Eocene paleovalleys in the Eifel:
mapping, geology, dating and implications for the reconstruction of the paleosurfaces and vertical movements of the lithosphere at the edges of the Rhenish shield

Werner LÖHNERTZ (1)

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Introduction

Since the beginning of geomorphological research in the Rhenish shield it has been a matter of interest to find the origin of the great flat erosion surfaces. In the last 3 decades it has become more and more important to search for an explanation of the consistent horizontality ("Horizontalkonstanz") of plains and terraces in the Shield.

For a long time all erosion surfaces in the Eifel area were considered as the last stage of denudation processes (peneplain, Rumpffläche; for the Eifel area see Quitzow, 1969), but due to the morphological research of Louis (1953) in the Eifel-Mosel area these theories were sincerely questioned. Since 1977 Löhnertz with the help of many colleagues was successful - during the "Priority research programme of the DFG, the driving mechanism of epirogenic movement: Rhenish shield" - to confirm the theory of a great valley filling ("Talverschüttung") first mentioned in Louis (1953). As a consequence of this proof there was and is a need for a new model of landscape evolution of the Rhenish shield.

Evolution to the Middle Eocene

Sediments of the late Cretaceous and flints on planation surfaces of the Ardenne (Albers and Felder, 1979) and northern parts of the Eifel (Ribbert, 1983 and 1997) and in the Old-Pleistocene terraces of the Mosel and its tributaries coming down from the Eifel (Altmeyer, 1982; Löhnertz 1982, and 1994) demonstrate a cover of great parts of the northern Eifel during the Upper Cretaceous. Because of the fact that the flints are only the remnants of a considerably greater sediment cover, the very high portion of flints in the t_1/t_2 terraces of the Mosel (1-2% for example in the t1 Zeltingen/Moselle; Löhnertz, 1982) lead to the conclusion of an important Cretaceous cover in the northern part of the Eifel. Obviously at this time these parts of the Eifel were situated far below sea level.

Some quarzitic monadnocks like the Schnee-Eifel, an already marked cuesta formed by the Buntsandstein and a high levelled area near Kelberg caused a morphological frontier to the Eifel-Mosel area in the south: there are well-rounded flints ("flint eggs") in Oligocene sediments at the northern border of the Eifel as an evidence for the erosion of Cretaceous sediments in the north (Albers & Felder, 1981). Furthermore flints in Palaeocene sediments in the northern part of the Eifel are proof of *in situ* weathering and vertical displacement of Cretaceous remnants (Ribbert, 1997). On the other hand there are no flints in Lower and Middle Tertiary sediments of a Saar river prototype running along the southern slope of the Eifel.

This fact and the preservation of flints and Palaeocene clay in a position of more than 600 m above sea level just in front of the Buntsandstein cuesta gives a first but very clear indication that there was no efficient erosion and denudation during Tertiary times in the central parts of the Eifel. This can be further proved by the position of the centre of the centrifugal drainage pattern of the Eifel area today. Despite the very different distances and differences in elevation to the main streams - short and steep to the north and very long and gentle to the south - this centre is still situated at the southern border of Cretaceous sedimentation.

The flints are remnants of the limestone of Lixhe and Lanaye (Upper Maastrichtian by Albers & Felder, 1979) and the following fluvial sediments in the area of Arenrath and Gut Heeg are dated by Nickel (1994) as Middle Eocene. In this interval there are only residuals of paleoweathering surfaces (Felix-Henningsen, 1990) and some small deposits of very fine sediments: (i) In the basin of Antweiler at the northern border of the Eifel (late Montian, Kempf, 1993), (ii) in dolinas on the planation surface in the northern Eifel near Dahlem (?Palaeocene, Ashraf *in* Ribbert, 1997), (iii) under Eocene clay at Binsfeld - Speicher (v.d.Brelie *et al.*, 1969; Löhnertz,

(1) Hermann-Josef-Kolleg, Postfach 220, 53922 Kall-Steinfeld, Germany. werner@loehnertz.de

1978a-b; Gregor and Löhnertz, 1984) and (iv) as xenoliths of a light grey clay or as displaced paleosoils in the pyroclastica of the Eckfeld maar (Löhnertz, 1978c; Pirrung, 1998; Fischer, 1999). Recently it was possible to find some clay lateral to the Middle Eocene sediments of Arenrath and Bergweiler similar to the Palaeocene clays of the basin of Antweiler (Löhnertz, in prep.)

Evolution of valleys in late Middle Eocene

Well known sands and coarse gravel, so-called "Vallendar Schotter", were first dated in 1977 by palynostratigraphic investigations as "Borkener Pollenbild", that is Middle Eocene (v.d.Brelie *in* Löhnertz, 1978). It was Nickel (1994) who confirmed this stratigraphic position - now Zone SPP 15 D, late Lutetian - that is only little younger than the nearby maar sediments of Eckfeld (Neuffer *et al.*, 1994). Considering the results of an investigation of the Hydropterid floras (Kempf, 1993) which gave Lower Priabonian (Lower Headon Beds, Upper Eocene) there still remains some uncertainty. As the lower parts of Oligocene ("Haselbacher Serie"), an age given by Gregor after investigations of rare paleocarpological material (*in* Gregor and Löhnertz, 1986), can be excluded now, a stratigraphic position in the highest parts of the Middle Eocene may be realistic.

Tertiary sediments have been known well for a long time from various places in the Rhenish shield. But if there are immense and very homogeneous layers of Devonian in the base, it is not possible to exclude a tectonic layering with certainty. Corresponding Tertiary sediments at the base of Pleistocene layers are normally explained by post sedimentary tectonic.

Although there are small post sedimentary faults in the centre of the Eocene Arenrath basin too, the position of Eocene gravel just in front of the Buntsandstein cuesta, partly on Devonian partly on Buntsandstein, offers no possibility to explain by tectonic the high difference in elevation between the planation surface on top of the Buntsandstein and the Eocene valley. Obviously there was a river erosion at the end of the Middle Eocene cutting up to 200 m below the nearby planation surfaces. This erosion formed a well marked Buntsandstein cuesta of considerable height. A similar morphology and also similar sediments can be found in Sri Lanka (Schnütgen and Späth, 1978; Wirthmann, 2000).

The so-called Vallendar - Schotter consists of milky quartz gravels to nearly 100%, in the mass out of the Buntsandstein, and subordinately some quartzite, sandstones and slate. Indicator gravels especially out of the Permian volcanic rocks in the Upper-Nahe-area permit the reconstruction of a Saar river prototyp running along the southern slope of the Eifel and of some tributaries, above all the N-S orientated so-called "Manderscheider Talung" (Löhnertz, 1994). As there was a time of strong volcanism shortly before in the Hocheifel and near Eckfeld it should be an obvious conclusion that the deep valley formation is due to tectonic uplift. Some recent datings of volcanism in the Hocheifel by D.F. Mertz (Mainz) show a rather narrow period of volcanic activities, giving a better concordance between tectonic and morphological events than assumed in former times.

The preservation of Eocene sediments even in highly exposed positions, the fine conservation of fossil plants, even trees in lignitic state, in permeable sediments and the position of these sediments right in front of the fossilized cuesta demonstrate an immediate conservation by a very important cover of sediments. Again, post Eocene weathering and denudation in the Eifel area must have been marginal. The lack of Buntsandstein rocks in the drill samples of Eckfeld (Fischer, 1999) and the reconstruction of the exhumed pre Triassic landscape (Löhnertz, 1994; Pirrung, 1998) also demonstrate a well developed landscape in Eocene times, not denudated more than 40 - 60 m since the Eocene. Even weathering since Eocene has not been as efficient as commonly thought. Eocene basaltic volcanoes in the Hocheifel are only scarcely weathered, they were obviously not exposed to tropical weathering processes for a long time (Büchel, 1992). Finally the lack of any cryoturbation at the top of the Eocene sediments shows rather clearly that all surfaces today are due to very young erosion.

Valley filling and lateral erosion from the Upper Eocene to the Middle Oligocene

Mordziol (1936) was the first who expressed the idea of a great valley filling after the "Vallendar - Schotter" which he therefore called a "Primordial-Fluvial". The same idea was deduced in the morphological work of Louis (1953) and proved by Löhnertz (1978b). Fossiliferous cherts in the surroundings of Bitburg in the southern Eifel were first dated by Baeckeroot (1929) as Aquitanian. New collections of this material by Löhnertz were dated by Kadolsky *et. al* (1979, 1983) as Rupelian, deposited under slightly brackish conditions.

Again it was possible to exclude tectonic movements due to the positions of the sediments at the top of Mesozoic layers. The position of the Oligocene fossiliferous cherts on the surfaces of the Upper Muschelkalk cuesta and in fluvial deposits of the Salm, coming at least from the surfaces at the top of the Buntsandstein, demonstrate that the Eocene valley in front of the cuesta has been filled up again. Findings of (i) a Middle Oligocene fauna in the rather young Meerfelder Maar (Sonne and Weiler, 1984), of (ii) Middle Oligocene foraminifers (V. Sonne *in*: Zöller, 1983) and (iii) of beach-ridges in the Hunsrück-Mosel-area (Zöller, 1984), and (iv) investigations of sediments along the Rhine valley (Semmel,

1999) have confirmed the datings of the so-called "Trogregion" at 400 m above sea level. Also confirmed was the theory of Löhnertz (1978b) that the valley filling took place near sea level and was caused by an eustatic rise of the sea level. This rise of the sea level was postulated as a worldwide event from Vail *et al*., 1977 too.

As most Oligocene shorelines are well-known in the Paris and Mainz basins as well as in the Lower Rhine embayment, conditions of sedimentation should be: (i) some distance from the sea, (ii) following an ingression and (iii) in an estuarian or lagoon environment (Kadolsky *et al*., 1983). The term "transgression" (Kadolsky *et al*., 1983; Demoulin, 1989) should therefore now be avoided. Recent investigations lead to new and far reaching conclusions. It seems easy to understand how the "Trogregion", the today´s 400 m level, was formed at the end of an ingression and on top of the valley filling by lateral erosion over a long time, but how was it possible that this planation surface has a nearly horizontal position all along the major rivers of the Rhenish shield and that there is neither slope nor even crossfall in the region of the Middle-Mosel-area, although the "Trog" is extended there nearly 20 km in width?

This significant horizontality of the 400m-level in the Rhine and Mosel river system can only be explained by the fact that the sea level remained a base-level of erosion for a very long time. There is obviously no other environment where geomorphic processes produce forms, levels or terraces of such a significant horizontality. To prove this idea it may be helpful to see the drainage basin of the Amazon: Deeply incised valleys during sea level lowstands are now flooded several hundred km inland, the average slope in these parts is only about 1 cm/km and there is a wide area of tidally influenced depositional environments (Sioli, 1984) far inland. In Oligocene times distances from the Eifel-Mosel-area to the Mainz or Paris basins, to the Lower Rhine embayment or to the Upper Rhine graben are hardly more than 200 km, horizontality of river slopes near sea level and slightly brackish conditions are quite conceivable.

Ingression was only possible against the slope of the Eocene drainage system. It is therefore not contradictory if Kadolsky *et al.* (1983) see an influence of the Paris basin in her fauna, Sonne and Weiler (1984) see a correspondence with the Mainz basin and Demoulin (1989) sees a transgression from the North. The different influences may give a chance to reconstruct Eocene slopes of the Rhenish shield.

Transition stage in Oligo/Miocene

The base-level of erosion in greater parts of the Rhenish shield must have existed near sea level for a very long time. Fish species crossing the Rhenish shield from the North sea basin to the Mainz basin (Martini, 1981) demonstrate that at the moment of the relative-highest sea level, the western part of the Rhenish shield was completely surrounded by marine or brackish waters, an island only above the today's 400 m contour line, with flooded and sediment filled valleys far inland. The best model to explain the morphological processes on the surface of the Shield up to the Miocene may be that of a "transition stage". A flat relief of less than 200 m differences in altitude and a fossilization of the landscape by a sediment cover - for parts of Luxembourg see Kienzle (1968) - prevented deep weathering and denudation, on the other hand the base-level of rivers at the sea level prevented greater sedimentation. Denudation and sedimentation put together there were only little changes of the relief.

Formation of bog iron ore and silcretes, dry up events, changing salinity, freshwater sediments and nearly synsedimentary silicification of limestones ("fossiliferous cherts") at Idenheim/Bitburg (Kadolsky *et al*., 1983) are indicators of more superficial processes, the beach-ridges of Rödelhausen/Hunsrück (Zöller, 1984) and the very well rounded gravel from the Fieberberg/Kröv at the Middle-Mosel-area, so-called "Rundschotter" and not the typical "Kieseloolith-Schotter" (Löhnertz, 1982), are indicators of shores of greater lakes with surf waves and corresponding gravels. Sedimentation took place in smaller basins at the top of the valley filling as Upper Oligocene sediments at the Maifeld/Lower Mosel area can prove (Heizmann and Mörs, 1993).

In late Oligocene the removal of the huge mass of Eocene/Oligocene sediments started. Clay and sands from the Upper Oligocene in front of the northern border of the Rhenish shield (Meyer, 1994) and the Miocene cover above the coal in the Lower Rhine embayment are evidence. It was at the beginning of these clearances that the prototypes of today's rivers and the channel pattern developed epigenetic on the surface of the valley filling. The Rhine started now its crossing of the Rhenish shield to the north (Boenigk, 1982) certainly joined by the whole Mosel system. It was even now that rivers like the Kyll which to this time had been flowing consequently with the gradient of the Mesozoic layers in the direction of the Paris basin, changed their ways into the direction of the nearer base-level of the Lower Rhine embayment. Due to sea level lowering there is no need to conclude that there was an uplift of the Rhenish shield in order to start erosion.

As some of these prototypes are crossing the Eocene valleys, even some former barriers like the Kondelwald, and as the Rhine for the first time crosses the Rhenish shield running north (Boenigk, 1982), the theory of valley filling is demonstrated again. A high dominance of quartz gravel shows that it is pure removal because there is obviously no considerable erosion in the unweathered rocks beneath the Tertiary cover. This was also proved by Negendank (1978) in his study of the heavy minerals in the fluvial sediments of the Mosel system.

Some new considerations on post Miocene evolution

It seems that all attempts have failed to explain the unusual and significant horizontality of the Late Tertiary and Old Pleistocene terraces in the Rhine-Mosel-river system, the so-called “Horizontalkonstanz” (Philippson, 1927; Birkenhauer, 1971; Semmel, 1979; Löhnertz, 1982). Even the latest attempts by Ploschenz (1994), Hoffmann (1996) and Meyer & Stets (1998) are not really convincing. It seems unbelievable that hundreds of tectonic movements along several rivers - basis of these ideas - have, just by chance, the result of strict horizontality (Löhnertz, in prep.) Why should the tectonic movement - up as well as down - break off exactly when reaching horizontality?

It seems by far more sensible to look no longer for a post sedimentary cause but to see it as a matter of origin. The strict horizontality of the terraces including the younger main terrace (jHT), or the t4 according to Bibus & Semmel (1977), is due to the fact of continuous position of the river base-level of erosion near sea level (Löhnertz, in prep.). Clearances, lateral erosion and sedimentation took place under conditions without any considerable slope. To repeat again, only at sea level, in coast - proximal settings and along the adjoining lower parts of rivers without or with minimal slope is there the possibility to create horizontal terraces. And what is more, only these very special conditions can create, due to repeated lowering of sea level, two or more terraces lying horizontally and parallelly one on top of the other as can be seen along Rhine, Lahn or Mosel today.

Regarding the processes during Late Tertiary and Old Pleistocene times it seems necessary to give up the idea of rivers cutting with great activity into the Rhenish block like a saw into the already elevated and fixed log and to replace it by the idea of a lowland with gentle ranges of hills outside the valleys, which is uplifted extremely slowly from far below like a log against the fixed and horizontally swinging saw. The main counterargument that the coarse gravel of the Pleistocene terraces requires a greater slope, is not really decisive because the transport of the sediments should be seen as a result of extremely jerky and discontinuous discharge of snow water with corresponding high velocities. A good model may be the lower parts of the rivers Lena or Ob in Siberia with a minimal slope of 1,5 cm/km, velocities up to 1,6 m/sec - enough to move coarse gravel -, differences between highest and lowest water levels of more than 15 m and strong lateral erosion (Franz, 1973).

The formation of very flat valley floors up to 5 km in width, for example in the famous Middle Mosel area near Mülheim - Burgen -Wintrich, was furthermore due to the fact that in great parts the rivers had only to remove Tertiary sediments and to exhume Tertiary forms. Sands of Tertiary bearing can be found in contact to Pleistocene sediments down to the tM1-level (Louis, 1953; Kremer, 1954; Löhnertz, 1982; Negendank, 1983), in the Lower Mosel area and in the southern Eifel sediments of the tM4/jHT are lying above the Eocene even today.

The strong and fast uplift after 800 000 B.C. (Meyer & Stets, 1998) enlarged decisively the fluvial erosion. The present strongly inclined rivers cut their way back almost to the top of the hills and together with the periglacial processes they formed today’s surfaces. The distinct increase of erosion power is documented in the great differences in the composition of sediments of the Main and Middle terraces. The denudation since that time must have been really considerable as it can be seen by the exposure of the stumps of Eocene volcanoes out of their Devonian mantle (Büchel, 1992). It is decisive, too, to mention last but not least, that this uplift since 800 000 B.C. has been sufficient to create all the differences in elevation between today’s surfaces of the Eifel in relation to the southern forelands (Löhnertz *in:* Kadolsky *et al*., 1983). There is no need to create a more complex nor multiphase model of landscape evolution.

Conclusion

During morphological evolution of the Eifel since the Cretaceous there are only two phases of linear erosion due to epirogenic uplift: in late Middle Eocene and since 800 000 B.C. Both phases can be correlated with tectonical activities and volcanism. Between these two phases there was an extremely long time of stability and it was the changing sea level that caused sedimentation and later removal of a huge cover. This theory of Löhnertz - best documented and described by Bibus (1989) - is now enlarged by the attempt to explain furthermore the strict horizontality of Late Tertiary and Old Pleistocene terraces by looking at the position of river base-levels far inland near sea level. Future models should give special attention to the processes in coast - proximal lowlands with ingressions and flooded valleys far inland.

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