THE RIES CRATER AND LUNAR BASIN DEPOSITS. F. Hörz, NASA Johnson Space Center, Houston, TX; H. Gall, Univ. of München, München, Germany; R. Hüttner, Geologisches Landesamt, Freiburg, Germany; V. R. Oberbeck, NASA Ames, Moffett Field, CA; R. H. Morrison, LFE Corp., Richmond, CA

The depositional history, mechanism(s) of emplacement and areal extent of continuous deposits surrounding large lunar impact craters, in particular basin forming events, have recently received considerable attention because of their implications to the source area of returned lunar rocks, specifically from the Apollo 14 and 16 landing sites. Moore et al. (1) and Chao et al. (2) postulate that the entire lunar globe will be draped by a continuous layer of e.g., Orientale ejecta. Oberbeck et al. (3, 4, 5) maintain that such ejecta at the end of their ballistic trajectory beyond a certain threshold distance will cause a secondary cratering action that results in excavating, reworking, mixing and flow of considerable amounts of local materials. Thus the amount of primary ejecta in the deposits associated with large scale lunar impacts remains controversial.

Photogeologic studies of lunar impact craters ranging in size from .1 to \( \approx 100 \) km combined with laboratory cratering experiments and theoretical considerations reveal that reworking of the local terrain is insignificant for craters <2 km diameter because of relatively low terminal ejecta velocities within the continuous deposits. As a consequence the incorporation of locally derived materials into the ejecta deposits may not be studied at nuclear explosion sites and small terrestrial impact structures, e.g., Meteor Crater, Arizona. The Ries Crater, Germany, an impact structure of 23 km diameter, however, should offer an excellent test; it is, in our opinion, the only suitable terrestrial analogue to study the nature of large scale impact deposits in the field.

Owing to a fortunate geologic circumstance, the Ries is ideally suited to assess the phenomenon of local mixing: approximately 7-10 km south of the present crater rim, a Miocene cliff line defines the geological contact between upper Jurassic limestones and Tertiary sediments (marls and sands derived from the Alps, which occur \( \approx 150 \) km further to the south). These tertiary sediments were never present at the location of the crater cavity and thus cannot be primary Ries ejecta. Numerous outcrops and detailed geological mapping with a bore stick (6, 7) to the south of the above cliff line show that these sediments are an integral part of the Ries continuous deposits. Local materials are mixed with primary crater ejecta to various degrees with breccias of more and more local character generally becoming more abundant at increasing radial distances. The amount of local material may actually increase to >90% at the periphery of the continuous deposits. In certain areas the local contributions are actually so dominant that only recent bore stick mapping revealed the presence of potential primary ejecta (i.e., upper Jurassic limestones, etc.) intimately mixed with local sediments that were previously interpreted as undisturbed, but that now must be considered part of the Ries breccias (7). This field evidence is corroborated by Schneider (8), who - on the basis of accessory minerals in various Ries breccias - identifies "a breccia type that does not contain materials from within the crater cavity". In general, these breccias are fine grained and thoroughly mixed, leading (8) to
the conclusion that "the mixing must have occurred in mid-air", though Hüttner (6) and others prefer a ground hugging flow regime. The thickness of these breccias is not well documented, but in the order of 10 m.

Two unusually striking features are of importance: 1) the breccias contain occasionally exceptionally large clasts of unambiguous local derivation measuring tens of m in diameter, e.g., \( \sim 50 \times 50 \times 30 \) m near Oppertsbofen. This implies that the excavation process must have operated in certain localities to depths of a few tens of m. 2) Limestone clasts dislodged from the very cliff line can easily be identified because they contain mollusca (= pholade) bore holes. Such boulders present excellent markers and are found as far as 7 km to the south of their original position. Their distribution is unambiguous evidence that considerable lateral transport of local materials took place.

Though the evidence of local mixing is most easily recognized in the southern part of the Ries deposits because of the existence of specific Tertiary sediments, it is persuasive also in the eastern and western parts of the breccia deposits and was actually described from there as early as 1905 (9). Interaction of the ejecta with the pre-impact surface is also observed on the very crater rim e.g., at the Hohlheim quarry, where not only approximately 5 m of a pre-existing weathering horizon was completely removed, but where also abundant "Schliffflächen" (= giant slickensides;[10]) occur, the largest possibly measuring 8 m in depth and 40 m in width, thereby indicating that in addition to the weathering horizon, appreciable amounts of competent limestone were stripped off. Because such Schliffflächen are known from approximately 40 localities between 0 and 14 km distance from the crater rim (10), it must be postulated that the pre-existing weathering horizon was removed at all such localities, i.e., local materials must have been incorporated into the Ries deposits.

In summary, locally derived breccias are widespread at the Ries Crater and, in fact, the dominant breccia type at the periphery of the continuous deposits. A "mixing zone" of at least 5 m depth can be inferred from the Schliffflächen for almost the entire crater surroundings. Depths of excavation of \( \approx 10 \) m can be postulated for most of the Tertiary breccias to the south of the cliff line. The presence of giant clasts within these breccias is evidence that, on occasion, materials may have been dislodged from depths significantly deeper, i.e., a few 10's of m at ranges as far as 18 km from the crater rim. The presence of Schliffflächen and pholade boulders is evidence of lateral transport by flow (6, 7, 10).

Chao (11) recently critiqued the Oberbeck et al., hypothesis by rephrasing the earlier conclusions of (6, 7, 10, 12). He incorrectly proposes that the presence of a ground hugging flow regime (6, 10) is inconsistent with the Oberbeck et al. hypothesis. He furthermore neglects the magnitude of the mixing process, i.e., the widespread nature of local breccias. Though admittedly the emplacement mechanism of the Ries deposits must remain the subject of future field investigations, it appears that the evidence presented is consistent with the Oberbeck et al. thesis. If applied to continuous deposits of large scale lunar impacts, the Ries evidence, however, strongly argues against a moon wide layer consisting of primary ejecta of the Orien-
THE RIES CRATER AND LUNAR BASIN DEPOSITS

F. Hötz

te event as suggested by (1, 2).

References: