The Bohemian Massif as a Catchment Area for the NW European Tertiary Basin

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ABSTRACT: On the basis of new paleontological results, isotope ages and a compilation of heavy mineral assemblages, improved paleogeographic maps of North Bohemia – East Germany were created. They show direct connections between the north Bohemian area and the NW European Tertiary Basin for eight time intervals. The high content of the heavy mineral sillimanite in the sediments of the Lusatian area since the beginning of Middle Miocene indicates the sedimentary influence from Bohemia. Before, only water reached the NW European Tertiary Basin, because the Ohre Rift basins functioned as a sediment trap.

KEY WORDS: Tertiary; North Bohemia; East Germany; sedimentology; paleogeography; heavy minerals.

Introduction

In the Tertiary, the northern part of the Bohemian Massif was a component of the catchment area of the NW European Tertiary Basin (in the sense of Vinken ed. 1988). This opinion has been unchallenged by the geological community for years. Whether the clastic material from the Bohemian Massif really reached the basin is still under discussion. At several places along the fluvial distributary system, relics of its sediments are still preserved. These sediments have been dated by different methods to the Upper Eocene up to Upper Miocene. Pliocene sediments have not been proved reliably.

A major source of difficulties with the correlation of the stratigraphic records of the North Bohemian Tertiary basins and the NW European Tertiary Basin is the isolated look at the individual basins and their different stratigraphic nomenclature. New biostratigraphic classifications, improved lithostratigraphic correlations as well as new and better isotopic data allow a new look at the problem.

Younger paleogeographic reconstructions of the western and central European region, such as Vinken ed. (1988) and Ziegler (1990), used only long time intervals and are very generalized. Therefore, they provide only a background for detailed investigations.

The stratigraphic record of the NW European Tertiary Basin is well defined by sequence stratigraphy (Suhr 1998, Lange and Suhr 1999). Sea-level changes were the main impulse for the sedimentation. Each sequence starts with a lowstand, which is often a hiatus in the record. The transgressive and highstand systems tracts are documented by sediments. Correlation of the sedimentary record with the sequence division results in a good time chart for the whole succession. This chart is necessary for the correlation with the dated volcanic events in the environment of the Ohře Rift.

Upper Cretaceous – Lower Eocene

Volcanic events in the Late Cretaceous to Early Eocene (Ulrych et al. 1999, Panasiuk 1986) have no sedimentary equivalents in the North Bohemian basins and on the margin of the NW European Tertiary Basin. In the more central parts of the NW European Tertiary Basin sedimentary relics of this age have been preserved (Vinken ed. 1988) but they lie so far from North Bohemia that it is not possible to discuss the connection of both areas.

Middle Eocene

The oldest Tertiary sediments (Middle Eocene) were deposited near Velky Luh in the Cheb Basin (maar sediments) (Konzalová 1972, 1976, Kvaček et al. 1989, Fejfar and Kvaček 1993) and in the lower part of the Borna Formation (Krutzsch et al. 1992), with fluvial gravels and the so-called Saxo-Thuringian Lower Seam in the Weisselster Basin (Eissmann 1994), a marginal part of the NW European Tertiary Basin. More to the east, the now isolated basins of Nichtewitz (near Torgau) and Schlieben (north of Torgau) also contain Middle Eocene sediments with coal seams (Lotsch 1969), equivalent to the Saxo-Thuringian Lower Seam. Sediments of the pathways connecting the two areas of this age are unknown. It is, however, very probable that water was flowing from the North Bohemian area to the north in direction to the Weisselster Basin.

Upper Eocene

The Upper Eocene deposits (see Fig. 1) are widespread and the paleo-drainage pattern is better understood. If we follow Domácí (1976), the North Bohemian region was a fluvial-dominated plain and the areas of strongest subsidence were flooded by lakes (see Fig. 1). The main inflow came from the Plzeň area. The water transported debris from a thick weathering crust of crystalline rocks. The resulting heavy mineral assemblage in the Staré Sedlo Formation is dominated by stable minerals like zircon, rutile and anatase. In the heavy mineral assemblage of the later Cheb Basin, a local influence of topaz from the Fichtelgebirge can be observed (Peterek 2001, Schröder and Peterek 2001). The Upper Eocene age of the Stare Sedlo Formation is proved by paleobotanical and palynological data (Konzalová 1972, 1976, Knobloch 1989, Kvaček et al. 1989, Knobloch et al. 1996, Knobloch and Konzalová 1998). In the Bílina area, another type of Upper Eocene sediments occurs (Bellon et al. 1998). It is represented by the limnic diatomite near the village of Kučlín (Horáčková 1967). Fluvial sediments of probably Upper Eocene age occur also in the graben of Hrádek in the Zittau Basin (Václ and Čadek 1962, Dittrich 1988, Fejfar and Kvaček 1993). Unfortunately, paleontological evidence of its age is still missing. Only the position of the sediments below the Lower Oligocene seam horizon, which is correlated with the Josef Seam in the Sokolov and Cheb basins, is an indication of this age.

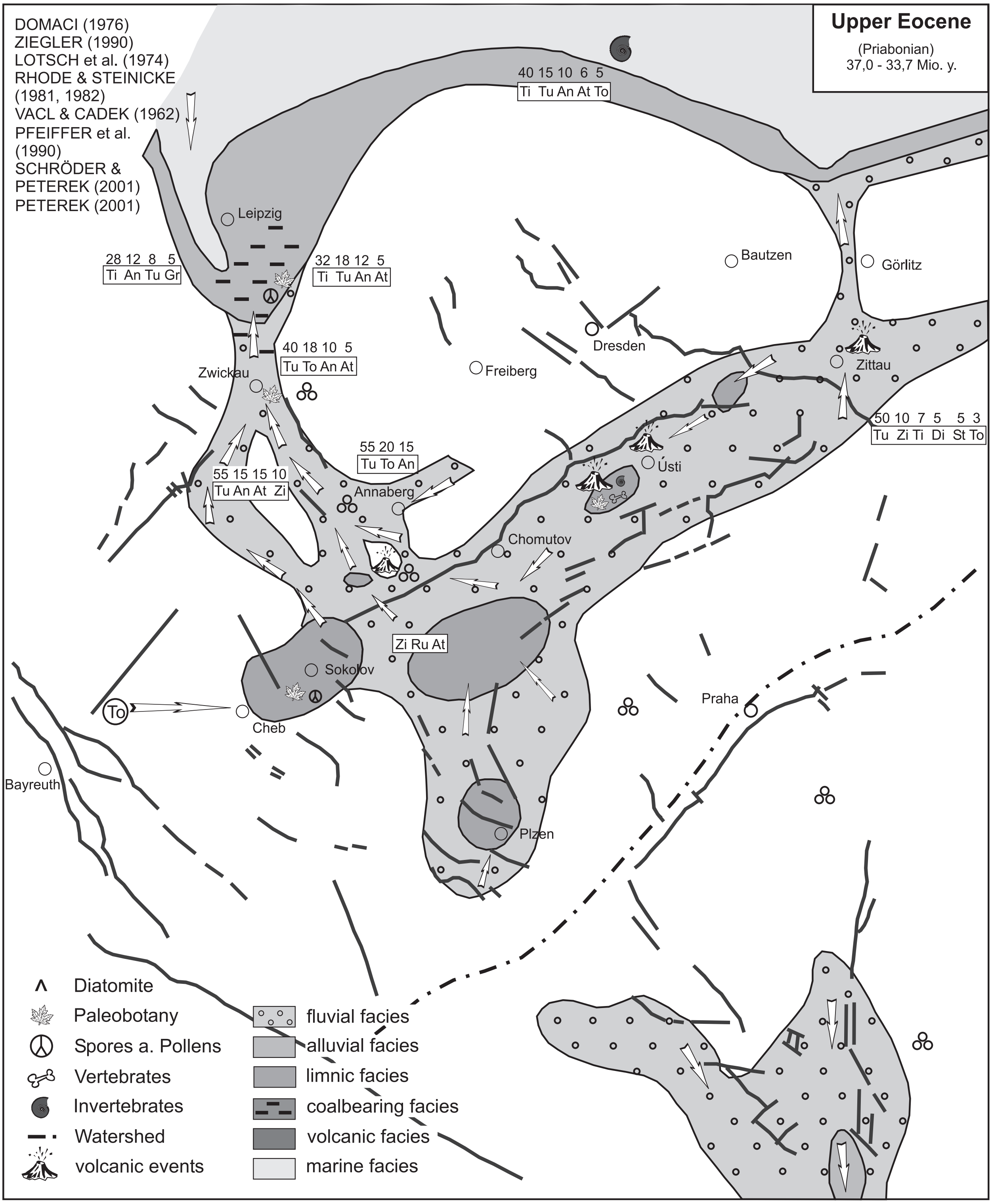

Fig. 1. Paleogeographic map of the Late Eocene.
AN – andalusite, At – anatase, Di – disthene, Ep – epidote, Gr – garnet, Ru – rutile, Si – sillimanite, St – staurolite, Ti – titanite, To – topaz, Tu – tourmaline

Simultaneous volcanic activity has been documented in the Bílina area, in the České středohoří Mts. (Bůžek et al. 1978), probably in the Zittau Basin and in the area of Oberwiesenthal (Pfeiffer et al. 1990) in the Ore Mountains (Krušné hory, Erzgebirge). This activity was, however, only of local significance, perhaps with the exeption of the area of České středohoří Mts. (Cajz 2000).

Water flowing from the south caused an outflow to the north. Lake basins served as sediment traps; therefore, all the sediments north of the subsidence area are free of Bohemian de-

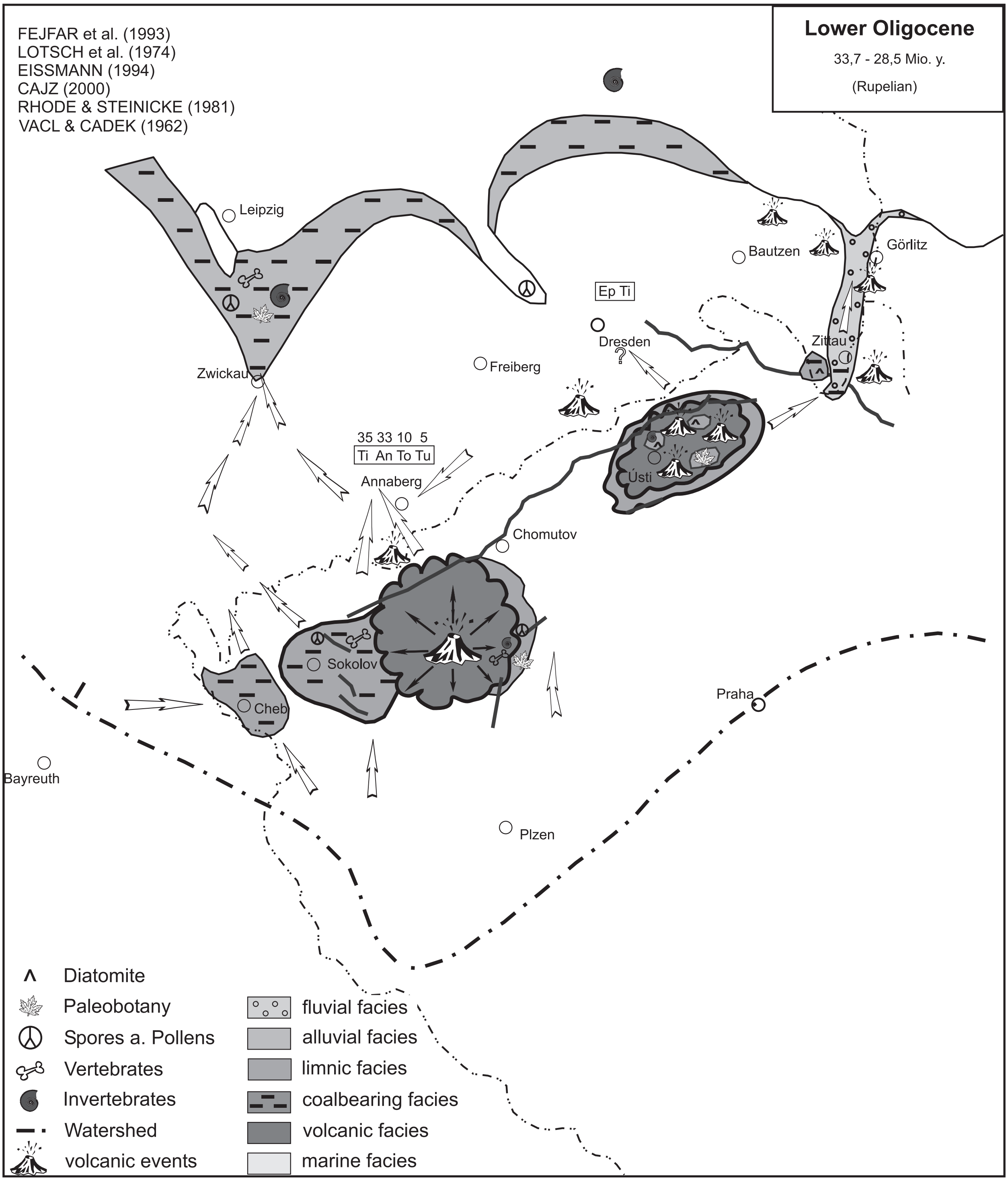

Fig. 2. Paleogeographic map of the Early Oligocene in the North Bohemian – East German region. Abbreviations of heavy minerals: see Fig. 1.

bris and heavy minerals. The deposits in the Ore Mountains are dominated by local debris and local heavy minerals, like tourmaline, topaz and andalusite (Rohde and Steinike 1981). These minerals show the influence from the contact areas and the greisen zones of the granites in the western Ore Mountains.

The river system connecting the sediments of the Staré Sedlo Formation with those of the "Zwickau-Altenburg River" (Richter 1963) can be reconstructed to some extent. Former reconstructions show the courses of valleys, which generally cross the Ore Mountains in northerly direction and bend to the west near Zschopau. Recent attempts to reconstruct the Tertiary river course assume that the older valleys could have been only where the present relief is clearly below the level of erosion in the Tertiary. For the location of these areas, digital altitude values were calculated against the values of the outcrops of Upper Eocene sediments. The resulting picture reveals that the former courses do not fit with the altitudes. More plausibly, the courses run along the regional faults, which are still used by the present rivers (Standke and Suhr 1998, Cajz et al. 2000).

Also the highest terrace gravels of the Plauen Reichenbach region are a particular river course from Rotava across Plauen, Reichenbach to Zwickau. Its Upper Eocene age was proved by the heavy mineral analysis of Rohde and Steinike (1982). In the surroundings of Zwickau, both river courses unified and flowed to a large alluvial plain in the Weisselster Basin. In Mosel, north of Zwickau, there is paleobotanical evidence for Upper Eocene age (Fischer 1950) of the gravels. The heavy mineral assemblage shows strong influence of the Ore Mountains and an additional part from basic volcanism, like anatase and titanite. The titanium minerals may pose remains of air fall tuffs, also a high content of montmorillonite in the clay fraction indicates an influence of basic volcanism (Rohde and Steinike 1981). This influence is detectable in the whole region of the southern margin of the NW European Tertiary Basin.

West of Leipzig, the alluvial sediments of the Upper Borna Formation interlink with marginal marine sediments of the Domsen Member (Eissmenn 1994). In the Schönewalde – Calau area, fully marine Upper Eocene sediments of the Upper Schönewalde Formation are present and contain foraminifers.

A possible outflow is suggested also for the region of Zittau – Görlitz but, besides the undated sediments in the graben of Hradek, no further evidence is available.

Lower Oligocene

In the Early Oligocene (Fig. 2), the main volcanic activity started in the area of Doupovské hory Mts. (Hradecký 1997) and in the Česke středohoří Mts. (Cajz 2000). Individual volcanic events of this age have been reported from the Upper Lusatian region and the Ore Mountains. The volcanism was generally highly explosive and ejected huge amounts of pyroclastic material. In the Hammerunterwiesenthal – České Hamry area, two maar structures (Suhr and Goth 1996, Cajz et al. 2000) were blasted out.

The Cheb and Sokolov basins show subsidence with the formation of the Josef Seam, that interlinks in its highest parts with pyroclastic deposits. On the eastern margin of the Doupov volcano, basic tuffs were falling into a limnic environment, forming tuffites with remains of mammals and snails (Fejfar and Kvaček 1993, Fejfar 1987). In the České středohoří Mts. the volcanic activity produced a thick sequence of waterlain pyroclastics, lava flows and intercalated sediments, like clays and diatomites with fossils (Bellon et al. 1998).

The drainage pattern was similar to that in the Late Eocene, and the Cheb Basin was drained to the north. Outflows across the Ore Mountains were still in use, as shown by the upper parts of sediment accumulations at Rýžovna, Bärenstein, Pöhlberg and Scheibenberg (Lomozová and Mrňa 1967, Rohde and Steinike 1981). These sediments contain heavy mineral assemblages with very high amounts of titanite together with the local spectrum. This documents the strong influence of explosive volcanic activity in this area. River courses in the western Ore Mountains were directed to an alluvial plain in the southern part of the Weisselster Basin. This alluvial plain shows interlinking between fluvial-limnic sediments with marginal marine deposits, the so-called Böhlen Member with the Böhlen Main Seam (Eissmann 1994). Farther to the north, the Lower Oligocene sequence is developed in marine facies, as the Rupel Clay.

Fluvial-limnic sediments, which may belong to a drainage path in the eastern part of the North Bohemian basins have been preserved in the Zittau Basin (Dittrich 1988, Kasinski 2000).

The far ingression of the Early Oligocene sea into the Elbe Zone (Goth: Lower Oligocene microphytopankton near Meissen; oral information) indicates a subsidence of this zone. For the first time, water was flowing this way from North Bohemia to the NW European Tertiary Basin.

Nevertheless, Bohemian material is not detectable in the sediments of the Elbe Zone. Instead, their heavy mineral assemblages show a local origin (Ahrens et al. 1974). The swamps and limnic basins of N Bohemia functioned as sediment traps.

Upper Oligocene

In the Late Oligocene (see Fig. 3) the western part of the Ore Mountains started to rise (Pietzsch 1963) and cut off the fluvial connection across this area. Drainage of the Cheb Basin was directed to the Sokolov Basin and, from there, around the Doupovské hory Mts. to the NE.

As before, the centres of subsidence in the North Bohemian basins served as sediment traps (Elznic et al. 1998). No evidence of Bohemian material was found in the sediments of the NW European Tertiary Basin. The heavy mineral assamblage of the Cottbus Formation (Hartsch 1988) is characterized by garnets and epidotes coming from the Cretaceous sandstones and andalusite from the West Lusatian granodiorite. Some influence from the West Sudetic region cannot be excluded.

Contents of titanite show the influence of explosive volcanism in E Lusatia documented, e.g., by the maar structures of Kleinsaubernitz and Baruth (Suhr and Goth 1999).

The Late Oligocene Thierbach river in the Weisselster Basin, missing topaz in its heavy mineral assemblage (Ahrens et al. 1974), comes rather from the SE and shows influence of the Granulite Mountains and the NW Saxonian Permian volcanic complex (Pöppelreiter 1992). Lotsch et al. (1994) suggested that the river systems of the Hlavačov gravel in N Bohemia and the system of the Thierbach river were connected across the middle part of the Ore Mountains. But the low sillimanite content in the Thierbach gravels can be more readily explained by a local source in the Granulite Mountains (Lange 1995, p. 56).

Lowermost Miocene

In the earliest Miocene (see Fig. 4), the subsidence of the Cheb and Sokolov basins continued with the formation of coal seams. Two different subsidence centres existed in the Most–Chomutov Basin. The eastern centre developed a coal seam (Elznic et al. 1998), the western centre did not. The water outlet from the North Bohemian basins was leading across the eastern Ore Mountains (Hurník and Krutský 1995), because the western part was still

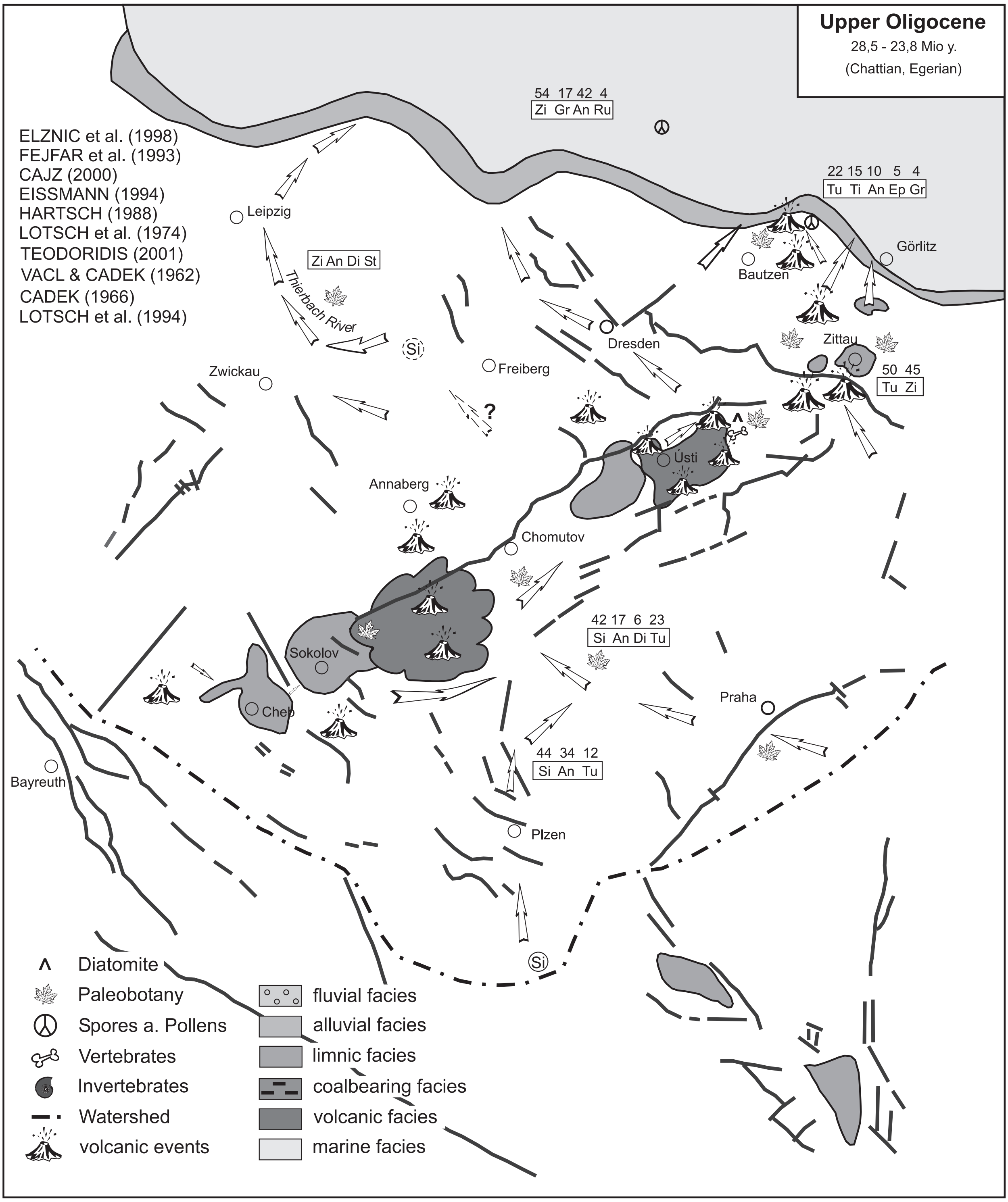

Fig. 3. Paleogeographic map of the Late Oligocene in the North Bohemian – East German region. Abbreviations of heavy minerals: see Fig. 1.

uplifted and the way along the Elbe Zone was blocked by the huge volcanic events in the České středohoří Mts. (Cajz 2000). Remains of this water course is possibly represented by the Tertiary sands below the basaltic trap of Landberg east of Freiberg. The outflow through the Zittau Basin was in use the whole time. Also the Cheb Basin had its outflow farther to the NE.

The 4th Miocene Seam Horizon (lowermost Miocene) on the margin of the NW European Tertiary Basin interlinks with fluvio-limnic sediments in the south and marginal marine sands in the north. The heavy mineral assemblages of these sediments are of local origin – no Bohemian material has been discovered yet.

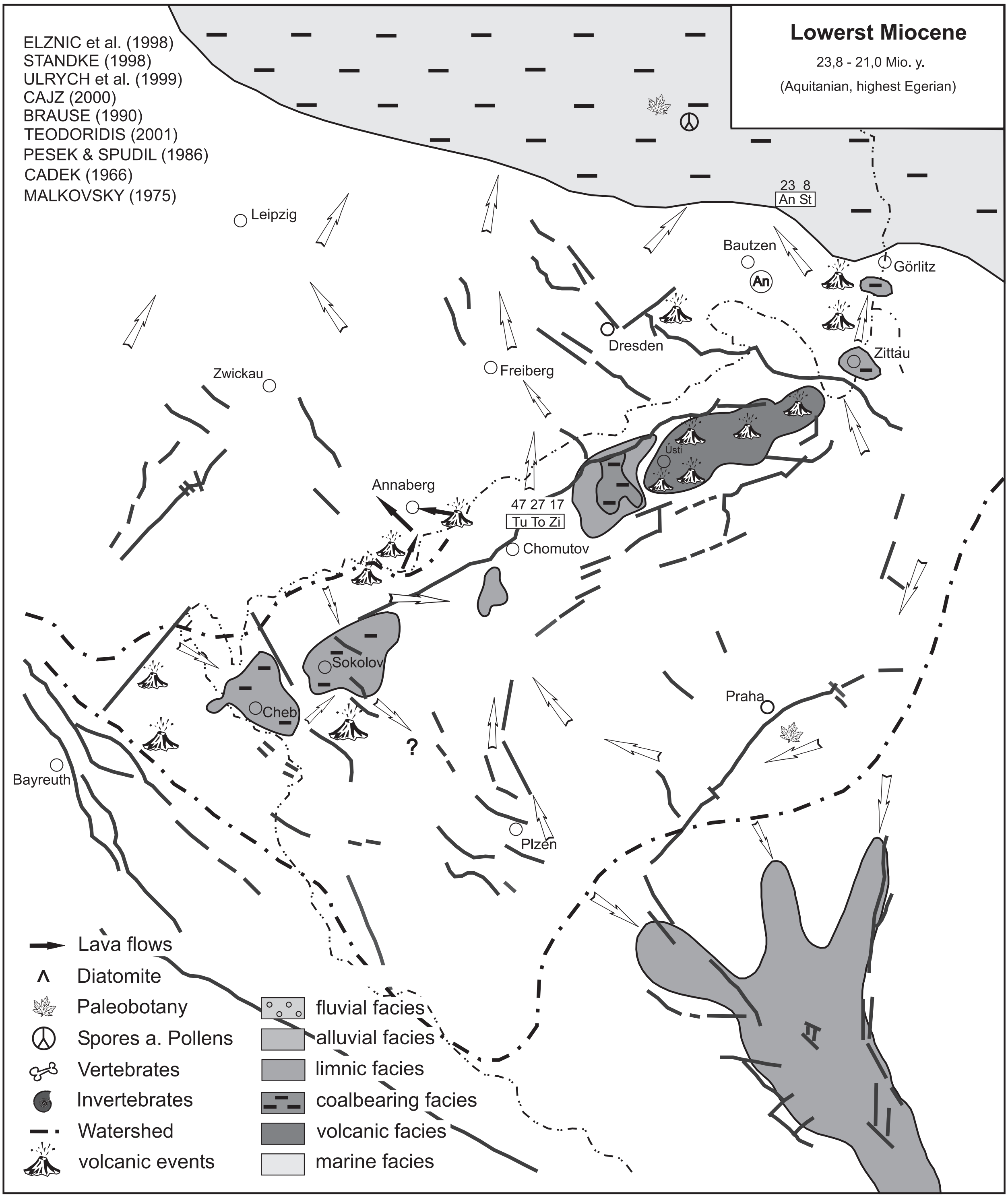

Fig. 4. Paleogeographic map of the earliest Miocene in the North Bohemian – East German region. Abbreviations of heavy minerals: see Fig. 1.

Middle Lower Miocene

In the middle part of the Early Miocene (see Fig. 5), the subsidence areas were extended (Elznic et al. 1998). The eastern part of the Ore Mountains started to rise and barred the former outflow. The dammed water found its way to the Elbe Zone. Coarse sediments in the northern part of the basin show the effect of the rising Ore Mountains (Elznic et al. 1998). Also the Lusatian Massif was rising, and its weatering crust was eroded and deposited in the form of a large alluvial fan of the Spremberg Formation. Towards the end of this time interval, marine transgression resulted in an increase in groundwater table, hence

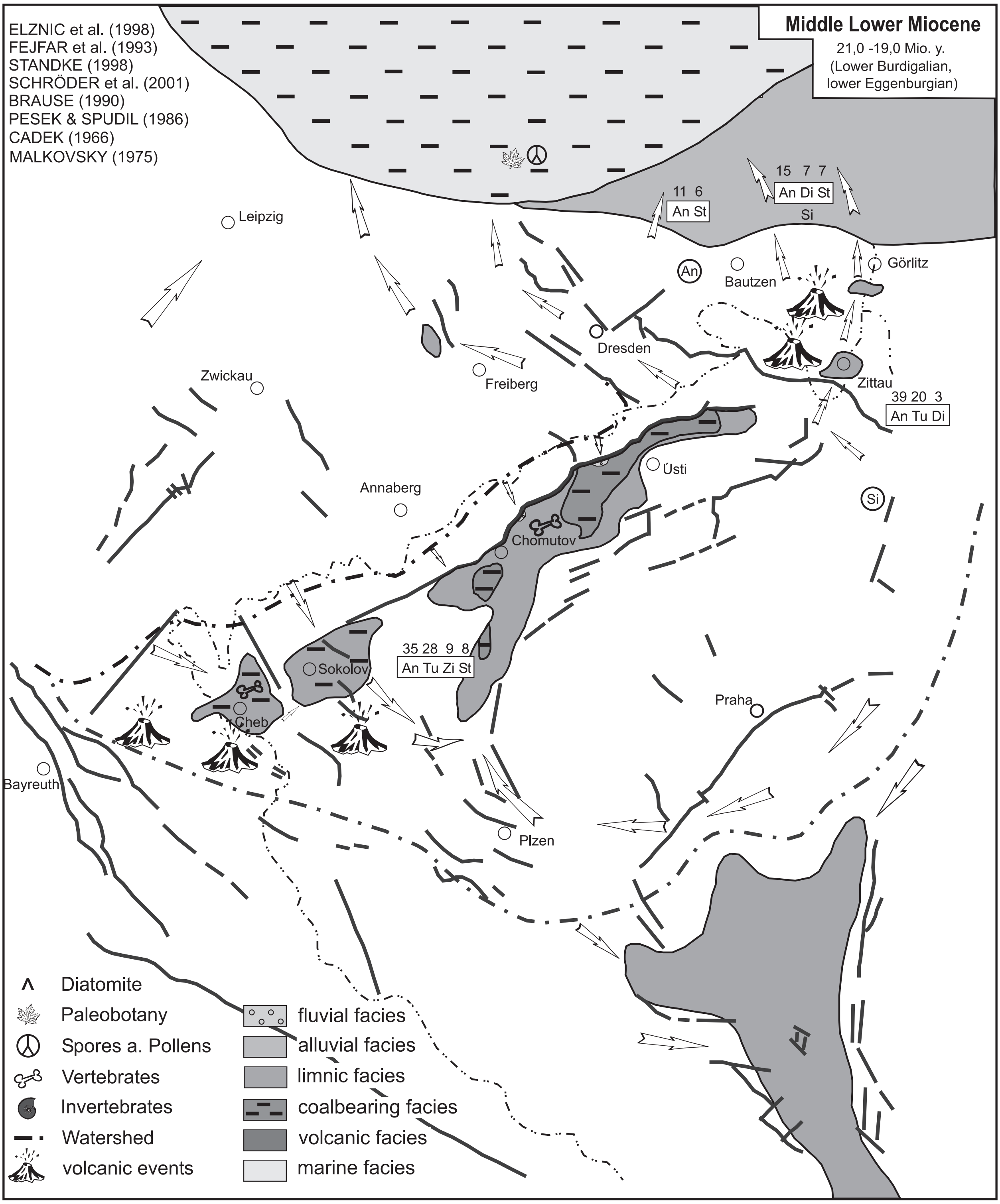

Fig. 5. Paleogeographic map of the mid Early Miocene in the North Bohemian – East German region. Abbreviations of heavy minerals: see Fig. 1.

also the formation of swamps of the 3rd Miocene Seam Horizon (Standke 1998).

Heavy mineral assemblages in the Spremberg Formation show local influence only, with the exception of the easternmost part of Lusatia, where the low content of sillimanite indicates an influence from the western Sudetes via the Zittau Basin (Tietz and Czaja 1999).

In the western part of the North Bohemian subsidence zone, the drainage patterns were very similar to those in previous times.

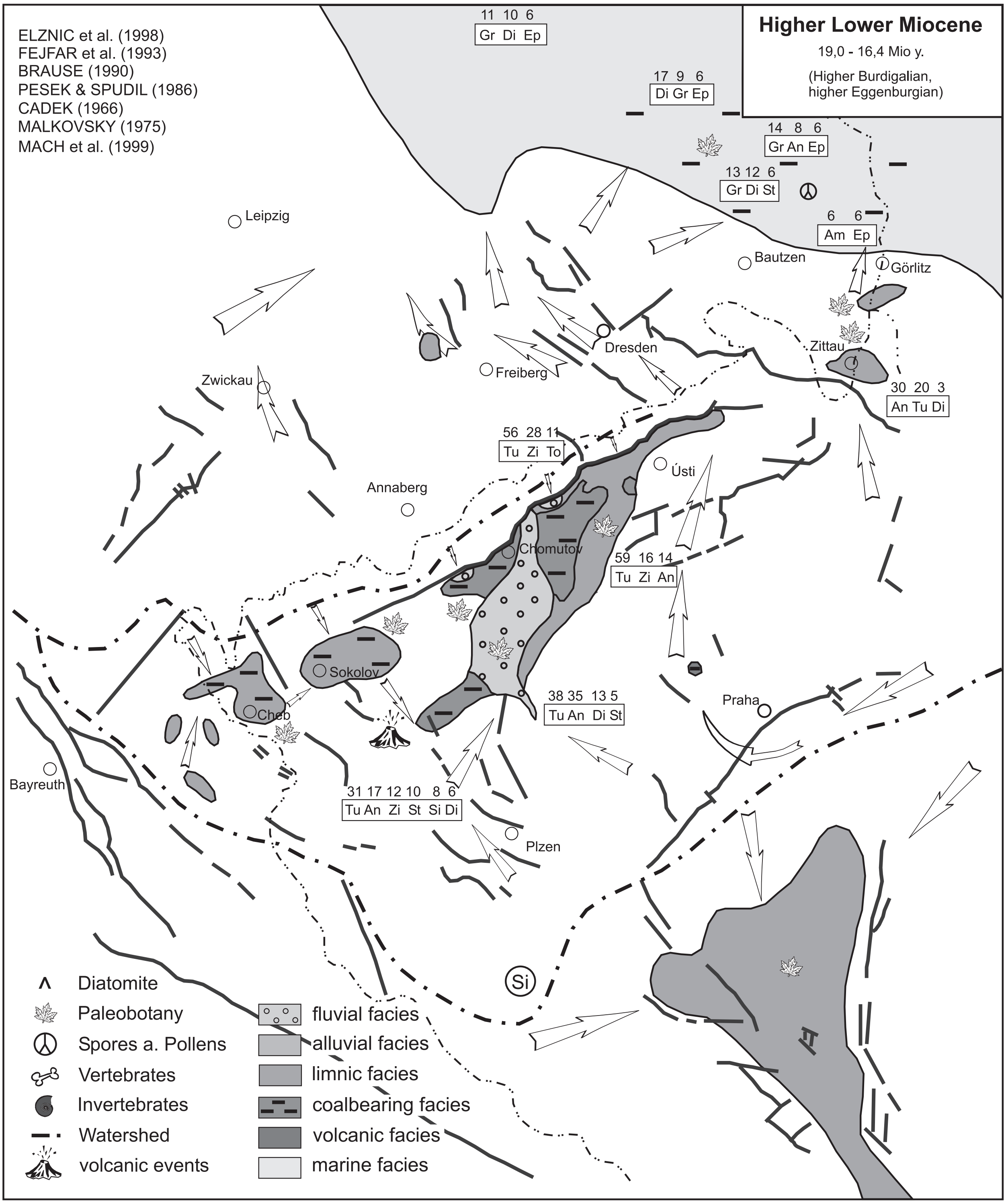

Fig. 6. Paleogeographic map of the late Early Miocene in the North Bohemian – East German region. Abbreviations of heavy minerals: see Fig. 1.

Upper Lower Miocene

In the late Early Miocene (see Fig. 6), a huge limnic delta developed in the area of Žatec and Bílina (Elznic et al. 1998). Beyond this delta, swamps of the Main Seam grew in their extent and the water was leaving the basin along the Elbe Zone free of sediment. The source area of the basin shifted more to the SW by this time, as indicated by the sulphur isotopic composition of the Main Seam (Mach et al. 1999). The western basins are also characterized by swamps of the Main Seam. Their drainage pattern persisted.

Lagoonal sediments of the Lower Brieske Formation were deposited in the Lusatian region.

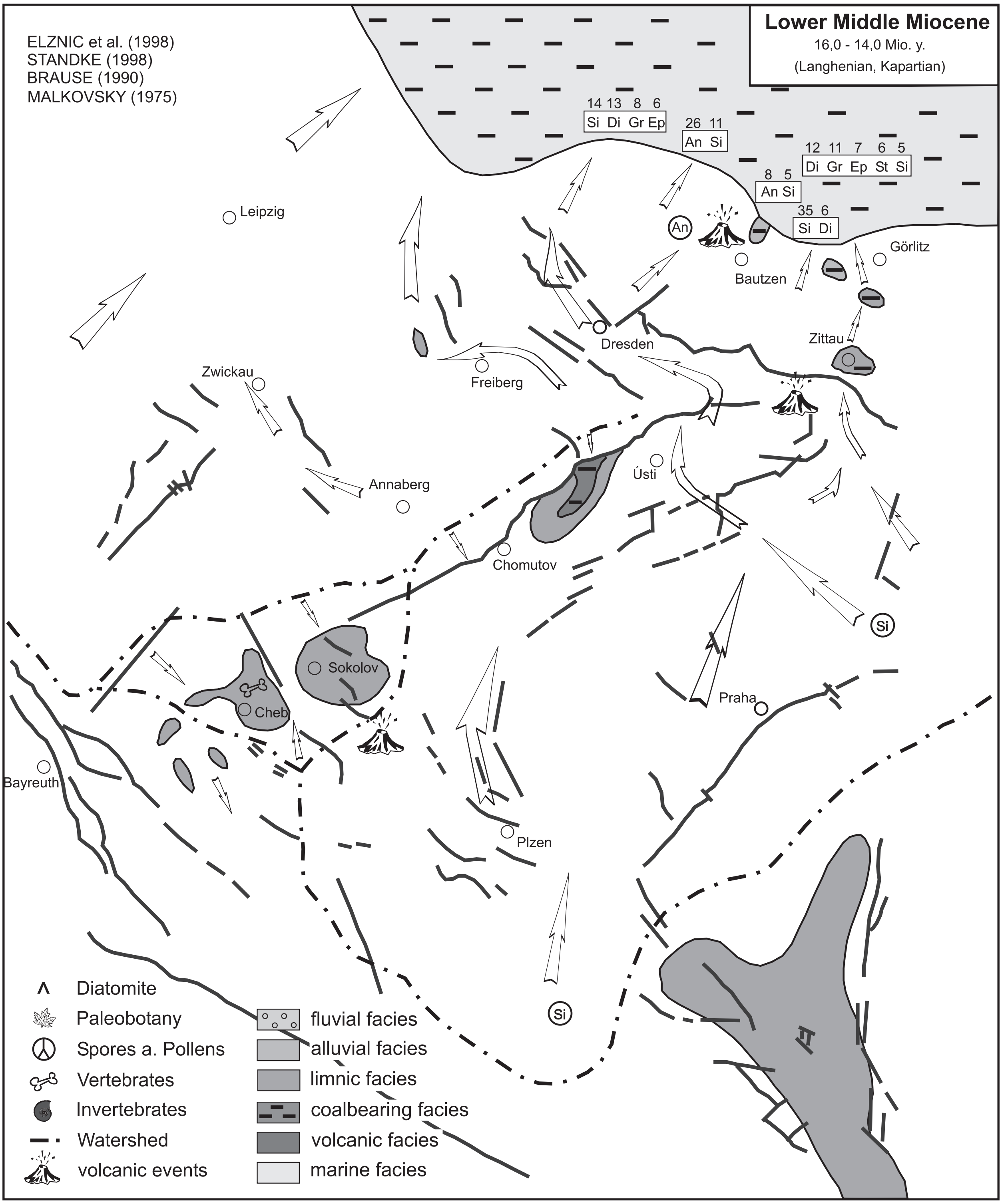

Fig. 7. Paleogeographic map of the early Middle Miocene in the North Bohemian – East German region. Abbreviations of heavy minerals: see Fig. 1.

Their heavy mineral assamblages are characterized by garnet and epidote showing a strong influence of Upper Cretaceous sandstones of the Elbe Zone. Also the discovery of Upper Cretaceous foraminifers in the Lower Brieske Formation points to the same conclusion (Ahrens, pers. comm.). Similar to the preceding time interval, the sediments of the eastern part contain low amounts of sillimanite coming from the West Sudetic mountains across the Zittau and Berzdorf basins.

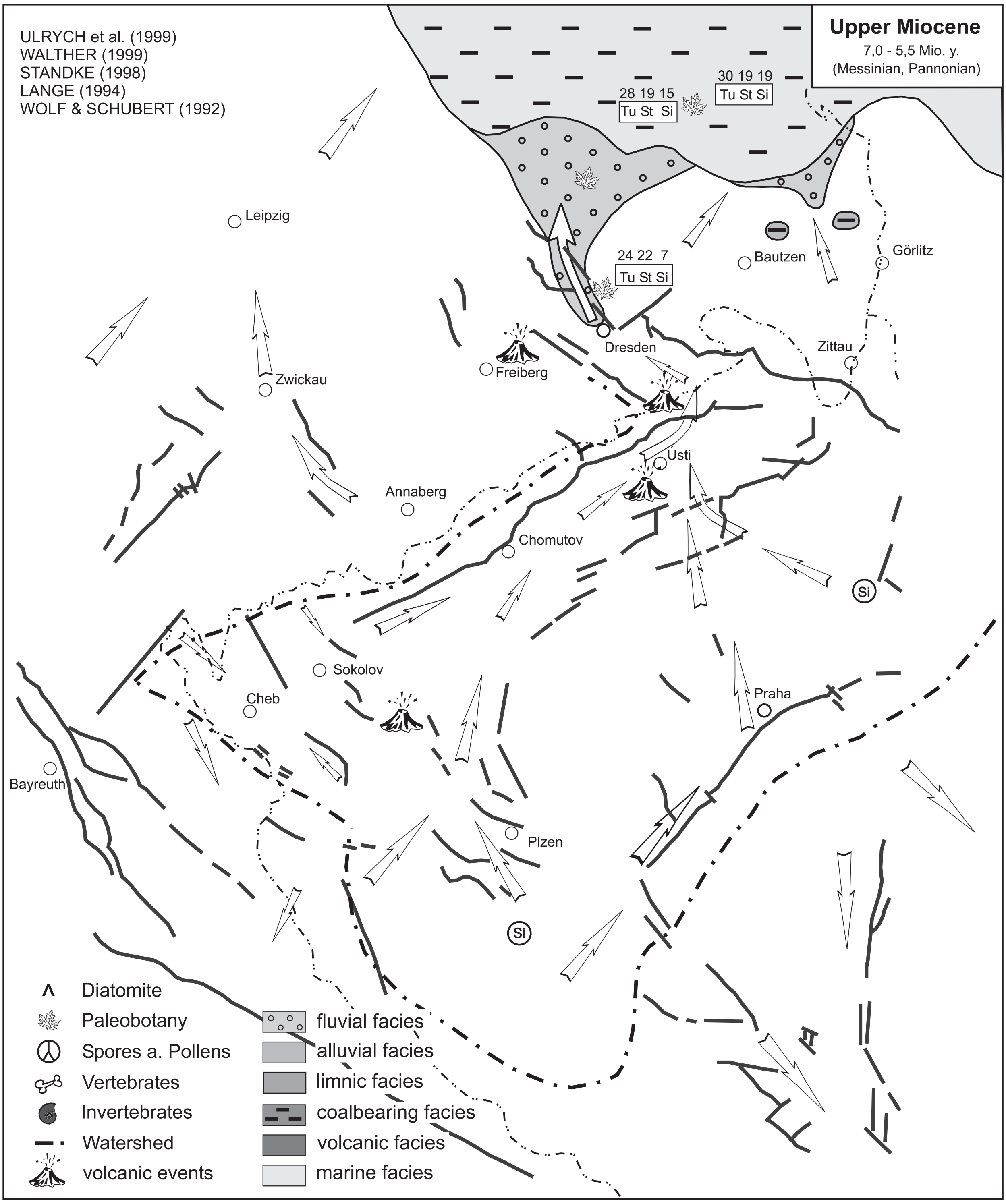

Fig. 8. Paleogeographic map of the Late Miocene in the North Bohemian – East German region. Abbreviations of heavy minerals: see Fig. 1.

Lower Middle Miocene

The next time interval, the Lower Middle Miocene (see Fig. 7), shows a different paleogeographic picture. The Sokolov and Cheb basins became drainless (Šmejkal 1987, Obrhelová and Obrhel 1987), as shown by sulphur isotopes and fish fauna of the Cypris Formation. The Most–Chomutov Basin survived as a small depression, with the Lom Seam in its central area (Elznic et al. 1998). This basin no longer functioned as a filter for waters coming from the southwestern parts of North Bohemia. This catchment area consists of katazonally metamorphosed rocks containing fibrous sillimanite.

Sediments of the Upper Brieske Formation of the Lusatian region corresponding to this time interval contain Bohemian material for the first time. Wolf and Schubert (1992) described up to 35 % of fibrous sillimanite in the heavy mineral assemblages.

The appearance of the Bohemian clastic material in the NW European Tertiary Basin exactly corresponds to the time when the subsidence in the North Bohemian region stopped, with the exception of its western part (Schröder and Peterek 2001), and the basin filled up. The outflow across the Zittau and Berzdorf basins was still in function.

Upper Miocene

In the Late Miocene (see Fig. 8), no subsidence has been documented in the North Bohemian region. Relics of fluvial sediments are present only outside the old North Bohemian subsidence zone.

In Saxony, coarse gravelly sediments of the Rauno Formation indicate an uplift of the Ore Mountains and the Lusatian massif (Lange 1995, Lange and Suhr 1999). This uplift was connected with a minor volcanism in the eastern part of the Ore Mountains and in the Elbe Zone. Coarse fluvial gravels now contained also Bohemian marker boulders.

Rich leaf floras and index taxa of marine microphytoplankton indicate an Upper Miocene age for the Rauno Formation. The Elbe gravel of Ottendorf Ockrilla is of uppermost Miocene age as indicated by its leaf and seed flora (Walther and Kvaček 1998).

Heavy mineral assemblages of the Upper Miocene sediments show a strong Bohemian influence with high amount of fibrous sillimanite (Wolf and Schubert 1992, Lange 1995). Nevertheless, the dominant amounts of tourmaline and staurolite indicate erosion in the Ore Mountains, which is also confirmed by pebbels from this area.

Pliocene

Pliocene deposits are known only from the Cheb Basin. In other regions, their equivalents have been eroded during the Pleistocene.

Remark

The paleogeographic reconstructions of the Lower und Middle Miocene used the paper of Elznic et al. (1998), which is based on a geochemical correlation in the Chomutov–Most Basin. The log correlation by Mach (1997) yields somewhat different courses of isochrones, but the general drainage pattern is not influenced by this differences.

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