The Eckfeld Maar (Vulkaneifel, Germany) - a key locality for the understanding of the Eocene paleoenvironment of the western Rhenish shield

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Introduction

Ancient maar lakes are of outstanding importance for the reconstruction of continental paleoecosystems. Many of our most famous Cenozoic and even some Mesozoic "fossillagerstätten" meanwhile turned out to be ancient maar craters (e.g. Liu *et al.,* 2000; Lutz *et al*., 2000). Their sediments do not only yield plenty of fossils allowing for a reconstruction of flora and fauna and their local or regional development. They also provide with high resolution unique data for paleoecological and paleoclimatological research. Their laminites (at least in some cases) are varves that are documenting annual or even seasonal periodicities. Additionally, the research at Eckfeld considerably contributes to our understanding of the development of the regional paleorelief and the drainage system of the Westeifel in the Palaeogene.

Geological setting and local paleogeography

The Eckfeld Maar and two neighbouring volcanoes are surrounded by marine sand- and siltstones of Lower Devonian age and are alined along a NNE-SSW trending fault (Fig. 1). They are situated near the southern margin of the Tertiary Hocheifel Volcanic Field (THV), the center of which, the so-called Kelberg High, was considerably elevated in late Palaeogene times. The THV consists of about 400 distinct volcanic structures. According to conventional K-Ar dating the THV was active from 45 to 24 Ma (Cantarel and Lippolt, 1977; Müller-Sohnius *et al*., 1989). However, current studies using $^{40}Ar/^{39}Ar$ laser fusion technique revealed that all volcanoes dated so far erupted in the Middle to Late Eocene (Fekiacova *et al*., 2003).

The Eocene morphology of the Westeifel region and its drainage system have been reconstructed by Löhnertz (1994). Additional contributions have been published by Pirrung (1998), Fischer *et al*. (2000), and Pirrung *et al.* (in press): Presumably less than 4 km W of the Eckfeld Maar the Buntsandstein formed a 200 m high cuesta. A small river that most likely originated on the elevation of the THV near Kelberg followed its margin southward into the Arenrath basin where it joined the Proto-Saar river.

Genesis

For the Eckfeld structure a maar origin was suggested for the first time by Löhnertz (1978). His opinion was strongly supported by evidence from a core drilled in the centre of the Middle Eocene sediments in 1980 (Negendank *et al.*, 1982). In 1996 a multidisciplinary research program was started and new cores were drilled at three locations within the crater. Final proof for the maar hypothesis is now based on both, sedimentological and petrographical evidence as well as on additional geophysical investigations (e.g. Pirrung 1998; Fischer *et al*., 2000; Wonik, 2000). The crater had an initial diameter of 900 - 1000 m and a depth of up to 210 m. After volcanic activity had ceased the crater walls and the surrounding tuff ring stabilised by mass movements towards the central crater floor and groundwater rapidly filled the crater.

The Eckfeld Maar lake

In this (110 - 150 m) deep lake conditions soon changed from oligotrophic to meso- and eutrophic as is indicated by the early and abrupt formation of laminated organic-rich sediments ("oilshale") that successively filled the basin. However, due to later erosion caused by the Pleistocene uplift of the Rhenish Shield, there is not enough oilshale preserved that would allow for an investigation of the complete sequence of lake sediments. With a sedimentation rate of 0.4 to 0.5 mm per year the oilshale outcropping in the centre of the maar represents 82.000 years of lake history (Mingram,

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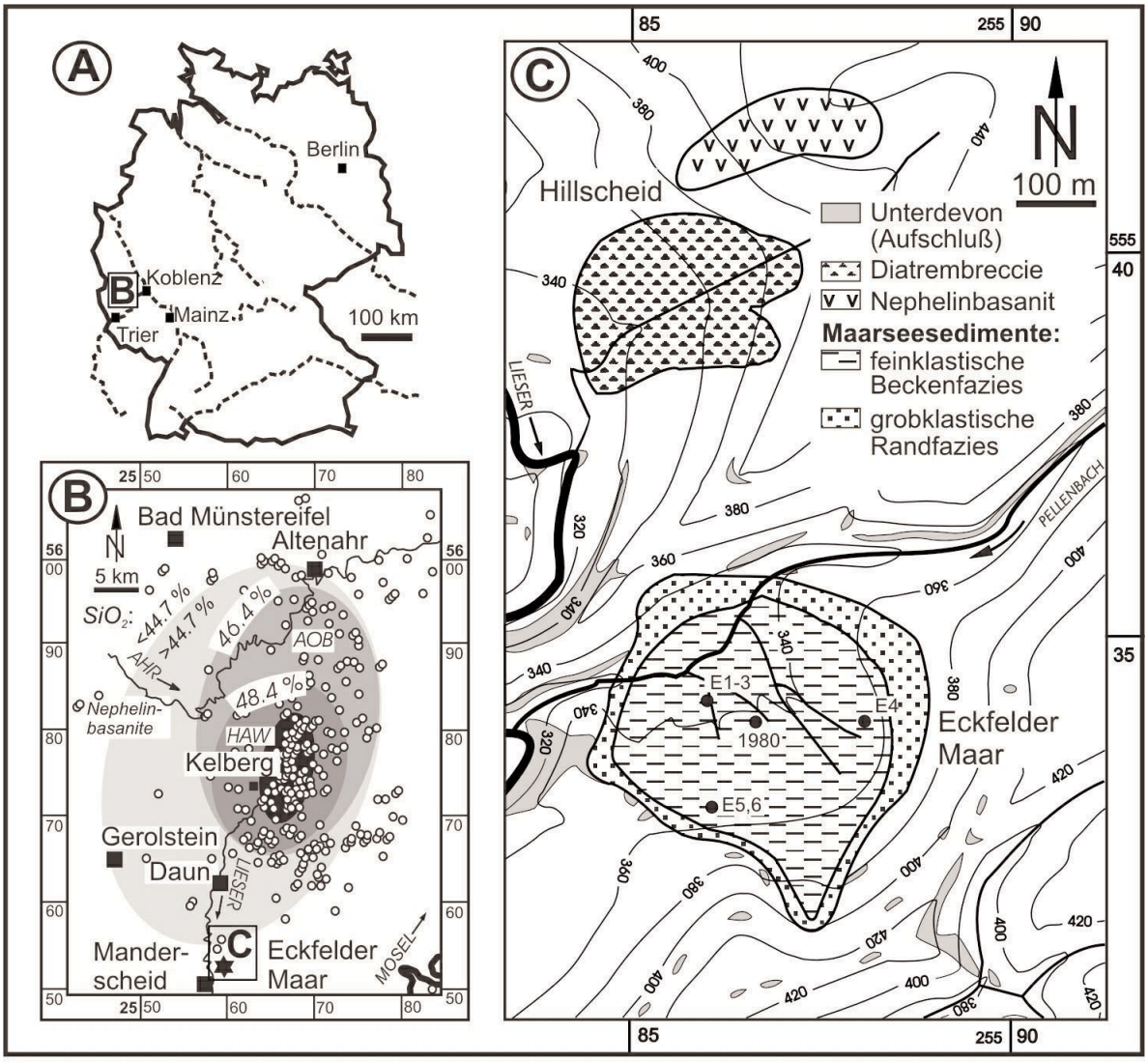

Fig. 1A-C.- Eckfeld Maar volcanic complex. Fig. 1A: General location. Fig. 1B: Tertiary Hocheifel Volcanic Field: AOB = Alkali-Olivine Basalts, HAW = Hawaiites. Fig. 1C: Simplified geological map of the Eckfeld Maar and its two neighbouring volcanoes: 1980, E1-6 = drilling locations. The excavation site lies immediately N of E1-3. Modified after Fischer (1999).

1998), when the lake was still very deep and chemically stratified (meromictic). Anoxic, alcaline conditions and the accumulation of electrolytes and toxic gases in its monimolimnion prevented bioturbation. This explains the perfect preservation of both, lamination and individual fossils (e.g. Neuffer *et al.,* 1996; Bullwinkel & Riegel, 2001). Obviously, the chemistry of the monimolimnion also influenced the aquatic flora and fauna within the mixolimnion: slumping episodically caused a partial mixing of both water bodies resulting in a more or less severe poisoning of the mixolimnion. As a consequence, a low diversity of the aquatic biota and the presence of euryhaline species can be observed, which from time to time developed in huge numbers (e.g. Gruber and Schäfer, 2000; Lutz, 2000; Lutz and Neuffer, 2001).

Flora and Fauna

The spectrum of fossils includes almost everything from complex organic molecules to articulated mammals with soft tissue preservation. The fossil record is documenting both, a highly diverse terrestrial flora and fauna, while the aquatic life was, as already mentioned, rather poor in species.

The flora comprises algae, fungi, bryophytes, ferns, gymnosperms, and angiosperms. Up to now more than two hundred taxa have been identified (Wilde and Frankenhäuser, 1998). The macrofossil record is dominated by thousands of leaves (Fig. 2), fruits, and seeds of mono- and dicotyledonous angiosperms. Besides, about 700 flowers and inflorescences with pollen *in situ* are of

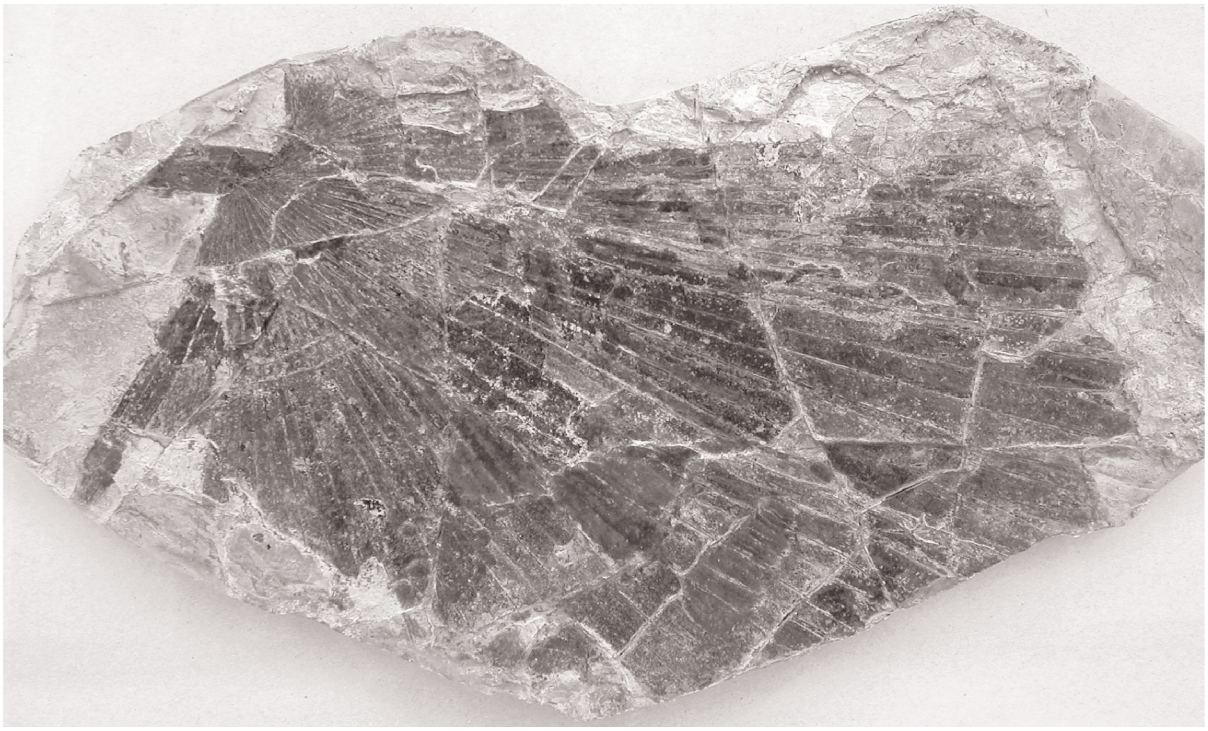

Fig. 2.- Fragment of a palm leaf (Arecaceae). Height ca. 40 cm. Inv.-Nr. MNHM PB 1999/1-LS.

outstanding importance. Furthermore, aspects of insect-plant interaction may be studied. The exceptional potential of that kind of preservation is demonstrated e.g. by honey-bees (Apidae: *Electrapis* spp.) still carrying their last pollen load and a leaf showing the characteristic damage produced by leaf-cutting bees (Wappler and Engel, 2002).

Animal life in and around the Eckfeld Maar lake is documented by rhizopods, freshwater-sponges, gastropods, bivalves, crustaceans, spiders, insects, fishes, amphibians, reptiles, birds, and mammals. Among the mammals (> 20 species) first finds of primates (Franzen, 1998) and six articulated skeletons of the dawn-horse *Propalaeotherium* are most spectacular. One specimen is a pregnant female which has its digestive tract still stuffed with leaf-cuticles. Equally important are uncompressed skulls of this genus (e.g. Neuffer *et al*., 1996).

Age of Eckfeld Maar

Biostratigraphically, the Eckfeld Maar represents mammal level MP 13 (European Land Mammal Age / ELMA Geiseltalian: Franzen, 1993). This is corroborated by palynological studies (Nickel, 1996). In one of the cores drilled in 1996 fragments of alkali basalt were recovered from the diatreme breccia below the lake sediments. These were dated by laser $^{40}Ar/^{39}Ar$ technique yielding an age of 44.3 Ma. Based on volcanological and geological evidence and considering the analytical error it appears that by this age the lake sedimentation and therefore the accumulation of the fossils took place. This agrees perfectly with a previous biostratigraphical estimate of 45 Ma (Mertz *et al*., 2000).

Paleoclimate

Many bioindicators (e.g. palms: Fig. 2, insects, crocodiles) are available that are pointing towards a humid paratropical climate. Other evidence of paleoclimatological relevance comes from studies of oxygen- and carbon-isotopes from siderite, diatoms, and wood-fragments (e.g. Felder *et al*., 2000, 2002; Sabel *et al*., 2000).

First results from spectral analysis revealed two prominent peaks: the 11 years Schwabe- and the ca. 22 years Hale-cycle (Vos and Mingram, 2002). This, together with pronounced seasonality due to the paleolatitudinal position of Eckfeld (ca. 42° - 44° N), makes it very likely that the lamination of the oilshale does represent varves rendering Eckfeld a suitable object for an analysis of Eocene solar-terrestrial relationships.

Paleoenvironment

The fact that the Eckfeld sediments document a late Middle Eocene paleoecosystem with high resolution allows for a detailed reconstruction of the paleoenvironment within its catchment area and its variations over a period of approximately 82.000 years.

Singular or rare changes of the hydrology of the lake are documented e.g. by mass mortality layers of certain

organisms (comp. above). The highly diverse insect taphocoenosis gives important hints on the presence of certain biotopes and habitats, some of them apparently existing only for rather short periods (Wappler, in prep.). The bivalves - together with sedimentological, geochemical, and taphonomical data - tell us, during which periods the lake was isolated or connected with the local drainage system (e.g. Lutz and Neuffer, 2001). The long term development of the terrestrial flora - from a pioneer vegetation on the inner slopes of the crater to the first establishment of a submerse aquatic flora growing on a more and more stable and shallow littoral - can be reconstructed from thousands of plant remains (e.g. Nickel, 1996; Wilde and Frankenhäuser, 1998).

W. Löhnertz had collected rich tapho-floras (e.g. Gregor and Löhnertz, 1985) from late Middle Eocene (Nickel, 1994) channel-fill or flood basin deposits within the Proto-Saar valley. Together with additional plant fossils from more recent excavations at Gut Heeg these taphocoenoses will allow for a reconstruction of the riverside flora(s?) of the Westeifel in late Middle Eocene times.

Current and future research

In many respects the Eckfeld Maar is strikingly similar to Messel for which - after decades of controversy - a maar origin recently has been proved by geophysical and sedimentological evidence (Harms, 2002). Therefore these similarities are no longer surprising. As the Messel lake had a diameter of at least 1500 m (Harms, 2002) whereas the Eckfeld lake presumably had a diameter of only 700 - 800 m a comparative analysis of both systems will help deciphering the taphonomical processes determining the composition of fossil assemblages in maar lakes. Without understanding these processes reliable reconstructions of the local/regional biocoenoses, which are a prerequisite for studies concerning e.g. aspects of paleobiogeography and -ecology, are impossible. Thus the multidisciplinary research at Eckfeld and Messel will considerably contribute not only to a reconstruction of the local paleoecosystems but also to an understanding of the Geiseltalian in general, the last period with a world-wide greenhouse climate.

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