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The Early Miocene Lignite Opencast Mine of Oberdorf N Voitsberg (Styria, Austria): A Multidisciplinary Study

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Contents

1. Historical Background

Neogene coal deposits in Austria have been mined from various tectonic units, including the Molasse Zone, the Intraalpine Basins (e.g., the Vienna, Korneuburg, Pannonian, Styrian, Lavant Valley and Klagenfurt Basins), the Noric Depression, and the inner alpine Neogene deposits (e.g., Enns Valley) (STEININGER et al., 1989; WEBER & WEISS, 1983).

The Miocene of the Styrian Basin, especially the Western Styrian Basin, was a very rich browncoal area, and according to WEBER & WEISS (1983) it can be separated into several browncoal provinces (see EBNER & STINGL, this volume, Text-Fig. 1). These include the Eibiswald embayment to the south (with the Wies, Hörmsdorf-Eibiswald, Vordersdorf, Aibl and Wernersdorf browncoal areas), which were quarried from 1790 to 1975, as well as the St. Florian embayment to the north (where only one minor coal seam is known) and the Stallhofen embayment, to the north (with the Mantscha, Wetzelsdorf, Eggenberg, Straßgang, Raßberg, Stiwoll, St. Oswald, Plankenwarth, Rein and the Köflach-Voitsberg browncoal areas). The browncoal deposits in the Stallhofen embayment were quarried from 1766 onwards.

There have been a number of mines in the Köflach-Voitsberg area, including the Piberstein, Karlschacht Grube, Karlschacht Tagbau, Marienschacht, Karlschacht Tagbau 2, Piber, Bärnbach und Grubhof, Oberdorf, and Zangtal und Kowald mines (for details see WEBER & WEISS [1983] and EBNER & STINGL [this volume, Text-Fig. 2]). All mines in the Stallhofen embayment ceased operations nearly completely in the 1980's. Only the open pit mine in Oberdorf is still operating and provides the last opportunity for performing an extensive multidisciplinary study.

The lithologic sequences are only vaguely known for most of these browncoal pits in the Western Styrian Basin, which hinders lithologic correlations across these browncoal provinces. This also prevents assigning the rich plant and vertebrate remains recovered from these pits in former times to various lithologic horizons and prevents extracting data for detailed biostratigraphic data and palaeoenvironmental studies.

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2. Geologic Framework and Basin Configuration

The overall geologic framework of the Neogene Styrian Basin shows it to be a northwesternmost subbasin of the Pannonian Basin System that is surrounded by Alpine fold belts (the Eastern Alps, Carpathians, and Dinarides). Palaeogeographically the basin deposits belong to the Central Paratethys province. The Middle Styrian Swell subdivides the Styrian Basin into a Western Styrian Basin and an Eastern Styrian Basin. The South Burgenland Swell separates the Styrian Basin from the Pannonian Basin itself (see EBNER & STINGL, this volume, Text- Fig. 1).

The Western Styrian Basin is divided into three subbasins. The southernmost subbasin is the Eibiswald Embayment, which is succeeded northward by the St. Florian Embayment and, at the extreme north, by the Stallhofen Embayment. The Köflach-Voitsberg Embayment with the Oberdorf open pit mine is a marginal embayment of the Stallhofen Embayment, as is the small Rein Basin.

The filling of the Western Styrian Basin generally took place from the Ottnangian into the Badenian (middle Early Miocene to lower Middle Miocene), and only minor Sarmatian deposits are known.

The basin configuration of the Oberdorf open pit mine has been studied by seismic and geoelectrical measurements in combination with well data. These studies have brought new insights into the geometry and lithofacies distribution of the pre-Tertiary basement. The axis of the syncline trends N–S and, toward its southern end, makes a sharp turn westward that is accompanied by a slight steepening. The base of the syncline in the north is at an elevation of about 320 m and is below 310 m in the south. The base of the syncline evidently was formed by an uplift of carbonates and a sliver of crystalline rocks in the southeast, surrounded by Gosau deposits to the west, north and east (see GRASZL et al., this volume).

3. Sedimentology, Coal Petrology and Chemofossils

Sedimentology

The siliciclastic deposits of the Köflach-Voitsberg-Formation, in the Early Miocene lignite-bearing sequences of the Köflach/Voitsberg lignite mining district, are mostly associated with marginal fluvial environments. Characteristic flood plain and flood basin sediments alternate with crevasse splay deposits and channel fillings. Palaeosols occur frequently and are characterized either by red earth, or by bluish-greenish, siderite-bearing horizons that are evidence of waterlogged soils in a swampy environment. The frequent occurrence of fusain layers indicates palaeoforest fires.

A composite section of the Köflach-Voitsberg Formation, about 165 meters thick, can be reconstructed in the Oberdorf open pit mine. The lower sediments, in the footwall, are exposed in a mighty outcrop 15 meters thick. This lower sequence is dominated by clayey sediments, with a sandy-silty portion at its base and a prominent gravel bed in the middle. Ripple crossbedding, root remains and fossil wood become frequent above the gravel bed, and a layer with diaspores and leaves occurs just below the lower coal seam.

The main coal seam is about 35 meters thick, divided into a lower and an upper seam by a seamparting member up to 17 meters thick which contains ripple crossbedding, wood and root remains, and by two horizons with leaves and diaspores in the upper part and a tree stump horizon near the top of the seamparting member.

The hanging wall sequence is about 115 meters thick, dominated by clayey silts in the lower part (approx. 30 meters), sandy silts with gravel horizons, two distinctive carbonaceous clay horizons and two minor coal seams in the middle part (approx. 40 meters), and clay and clayey silts with tuffaceous horizons in the upper part (approx. 45 meters). At the base of the middle part of the hanging wall sequence there is another tree stump horizon with leaves overlain by a horizon with molluscs (mainly gastropods) and, just below the first carbonaceous clay layer, a horizon rich in vertebrate remains, gastropods and diaspores (= OB 3 at meter 100, see HAAS, this volume; DAXNER-HÖCK et al., 1998). Upsection, a second horizon with vertebrate remains, gastropods and diaspores (= OB 4 at meter 105, see HAAS, this volume; DAXNER-HÖCK et al., 1998) lies just below the first small coal seam, followed upward by two horizons with diaspores, leaves and gastropods, one between the two coal seams and one between the upper coal seam and the upper carbonaceous clay.

The heavy mineral distribution suggests two distinct erosional sources: a low grade metamorphic upper greenschist facies source area in the main seam parting, and a medium grade metamorphic amphibolite facies source area in the hanging wall sediments. Modeling of the coal seam distribution indicates correlation of the Oberdorf eastern subbasin with the adjacent Oberdorf western subbasin and with the Zangtal open pit mine, and demonstrates the complexity of the subsidence history within these basins (see HAAS, this volume for detailed Figures of the section).

The lignite deposits of the Oberdorf open pit mine (Lower Miocene) are overlain unconformably by the Stallhofen Formation (Middle Miocene) which includes tuffs/tuffites (Lobmingberg Member) in its basal parts. These rhyolitic tuffs are partly altered to bentonite and interpreted as subaqueous fallout tephras (EBNER et al., this volume).

Coal Petrology

Petrological and palynological data have been used to study vertical facies variations within the lower and the upper Oberdorf coal seam and within coaly layers in the hanging wall sediments. The lower seam and the upper seam originated in a relatively wet, non-marine, low-lying moor with relatively high pH-values. The seams are characterized by an upward increase in tree density. Pollen from a mixed mesophytic forest and a swamp forest are most abundant (KOLCON & SACHSENHOFER, this volume).

Chemofossils

In some samples (resin, wood, lignites) from the Köflach-Voitsberg lignite mining district a few biological markers ("chemofossils") – phyllocladane, isophyllocladene, norpimarane and simonellite – have been identified by a combination of gas liquid chromatography and mass spectrometry. The most convincing botanical affinities of phyllocadane points to Taxodiaceae (*Sciadopites, Cryptomeria*), since no retene, especially b-phyllocardene, has been found. This confirms that the organic compounds in the samples are still in a rather early to intermediate state of diagenesis (VAVRA, this volume).

4. Palaeobotany (Palynomorpha, Diaspores, Leaves and Wood Remains)

Palynological Investigations

Rich palynomorph assemblages were recovered from lignite deposits of the Oberdorf open pit mine. The assemblages are dominated by pollen taxa of Taxodiaceae, Juglandaceae, Fagaceae, Oleaceae, Betulaceae and Rosaceae. The palynological data indicate the existence of a swamp forest, associated riparian vegetation, and a mesophytic broad-leaved forest. The occurrence of certain palynomorphs (*Alangium, Lithocarpus, Distylium, Engelhardia, Mastixia*) suggest a warm temperate climate (ZETTER, this volume).

Diaspore Assemblages

The lignite-bearing sediments of the Köflach-Voitsberg lignite mining district are rich in fruits and seeds. Numerous samples from all levels have been analyzed. The diaspore spectra represent conifers (e.g. *Sequoia, Glyptostrobus, Cephalotaxus*), evergreen and deciduous trees, shrubs (e.g. *Symplocos, Trigonobalanopsis, Mastixia, Fagus, Magnolia*), and lianas, which today preferably grow under subtropical or temperate climatic conditions. Finds of herbaceous elements (e.g. *Sparganium, Carex*) are rarer and aquatic plants (e.g. *Stratiotes, Ceratophyllum, Potamogeton*) are exceptionally rare. The floristic compositions of the investigated samples indicate wetland habitats (swampy forests, bogs, variable riverside forests) and mesophytic forests (MELLER, this volume).

Leaf Assemblages

The lignite deposits of the Oberdorf open pit mine are rich in leaf assemblages. The botanical identifications are based on morphological and cuticular analyses. The floristic composition of different levels and sections varies considerably. The top of the footwall and the base of the seam are the most species-rich sediments (leaves, diaspores, pollen). Although heavily fragmented, taxa assigned to mesophytic forests are better represented there than in any other part of the sequence. Among the leaves, evergreen Fagaceae div. sp. and Lauraceae div. sp. indicate associations best compared to Younger Mastixioid ones. This interpretation coincides with that based on diaspore and pollen investigations (KOVAR-EDER et al., in press, MELLER et al., in press). In clayey (/silty) seam partings *Quercus rhenana* (KRÄUSEL & WEYLAND) KNOBLOCH & KVACEK is the monodominant associated with *Glyptostrobus europaea* (BRONGNIART) KNOBLOCH (twigs, cones, seeds). All other components constitute mere accessory elements in these assemblages. The coarse sandy main seam parting of the western subbasin is characterized by a stronger fluviatile influence. The assemblages are species poor and the prevalent taxa there are *Salix varians* GÖPPERT, *Cephalotaxus* ? *europaea* MAI, and *Sequoia abietina* (BRONGNIART) KNOBLOCH (KOVAR-EDER & MELLER, in press). The upper part of the hanging wall sediments in the eastern subbasin are rich in silty (/clayey) layers with almost entire, closely packed leaf remains. *Cercidiphyllum, Alnus, Salix, Acer*, and *Fraxinus* are abundant there. Leaf-taxa characteristic of lignitic clays and mesophytic forests are largely absent (evergreen Fagaceae, Lauraceae).

These differences most likely resulted from changing environments in the Oberdorf region during the depositional phase, rather than to climatic changes (KOVAR-EDER, this volume).

Petrified, Lignified and Carbonized Wood Remains

All identifiable samples so far examined belong to the Gymnospermae. They show uniseriate rays and no resin ducts or spiral thickenings. Horizontal walls of axial parenchyme have no thickenings. A petrified sample with 2 to 5 well-preserved taxodioid crossfield pits belongs to *Taxodioxylon sequoianum* (MERCKLIN) GOTHAN, which corresponds to the wood of living *Sequoia sempervirens* ENDL. The other wood remains that lack preserved crossfield pits belong either to this species or to the genus *Glyptostrobus*, or to other genera of the Taxodiaceae or Cupressaceae.

Since all petrified fragments, as well as most of the fusain samples, show degraded and collapsed early wood zones, they must have undergone extensive decomposition before petrification or charcoalification (CICHOCKI, this volume).

5. Vertebrate Palaeontology Results

A rich vertebrate fauna has been recovered in the hanging wall sediments of the eastern subbasin in Oberdorf from two horizons (O3 and O4). This locality is very rich in isolated teeth, bone fragments and a few jaws from amphibians, reptiles and mammals.

The vertebrate fossils were studied by an international group of specialists, and the results were recently published in one volume (see below). As there are no significant differences between the two vertebrate faunas (with a total number of more than 80 species) of the two fossil horizons (O3 and O4), they are treated as a unit and are considered to be coeval.

While small mammals, amphibians and lizards are quite well represented in numbers of fossil specimens and species, the record of large mammals, birds and lagomorphs is rather poor. Nevertheless, the remains of two birds are evidence of a large passerine bird and the first record of an Early Miocene duck from non-palustrine deposits in Europe (MLIKOVSKY, 1998).

The ophidian fauna consists of Colubridae, Boidae and two different poisonous snakes, one of which is a viper and the second a questionable relative of a cobra (SZYNDLAR, 1998). Lizards are very abundant in Oberdorf but the study of them is incomplete. The amphibian fauna (SANCHIZ, 1998) is composed of Anura, Caudata and Allocaudata totaling at least ten species. *Triturus roehrsi* and *Latonia ragei* are two amphibians that are rare at Oberdorf, but dominant elsewhere.

Among the mammals a small pig, *Aureliachoerus minus*, and a rhino have been recognized by a few teeth (MADE, 1998a, 1998b). About 140 postcranial bones, teeth and antlers from cervids and tragulids were attributed to six species of ruminants by RÖSSNER (1998). Two groups of small mammals, the rodents and insectivores, are very diverse (ZIEGLER, 1998). Nineteen species of insectivores, one marsupial, and 7 species of bats have been determined. The second group of small mammal species is made up of the rodent families Gliridae, Sciuridae, Petauristidae (studied by BRUIJN, 1998), Cricetidae, Eomyidae, Platacanthomyinae, and Anomalomyinae (studied by DAXNER-HÖCK, 1998). DAXNER-HÖCK et al. (1998; Tab. 2) break the mammal species down as follows (n = number of species):

- Mammals (n = 56)
  - 12 % large mammals
  - 88 % small mammals

- Small mammals (n = 49)
  - 2 % Lagomorpha
  - 2 % Marsupialia
  - 14 % Chiroptera
  - 37 % Insectivora
  - 45 % Rodentia
- Rodents (n = 22)
  - 4,5 % Platacanthomyinae
  - 4,5 % Eomyidae
  - 9 % Anomalomyinae
  - 9 % Cricetidae
  - 13,5 % Petauristidae
  - 13,5 % Sciuridae
  - 46 % Gliridae

All authors agree that the vertebrate fauna is of late Early Miocene age. Following MEIN's (1975, 1989) biozonation, the mammals indicate Mammal zone MN4. The mammalian fossil layers are situated within a normal polarity interval, which this fauna suggests is Chron C5Dn, indicating an age of 17.2–17.6 Ma.

6. Palaeoenvironmental Results

Palaeoenvironmental reconstruction (HAAS et al., this volume) of the Early Miocene lignite-bearing Köflach-Voitsberg-Formation in the Oberdorf open pit mine shows that subsidence of the Köflach/Voitsberg basin is related to NE-directed extension and to the formation of shallow (half)grabens. Extensional faulting in a lowland created shallow depressions which captured the local drainage system during incipient lateral movement of the Styrian crustal wedge.

Palaeoenvironmental analysis of the sedimentary sequences defines a predominantly marginal fluvial environment with characteristic flood plain – and flood basin – sediments, alternating with crevasse splay deposits and channel fills. But palaeosols also frequently occur which mostly have the characteristics of temporarily waterlogged soils.

Petrographic investigation of the approximately 30 m thick lignites shows that the coal consists of fine detritic plant material and less frequently of fossil wood. The lignite is generally rich in ash content, which confirms its inferred origin in a lowland moor.

The lignite-bearing sequence in the Oberdorf open pit mine is extremely rich in fossil plant remains (diaspores, leaves, palynomorphs) at almost all stratigraphic levels. Woody genera are dominant. Herbaceous elements reflecting forest floor or reed-like facies and aquatic plants are well represented in the pollen record. The diaspore and leaf record is species-poor, and the herb record is generally lacking. The reconstructed palaeoclimatic conditions are estimated to be 14–17°C mean annual temperature and 1000–2000 mm mean annual precipitation.

Two vertebrate faunas from the hanging wall of the eastern subbasin (fossil horizons O3 and O4) are very rich in amphibians, lizards, snakes and mammals. More than 80 vertebrate species are recorded almost exclusively by isolated teeth and disarticulated bones. This kind of selection and concentration of fossils is inferred to result from taphonomic processes. Although partly omnivorous or insectivorous, most of the mammals were plant eaters that lived in a forest environment and consumed its rich supply of fruits, berries, seeds, leaves and roots. The majority of the small vertebrates are thought to have lived in underground burrows, in bushes or under rotting logs, although the flying squirrels needed tall trees for their activities.

7. Palaeomagnetism and Magnetostratigraphy

Palaeomagnetic analyses suggest that a 20° counterclockwise rotation of the basin has taken place with respect to present north, and that the basin was at a palaeolatitude of 34°5´.

All sediments of the footwall sequence, and parts of the hanging wall sequence sediments up to 13 meters above the uppermost main coal seam, are reversely magnetized, and the rest of the sediments of the hanging wall sequence are normally magnetized. The rich mammal fauna from the upper part of the hanging wall sequence, indicative of Neogene Mammal Zone MN4, allows correlation of the normally magnetized part of the section with Chron C5Dn, and correlation of the lower, reversely magnetized, part of the section with Chron C5Dr of the GPTS. The age of the polarity change C5Dr/C5Dn is, according to the GPTS, at 17.6 Ma. and indicates an Ottnangian age for the section within the Central Paratethys Time Scale (MAURITSCH, H.J. & R. SCHOLGER, this volume).

8. Stratigraphic Results

As stated above the entire sediments of the footwall sequence and parts of the hanging wall sequence sediments up till 13 meters above the upper main coal seam are reversely magnetized, the rest of the hanging wall sequence sediments are normally magnetized. The rich mammal faunas from the upper, normally magnetized part of the hanging wall sequence, indicative of Neogene Mammal Zone MN4, allow for a biostratigraphic correlation of the normal magnetized part of the section with Chron C5Dn and the lower, reversely magnetized part of the section with Chron C5Dr of the GPTS. The age of the polarity change C5Dr / C5Dn is according to the GPTS at 17.6 Ma. By this correlation the mammal faunas fall within Chron C5Dn and have an inferred age of 17.2–17.6 Ma. This implies an Ottnangian age for the section, based on the Central Paratethys Time Scale.

The leaf-, diaspore- and the microfloras support this correlation. Leaf taxa of the Lauraceae, Fagaceae, and Cupressaceae, which are thought to be characteristic of mesophytic forests, are of some biostratigraphic value. They are exclusively present at the top of the footwall and the base of the seam. The co-occurrence of *L. markvarticense* KVACEK, *L. pseudovillense* KVACEK, and *Trigonobalanopsis rhamnoides* (ROSSMÄSSLER) KVACEK & WALTHER, and *Tetraclinis salicornioides* (UNGER) KVACEK supports an Early Miocene age for this part of the lignite-bearing sequence. Conservative taxa restricted to the Palaeogene as well as progressive taxa well known from Middle and Late Miocene deposits are completely absent.

Records of the diaspore taxa *Poliothyrsis eurorimosa* MAI, *Manglietia germanica* MAI, *Litsea sontagii* GREGOR, *Gironniera verrucata* MAI in MAI et WALTHER are limited to the Late Oligocene to the Lower/Middle Miocene, but generally are not numerous. *Trigonobalanopsis exacantha* (MAI) KVACEK & WALTHER (the fruits of the tree bearing the leaves of *T. rhamnoides*) are more common in Lower Miocene localities than in older or younger ones. In the latter they are restricted to

climatically favorable regions such as the Rhenish Embayment and N Italy. As in the leaf record, diaspore taxa most characteristic of the Palaeogene are completely absent.

The microflora is composed of elements most characteristic of the Late Oligocene, plus others known as well from the Middle and Late Miocene, and therefore does not contradict the leaf and diaspore records (STEININGER et al., this volume).

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References

BRUIJN DE, H. (1998): Vertebrates from the Early Miocene lignite deposits of the opencast mine Oberdorf (Western Styria Basin, Austria). 6. Rodentia 1 (Mammalia). – Ann. Naturhist. Mus. **99A**, 99–137, Wien.

CICHOCKI, O. (1998, this volume): Petrified, Lignified and Carbonized Wood Remains from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 469–473, Wien.

DAXNER-HÖCK, G. (1998): Wirbeltiere aus dem Unter-Miozän des Lignit-Tagebaues Oberdorf (Weststeirisches Becken, Österreich). 7. Rodentia 2 und Lagomorpha (Mammalia). – Ann. Naturhist. Mus. Wien, **99A**, 139–162, Wien.

DAXNER-HÖCK, G., HAAS, M., MELLER, B., & STEININGER, F.F. (1998): Wirbeltiere aus dem Unter-Miozän des Lignit-Tagebaues Oberdorf (Weststeirisches Becken, Österreich). 10. Palökologie, Sedimentologie und Stratigraphie. – Ann. Nat. Hist. Mus. Wien, **99A**, 195–224, Wien.

EBNER, F., MALI, H., OBENHOLZNER, J.H., VORTISCH, W. & WIESER, J. (1998, this volume): Pyroclastic Deposits from the Middle Miocene Stallhofen Formation. – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 425–428, Wien.

EBNER, F. & STINGL, K. (1998, this volume): Geological Frame and Position of the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 403–406, Wien.

GRASZL, H., NIESNER, E., SCHMÖLLER, R. & WEBER, F. (1998, this volume): Basin Configuration of the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 407–411, Wien.

HAAS, M. (1998, this volume): Sedimentological Investigations in the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 413–421, Wien.

HAAS, M., DAXNER-HÖCK, G., DECKER, K., KOLCON, I., KOVAR-EDER, J., MELLER, B. & SACHSENHOFER, R.F. (1998, this volume): Palaeoenvironmental Studies in the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 483–490, Wien.

KOLCON, I. & SACHSENHOFER: R.F. (1998, this volume): Coal Petrology and Palynology of the Early Miocene Lignite Seam from the Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 433–440, Wien.

KOVAR-EDER, J. (1998, this volume): Leaf Assemblages from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 447–452, Wien.

KOVAR-EDER, J. & MELLER, B. (in press): The plant assemblages from the main seam parting of the western sub-basin of Oberdorf, N Voitsberg, Styria, Austria (Early Miocene). – Cour. Forsch.-Inst. Senckenberg.

KOVAR-EDER, J., MELLER, B. & ZETTER, R. (1998): Comparative investigations on the basal fossiliferous layers at the opencast mine Oberdorf (Koeflach-Voitsberg lignite deposit, Styria, Austria; Lower Miocene). – Rev. Palaeobot. Palynol.

MADE VAN DER, J. (1998a): Vertebrates from the Early Miocene lignite deposits of the opencast mine Oberdorf (Western Styria Basin, Austria). 8. Rhinocerotidae (Mammalia). – Ann. Naturhist. Mus. **99A**, 163–168, Wien.

MADE VAN DER, J. (1998b): *Aureliachoerus* from Oberdorf and other Aragonian pigs from Austria. – Ann. Naturhist. Mus. **99A**, 225–277, Wien.

MAURITSCH, H.J. & SCHOLGER, R. (1998, this volume): Palaeomagnetism and Magnetostratigraphy from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 429–432, Wien.

MEIN, P. (1975): Résultats du Groupe de Travail des Vertébrés. – In: SENES, J. (ed.): Report on Activity of R.C.M.N.S. Working Groups, 6. Congress of the Regional Committee of Mediterranean Neogene Stratigraphy, Proceed. **1**, 78–81, Bratislava.

MEIN, P. (1989): Updating of MN Zones. – In: LINDSAY, E.H., FAHLBUSCH, V. & MEIN, P. (eds.): European Neogene Mammal Chronology, 73–90, NATO ASI series A 180 (Plenum), New York.

MELLER, B. (1998, this volume): Systematisch-taxonomische Untersuchungen von Karpo-Taphocoenosen des Köflach-Voitsberger Braunkohlenrevieres (Steiermark, Österreich; Untermiozän) und ihre paläoökologische Bedeutung. – Jb. Geol. B.-A., **140**/4, 497–656, Wien.

MELLER, B. (1998, this volume): Diaspore Assemblages from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 453–460, Wien.

MELLER, B., KOVAR-EDER, J. & ZETTER, R. (in press): Lower Miocene diaspore, leaf, and palynomorph assemblages from the base of the lignite-bearing sequence in the opencast mine Oberdorf N Voitsberg (Styria, Austria) as indication of a "Younger Mastixioid" vegetation. – Palaeontogr. B.

MLIKOVSKY, J. (1998): Vertebrates from the Early Miocene lignite deposits of the opencast mine Oberdorf (Western Styria Basin, Austria). 4. Aves. – Ann. Naturhist. Mus. **99A**, 39–42, Wien

RÖSSNER, G.E. (1998): Wirbeltiere aus dem Unter-Miozän des Lignit-Tagebaues Oberdorf (Weststeirisches Becken, Österreich). 9. Ruminantia (Mammalia). – Ann. Naturhist. Mus. **99A**, 169–193, Wien.

SANCHIZ, B. (1998): Vertebrates from the Early Miocene lignite deposits of the opencast mine Oberdorf (Western Styria Basin, Austria). 2. Amphibia. – Ann. Naturhist. Mus., **99A**, 13–29, Wien.

STEININGER, F.F., RÖGL, F., HOCHULI, P. & MÜLLER, C: (1989): Lignite deposition and marine cycles. The Austrian Tertiary lignite deposits – A case history. – Sitzber. Österr. Akad. Wiss., math.-naturwiss. Kl., Abt. I, **197**, 309–332, Wien.

SZYNDLAR, Z. (1998): Vertebrates from the Early Miocene lignite deposits of the opencast mine Oberdorf (Western Styria Basin, Austria). 3. Serpentes (Reptilia). – Ann. Naturhist. Mus. **99A**, 31–38, Wien.

VÁVRA, N. (1998, this volume): Chemofossils ("Biological Markers") from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 441–445, Wien.

WEBER, L. & WEISS, A., (1983): Bergbaugeschichte und Geologie der Österreichischen Braunkohlenvorkommen. – Arch. Lagerst.forsch. Geol. B.-A., **4**, 317 S. Wien.

ZETTER, R. (1998, this volume): Palynological Investigations from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – In: STEININGER, F.F. (ed.): The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria), Jb. Geol. B.-A., **140**/4, 461–468, Wien.

ZIEGLER, R. (1998): Wirbeltiere aus dem Unter-Miozän des Lignit-Tagebaues Oberdorf (Weststeirisches Becken, Österreich). 5. Marsupialia, Insectivora und Chiroptera (Mammalia). – Ann. Naturhist. Mus. **99A**, 43–97, Wien.

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