Phreatomagmatic Structures in the Northern Environs of the Ohře Rift (Saxony)

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ABSTRACT. The preservation of phreatomagmatic structures (maars) depends on their position in uplifted/subsided areas after their formation. In both cases it is difficult to identify older (Tertiary) phreatomagmatic structures. In uplifted areas they are deeply eroded. In subsiding areas the structures are buried deep beneath younger sediments. Maars can be discovered only with the help of geophysical methods (gravimetric and magnetic measurements) or incidentally by drilling. Three structures were identified as undoubtedly of phreatomagmatic origin: two in the Lusatian area and one in the Erzgebirge Mts. A few more structures are possible to be found in both areas. The fill of the maar of Hammerunterwiesenthal–České Hamry is incised by the valley of the Pöhlbach River in the Erzgebirge Mts. and the maars of Kleinsaubernitz and Baruth in the Lusatian region were investigated by two boreholes.

KEY WORDS: Maar, phreatomagmatic structure, Ohře Rift, Erzgebirge/Krušné hory Mts., Lusatia.

Introduction

Maars – products of phreatomagmatic eruptions – occur in many ancient and modern volcanic regions. According to Lorenz (1985), maars are small monogenetic volcanoes largely represented by craters cut into pre-eruption surfaces. They usually reach max. 2 km in diameter and 400 m in depth and rank second among the most common types of volcanoes in the world.

Maars are formed by explosive volcanic activity at subaerial plate margins and in intraplate settings. The reason for such phreatomagmatic activity is the complex interaction between ascending magma and ambient water, mostly groundwater, giving rise to powerful water-vapour explosions. From this point of view, there is a close relationship between the surface drainage patterns (valleys) and places of phreatomagmatic eruptions (Lorenz 1985). A typical maar structure consists of maar crater, a ring wall and maar lake in its superficial part. Lake deposits with marginal and basinal facies, syneruptive pyroclastics in their maar diatreme and a root zone with magma intrusions, are developed in the subsuperficial part of the maar. The structure continues to the depth by a feeder dyke-system.

Preservation of maars

The preservation of maar structures over longer periods of the Earth's history is very problematic. It depends on their position in a subsidence- or uplift-dominated areas. Maars located in uplifted areas are eroded to different levels, based on the rate of erosion. The deeper the level of erosion, the bigger the difficulties in identifying the remaining structures as maars. Many subcircular occurrences of volcanic rocks may represent deeply eroded maar structures, like the diatremes of Swabian and South Africa.

Maars located in subsiding areas are buried by younger sediments. This fact hinders the identification of such maar structures as there is no such indication on the present surface. Buried maars can be discovered by means of geophysical survey, such as gravimetric or magnetic survey, or incidentally by drilling.

Maars of the Bohemian Massif

Maars in the northern environs of the Ohře Rift

Phreatomagmatic structures do occur in the Ohře Rift as they do in other volcanic areas. From the territory of the Czech Republic, maars were described by Kopecký et al. (1967) and Brus and Hurník (1984). Only recently, maar structures were identified for the first time in the northern environs of the Ohře Rift (Saxony) by Suhr and Goth (1996). Three structures were proved as undoubted maars here: two in the Lusatian region and one in the Erzgebirge Mts. Some more structures are probably present in both regions (see Fig. 1).

Maar of Hammerunterwiesenthal–České Hamry

The documented phreatomagmatic structure in the Erzgebirge Mts. is located precisely at the German–Czech state border at the villages of Hammerunterwiesenthal and České Hamry, approximately 15 km south of the town of Annaberg-Buchholz, in the proximity of the famous basaltic hills of Scheibenberg, Pöhlberg, Bärenstein and Špičák. The maar-filling rocks are exposed in several quarries. The margins of the maar were determined by magnetic measurements, unfortunately on the German side only. Results of detailed geophysical and geological investigations along with the data of Malásek et al. (1980) were incorporated in Fig. 2. The nearly circular volcanic body of tuffs and volcaniclastic deposits is surrounded by gneisses, crystalline limestones and a small phonolite intrusion. Three intrusions of phonolite and tephrite (after Malásek et al. 1980), partly buried under volcaniclastic material, are located in the central area. The basement of the structure is cut by a vein with baryte and fluorite (Niederschlag–Kovářská vein structure) in the eastern part. This vein system could have drained water from an ancient valley to the ascending magma under the ground. Such process might have triggered a phreatomagmatic explosion at this site.

Relationships between the individual rocks types under the surface are shown in a cross-section (Fig. 3). The fill of the maar crater consists of syneruptive pyroclastics and posteruptive lake sediments with intercalations of volcaniclastic turbidites or debris flows. K/Ar determinations (Hesz, friendly oral information) indicate the age of the fill of ca. 31 Ma. The same age was determined for syngenetic intrusions of leucitite. Postgenetic intrusions of phonolite clearly differ from the syngenetic intrusions in age, about 28 Ma (Pfeiffer et al. 1984), and form laccoliths in the sedimentary fill of the maar crater. The relief has been eroded by at least 100 m since the Oligocene.

A detailed profile (Fig. 4) across the outcrop at the quarry entrance (890 m a.s.l.) shows typical marginal sequences of the

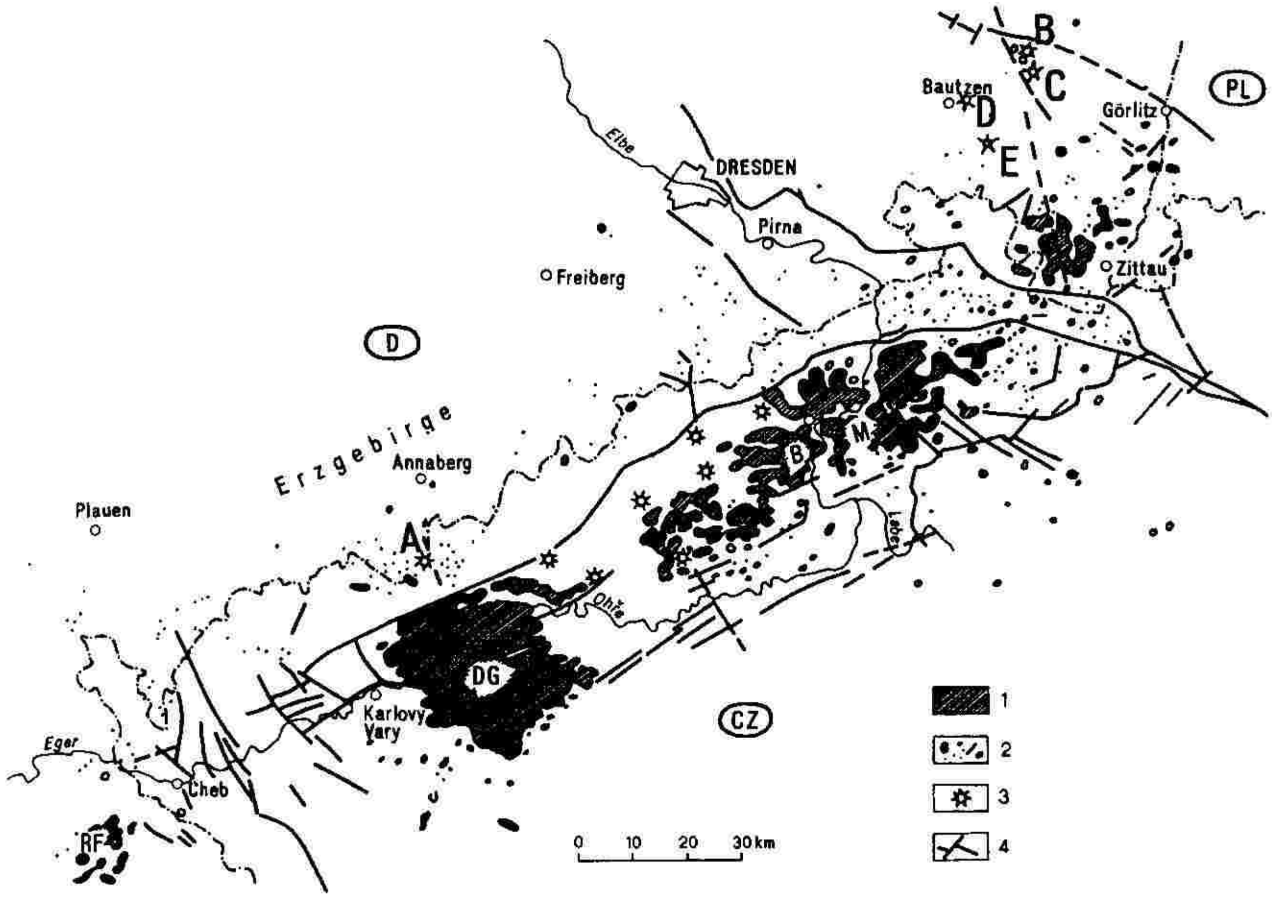

Fig. 1. Volcanic rocks in the environs of the Ohře Rift. 1 – large areas with volcanics (incl. pyroclastics); 2 – individual volcanics bodies (diatremes, dykes, necks); 3 – phreatomagmatic structures; 4 – faults; A – the maar of Hammerunterwiesenthal–České Hamry; B – the maar of Kleinsaubernitz; C – the maar of Baruth; D – a possible maar of Kerkwitz; E – a possible maar of Cunnewalde; RF – Reichsforst; DG – Doupovské hory Mts; BM – České středohoří Mts.

maar fill. Bedding planes of the coarse marginal facies dip to the centre of the structure. Lithological sections beneath the younger phonolite intrusion in the "Richter" Quarry (Fig. 5) show fine laminated lacustrine limestones and clastics with intercalations of coarse debris flows and turbidites. The fine laminated limestones in the lower part of the section are non-fossiliferous. Some of the laminated clastics are rich in plant fossils, such as leaves, seeds and wood remains, as described by Walther (1998). Fishes, poorly preserved gastropods, insects and a skeleton of salamander *Archeotriton basalticus* (Böhme 1998) are also present. The fossils indicate a Lower Oligocene age, which is in good agreement with the radiometric data. Leucitite agglomerates (Lapp 1997) are exposed in the lower part of the section and document synsedimentary volcanic activity in the maar lake. A similar section was documented by Malásek et al. (1980) from a borehole in the Czech part of the structure.

Maars of the Lusatian region

Moderate subsidence in the Lusatian region during the Lower Miocene led to the burial of the phreatomagmatic structures by younger sediments. Two phreatomagmatic structures were subjected to geophysical investigations and documented by deep boreholes. Another two possible structures are indicated by geophysical anomalies only (see Fig.1).

Three characteristic rounded anomalies up to 10 mGAL were indicated by regional gravimetric survey in the area northeast of the town of Bautzen. The largest anomaly is located near the village of Kleinsaubernitz. The second was found east of Baruth. The third anomaly, which is the least prominent, has not been tested yet. The research was focused on the two anomalies in the areas of Kleinsaubernitz and Baruth.

These two gravity anomalies coincide with distinct magnetic anomalies. Such combination of anomalies is characteristic of most of the known buried maars. The other strong magnetic indications are associated with basaltic occurrences and do not coincide with gravity anomalies. A borehole was drilled in the centre of the biggest combined anomaly in 1970 to explain its cause. This borehole produced a suprising drill core (Figs. 6 and 7). After penetrating about 200 m of Miocene sediments in the development typical for this region with four lignite seams, the borehole reached fine laminated lacustrine sediments (diatomites, oil shales) of Tertiary age with intercalations of turbidites and debris flows more than 300 m in thickness. Their succession is deformed by slumps. Besides boulders of ambient country rocks like granodiorite and Lower Carboniferous shale and conglomerate, tuff particles and basalt bombs were also encountered in coarser sediments. The lacustrine sediments were dated to the Upper Oligocene, based on a microfloral analysis (Goth, friendly oral information).

Only five kilometres to the southeast, another gravity anomaly was further investigated by a combination of geophysical methods such as detailed gravimetry, special seismic and other methods by Geowissenschaftlichen Gemeinschaftsaufgaben, Hannover and the University of Leipzig, with the aim to find

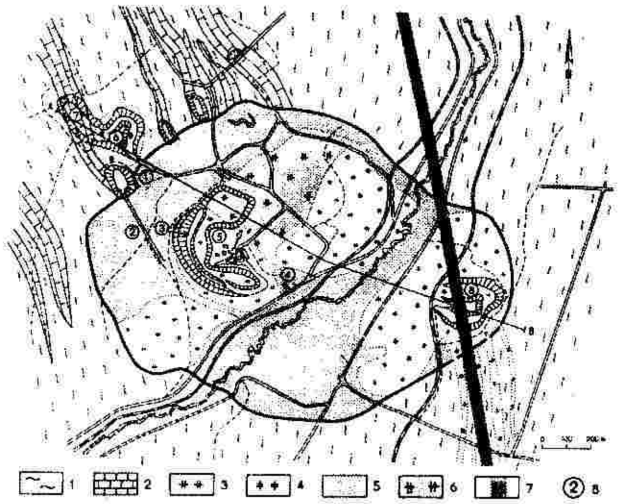

Fig. 2. Geological map of the maar of Hammerunterwiesenthal–České Hamry.
1 – muscovite gneiss; 2 – crystalline limestone; 3 – phonolite; 4 – tephrite; 5 – redeposited volcaniclastics and lacustrine sediments; 6 – phonolite under redeposited volcaniclastics; 7 – vein system of Kovářská–Niederschlag; 8 – outcrops.

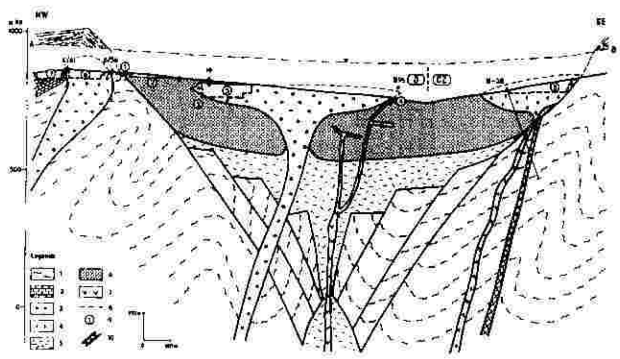

Fig. 3. Geological cross-section of the maar structure of Hammerunterwiesenthal–České Hamry. 1 – muscovite gneiss; 2 – crystalline limestone; 3 – phonolite; 4 – tephrite; 5 – pyroclastics; 6 – redeposited volcaniclastics and lacustrine sediments; 7 – leucitite; 8 – syneruptive surface; 9 – outcrops; 10 – vein system of Kovářská–Niederschlag.

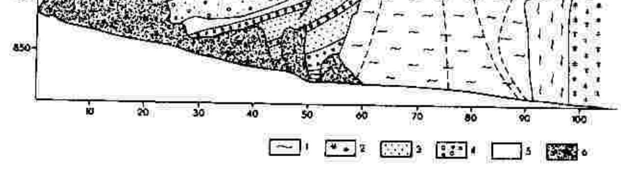

Fig. 4. Cross-section of the quarry entrance at level 890. 1 – muscovite gneiss; 2 – intrusive phonolite; 3 – fine-grained volcaniclastics; 4 – coarse-grained volcaniclastics; 5 – phonolitic lava; 6 – debris.

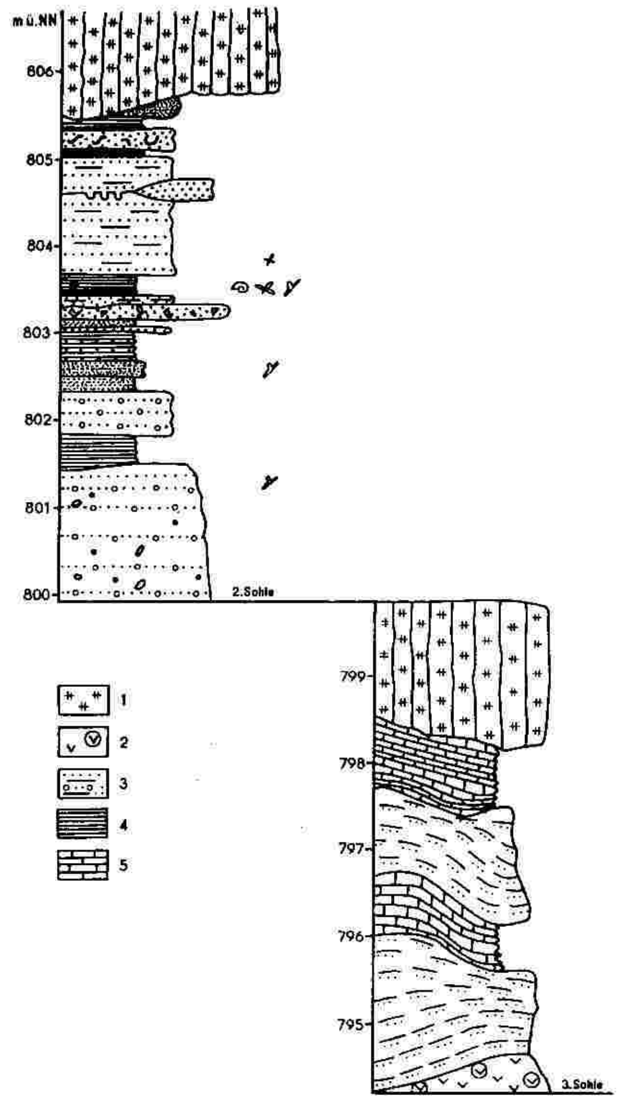

Fig. 5. Lithological section of lacustrine sediments below the intrusive phonolite in the "Richter Quarry" of Hammerunterwiesenthal. 1 – phonolite; 2 – leucitic agglomerate; 3 – coarse volcaniclastics; 4 – fine laminated clastic sediments; 5 – fine laminated limestones.

the optimum location for a borehole. The borehole was drilled in May and June 1998 and confirmed the results from geophysical investigations (Fig. 8). Beneath only 50 m of Miocene sediments with a lignite seam, the following succession was found (from top to bottom): 24 m of pure diatomites from a maar-lake, about 110 m of oil shales with turbidites, 70 m of oil shales alternating with coarse debris flows, 12 m of scoria, 20 m of light kaolinitic clays and, in the deepest part, big boulders of a collapse breccia from granodiorite with green tuff intercalations.

A preliminary reconstruction of landscape at the time of volcanic activity, probably Upper Oligocene, shows two large maars and two scoria cones with lava lakes, now basaltic hills.

The fourth structure remains enigmatic because a strong magnetic indication was observed but no basic volcanics were found on the present surface. Perhaps the structure represents an initial maar filled with lava. The research on phreatomagmatic structures in the northern environs of the Ohře Rift will continue.

Fig. 6. Schematic section of the Kleinsaubernitz borehole (Kls 1/70). Dashed lines – oil shales; fine lines – diatomites; vertical lines – clays; black – lignites.

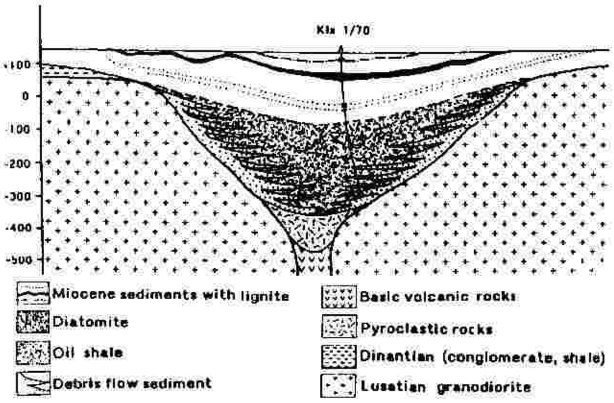

Fig. 7. Schematic drawing of the maar of Kleinsaubernitz.

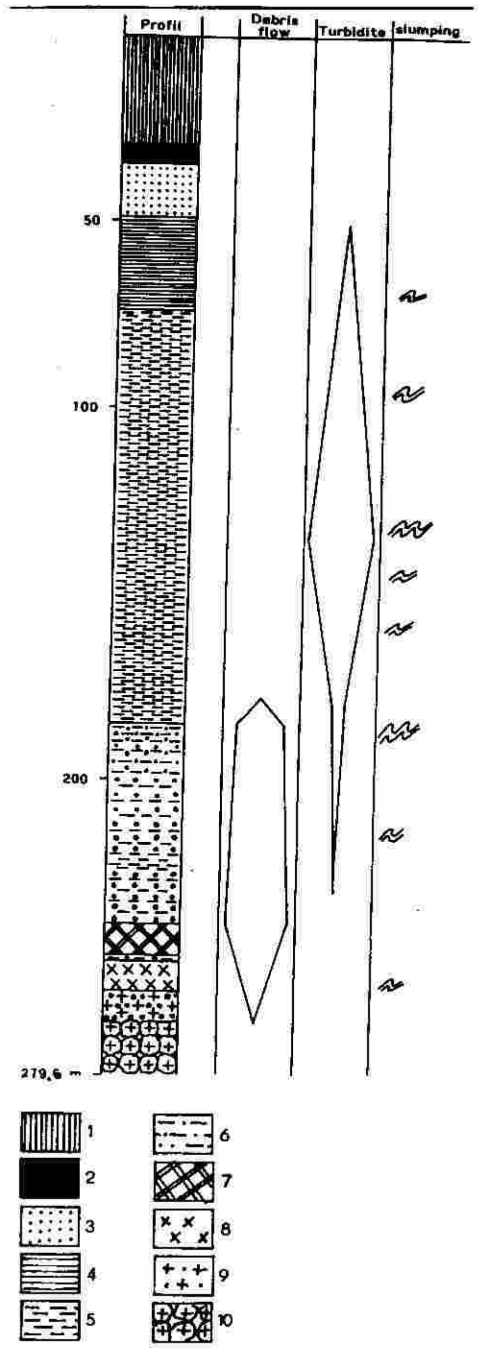

Fig. 8. Schematic section of the Baruth borehole (FB Bth 1/98). 1 – clays; 2 – lignite; 3 – sand; 4 – diatomite; 5 – oil shales; 6 – debris flows alternating with oil shales; 7 – scoria; 8 – redeposited disintegrated granodiorite; 9 – boulders of granodiorite and basalt; 10 – collapse breccia of granodiorite with tuff intercalations.

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