in the north, where they consist of softer Middle Jurassic, Lower Jurassic and Keuper rocks. The basin rim has a somewhat polygonal outline, probably due to pre-existing fracture systems. The central part of the basin forms a flat plain of circular outline, about 10 km in diameter. It is surrounded by a horseshoe-shaped ring of hills up to 50 m in height which is open to the north. Between this inner ring of hills and the outer rim is a marginal zone of hummocky and irregular relief. The interior of the basin is filled by Tortonian and Sarmatian (Upper Miocene) lake sediments, covered in part by alluvial and Pleistocene deposits. Upper Miocene fresh-water limestones occur on top of the hills of the horseshoe ring and along the inner slope of the outer rim. At a distance of a few km (at most 5 km), the present rim is surrounded by a watershed. Two rivers enter the basin, the Wörnitz from the north and the Eger from the southwest. The Wörnitz river, after joining the Eger, leaves the basin through a narrow outlet in the southeast. Inlets and outlets represent old valleys already existing before the impact.

Johnson & Vand (1967) carried out an harmonic analysis of the Ries crater morphology based on 1:25,000 topographic maps. A main rim was found, 24 km in diameter, and two secondary ones, 34 and 45 km in diameter, respectively. No geological or other field evidence is known for ground movements at such great distances outside the crater. The contours of the rims obtained in this analysis are slightly elliptical. The major axis has a general north-northwest — south-southeast direction. Masses excavated by the impact and raised from the crater floor occur in the horseshoe ring, within the hummocky zone between this ring and the outer rim and as an ejecta apron outside the crater. Impact breccias have also been found in boreholes below the lake sediments in the central crater.

Within and around the Ries crater the following main types of impact formations can be distinguished and mapped:

(1) Blocks of shattered but uniform masses of Mesozoic sediments, sometimes more than 1 km in size. Predominant are blocks and intensely fractured masses of Jurassic limestones. Such masses occur within the marginal zone of the crater and outside the rim, within the region occupied by multicolored breccia. The participation of lower members of the stratigraphic column diminishes with increasing distance from the crater (Hüttner, 1969). Smaller fragments of Upper Jurassic limestone also occur south of the Danube as boulders at the base of Pleistocene deposits (Reutersche Blöcke) and embedded in Upper Miocene fluviatile sediments which have the same age as the Ries event. Most of the known occurences in Miocene sediments are located 50—70 km south and southeast of the Ries center. An isolated mass of heavily fractured limestone, about 2 m in diameter, has been found 140 km southeast of the crater (Hüttner, 1969; Herold, 1969; Engelhardt, unpublished observations).

(2) Multicolored breccia (Bunte Breccie) is a weakly shocked polymict breccia composed of all kinds of sedimentary rocks in variable proportions, with a small admixture of material from the crystalline basement. The components range in size from large blocks to the finest grains. Multicolored breccia occurs within the marginal zone of the crater and outside of it. Around the crater the multicolored forms an apron extending from the rim

up to 26 km to the southwest and up to 24 km to the south-southeast, but only 3—4 km to the north. In the south the extension of the breccia is interrupted by the Danube valley. The thickness is very variable; the average may be 20—24 m, but maximum values up to 80 m have been observed in the southeast. The amount of older sediments and of crystalline material in the breccia diminishes with increasing distance from the center. Indications of shock metamorphism in the multicolored breccia are a few quartz grains with planar deformation structures and some fragments of crystalline rocks in stages I and II of shock metamorphism. The multicolored breccia was moved along the ground, as can be concluded from striations on the surface of underlying limestone, pointing to the crater centre, and from strong interaction and mixing with local unconsolidated Miocene sediments in the south (HÜTTNER, 1969; SCHNEIDER in ENGELHARDT et al., 1969, 1971).

(3) Fragmental material from the crystalline basement occurs as uniform blocks of granite or gneiss, up to some 100 m in size, or as monomict and polymict weakly to moderately shocked breccias. The larger blocks are situated predominantly within the horseshoe ring. Crystalline breccias occur at the inner ring, within the marginal zone and outside the crater, predominantly in two rays extending to the south and southeast. Monomict breccias consist of fragments of one crystalline rock and show only minor shock effects (up to stage I of shock metamorphism). Polymict breccias are mixtures of different gneisses, granites and amphibolites. Shock effects include stages I and II of shock metamorphism, but no melting. Coesite and stishovite have been found in these breccias (HÜTTNER, 1969; DRESSLER, GRAUP & MATZKE, 1969; ABADIAN, 1972; GRAUP, 1971; STÖFFLER in ENGELHARDT et al., 1969).

(4) Suevite is a strongly shocked breccia consisting of crystalline rock fragments, a few sedimentary rocks, mineral fragments (predominantly quartz), glass fragments and glass bombs in a groundmass of montmorillonite. Crystalline rock and mineral fragments occur in all stages of shock metamorphism up to complete melting. Coesite and stishovite have been found in shocked rock fragments (STÖFFLER, 1971b). Characteristic constituents are aerodynamically shaped bombs (Fladen) consisting of a heterogeneous schlieren-rich, mostly devitrified glass with inclusions of many mineral fragments (predominantly quartz), lechatellerite and vesicles. The chemical composition of the glass of all suevite occurrences is very uniform, corresponding to a gneiss of granitic norm (HÖRZ, 1965; ENGELHARDT & HÖRZ, 1965; ENGELHARDT, 1967). The Ni-content seems to be higher than that of the crystalline source rocks (STAEHLE, 1970). As can be concluded from the remanent magnetization, the average temperature of the suevite at the time of its deposition was above the Curie temperature of magnetite, i.e. >580 °C. Vertical vents formed by escaping vapor or gases and early hydrothermal alterations show that the suevite mass included a certain amount of volatiles.

Suevite occurs (1) as a blanket underlying the lake sediments in the central basin (fall-back breccia) and (2) at the surface as isolated spots in the marginal zone and outside the crater, especially to the south and east (fallout breccia), up to 20 km from the crater rim. In most cases fallout suevite is underlain by multicolored breccia. The occurrences at the surface may be remnants of an originally more continuous blanket of variable