through the atmosphere and water column. Layer 4 was deposited by traction currents, possibly in distinct episodes, at an undetermined time after impact. It represents proximal debris reworked into distal areas by storms or turbidity currents. Recognition of the ejecta has been facilitated by the timing and location of the impact. Had the debris been ejected into a vigorous sedimentary environment, such as characterizes many of the formations in the Adelaide Geosyncline, mixing with surrounding sediments would have masked its distinctive character. Likewise, impact into an area of diverse lithologies would have hindered recognition of this event.

In attempting to locate the site of impact in the Gawler Range Volcanics, our attention was drawn through discussions to the large circular structure now occupied by the sand-plain and salt-lake depression of Lake Acraman (Fig. 1). This major impact structure, the largest known in Australia, was independently discovered by G. E. Williams (*9*). Rocks from the impact site match the ejecta fragments described, even though the present land surface at Lake Acraman is below that of the original crater floor. Lake Acraman lies 300 km west of Bunyeroo Gorge, the locality where the largest fragments have been recorded. This would have been a minimum distance at the time of impact because subsequent folding and thrust faulting within the Adelaide Geosyncline would have shortened the crust between these sites, possibly by tens of kilometers.

Fig. 5. Photograph of small shatter cones on a fractured surface of a 12-cm dacite fragment collected from the base of the impact ejecta horizon north of Bunyeroo Gorge (scale bar, 1 cm).

The Bunyeroo ejecta horizon represents an ancient widely dispersed ejecta blanket of known source which can provide valuable information on the nature and effects of large terrestrial impacts.

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The Acraman Impact Structure: Source of Ejecta in Late Precambrian Shales, South Australia

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A major probable impact structure occurs in middle Proterozoic dacitic volcanics in the Gawler Ranges, central South Australia. The structure has an inner depressed area about 30 kilometers in diameter that contains the Lake Acraman salina, an intermediate depression or ring about 90 kilometers in diameter, and a possible outer ring approximately 160 kilometers in diameter. Outcrops of dacite in Lake Acraman are intensely shattered and contain shatter cones and multiple sets of shock lamellae in quartz grains. The Acraman structure is the largest probable impact structure known in Australia and is the likely source of dacitic ejecta found in late Precambrian marine shales some 300 kilometers to the east.

The Acraman structure in the Gawler Ranges, South Australia, is the largest probable impact structure known in Australia (*1*) and the likely source of coarse, shock-metamorphosed ejecta found in late Precambrian shales some 300 km away (*2*). The linking of a large terrestrial circular structure with widely dispersed coarse ejecta may throw light on ejecta dynamics and transport and provide other data valuable to meteoritics.

Lake Acraman (latitude 32°01′S, longitude 135°26′E) is a hexagonal-shaped salina (elevation 133 to 138 m) about 20 km in diameter (Figs. 1 and 2) surrounded by a roughly circular alluvial depression (elevation, 140 to 200 m) about 30 km across. The principal lithological unit in the region is the coarsely porphyritic Yardea Dacite which, with minor rhyodacites, rhyolites, and basalts, constitutes the middle Proterozoic Gawler Range Volcanics, about 1590 million years old (*3*). The Yardea Dacite is the uppermost layered member of the Gawler Range Volcanics and has a thickness of at least 250 m. Around the Acraman depression the dacite forms prominent ridges and hills that rise up to about 280 m above the bed of the lake. This high ground, as defined by the generalized 200-m contour, forms a broad "horseshoe" with a full width of about 90 km that opens to the west-northwest (Fig. 1). The elevated terrain is bordered to the east and northeast by the arcuate western margin of the Lake Gairdner salina; to the southeast and south it is traversed by a broadly arcuate depression about 2 to 4 km wide and about 75 km long, termed here the "Yardea corridor."

The geomorphological elements around Lake Acraman suggest a multiringed structure with Lake Acraman at its center. The Yardea corridor marks an intermediate ring about 90 km in diameter, and a possible outer ring 150 to 160 km in diameter is suggested by the eastern margin of Lake Gairdner and the southern limit of the

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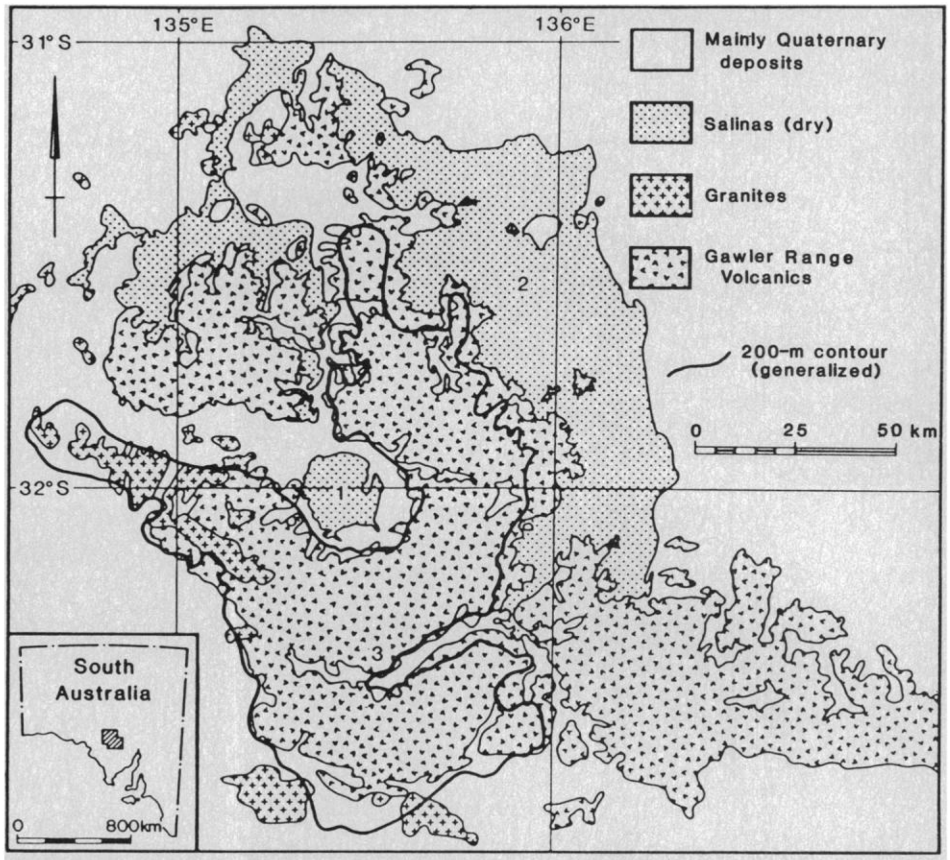
Fig. 1. Geologic map of the Gawler Ranges region, South Australia, showing the distribution of the middle Proterozoic Gawler Range Volcanics and penecontemporaneous granitic rocks. 1, Lake Acraman, within the inner depression; 2, Lake Gairdner, whose eastern margin forms part of an outer ring; 3, Yardea corridor, which defines an intermediate ring. The 200-m contour is taken from the Port Augusta (SI 53) and Tarcoola (SH 53) 1:1,000,000 topographic sheets.



Gawler Ranges, which approximates the 200-m contour (Fig. 1). The inferred multiringed structure transects and displaces stratigraphic trends in the volcanics and is unrelated to cauldron subsidence within the Gawler Range volcanic complex (*4*).

Outcrops consisting entirely of variably shattered Yardea Dacite occur at the margins of several islands within Lake Acraman (Fig. 2). The shattering ranges from a closely spaced reticulate fracturing that produces an irregular mosaic of rock fragments up to several centimeters in diameter (Fig. 3A) to an intense shattering that has broken down the rock virtually to its constituent millimeter-sized grains. Conical structures with longitudinally striated fracture surfaces (Fig. 3B) are identifiable as shatter cones, although they are not as well formed as those developed in fine-grained rock such as quartzite in other circular structures (*5*). In addition, freshly broken surfaces of the shattered dacite commonly display radially arranged striae having the appearance of small shatter cones (Fig. 3C). Unshattered meltrock with textures typical of quenched glassy material envelops blocks of shattered dacite at one locality.

The shattered dacite consists mainly of feldspar phenocrysts in a granophyric matrix. Deformed, fractured textures are characteristic. The fractures, which occur both in feldspar phenocrysts and matrix, are defined by either limonite-lined veinlets or zones made up of clear, recrystallized felsic minerals lacking the finely divided iron oxide inclusions that typically occur in the feldspars. Up to 90% of quartz grains in thin sections of the shattered rock exhibit closely spaced, parallel planar lamellae, decorated with cavities and finely divided material, that do not transgress grain boundaries (Fig. 3D). As many as four different sets of lamellae have been observed in the same grain. These lamellar features are identical to the shock lamellae developed in quartz grains in probable impactites (*6*). The attitudes of 54 sets of lamellae measured in two thin sections group around the $\omega\{10\bar{1}3\}$ (dominant), $\{22\bar{4}1\}$, and $\xi\{11\bar{2}2\}$ (minor) crystallographic orientations. Lamella densities range up to about 600 per millimeter. These features indicate type C shock deformation (*6*) and shock pressures of about 150

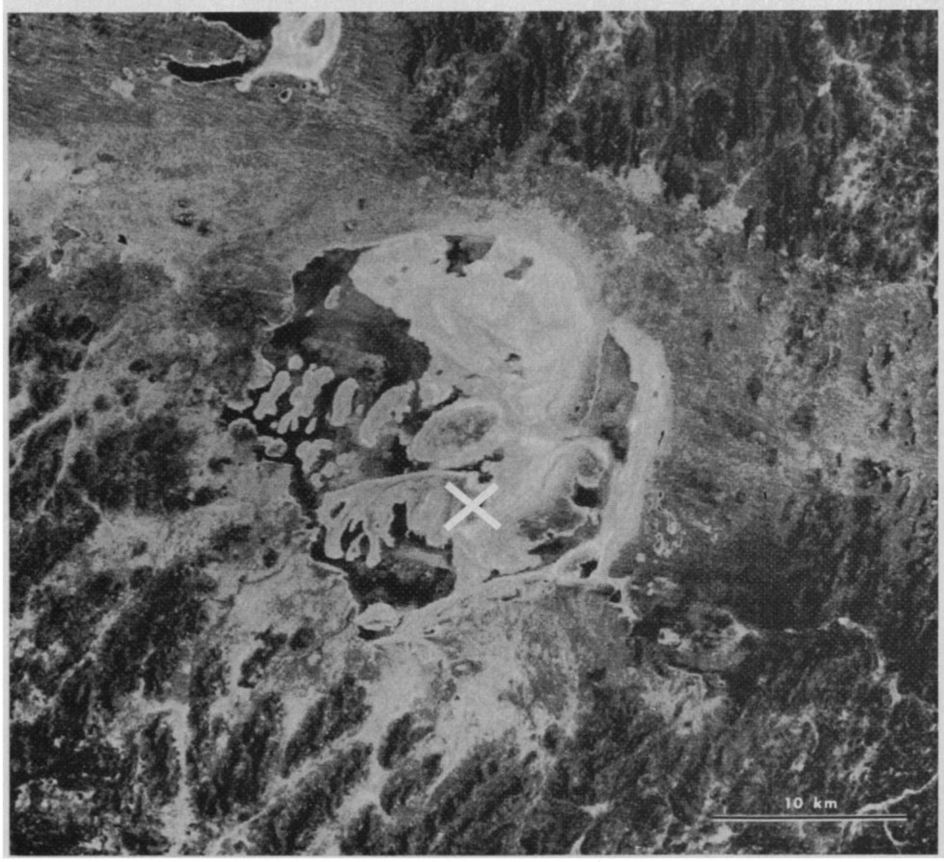


Fig. 2. Landsat image of Lake Acraman and the Acraman depression. The islands within the lake are mainly of eolian sand; the X marks the locality of the shock-metamorphosed rocks shown in Fig. 3. The hexagonal outline of the lake may be partly controlled by bedrock jointing. A structural lineament, one of several that traverse the region, occurs on the northern side of Lake Acraman. North is to the top of the image.

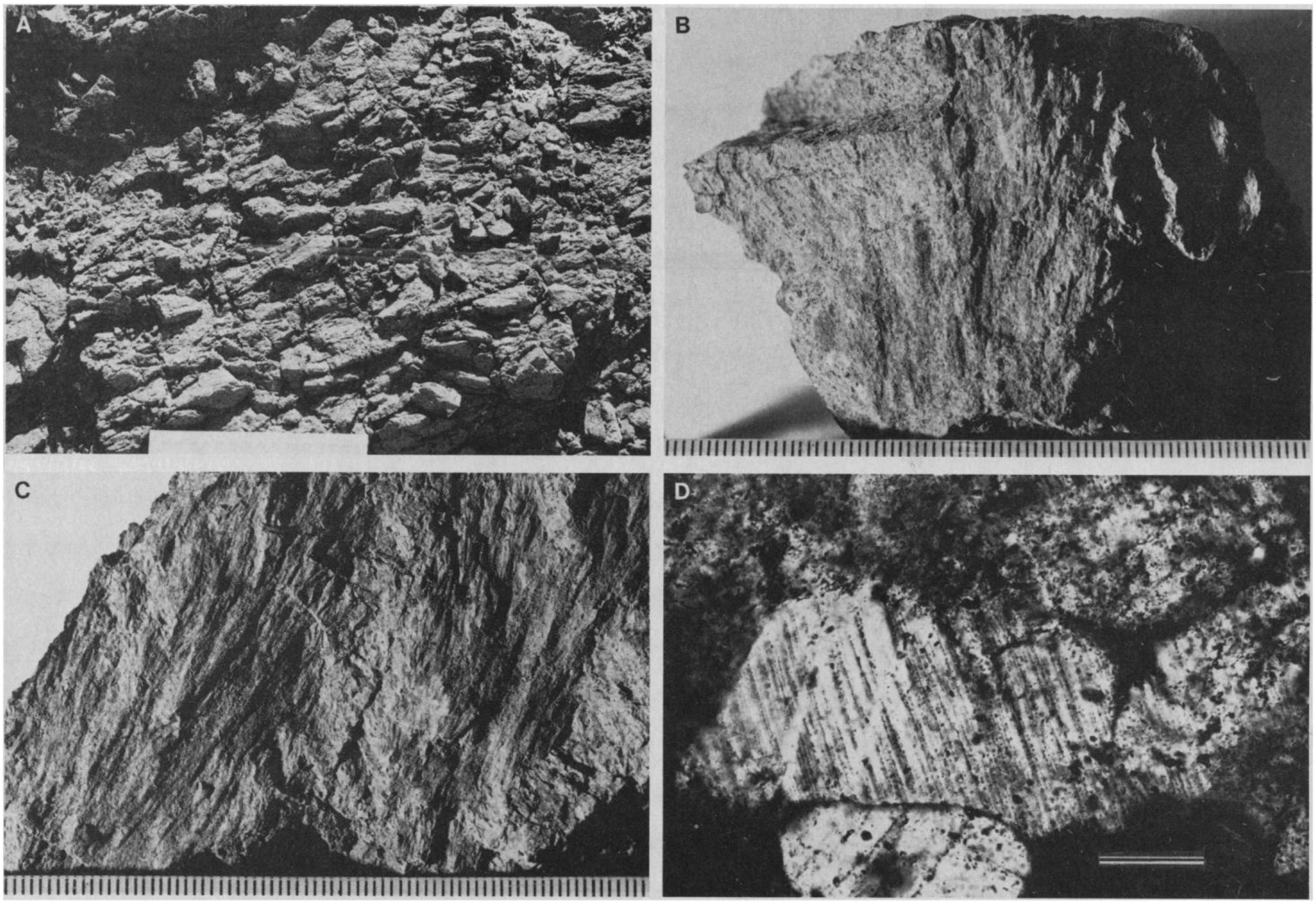


Fig. 3. Shock-metamorphosed Gawler Range Volcanics from Lake Acraman. (A) Outcrop of shattered rock. Scale, 15 cm. (B) Shatter cone. Scale graduated in millimeters. (C) Freshly broken surface of shattered rock showing radially arranged striae similar to small shatter cones. Scale graduated in millimeters. (D) Decorated planar features in quartz, with $\{22\bar{4}1\}$ orientation in the large grain; crossed polars. Scale bar, 50 μm.

kbar (*7*). To my knowledge, shock deformation has not been observed in the surrounding annulus of Gawler Range Volcanics, although no systematic search has been conducted.

The presence within Lake Acraman of intensely shattered basement rocks containing features ascribed to shock-metamorphism (*5, 6*) argues strongly that the Acraman depression marks the site of a major hypervelocity impact. Furthermore, the occurrence of multiple rings is typical of very large probable impact structures (*8*). The inferred Acraman structure has four major elements (Fig. 1): (i) a possible outer ring 150 to 160 km in diameter; (ii) an intermediate depression or ring about 90 km in diameter; (iii) an inner depression about 30 km in diameter; and (iv) a possible central uplifted area within Lake Acraman. Taking the diameters of the outer two rings as 90 and 160 km gives a ring spacing ratio of 1.8, which is in agreement with ratios determined for other multiringed structures of probable impact origin (*8*).

The shattered bedrock within Lake Acraman is below the level of the crater floor. The dimensions of the transient cavity and final collapse crater therefore are uncertain, although the extent of the Acraman depression suggests a transient cavity at least 30 km in diameter and several kilometers deep (*9*). The final collapse crater may have extended as far as the outermost ring at 160 km diameter. A Precambrian age for the Acraman structure is suggested by the deep level of erosion.

The Acraman structure is the largest probable impact structure recognized in Australia and is among the largest such structures known in the world. The Acraman impact is the likely source of the horizon of dacitic ejecta reported by Gostin *et al.* (*2*) within the 600 million-year-old Bunyeroo Formation some 300 km to the east, because of the similarity of (i) lithologies, isotopic ages, and shock metamorphism of ejecta and rocks from Lake Acraman; and (ii) the dimensions, locations, and estimated ages of the respective features. As such, the Acraman structure is the first terrestrial impact structure to be identified as the source of widely dispersed coarse ejecta. The linking of the Acraman structure to the ejecta horizon in the Bunyeroo Formation may provide valuable information on the ballistics and distribution of ejecta from a major terrestrial impact.

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Interleukin-2 Induction of T-Cell G_1 Progression and c-*myb* Expression

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In studies to determine the biochemical mechanisms responsible for cell proliferation, synchronized T cells were used as a model for cellular growth control. By metabolic and morphologic criteria, it was found that activation of the T-cell antigen receptor rendered the cells responsive to interleukin-2 (IL-2), but did not move them through the cell cycle. Instead, IL-2 stimulated G_1 progression to S phase, or lymphocyte "blastic transformation." During IL-2–promoted G_1 progression, expression of the cellular proto-oncogene c-*myb* was induced transiently at six to seven times basal levels, maximal levels occurring at the midpoint of G_1.

DESPITE THE DISCOVERY THAT MItogenic lectins induce T-cell proliferation (*1*), experimental approaches to the biochemical mechanisms responsible for promotion of T-cell cycle progression were fruitless until the elucidation of the crucial role of interleukin-2 (IL-2) [reviewed in (*2*)]. It is now recognized that T-cell DNA replication and mitosis, although dependent on activation of the T-cell antigen-receptor complex (*3*), is actually determined by a critical threshold of signals generated by the interaction of IL-2 with its specific membrane receptors (*4*). Even so, whether activation of the T-cell antigen-receptor complex promotes movement of the cells through G_1 to a point that requires IL-2 just before S phase, or whether IL-2 itself is responsible for G_1 progression, has remained unclear. Moreover, the intracellular molecular pathways triggered by IL-2 have thus far remained obscure.

To identify the metabolic and morphologic changes that occur during cell cycle progression, we synchronized human peripheral T cells into the G_0 phase of the cell cycle according to the following protocol (*4, 5*). Freshly isolated peripheral mononuclear cells are stimulated to express IL-2 receptors transiently by activation with monoclonal antibodies reactive with T3 (anti-T3), and then to undergo an asynchronous proliferative clonal expansion by supplementation with immunoaffinity-purified IL-2. After 14 days of culture, when IL-2 receptors are no longer expressed and the cells have reaccumulated in G_0, more than 99% of the cells are once again small resting T cells, and most ($\geq$90%) express the T8 surface glycoprotein (*4–7*). Maximum IL-2 receptor expression can again be effected within 12 hours, in the absence of detectable IL-2 production, by stimulation with phorbol butyrate (*6, 7*), thereby permitting the dissociation of the effects of antigen receptor activation from those resulting from IL-2 receptor stimulation. This synchronized T-cell–IL-2 model system (*4*) is obligatory for the experimental dissection of the events that occur during T-cell cycle progression, because the effects of antigen receptor activation cannot be separated from IL-2 receptor triggering if primary, freshly isolated mononuclear cells are used. In the presence of accessory cells, polyclonal activating agents (mitogenic lectins, phorbol esters, and anti-T3) lead to both IL-2 production and IL-2 receptor expression by primary T cells within a few hours (*3, 5*). In contrast, phorbol esters stimulate only IL-2 receptor expression by T cells synchronized at 14 days, provided accessory cells are absent (*6, 7*).

When synchronized T cells are used, it is evident that activation of the T-cell antigen-receptor complex does not of itself move the cell population through G_1, which is generally defined as a gradual increase in cell size and cytoplasmic RNA content, culminating in DNA synthesis (*8*). Rather, IL-2 promotes both metabolic and morphologic changes in the cell population that are indicative of G_1 progression (Fig. 1). Cellular RNA content, monitored by tritiated uridine incorporation, increases only when IL-2 is added (Fig. 1A). Moreover, S-phase transition, which is dependent on IL-2, becomes detectable via tritiated thymidine incorporation only after 10 to 12 hours of IL-2 exposure, is maximal at 24 hours, and declines progressively over the next 24 to 48 hours (Fig. 1A). These metabolic changes are consistent with the IL-2–induced morphologic changes characteristic of G_1 progression (Fig. 1B). The cells remain small with dense nuclear chromatin after activation of the T-cell antigen-receptor complex, and only begin to undergo "blastic transformation" 5 to 10 hours after IL-2 exposure. Therefore, in terminology adopted from the extensively studied 3T3 cell cycle (*9, 10*), T cells become "competent" upon triggering of the T-cell antigen-receptor complex, whereas interaction of IL-2 with its receptor promotes T-cell cycle "progression."

T-cell competence induced by mitogenic lectins and phorbol esters is known to be associated with the expression of the cellular proto-oncogene c-*myc* (*11, 12*). In an effort to identify the expression of proto-oncogenes associated specifically with IL-2–induced metabolic and morphologic progression through G_1, we tested several additional oncogenes with the synchronized T cell–IL-2 model system. Expression of the cellular homolog of the oncogene of avian myeloblastosis virus (c-*myb*), which codes for a nuclear binding protein of unknown function (*13*), was noteworthy in the earliest experiments. As shown in Fig. 2, c-*myb* messenger RNA (mRNA) was undetectable in G_0 cells, whereas cells activated with phorbol butyrate and then exposed to IL-2 contained a single 3.8-kb species, the anticipated size of human c-*myb* mRNA (*14, 15*).

A detailed time course of c-*myb* expression after phorbol butyrate–induced competence and during IL-2–promoted G_1 progression revealed that c-*myb* was expressed solely during G_1 progression (Fig. 3). As shown in Fig. 3A, expression of c-*myb* remained at basal, undetectable levels throughout a 12-hour exposure to phorbol butyrate, whereas expression of c-*myc* increased tenfold during this interval. In contrast, c-*myb* expression first becomes detectable only during IL-2–

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