THE TRANSIENT CAVITY OF THE RIES CRATER, GERMANY. F. Hörz, NASA Johnson Space Center, Houston, TX 77058 and Rolf Ostertag, Lunar and Planetary Institute, Houston, TX 77058 and Univ. of Münster, 44 Münster, Germany.

Recent reinterpretation and recognition of a concentric slump zone at the periphery of the Ries Crater (1), new information from a deep drill hole (2) and continued geophysical investigations (3), reveal significant new insight into the Ries' subsurface structure (Fig. 1a). In a variety of ways the Ries appears incompatible not only with single bowl-shaped "small" craters, but also with complex "large" craters lacking any significant central uplift (4). Thus considerable ambiguity about the transient crater cavity exists as exemplified by two drastically different model cavities (Fig. 1b (5) and 1c (3)). In the following we suggest that most of the features observed may also - and perhaps best - be explained with a "terraced" crater cavity (Fig. 1d) following small scale cratering experiments (6, 7) and the suggestion of "nested" craters (8).

The stratigraphy of the Ries is made up of ≈250 m of competent upper Jurassic limestones and ≈350 m of Lower Jurassic and Triassic incompetent sediments (shales, clays, sandstones, marls) which unconformably overlie a crystalline basement. Thus the principal strength discontinuity giving rise to a terraced crater is located within the deep seated sediments at or close to the crystalline basement. Although this discontinuity was clearly recognized to be important (1, 2 and others), the suggestion of a terraced transient crater cavity was never detailed.

The principal features of this hypothesis for the Ries crater are sketched in Fig. 2: At t_1 the crater grows in the sediments as a simple bowl having a depth/diameter ratio of ≈1:5. At t_2 the transient cavity flattens out as it encounters the competent basement at 600 m depth when the minimum diameter is ≈3 km (9). The diameter after flattening may be about 6-7 km (6) and sediments are being ejected full force. At t_3 a small cavity develops in the basement and ejection of sedimentary materials continues independently at the radially growing terrace "lip." At t_4, material is being ejected from the crystalline crater as well as from the terrace lip in analogy to the two independent ejecta plumes observed in small scale laboratory experiments using layered target media (7). Ejection of sediments from the terrace lip has virtually ceased at t_5 and the transient terrace has reached its maximum D (17-20 km). Crystalline materials including suevite are the principal ejecta emanating from the still growing crystalline cavity. At t_6 the crystalline crater has reached its maximum dimensions: ≈8 km radius and ≈1600 m deep into the basement. Suevite has been ejected along very steep trajectories based on the large volumes of "fallback" in the present crater and in agreement with (7). While suevite is being ejected, the terrace lip starts to slump forming the "Kraterrand zone," (1) i.e., an annulus between ≈r 10 km and 13 km characterized by giant slump blocks of 100's of m, if not km in dimension. Finally, the walls of the inner crystalline crater fail via inward and upward motions (4) giving rise to a modest central peak ring, leveling most of the bowl shaped cavity and leading to an increase in D to ≈12 km, the location of the present-day, "inner-ring."

The "crystalline" crater - in accordance with (3) - is essentially a complete crater in itself, the "inner ring" being its exposed rim. This rim is presently ≈400 m above the original crystalline basement, i.e., perfectly compatible with the rim height/diameter data of (9). It is entirely dominated by crystalline materials and deep seated sediments, the latter on occasion in inverted stratigraphy (10). The northern part of this rim appears terraced (3), which, together with other observations (e.g., 4, 11 and others), is to be expected from an ≈8 km transient diameter, terrestrial crater, the rim of which has slumped into the cavity. A deep drill hole (2) confirms significant

TRANSIENT CAVITY OF THE RIES CRATER...

F. Hörz and R. Ostertag

lateral mass movement just inside this rim. The "central peak ring" constitutes the central uplift of the crystalline crater; its dimensions are compatible with a 12 km final diameter "complex" crater (≈200 m high, D = 4-5 km; see (3)). The marked hiatus between the deposition times of suevite and Bunte Breccia confirms that two independent ejection regimes were operating.

We now turn to the "apparent" crater rim (D = 26 km) and the "Kraterrand zone" just inside, for which (1) and others described both inward and outward movement of huge, sedimentary blocks. Topographically most of this zone is lower than the original target surface indicating that inward slumping was the dominant process (1). These complex structural relations of inward and outward movements can readily be explained if one assumes that the terrace lip was draped by "outward" moving ejecta blocks prior to slumping. The comparatively thin breccia deposits (10-10's of m) just outside the 26 km rim fit well into this concept, as most of the thick deposits at the terrace lip have slumped into the crater. Indeed, the total thickness of ejecta even at the terrace lip (200-300 m at most) seems small compared to the rim height/diameter data of (9) and we interpret this again in favor of a terraced rather than bowl shaped transient cavity. The Kraterrand zone is typically 2-3 km wide, although in the NE and SE corner one may postulate 5 km width. Thus, slumping was extensive. Very importantly, however, seismic investigations revealed that the crystalline basement is disrupted only to r ≈10 km (3), meaning that it is virtually intact below the Kraterrand zone and the apparent rim. The deep thrust faults postulated for various Canadian craters (4) appear to be absent in the rim area and Kraterrand zone of the Ries; the slumping is confined to depths <600 m, the thickness of the sediments. This appears to favor again a transient terrace within the sediments which had no effects on the crystalline basement.

The "megablock zone" of (3) includes the Kraterrand zone and extends from approx. r = 6 to 13 km filling the entire structure between the inner and outer rims. Following (3) we interpret this fill also as a mixture of slump blocks from the crater periphery and genuine ejecta from the 12 km crystalline crater. Based on the models of (4), however, slumping of a 12 km transient cavity may not lead to a final crater of 26 km diameter, i.e., a twofold increase in radius due to post impact modifications. We therefore suggest again that a somewhat larger terraced cavity of D ≈17-20 km may better account for the final Ries diameter.

In summary, the salient features of this model are two independently growing "craters" which have two different ejecta plumes and distinct chronological and structural consequences, all of which are compatible with a large body of field evidence. Two ejection regimes and the existence of a complete crystalline crater seem to argue particularily against a bowl shaped crater in a homogeneous target. A rigorous test of the various hypotheses, however, is not possible at present because volume estimates for the various lithologies excavated in the Ries are still afflicted with substantial uncertainties.

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TRANSIENT CAVITY OF THE RIES CRATER

F. Hörz and R. Ostertag

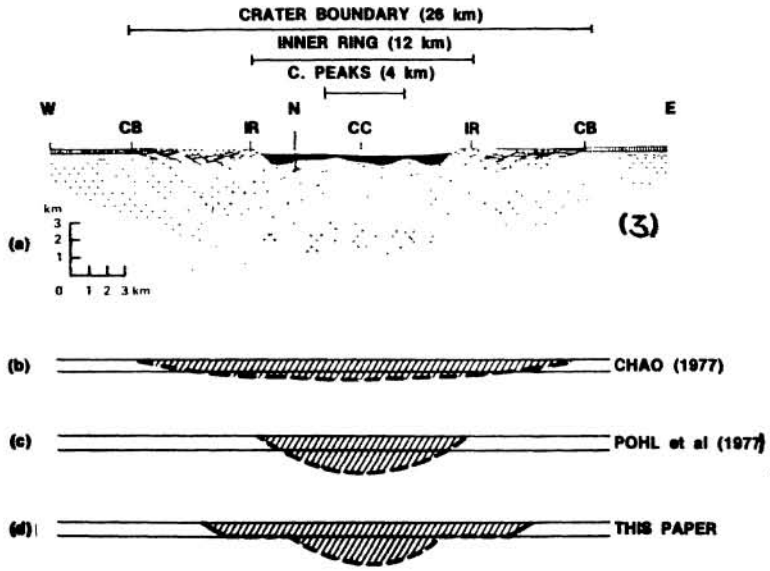

Fig. 1

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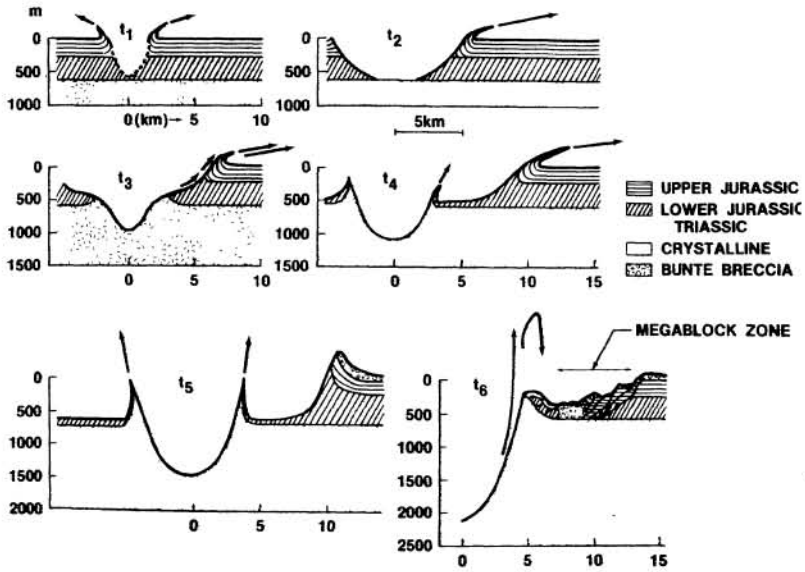

Fig. 2