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EVALUATION OF NATURAL LANDSCAPE IN THE TAUNUS FORELAND AND THE LOWER MAIN PLAIN; AN ATTEMPT AT A GEOCHEMICAL CLASSIFICATION

The present article demonstrates the application of geochemical methods in the classification of natural landscapes.

Landscape geochemistry emerged in the 1940s in the USSR. Its aim is the analysis of chemical processes occurring in geographic environment The smallest geochemical spatial unit is the so-called "elementary landscape" which may be identified with facies or ecotype (Polynov 1956, Kondracki 1976). From the point of view of chemical elements migration three types of elementary landscapes can be distinguished: eluvial landscapes (independent of the influences of ground water), superaquatic landscapes (within the range of ground water capilary fringle) and subaquatic (underwater). According to Glazovska (1964. 1981). each of them may fall into several subdivisions depending on the degree of geochemical subordination and location with respect to the supply of chemical elements (Fig. 1). Thus, within eluvial landscapes one can distinguish autonomous eluvial landscapes (i.e. watersheds), subordinate transeluvial landscapes (i.e.

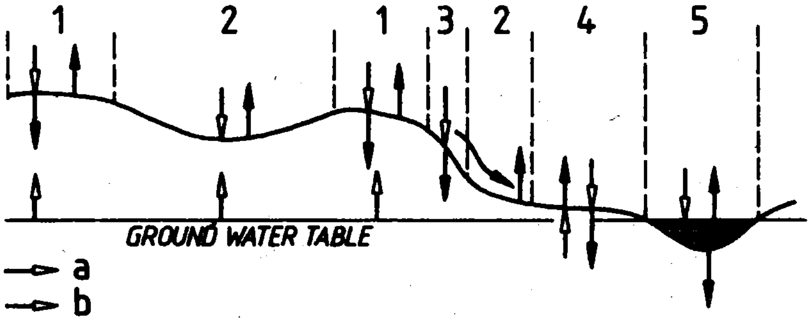

Fig. 1. Main types of elementary landscapes
1 — autonomous eluvial, 2 — subordinate transeluvial-accumulative, 3 — subordinate transeluvial, 4 — superaquatic, 5 — subaquatic.
a — substance supply from atmosphere and ground waters, b — drainage into the atmosphere and surface and ground waters

steep slopes) and subordinate transeluvial-accumulative (i.e. lower parts of slopes, dry valleys). Superaquatic landscapes may be subdivided into: autonomus (i.e. elevated peat-bogs on watersheds), subordinate (i.e. closed depressions), strongly subordinate transsuperaquatic (small river valleys) and weakly subordinate transsuperaquatic landscapes (big river valleys). Among underwater landscapes, proper subaquatic (i.e. lakes) and transsubaquatic landscapes (rivers) can be distinguished.

Of great importance for chemical elements migration in eluvial landscapes are mineral, chemical and physical characterisitics of the bedrock, which determine the nature of the so-called geochemical background (Glazovska 1964). From the point of view of eluvium types, one can distinguish ortoeluvial landscapes, developed on magmatic rocks, paraeluvial landscapes, developed on sedimentary rocks, and neoeluvial landscapes, developed on clastic rocks.

Geochemical history of elementary landscapes is an important criterion in their classification. For landscapes with single cycle evolution Glazovska (1964, 1981) suggests the term homogeneous or primary, for the ones which underwent serval cycles — heterogeneous with superimposed or secondary landscape process. The superimposition of landscape process occurs when the location of the unit as regards the supply of migrating elements remains unchanged, the change involving only the character of the process. A secondary process of elementary landscape evolution occurs in case of a change in supply by migrating elements.

Combination of elementary landscapes into higher range units is carried out by several methods and according to diverse criteria. For the purpose of the present article, the definition of a heterogeneous unit proposed by Polynov (1956) has been followed. Polynov used the term "local landscape" for elementary landscapes located within one geomorphological form and sharing the same landscape process.

Below, we shall present an attempt at a reconstruction of geochemical evolution of local landscapes in the Taunus tectonic foreland and the Lower Main Plain, as well as a proposal for their classification.

The area of our study stretches west of Frankfurt (West Germany) and covers hilly or flat aluvial plains on both banks of the Main. In young accumulative-erosive relief geochemical interrelationships are weakly developed. The dominating feature are local landscapes related to concave morphological forms i.e. autonomous eluvial landscapes, transeluvial and transeluvial-accumulative. They belong to the group of neoeluvial landscapes, rarely to the paraeluvial ones. Their common characteristics is the secondary character of the eluvial process. The evolution of eluvial areas occurred over a long span of time under the influence of diverse climatic conditions and was related to orogenetic movements of Palaeozoic and Cainozoic eras.

Toward the end of the Harz orogenesis, the whole of analyzed territory formed a part of a subordinate subaquatic landscape, which collected material from the deterioration of the Taunus mountains. At the bottom of the basin, red or purple conglomerates and breccia settled. The characteristic hue of the sediment is caused by the presence of a thin film of ferric oxydes and hydroxides around each grain (Leppla 1924). Thus Permian subordinate landscapes must have existed in oxidizing conditions. According to Perelman (1971), it was due to the absence of vegetation capable of surviving in dry and semi-dry climate, pteridophyte flora predominating the lower Permian being able to exist only in humid climate. Due to the drying of climate, the amount of organic substance in autonomous landscapes decreased, which resulted in the absence of the factor responsible for the reduction of ferric compounds in subordinate landscapes.

Speculation as regards further evolution of landscape during the Mesozoic era is difficult since sediments from this period are not available. It seems, however, that the examined area was an eluvial landscape which underwent intensive degradation processes in hot and humid climate. Traces of such processes in similar conditions are preserved in the adjoining Taunus mountains in the form of secondary quartz veins which were developed due to the coagulation of silica jelly from acid migrating waters in humid tropical landscapes.

Denudation processes characteristic of eluvial phase of evolution occurred in the examined area also during the Peleogene. Landscape changed its character as late as in the middle Eocene. Due to the intensification of Alpine orogenetic movements, the area appeared to be within the zone of sinking and became a subordinate landscape; first — superaquatic, later — subaquatic. The first marine transgression occurred in the middle Oligocene and left a series of argillo-arenaceous sediments. Since the climate was hot and humid, the mountain area adjoining the basin was covered with rich vegetation. Trunks of dead trees were buried in subordinate landscapes, thus originating brown coal deposits. Coal intercalation was particularly frequent among upper Oligocene marl deposited during the shallowing of the basin (Kümmerle 1969). Subordinate landscapes were subject to reduction processes, which is evidenced by large quantities of brass in coal deposits.

During the period of transition from the Oligocene to the Miocene, another deflection of Earth's crust occurred and was accompanied by marine transgression. In the earliest Miocene (Aquitanian) marl, argil and limestone deposits developed. Due to gradual shallowing and freshening of the basin during the Budrigalian, a series of limnic deposits developed with rich molluses fauna (Kümmerle 1969, Golwer 1980). It was also at that time that the activation of tectonic movements occurred and was accompanied by volcanic phenomena. These movements continued in the Pliocene and resulted in the division of the area into secondary paraeluvial

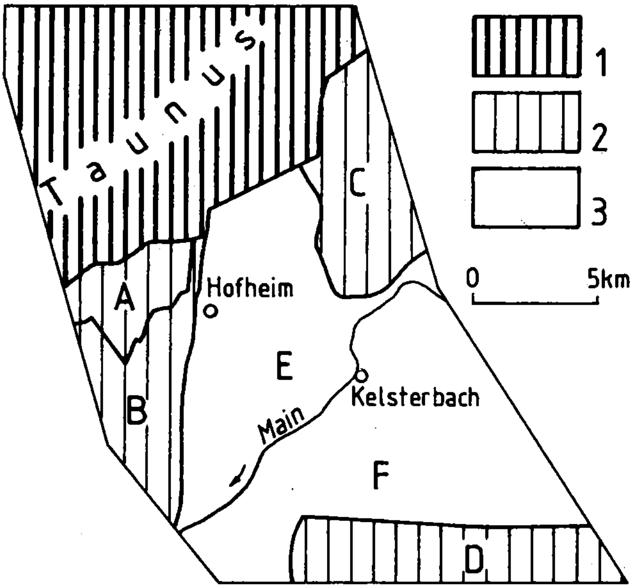

Fig. 2. Landscape differentiation model for the Taunus Foreland and the Lower Main Plain in the Pliocene

1 — primary eluvial landscapes, 2 — secondary paraeluvial landscapes, 3 — superaquatic landscapes.

Geological structure: areas beyond the Upper Rhine Fault:

A — Hofheim horst (Rotliegendes), B — Hofheim-Flörsheim horst (the Oligocene); areas within the Upper Rhine Fault: C — Höchst-Sulzbach horst (the Miocene), D — Walldorf horst (the Miocene), E — Hattersheim fault (the Pliocene), F — Kelsterbach low (the Pliocene)

landscapes of tectonic horsts and subordinate superaquatic fault landscapes (Fig. 2). The Pliocene denudation occurred under the influence of hot and humid climate. In these conditions "terra fusca" developed on elevated limestone, while kaolinite cover was formed on non-carbonate rocks. In subordinate landscapes non-carbonate argil, dust and sand settled, their thickness reaching 150 m. Frequently they contain brown coal intercalations together with remains of vegetation from former flood land, i.a. trees of the type of: *Populus*, *Fraxinus*, *Prunus*, *Ulmus*, *Betula*, *Liriodendron*, *Carya* (Golwer 1980).

One should also emphasize the fact that Tertiary tectonic structures have great influence upon the present hydrographic situation of the area. On the borderline between horst and faults, "cascades" of ground water develop (Thews 1969, Semmel 1983), which is visible in hydrochemical features of secondary eluvial landscapes (Ostaszewska 1987).

The cooling of the climate at the turn of the Quaternary period had an obvious effect on the change of the nature of sedimentation. In the examined subordinate landscapes new deposits of coarse (especially sandy and gravelly) materials settled. At the same time, the lowering tendency increased and the whole area again became accumulative in character. At the Taunus foreland big aluvial cones were developed by the streams flowing from the mountains. Further down to the south the accumulative area of the Main spread. Sand-gravel series of deposit from cold periods are separated by layers of argil and peat, which correspond to the warming up of the Tegelen, Waal and Cromer, and bear traces of typical Paleopleistocenic flora (Semmel 1969, 1980). Paleopleistocene deposits of the Main, that is of the so-called first terrace, reach maximum thickness of 30—40 m, which is the evidence of great intensity of lowering movements. In the course of time the movements slowed down and were succeded by upthrusting tendency. Thus, there began a new stage of the evolution of eluvial landscapes. The successive terraces of the Main are arranged in steps, which is typical of rivers cutting their deposits. Accumulation of materials occurred in periglacial climate, as manifested by existing frost structures, i.a. of ice wedges (Semmel 1969, 1980). The developing river plains were initially under a strong influence of ground waters, that is, they underwent the superaquatic phase of evolution. This is manifested by ferromangenese crust developed in the zone of ground water table fluctuation. They are particularly well developed in the second and third terrace in the pre-Riss glaciation (Semmel 1969). In the beginning of this glaciation both terraces entered neoeluvial phase of evolution. On the northern side of the Main loess deposits settled, which in a warmer climate developed into loessive soils (3 to 4 fossil levels).

Toward the end of the Riss glaciation, the fourth and fifth terraces joined the group of eluvial landscapes. Like the older terraces, they became a site of loess accumulation and of the development of light soils (1 or 2 fossil levels on the northern side of the Main).

Sixth and seventh terraces were the latest to enter the neoeluvial phase, i.e. toward the end of the Würm. Their surfaces have remained under the influence of ground water (i.e. in superaquatic phase) until the present. On the southern side of the Main in late Würm (dryas) deposits of eolic sands were formed, their thickness ranging from over 10 cm to a few metres. Their upper layer is enriched in allophanes which developed due to the weathering of volcanic tuffs which settled in the middle Alleröd (Plass 1980, Semmel 1980).

In the Holocene, under the influence of moderate climate two types of eluvial landscapes developed. Sandy landscapes with brown soils and mixed forests are typical of the area south of the Main. They abound mainly in local autonomous eluvial landscapes divided by superaquatic areas which are supplied by poor ground waters. Considerable contrast in migration conditions is related to good permeability of the bedrock (sand and gravel) and land form (dunes).

In the loess area north of the Main, the particular links of landscape chains are more developed. The surfaces of local divides are covered by loessive soils (autonomous eluvial landscape),. their slopes are subjected to erosion processes (transeluvial landscape), and in the lows the accumulation of colluvial deposits occurs (eluvial-accumulative landscape). Local transsuperaquatic landscapes are supplied by fertile ground waters. The differentiation of loessial landscapes is mainly the result of human activity[1]. Particular types of eluvial landscapes developed due to erosion processes of soil resulting from intensive farming. As a consequence of erosion, the loess cover was stripped exposing earlier layers: the Quaternary sands or Tertiary marl. Thus, in transit positions relics of former super- and subaquatic phases became the mother rock for present eluvial soils.

This reconstruction of the evolution of the area shows that the semingly monotonous aluvial plain on the Lower Main has, in fact, a complicated structure and complex functions. The weathering zone contains products of processes occurring in the Holocene, Pleistocene, Tertiary and Permian periods, all of which have a diversified chemical and mineral constitution. Therefore, the definition of the landscape as "secondary neoeluvial" or "secondary paraeluvial" lacks precision, as it does not render the diversity of the area. Thus, in order to indicate the successive stages of the evolution of landscape processes, it would be advisable to introduce the term of "multi-age generations of landscape" to landscape geochemistry.

Four generations of eluvial landscapes have been distinguished in the examined area. The first generation spreads over the area beyond the Upper Rhine Fault and consists of Rotliegendes formations which — in some places — are covered by Oligocene beach and river deposits (sub- and superaquatic phase). Toward the end of the Oligocene these landscapes entered the eluvial phase (its relics being, among others, Pliocene weatherings and Pleistocene fossil soils). Next generations are related to the Quaternary tectonic movements. The second generation consists of eluvial landscapes at the foothills of the Taunus and landscapes of second and third Main terraces. These areas became eluvial at the end of Great Interglacial period (Mindel a Riss). The next generation groups the fourth and fifth terraces which have become eluvial since the end of the one but last glaciation. The youngest (fourth) generation covers the landscapes of the sixth and seven terraces which reached eluvial phase toward the end of the Würm.

As mentioned above, present relations among particular landscapes depend, to a great extent, on the Tertiary tectonic structures (Fig. 2). Thus, the classification of eluvial areas proposed in this paper is as follows:

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[1] The whole area under investigation is influenced by anthropopressure (the vicinity of big industrial plants and agglomeration of Frankfurt). The problem requires a separate and thorough study and will not be dealt with in this paper.

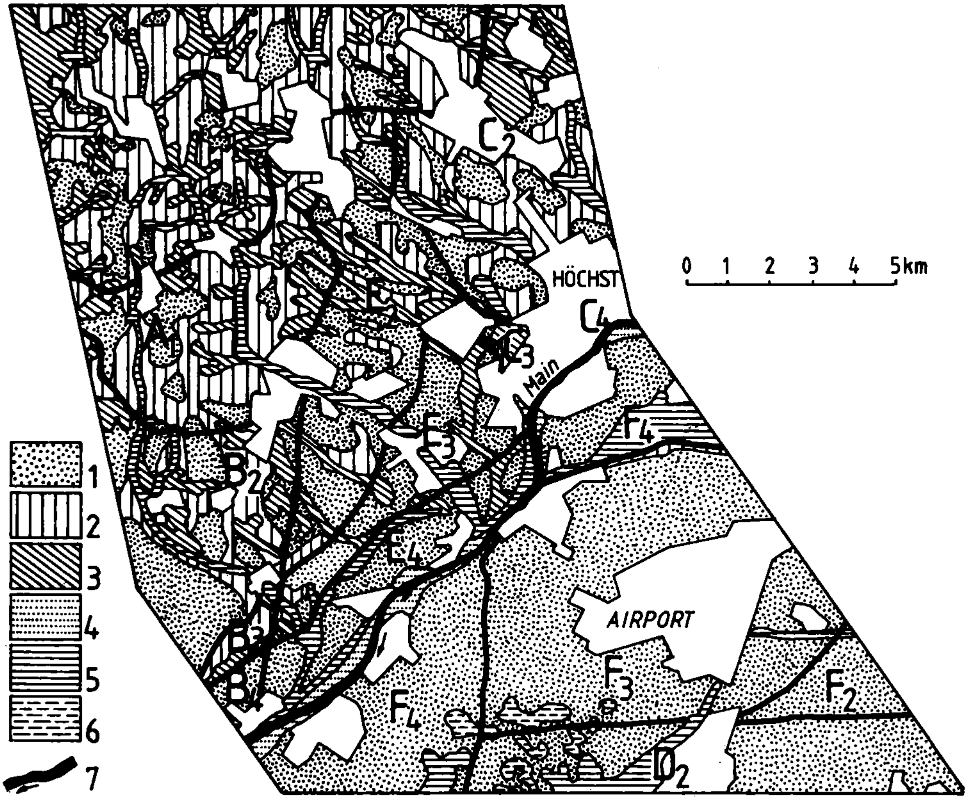

Fig. 3. Present local landscape differentiation in the Taunus Foreland and the lower Main Plain.
Local Holocene landscapes: 1 — autonomous eluvial, 2 — transeluvial, 3 — transeluvial-accumulative, 4 — weakly subordinate transsuperaquatic, 5 — strongly subordinate transsuperaquatic, 6 — subordinate superaquatic, 7 — transsubaquatic.
A1...F4 — local landscape groups. Other explanations in the text

— A1 — paraeluvial landscapes of Rotliegendes with superimposed neoeluvial processes in sands and/or loess; eluvial since the Neogene;
— B — paraeluvial landscapes of the Oligocene marl with secondary neoeluvial processes in sands and loess:
  B2 — eluvial since the Riss,
  B3 — eluvial since the Würm,
  B4 — eluvial since the Holocene;
— C — paraeluvial landscapes of the Miocene marl with secondary noneluvial processes in sands and loess:
  C2 — eluvial since the Riss,
  C3 — eluvial since the Würm,
  C4 — eluvial since the Holocene;

— D2 — paraeluvial landscapes of the Miocene marl with secondary neoeluvial processes in sands, eluvial since the Riss;
— E — secondary neoeluvial landscapes of the Pliocene and Pleistocene sands with superimposed neoeluvial process in loess:
  E2 — eluvial since the Riss,
  E3 — eluvial since the Würm,
  E4 — eluvial since the Holocene;
— F — secondary neoeluvial landscapes of the Pliocene and Pleistocene sands with superimposed neoeluvial process in dune sands:
  F2 — eluvial since the Riss,
  F3 — eluvial since the Würm,
  F4 — eluvial since the Holocene.

The distribution of the particular landscape groups is shown in Fig. 3. Our units correspond to landscape types distinguished by Perelman (1971) and kinds of landscapes according to Glazovska (1964). In terms of physico-geographic classification they should be considered as equivalent to terrain types, i.e. *ekochora* (Kondracki 1976, Richling 1982).

CONCLUSIONS

1. In slowly evolving landscapes, the Holocene geochemical interrelationships play a minor role. The structure and functioning of the surface depend on the relics of former evolutionary phases.

2. In intermontane landscape evolution, the movements of the Earth's crust play a significant role. They cause the change in migrating elements supply system, i.e. they control the sequence of eluvial, super- and subaquatic phases.

3. The existing methods of landscape categorization are not sufficient to grasp relationships in the areas with a complicated evolutionary cycle. Therefore the geochemical landscape classification requires further improvement.

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