The Burgschleinitz Formation consists of alternating, poorly sorted medium to fine sands with intercalated gravels. Sedimentary structures such as cross-bedding, lamination and current ripples, as well as typical molluscs and trace-fossils of the *Ophiomorpha* type indicate deposition in intertidal to shallow subtidal areas. Frequent coquinas, escape structures, hummocky cross-stratification and crystalline block layers, mostly containing bones of vertebrates, can be interpreted as the result of heavy storm events. The sediments of the Burgschleinitz Formation are primarily the result of a wave dominated, storm influenced shallow marine facies deposited in bays sheltered by islands formed of crystalline rock.

The Burgschleinitz Formation in the Kühnring sandpit consists of silty medium to fine sands deposited in the shallow marine sublittoral environment of a narrow bay open to the northwest. The foraminifera and molluscs in these sands are typical settlers on marine sandbottoms with seagrass. The top of this formation is a coarse clastic facies with bones of *Metaxytherium krahuletzi, Schizodelphis sulcatus, Brachyodus onoideus, Tapirus* sp. and teeth of crocodiles, breams and sharks like *Carcharocles megalodon* (DOMNING & PERVESLER in press, PERVESLER et al. 1995, 1998). Lithology of the inverse graded coarse layer at the base of a coarse clastic facies shows all the characteristics of a debris flow. This sediment body slid from the crystalline elevation into the shallow marine bay and probably filled an area of 60,000 m² with a 0.7 to 2.3 m thick layer, deplanating the relief. The debris flow integrated crystalline components from the near hinterland, as well as better reworked sediment portions and molluscs from the shallow marine areas. The top of the debris flow is covered with crystalline slabs 10 to 50 cm in diameter, occasionally up to 80 cm. Several more or less articulated skeletons of the seacow *Metaxytherium krahuletzi* (five adults and two juveniles) were found anchored by the crystalline slabs upon this debris flow. The fact that all sirenian bones were deposited exclusively on the debris flow proves that the animals belonged to the same population and died coincidentally.

Shallow marine sediments of the Burgschleinitz Formation in the old sandpits near Sonndorf contain two distinct layers with *Metaxytherium krahuletzi* bones. The lower bone layer is intercalated into a mollusc-shell-layer consisting of subtidal molluscs and also contains fossils of cirripeds, decapods, sharks, rays and fishes (Osteichthyes). The seacow specimens of this layer are more or less isolated bones belonging to *Metaxytherium krahuletzi*. The base of the upper bone layer is a mollusc-shell-layer with molluscs from the intertidal. The bone layer itself contains not only seacows, but also bones of *Brachyodus* and turtles and the teeth of sharks, rays and braces. The *Metaxytherium krahuletzi* remains, mostly ribs and vertebrae, but also skull fragments from adult and juvenile individuals, are dispersed over the horizon with no evidence of any articulation.

The *Metaxytherium krahuletzi* bone layers in the Eggenburg Bay seem to derive from mass mortality events and are always connected with increasing hydrodynamic energy in shallow marine nearshore depositional areas (deeper intertidal or shallow subtidal). Heavy storm events could have caused the death of these herbivorous animals by damaging their food resource.

Oberdorf N Voitsberg (Styria, Austria) – a Key Section in the Vegetation History of Early Miocene European Continental Deposits (JOHANNA KOVAR-EDER)

The Köflach-Voitsberg lignite area is situated at the northwesternmost margin of the Styrian Basin, 30 km W of Graz (Fig. 18). Oberdorf, the last Austrian opencast mine in operation, was subject to detailed, joint geoscientific investigations. The basin fill there has a thickness of about 300 m and is part of the Köflach/Voitsberg Formation (Fig. 18d). According to the sedimentological results, the deposits are exclusively of fluvial/lacustrine origin (HAAS 1998, 1999). The largely xylo-detritic and detrito-xylitic main seam of about 30 m thickness originated in a non-marine lowmoor (KOLCON & SACHSENHOFER 1998, 1999). Vertebrate assemblages at roughly 100-105 m have been dated to the Early Miocene, Ottnangian (Central Paratethys stage), MN 4 (Neogene mammal zone). The polarity change 13 m above the main seam was therefore correlated to C5Dr/C5Dn of the Geomagnetic Polarity Time Scale, 17.6 M.a. (DAXNER-HÖCK et al. 1998, MAURITSCH & SCHOLGER 1998). A tuffite at the base of the main seam can probably be correlated to the "Lower Rhyolite Tuffs" in the Pannonian Basin, indicating a (Late) Eggenburgian/Early Ottnangian age of this part of the sequence (HAAS 1999).

Assemblages of dispersed plant organs (leaves, fruits/seeds, and pollen/spores) were preserved in different parts of the sequence. The detailed palaeoenvironmental reconstruction is partly based on the systematic evaluation of the plant assemblages at all fossiliferous levels (HAAS et al. 1998).

A number of plant species have never been described before, e.g., some members of the tea family (KOVAR-EDER & MELLER 2000). Others are reported from Austria for the first time, e.g., *Magnolia liblarensis* (magnolia), *Cephalotaxus* (plum-pine), several laurel species and *Viola* (violet).

In the case of certain woody plants such as *Trigonobalanopsis* (beech family) and *Cercidiphyllum* (Katsura), vegetative and reproductive organs are preserved.

In the sediments at the base of the main seam, *Trigonobalanopsis* is best represented by leaves, cupules and pollen (KOVAR-EDER et al. 1998a, MELLER et al. 1999). These evergreen trees were probably common in the species-diverse hinterland forests.

Mass occurrences of *Cercidiphyllum* (KATSURA) leaves are bound to the hanging wall sediments, where they are frequently associated with fruits (Fig. 19a, c). Even fragments of twigs with adherent short shoots have been discovered in the fossil state for the first time (Fig. 19b); pollen grains of *Cercidiphyllum* have also been determined (KOVAR-EDER et al. 1998b).

The plant assemblage from the tuffite at the base of the main seam partly resulted from a volcanic eruption that coincided with the season in which many woody plants were flowering; deciduous ones were leafless or in the state of opening their buds; fruits and seeds had not yet developed. Buds/bud scales, lumps of immature pollen and leaves of evergreen woody species were stripped off their mother plants and quickly deposited in a backswamp together with ash and lapilli. Other plant material already accumulated in the backswamp previous to the tephra fall out (KOVAR-EDER et al. a, submitted; Fig. 20).

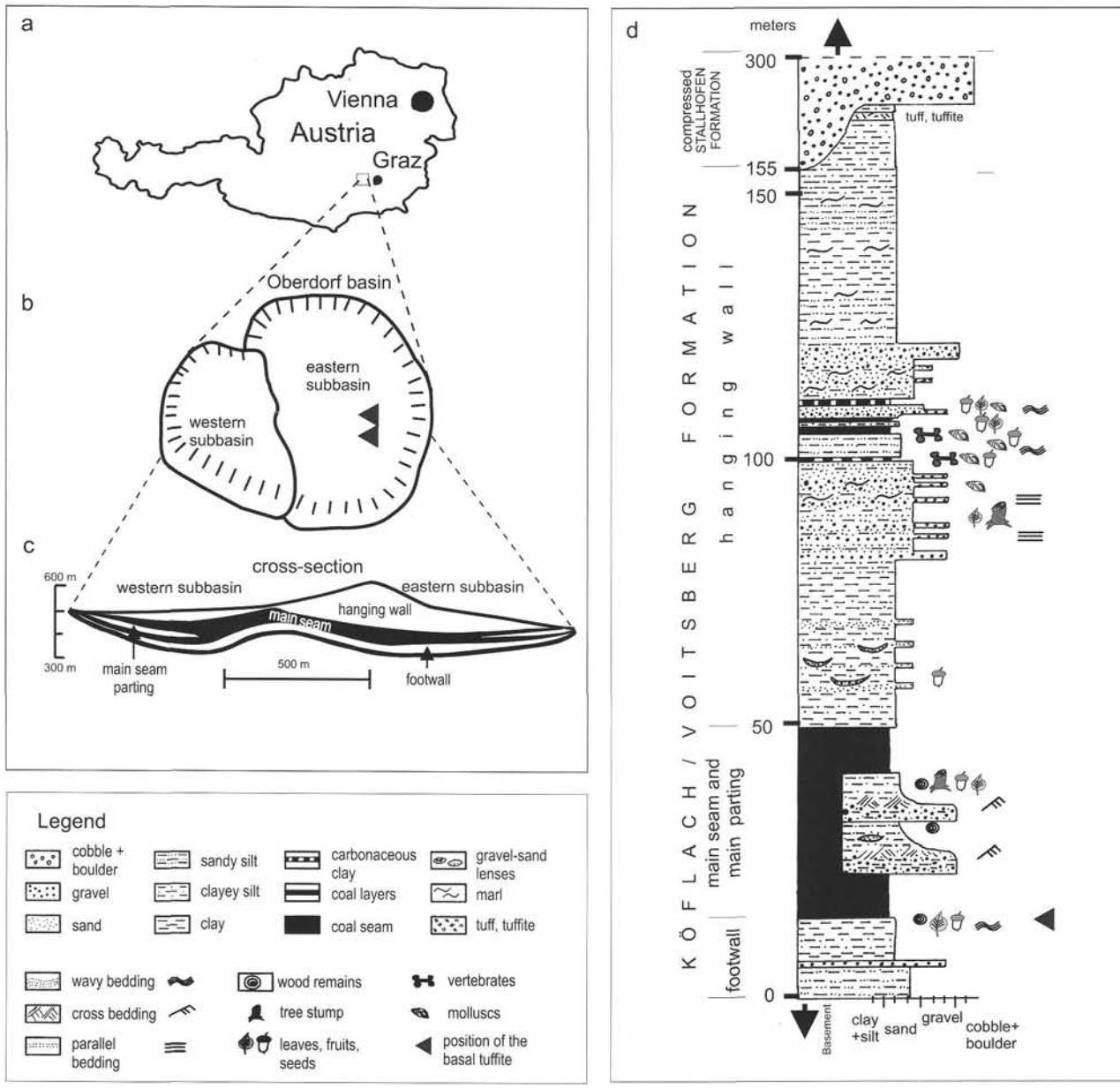


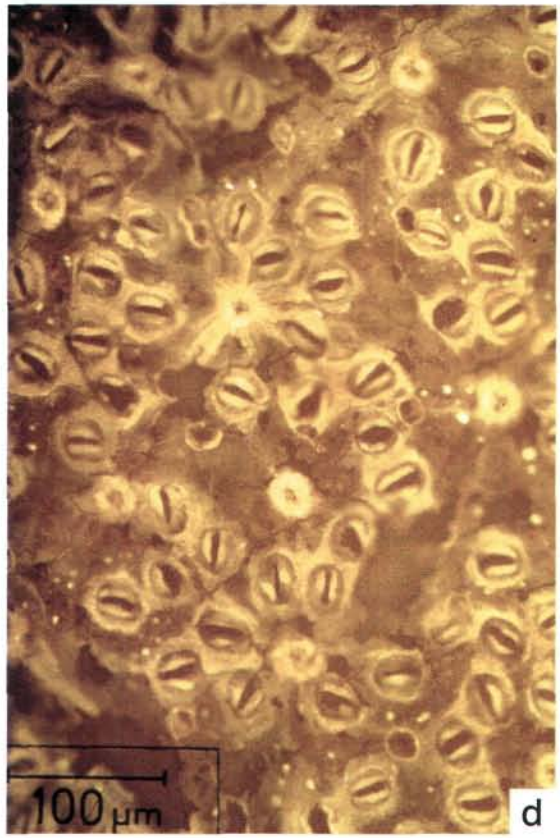
Fig. 18
a) Geographic setting of the Köflach-Voitsberg lignite area. – b) The opencast mine Oberdorf. – c) Schematic cross-section through the Oberdorf opencast mine. The main seam is split towards the W in the western sub-basin and towards the east in the eastern sub-basin. – d) Standard profile of the Köflach/Voitsberg Formation in Oberdorf (from HAAS et al. 1998, slightly modified). The vertebrate-bearing layers were found at 100-105 m. The polarity change C5Dr/C5Dn was observed in the lower part of the hanging wall sequence, 13 m above the main seam.

In the lowlands around Köflach-Voitsberg, extensive wetlands of marginal fluvial facies developed during the depositional phase. Swampy facies (Fig. 21) are best documented in clayey/lignitic sediments. Generally only few woody taxa prevail. *Glyptostrobus europaeus* (swamp cypress family, Fig. 19h) and *Quercus rhenana* (an evergreen oak relative, Fig. 19d) are most characteristic. They are accompanied by *Myrica* (wax myrtle, Fig. 19g), *Nyssa* (tupelo), *Rubus* (blackberry), and a few others (KOVAR-EDER 1996, MELLER 1998).

Sandy and silty/marly sediments from the main seam parting in the western sub-basin and the hanging wall in the eastern sub-basin offered the best insight into the composition of riparian forests (KOVAR-EDER & MELLER 2000 and in press): *Sequoia, Cercidiphyllum, Alnus* (alder), *Fraxinus* (ash tree, Figs. 19e, f), *Acer* (maple), *Salix* (willow), *Pterocarya* (wingnut), and *Prunus* (prune) are important trees and shrubs here. Aquatic plants, both submerged forms and

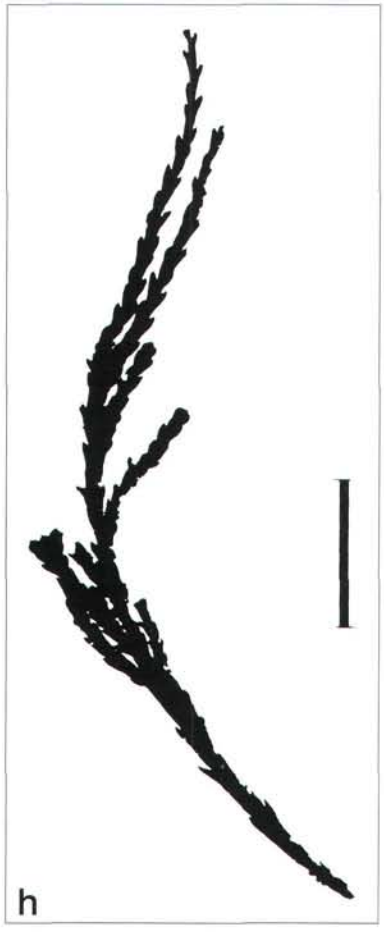
Fig. 19 →
a) and c) *Cercidiphyllum crenatum* (KATSURA), a leaf, c fruit. – b) *Cercidiphyllum* twig fragment with a short shoot bearing several growth rings. – d) Lower leaf surface of *Quercus rhenana* (evergreen oak relative), a characteristic swamp element in Oberdorf (fluorescence microscopy). – e) Leaflet of *Fraxinus ungeri* (ash tree). – f) *Fraxinus* winged fruit. – g) Leaf of *Myrica joannis* (wax myrtle). – h) Twig of *Glyptostrobus europaeus* (swamp cypress family). Scale bar 1 cm except in d) where it is 100 μm.

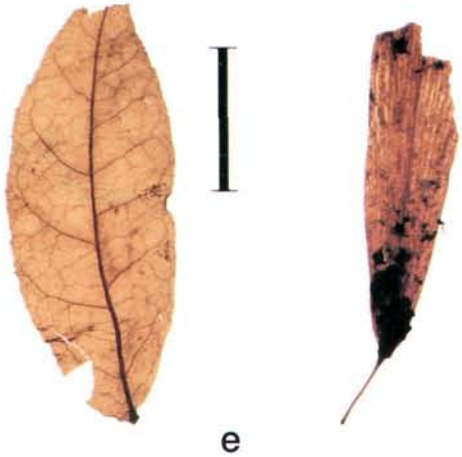

a


100 µm
d


b


c


h


e


f
g

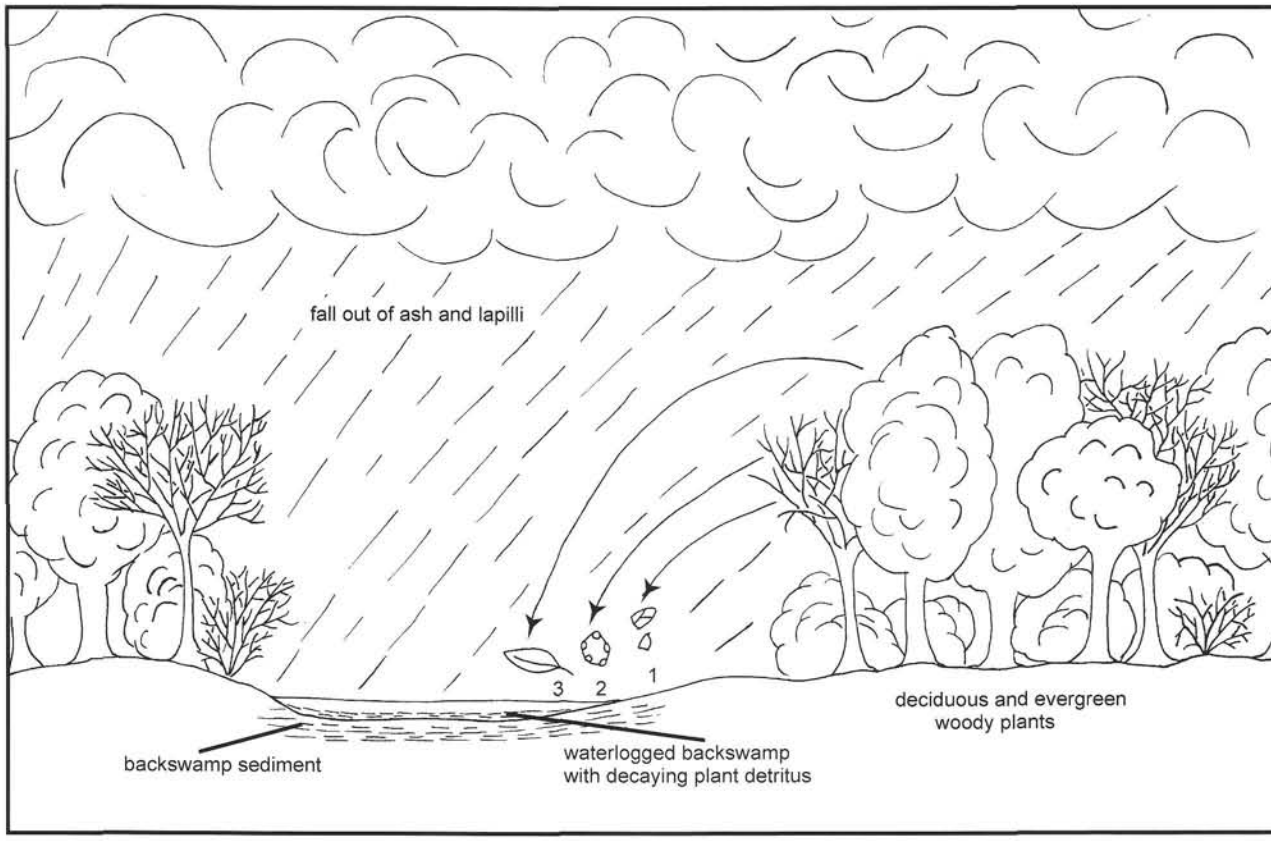


Fig. 20
Possible scenario that led to the formation of the plant assemblage recovered from the tuffite at the base of the main seam. 1 – buds/bud scales, 2 – pollen/pollen lumps, and 3 – leaves of evergreen woody plants were stripped off their mother plants due to a volcanic eruption during "springtime". Together with lapilli they were embedded in a waterlogged backswamp sediment that contained already decaying plant material.

those with floating leaves, as well as plants with reed-like associations, are generally rarer and species poorer in Oberdorf than in other European lignite areas. However, those discovered in the hanging wall sequence are indicative of ponds and lakes: *Potamogeton* (pondweed) and Characeae.

Frequent fusain fragments in many horizons indicate forest fires, as known from sub-tropical and tropical swamps today.

While the plant assemblages of the Oberdorf sequence distinctly trace facial changes within the wetland area during the depositional time, the composition of the hinterland forests remains virtually unchanged.

Species diverse, mostly evergreen forests covered natural levees and hills surrounding the Köflach-Voitsberg lowlands, as the Alpine orogen had not yet fully evolved. The sediments from the base of the main seam show a distinctly stronger allochthonous influence versus the greater autochthonous influence in the seam partings and the hanging wall sediments. Therefore the species spectrum of the hinterland forests is better represented in the plant fossil record at the base of the main seam than in any other part of the sequence. The laurel family is documented by eight species; others, such as the Symplocaceae and Juglandaceae (walnut family) are similarly diverse. Members of the Fagaceae (beech family), Ulmaceae (elms), Mastixiaceae (related to the dogwood family), Rutaceae (citrus family), Theaceae (tea family), Sapotaceae (sapote family), Ebenaceae (ebony family), and Sterculiaceae (chocolate family) were components of these forests. They provide first evidence for rich Younger Mastixioid vegetation from Austria (MELLER et al. 1999, ZETTER 1998). These hinterland forests show a close relationship to those described from Bohemia, Bavaria and Saxony of the Early/Middle Miocene.

The different wetland and hinterland biotopes were favourable habitats for amphibians, lizards, snakes, mammals and birds. Their teeth and bones have been found in the hanging wall sequence. Interesting representatives include rhino, pig, cervids and flying squirrels (DAXNER-HÖCK et al. 1998, HAAS et al. 1998, Fig. 21). The latter required high trees for gliding. Generally, forest dwellers prevail, supporting the interpretation of the plant fossil record.

These forest communities required warm, humid, subtropical climatic conditions similar to those occurring today in the ecotone between the mixed mesophytic forest and the evergreen broad-leaved forest region of E- and SE-Asia, with climatic conditions of 14-17 °C mean annual temperature and 1,000 to 2,000 mm annual precipitation (DAXNER-HÖCK et al. 1998).

The comparison of Oberdorf with other Early/Middle Miocene European lignite deposits revealed an even higher floristic variability of peat-forming plant associations than thus far expected (KOVAR-EDER et al. b, submitted).

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Fig. 21
Reconstruction of a swamp forest biotope with big *Glyptostrobus europaeus* trees (swamp cypress family), rhino, cervids and flying squirrels (plant reconstructions by W. Lumpe, Dresden; animal reconstructions from DAXNER-HÖCK et al. 1998).