NOTES ON THE GEOLOGY OF LIVERPOOL CRATER, NORTHERN TERRITORY, AUSTRALIA. E.M. Shoemaker and C.S. Shoemaker, U.S. Geological Survey and Lowell Observatory, Flagstaff, AZ 86001

The Liverpool Crater, Northern Territory, Australia is a partially exhumed, eroded impact crater located in the Arnhem Land Aboriginal Reserve at 12°24'S latitude and 134°03'E longitude. The crater was initially recognized as a possible impact site by Rix (1), and briefly visited by Guppy and Brett (2) who gave a preliminary description of the geology of the crater and, together with Milton, documented evidence of shock metamorphism. We reached the Liverpool Crater by helicopter in September, 1996, in the company of a television production team, York Films of London, and representatives of the local aboriginal traditional owners. Later in the month, we returned in our four-wheel-drive truck to complete the geologic mapping.

Rocks exposed in the vicinity of the Liverpool Crater include sandstone and volcanic rocks of the Kombolgie Sandstone of Mesoproterozoic age. Other mappable geologic units at the crater include two distinct breccia units, which, together, form a prominent ring-shaped ridge, a sedimentary deposit that fills the original crater, a Tertiary laterite formed chiefly on the sedimentary fill, and Quaternary alluvium (Fig. 1).

Upper Sandstone Member of Kombolgie Sandstone.--Nearly flat-lying beds of the upper member of the Kombolgie Sandstone are well exposed west and south of the Liverpool structure. The upper member is a medium-bedded, generally medium-grained, quartzose sandstone, commonly cross-bedded on a small scale. Some beds are sparsely conglomeratic.

Authigenic Breccia.--The Kombolgie is abruptly upturned, crushed, and brecciated at the margin of the impact structure. This zone of deformation has a sharp outer boundary against very gently deformed Kombolgie. In places there are large structurally coherent zones within the breccia, where the sandstone is generally nearly vertical or overturned. Elsewhere, the authigenic breccia consists of fine to coarse, anglular clasts, typically tens of cm across but including blocks up to meters across, set in a matrix of crushed sandstone. Generally, the clasts are crisscrossed with siliceously cemented fractures. The most intensely shocked material exposed is found in the matrix of the innermost exposures of the authigenic breccia.

Allogenic Breccia.--Allogenic breccia makes up most of the exposed breccia ring at the Liverpool structure. It rests with a knife-sharp, locally grooved and slickensided contact on the authigenic breccia or, in places, on gently deformed Kombolgie. In most places, the contact dips inward at angles of 40° to 50°, but around a broad exposure of the breccia on the southwest, the contact is a rolling surface with a gentle average inward dip. The allogenic breccia consists of multiple discreet units with well defined contact surfaces and has been emplaced as a sequence of slumps or flows. Abrupt changes in texture and clast size occur across some contacts. Clasts in the allogenic breccia range from sand splinters up to blocks several meters across. About half the bulk of the breccia consists of clasts ranging in size from about ten cm to a few tens of cm across. The clasts are angular to sub-rounded. Their lithology and bedding characteristics are similar to those of the undeformed Kombolgie southwest of the crater. Hardly any clasts in the allogenic breccia are crushed or deformed; they clearly have come from regions higher on the crater wall that were exposed only to relatively low shock stresses.

Yingundji Formation.--A sequence of beds laid down in the original crater and exposed interior to the breccia ring is here named the Yingundji Formation after the aboriginal name for the Liverpool Crater. Sedimentary breccia in the basal part of this sequence rests with sharp contact on the allogenic breccia and is crudely but distinctly bedded and finer grained than the allogenic breccia, from which it appears to have been derived. About 30 m of well indurated, gritty sandstone that constitutes the upper part of the preserved crater fill sequence is well exposed in an inner ring of outcrops toward the center of the structure. The lithology and sedimentary structures of the sandstone are remarkably similar to those of the Kombolgie Sandstone, as is the degree of induration. Small-scale cross beds are present and, in general, dip more or less toward the center of the crater, reflecting the direction of inward transport from the crater walls. Some beds are locally conglomeratic and contain quartz pebbles up to five centimeters across that have been reworked from the Kombolgie. Rarely, sandstone pebbles are present, which distinguishes the Yingundji from the Kombolgie.

Structure.--The impact structure is about six per cent wider in the NE-SW direction than it is NW-SE. This difference is due chiefly to broad zones of authigenic breccia and strongly deformed Kombolgie on the southwest and northeast sides. The center of the depositional basin within the crater is offset about 100 m to the northeast from the center of the structure, and the initial crater wall was much shallower on

the southwest side. These relationships indicate that the direction of travel of the impactor was from the southwest. The shallow average dip of the basal contact of the allogenic breccia on the southwest side suggests a relatively low oblique impact. Dips in the coherent parts of the authigenic breccia are consistently very steep to overturned on the uprange, southwestern side of the structure. On the downrange side, the deformation is much less systematic. The level of erosion of the Liverpool Crater appears to be relatively shallow. Probably no more than one or two hundred m of the upper crater wall or rim have been lost by erosion, and the original crater probably was no more than 20% larger than the diameter of the preserved allogenic breccia ring (taking an average dip of the basal allogenic breccia contact at 45_.)

Age.--The age of the Liverpool Crater must be considered indeterminate for the time being. It is entirely possible or even likely that it is Proterozoic. Although Guppy et al. (2) suggested that the crater fill might be Cretaceous in age, the remarkable similarity of the Yingundgi to the Mesoproterozoic Kombolgie, both in terms of sedimentary structure and induration, and the strong induration of the allogenic breccia both suggest a possible Proterozoic age.

REFERENCES: (1) Rix, P., 1965, Milingimbi, N.T., Bureau of Mineral Resources, Canberra, Australia, sheet SD 53-2 (explanatory notes), 13 pp. (2) Guppy, D.J., Brett, R., and Milton, D.J., 1971, Jour. Geophys. Res., v. 76, p. 5387-5393.

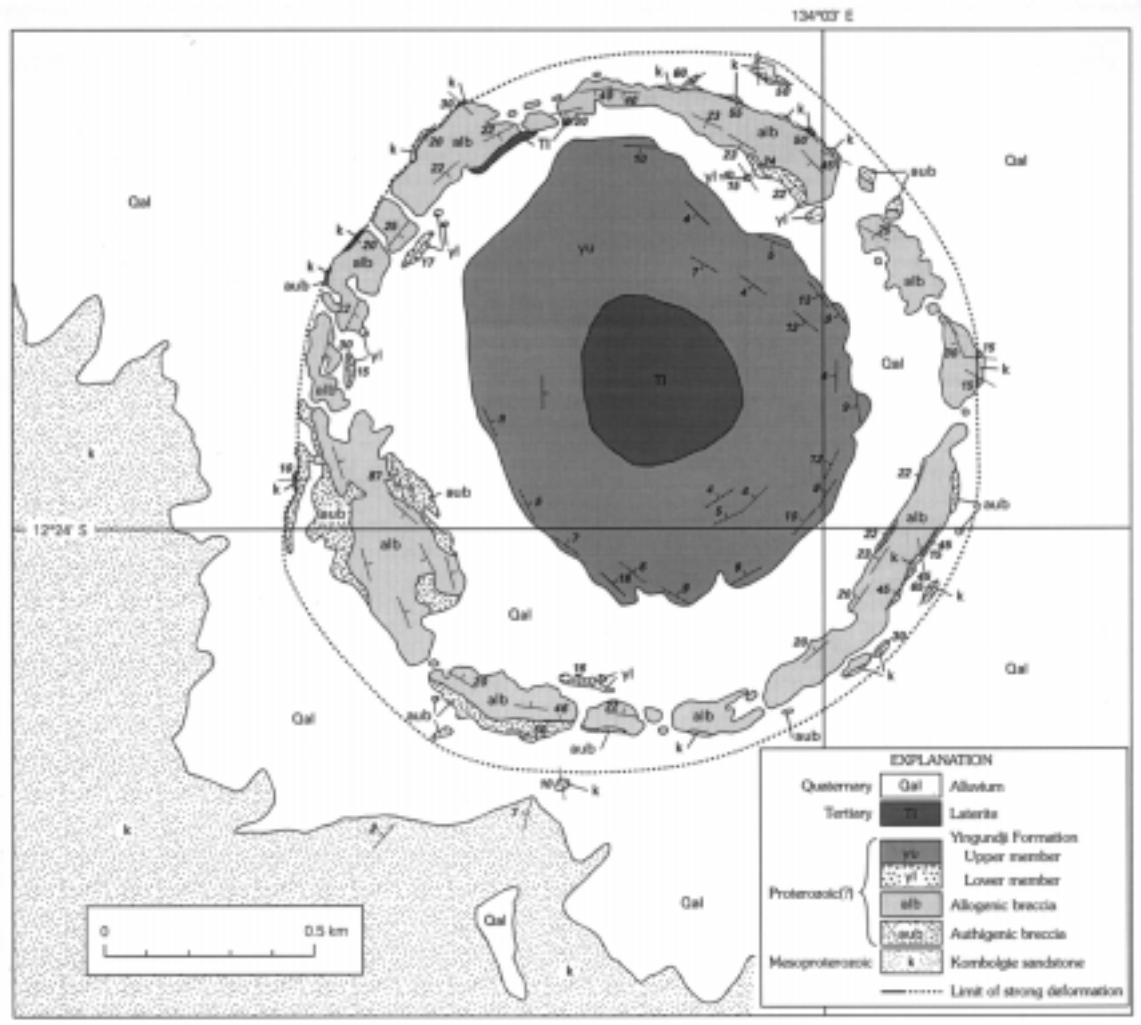

Figure 1. Geologic map of the Liverpool Crater, Northern Territory, Australia
Geology by E.M. Shoemaker and C.S. Shoemaker, September 11-20, 1996.