a sequence probably represents the primary ejecta fallout since it (1) is very widespread, (2) displays virtually perfect sorting and normal grading, resulting from its settling through a marine water column, and (3) invariably contains a sandy mudstone layer that directly overlies the basal breccia. Clast size analysis of the primary fallout sequence indicates that two distinct grain size populations are present (gravel and sand sized). These populations may be products of sorting by transport through the atmosphere or fragmentation processes during impact or subsequent transport.

Mass flow and storm reworking processes have been commonly superimposed on, and in places obliterated this primary sequence. To account for various sedimentological features, the following sequence of events probably took place: (1) Initial impact occurs, debris is ejected into the atmosphere, and a massive seismic event takes place with resulting disruption and slumping of muds in adjacent marine basins. (2) Ejecta entered the water column, with gravel-sized material deposited first. (3) Deposition of suspended host muds, together with continued settling of coarse sand, produced the sandy mudstone. (4) Continued hydrodynamic settling of sand-sized material produced the graded sand unit. This occurred several hours after ejecta entered the water column, assuming a 200-m water depth. Storm waves created during massive atmospheric disruption reached the depositional site during latter stages of sand deposition and resulted in hummocky and trough cross-stratification.

Evidence supporting an impact origin for the horizon includes the abundance of shattered mineral grains, the presence of multiple sets of shock lamellae in quartz grains, the presence of small shatter cones on large clasts, the local abundance of altered, tektitelike spherules [6], and anomalous Ir and other PGE values [3]. The correlation of the Bunyeroo ejecta with the Acraman impact structure is further supported by U-Pb ages obtained from severely shocked, euhedral zircons within the ejecta [1]; the dominant age of 1575 ± 11 Ma for the ejecta is consistent with derivation from the Gawler Range Volcanics, which has a U-Pb zircon age of 1592 ± 3 Ma. The geographic distribution of the ejecta and the lateral variation of clast size within the horizon also are consistent with the Acraman impact site as the source.

The Bunyeroo ejecta is enveloped in green shales that are several centimeters thick [2]. These shales and the sandy layers of the ejecta horizon are enriched in Cu carbonates, barites, and Fe oxides, minerals that are widespread in sediments of the Adelaide Geosyncline. Geochemical profiles of the ejecta horizon indicate anomalously high Ir, Au, Pt, Pd, Ru, and Cr relative to the host shales of the Bunyeroo Formation (Ir up to 2.0 ppb, Pt up to 270 ppb). Iridium enrichment up to 100 times the background value for the host shales has been recorded. As Ir values for the volcanic rocks that crop out at the Acraman impact site are <0.005 ppb, the high values for Ir and for other PGEs and Cr in the ejecta horizon strongly suggest derivation from the impactor itself. The marked enrichment in Ir in the Bunyeroo ejecta is similar to that in sediments at the Cretaceous-

Tertiary boundary, which has been attributed to a major impact event. The strong evidence for an impact origin of the Bunyeroo ejecta also points to a cosmic source for its PGE signature.

The shales above and below the Bunyeroo ejecta horizon also show Ir and Pt enrichments (0.073–0.45 ppb Ir, 3.1–313 ppb Pt), suggesting postdepositional mobilization of Ir and Pt. Interelement ratios of the PGEs within the ejecta horizon from different sites are also quite variable, again suggesting postdepositional, low-temperature mobilization of these elements. Indeed, all green shale horizons in the Bunyeroo Formation that were analyzed, regardless of their stratigraphic position, have relatively high levels of Ir and other PGEs. The diagenetic origin of these anomalies is indicated by their association with enrichments in Cu-V-Zn-Co-Ni in thin, permeable green-colored reduced beds in a predominantly red bed sequence. A redox precipitation model similar to that invoked for red bed Cu-U-V deposits has been proposed to explain the PGE anomalies in the green shales [5].

In summary, the Bunyeroo ejecta is unique as the only known example of a widely dispersed, coarse-grained ejecta blanket that is, moreover, strongly linked to a known major impact structure. The marked Ir-PGE anomalies in the ejecta horizon provide support for the hypothesis that meteorite impact events can produce Ir anomalies in terrestrial sediments. The findings also indicate that Ir can be mobilized and concentrated in sediments by low-temperature diagenetic processes. The identification of ejecta horizons in sedimentary rocks therefore should be based on the coincidence of shock-metamorphic features in the detritus and clear Ir anomalies.

References: [1] Compston W. et al. (1987) *Aust. J. Earth Sciences, 34*, 435–445. [2] Gostin V. A. et al. (1986) *Science, 233*, 189–200. [3] Gostin V. A. et al. (1989) *Nature, 340*, 542–544. [4] Wallace M. W. et al. (1989) *Aust. J. Earth Sciences, 36*, 585–587. [5] Wallace M. W. et al. (1990) *Geology, 18*, 132–135. [6] Wallace M. W. et al. (1990) *Meteoritics, 25*, 161–165. [7] Wallace M. W. et al. (1990) *Mines and Energy Review, South Australia, 157*, 29–35. [8] Williams G. E. (1986) *Science, 233*, 200–203. [9] Williams G. E. (1987) *Search, 18*, 143–145.

OPTICAL AND TEM STUDY OF SHOCK METAMORPHISM FROM THE SEDAN TEST SITE.

A. J. Gratz, Lawrence Livermore National Laboratory, Livermore CA 94550, USA.

Thus far, detailed petrologic studies of shock metamorphism have been performed on samples recovered from laboratory experiments and on a few natural impactites. The loading history of these samples is quite different: In particular, laboratory experiments spend only a short time (<1 μs) at peak pressure, whereas natural impactites may have stress pulses from 0.1–1 ms. On the other hand, laboratory experiments have known stress histories; natural impactites do not. Natural samples are also subjected to thousands or millions of years of postshock annealing and/or weathering. A useful intermediate case is that of nuclear detonation. Stress pulses for these events can reach 0.1 ms or higher, and samples are obtained in pristine condition. All three types of loading produce stresses of hundreds of kilobars.

Samples studied were taken from the Sedan nuclear test site, and consist of a coarse-grained granodiorite containing quartz, K-feldspar, cordierite, and hornblende. Samples were studied optically in thin section, then were thinned with an ion mill and studied by transmission electron microscopy (TEM).

Optically, quartz and K-feldspar displayed numerous sets of planar deformation features (PDFs) identical to the nondecorated PDFs seen in laboratory samples and many natural impactites. Other minerals showed less distinct shock damage, with some fracturing visible in cordierite and hornblende.

TEM study showed that the PDFs in quartz and feldspar corresponded to densely packed wide transformation lamellae identical to those described in laboratory studies. The transformation lamellae in both minerals were amorphous, with no sign of high-pressure phases. In the case of K-feldspar only, narrow sublamellae extended outward from some wide lamellae. Quartz, which was more abundant and studied more extensively, contained no shock-induced dislocations. Some planar features were also seen in cordierite, but could not be identified due to rapid beam damage. No shock defects were seen in hornblende in TEM.

The shock-induced defects present at the Sedan site are very similar to those seen in shock recovery experiments, and also to those present at certain natural events (e.g., Meteor Crater). This suggests that shock deformation in quartz is not strongly dependent on shock pulse duration, and that laboratory recovery experiments are useful simulations of natural impact events. The lack of evidence for high-pressure phases along transformation lamellae is in agreement with past studies, and supports the idea that direct, solid-state amorphization occurs along transformation lamellae. Finally, no evidence was seen for decorated PDFs. Presumably decoration is due to postshock annealing or weathering. Further work should focus on processes that lead to decoration of transformation lamellae.

SIMULATED METEORITE IMPACTS AND VOLCANIC EXPLOSIONS: EJECTA ANALYSES AND PLANETARY IMPLICATIONS.

A. J. Gratz and W. J. Nellis, Lawrence Livermore National Laboratory, Livermore CA 94550, USA.

Past cratering studies have focused primarily on crater morphology. However, important questions remain about the nature of crater deposits. Phenomena that need to be studied include the distribution of shock effects in crater deposits and crater walls; the origin of mono- and polymict breccias; differences between local and distal ejecta; deformation induced by explosive volcanism; and the production of unshocked, high-speed ejecta that could form the lunar and martian meteorites found on the Earth. To study these phenomena, one must characterize ejecta and crater wall materials from impacts produced under controlled conditions.

New efforts at LLNL simulate impacts and volcanism and study resultant deformation. All experiments use the two-stage light-gas gun facility at LLNL to accelerate projectiles to velocities of 0.2 to 4.3 km/s, inducing shock pressures of 0.9 to 50 GPa. We use granite targets and novel experimental geometries to unravel cratering processes in crystalline rocks.

We have thus far conducted three types of simulations: soft recovery of ejecta, "frozen crater" experiments, and an "artificial volcano." In the first case, a projectile impacts a granite disk, jetting ejecta, which is gently recovered in a soft-foam fixture to minimize postejection deformation. In "frozen crater" experiments, a granite block is snugly embedded in a large Al block with a narrow entry tunnel for the projectile. The projectile, which deforms on impact, seals most of the ejecta in place, minimizing postimpact material movement and allowing study of the shocked material close to its