thickness. The present spot-like occurrences may represent thicker suevite accumulations trapped in local pockets of the hummocky multicolored breccia relief. Suevite was deposited as the last of all masses ejected from the crater. As can be concluded from structures at the lower contact (SCHNEIDER, 1971), the suevite mass, as a hot density current, overflowed the crater rim and rolled over the first-formed deposits of multicolored breccia. Because the shapes of the bombs indicate their rapid flight through the air it is probable that the suevite current developed from the breakdown of an eruption column ejected more or less vertically from the crater center. Suevite breccias below the lake sediments represent that part of the material which landed within the crater. Although suevite deposits outside the crater never show laminated or dune-like structures their mode of formation may be somewhat similar to that of volcanic base surge deposits as described by WATERS & FISHER (1971). (HÜTTNER, 1969; ENGELHARDT et al., 1969, HÖRZ 1965; STÖFFLER 1966; FÖRSTNER 1967; CHAO 1968 and in unpublished records).

(5) Impact melt. Red vesicular rocks, occurring in two small outcrops near the eastern rim (Polsingen, Amerbach), may represent impact melts. The rocks show a fluidal texture and contain many crystalline fragments in a groundmass consisting of feldspar laths, pyroxene, some cristobalite and hematite. They may be outlying tongues of impact melt rock sheets which occur deeper in the crater (ENGELHARDT et al., 1969; DENCE, 1971).

Shatter cones are very rare in the Ries. Some not very well developed cones in a brecciated limestone from a crystalline breccia and some small ones in crystalline fragments have been found near the eastern rim. A large granite block with many well-developed shatter cones has been found in multicolored breccia at the southeastern rim (DRESSLER, GRAUP & MATZKE, 1969; GRAUP, 1970, unpublished observations; ENGELHARDT, 1970, unpublished observations).

Results of gravity measurements carried out in the Ries area have been summarized by JUNG, SCHAAF & KAHLE (1969) and KAHLE (1969). The residual field obtained by subtraction of the regional field from the measured gravity values shows a centrosymmetrical negative anomaly the center of which (—18 milligal) is located at the topographical Ries center. By integrating the gravity anomaly, a total deficient mass is obtained between 6.8×10^{16} and 7.7×10^{16} g.

The Ries crater shows negative magnetic anomalies which are mainly located within the inner crater. The measurement of the magnetization of suevite has shown that the anomaly is due to a suevite layer of varying thickness, up to 400 m, in the central crater (POHL & ANGENHEISTER, 1969).

Refractive seismic experiments from 1948 to 1952 and recent reflection profiles have revealed the complicated structure of the Ries crater. A profile, based on reflection data from outside the crater through the western rim and ending in the center (18 km), is shown in Fig. 2. An inner crater, 10 km in diameter, is surrounded by the inner horseshoe rim. Within the inner crater Tertiary sediments of about 350 m maximum thickness have been deposited after the Ries event. Below these sediments lies a layer of suevite of varying thickness, up to 300—400 m. The layer underlying the suevite is a breccia of unknown composition. The inner ring is probably composed

of fractured crystalline rocks. The marginal zone between the ring and the outer rim is mostly filled with various breccias. The western rim is clearly indicated by the abrupt disappearance of the reflections in the undisturbed Mesozoic layers and from the surface of the basement (ANGENHEISTER & POHL, 1969).

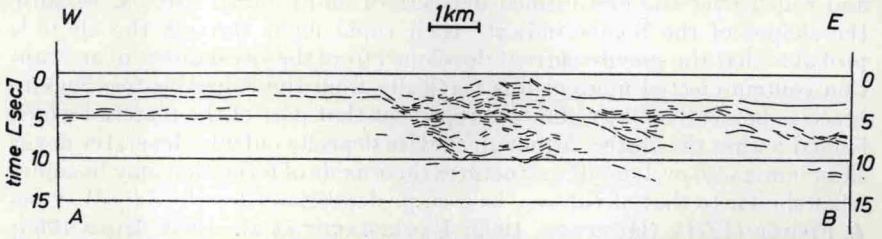

Fig. 2. Ries crater. Seismic reflection profile from outside the crater to the center. For location of the profile, see Fig. 1 (ANGENHEISTER & POHL, 1969).

Two drill holes have penetrated the lake sediments. The hole at Deiningen, approximately 1 km south of the topographic center, has revealed suevite underlying a sequence of 310 m of lake sediments. The hole at Wörnitzostheim, located in the southeast of the basin, in the marginal zone, close to the inner ring, has revealed 20 m of lake sediments, underlain by 80 m of suevite. Below the suevite lies 1.3 m of granite and multicolored breccia composed of Keuper and Middle Jurassic, in an inverted sequence (FÖRSTNER, 1967)[1].

The distribution of ejecta masses is not centrosymmetrical around the Ries crater. Multicolored breccia, crystalline breccias and suevite occupy larger areas south and southeast of the crater than to the north and northwest. To some degree, the present distribution may be influenced by erosion which was more intense in the north than to the south. However, the present asymmetry can probably not entirely be attributed to erosion alone. It might be that more brecciated material was ejected and deposited to the southeast and south than to the north and northeast. Asymmetrical features can also be recognized in the morphology of the crater. The horseshoe ring of crystalline material raised to the surface is open to the north or northwest and JOHNSON & VAND (1967) showed that the topographic crater shows an elliptical contour, the long axis pointing to the southeast. It is probable that these asymmetries originate from an oblique incidence of the impacting body which came in at a low angle from the north-northwest.

Age determinations (K—Ar) of glassy bombs from several suevite occurrences gave 14.8 ± 0.7 m.y. These values have been confirmed by fission track measurements. The same age was found for the moldavites and bentonitic glass tuffs which occur near Landshut, Bavaria, 90 km southeast of the Ries center, in Upper Miocene sediments. It was suggested that both moldavites and glass tuffs were produced by the Ries impact. Several theories have

[1] Note added in proof: A third drill hole, "Nördlingen 1973", located 4 km north of Nördlingen, has been completed in January 1974. The hole reached a depth of 1206 m and penetrated the following profile: 0—325 m: lake sediments, 325—605 m: suevite, 605—1206 m: crystalline breccia (Geol. Bavarica **72**).