JAHRBUCH DER GEOLOGISCHEN BUNDESANSTALT

Jb. Geol. B.-A.	ISSN 0016–7800	Band 140	Heft 4	S. 453–460	Wien, Juni 1998

The Early Miocene Lignite Deposit of Oberdorf N Voitsberg (Styria, Austria) | Editor: F.F. Steininger

Diaspore Assemblages from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria)

BARBARA MELLER*)

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Styria
Pannonian Basin
Styrian Basin
Lignite
Early Miocene
Fruits
Seeds

Österreichische Karte 1 : 50.000
Blatt 163

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Zusammenfassung

Die untermiozänen Sedimente des Köflach-Voitsberger Braunkohlenrevieres sind reich an Samen und Früchten. Es wurden zahlreiche Proben aus allen Bereichen der Sedimentabfolge untersucht. In den Artenspektren sind Koniferen (z.B. *Sequoia, Glyptostrobus, Cephalotaxus*), immergrüne und laubwerfende Bäume, Sträucher und Kletterpflanzen repräsentiert (z.B. *Symplocos, Trigonobalanopsis, Mastixia, Fagus, Magnolia*), die heute unter subtropischen oder temperaten klimatischen Bedingungen vorkommen. Krautige Elemente und Wasserpflanzen sind nur durch wenige Taxa repräsentiert (z.B. *Sparganium, Carex* und *Stratiotes, Ceratophyllum, Potamogeton*). Es lassen sich verschiedene Habitate, wie Sumpfwälder, Moore, diverse flußbegleitende Vergesellschaftungen und mesophytische Wälder rekonstruieren.

Abstract

The Early Miocene lignite-bearing sediments of the Köflach-Voitsberg lignite mining district are rich in fruits and seeds. Numerous samples from all different stratigraphic levels had been analysed. The diaspore spectra represent conifers (e.g. *Sequoia, Glyptostrobus, Cephalotaxus*), evergreen and deciduous trees, shrubs and lianas (e.g. *Symplocos, Trigonobalanopsis, Mastixia, Fagus, Magnolia*), which today grow under subtropical or temperate climatic conditions. Herbaceous elements (e.g. *Sparganium, Carex*) have been found more seldomly and aquatic plants (e.g. *Stratiotes, Ceratophyllum, Potamogeton*) are exceptionally rare. The floristic compositions indicate habitats such as swamp forests, bogs, variable riverside forests and mesophytic forests.

1. Introduction

This part of the multidisciplinary study about the Köflach-Voitsberg lignite mining area summarizes the palaeocarpological results of the different sedimentary levels of the eastern subbasin, as well as the previous results of the western and now refilled subbasin of the Oberdorf opencast mine (MELLER, 1992, 1995, 1996; MELLER, 1996, 1998). The lignite-bearing sequence can be separated into footwall sediments, one main seam, which is divided into an upper and lower seam by coarse- to medium-grained sands and silts at the western margin of the

*) Author's adress: Dipl.-Geol. Dr. BARBARA MELLER: Institute of Palaeontology, University of Vienna, Geocenter, Althanstraße 14, A-1090 Vienna, Austria.

western subbasin and by fine-grained sands to clays at the eastern margin of the eastern subbasin (HAAS, this volume) and the hanging wall sediments. The latter could be investigated in the eastern subbasin only. Precise lateral correlations of the main seam and the main seam partings in the western and eastern subbasins cannot be assumed, due to the possibility of variable seam parting geometries.

2. Methodology

More than 200 sediment samples have been taken from all the different stratigraphic levels within the whole opencast mine. Horizons with obvious organic material, where diaspores could be expected, were preferentially examined. Moreover, the outcrops and drill cores, which have been analysed by sedimentologists or coal petrologists have in particular been thoroughly examined. The sediment samples of the drill cores are still under investigation, because sample recovery was only possible after the sedimentological studies.

The preparation techniques to obtain fruits and seeds from the sediment samples have been described in MELLER (1995, 1998).

3. Floristic Composition of the Diaspore Assemblages

The occurrence and frequency of the preserved species have been used to characterize the floristic compositions. The different diaspore units, such as cones, seeds, aggregates or berries, and their varied potential for fossilization (lignified or non-lignified diaspores) create biases in the palaeoecological conclusions. Furthermore, one actuopalaeobotanical case study of coarse-grained diaspore deposits of fluviatile systems in Germany recognized the low correspondence between the frequencies of diaspores in deposits and in the surrounding vegetation there (GEE et al., 1997). Moreover, it can be assumed that allochthonous coarse-grained sediments contain elements of more than one habitat. Therefore, palaeoecological conclusions may be rather ambiguous. However, several samples from one layer and the regular co-occurrence of some species in numerous assemblages are appropriate to reduce this error.

Assemblages from the Top of the Footwall and Base of the Seam (Table 1)

The results of the joint palaeobotanical investigations of the samples from the top of the footwall and the base of the seam are already in press (KOVAR-EDER et al., in press; MELLER et al., in press). These samples, from both the western and eastern subbasins, are all characterized by poorly sorted clayey to silty sediment, with coarse brecciated components from the basement, and by their similar floristic compositions. They contain the species richest diaspore assemblages, as well as leaf and pollen assemblages (KOVAR-EDER and ZETTER, this volume) in comparison to all the other samples and stratigraphic levels in the Oberdorf opencast mine and the whole Köflach-Voitsberg lignite mining district. So far, no other locality in Austria has yielded such floristically rich diaspore assemblages (Table 1).

The main characteristics are the occurrence of *Trigonobalanopsis exacantha* (MAI) KVACEK & WALTHER, which is assumed to have been an evergreen Fagaceae, and Lauraceae, such as *Cinnamomum* sp., together with numerous, often evergreen and woody genera, which today mainly grow under subtropical climatic conditions (*Cinnamomum, Distylium, Gironniera, Litsea, Manglietia, Mastixia, Sinomenium, Symplocos, Toddalia, Ternstroemia, Turpinia, Zanthoxylum*). A remarkably high number of woody taxa are represented by only a few fragments (see Table 1). These assemblages are comparable to other lower to lower-middle Miocene assemblages from Central Europe (Wiesa, Lusatia; Wackersdorf, Bavaria; Hradek, Bohemia), which are assigned to the "Younger Mastixioid" flora (MAI, 1964, 1995). According to the modern distribution of some of the identified genera, the fossil assemblages seem to be similar in their floristic composition to recent evergreen broad-leaved forests growing in E and SE Asia today.

In these samples, the most abundant remains are *Sequoia abietina* (BRONGN. in CUVIER) KNOBLOCH, *Glyptostrobus europaeus* (BRONGNIART) UNGER, *Eurya stigmosa* (LUDWIG) MAI und *Symplocos salzhausensis* (LUDWIG) KIRCHHEIMER, probably indicating wetland and swamp forests. *Sequoia* may have grown in laurel-conifer bogs (MAI, 1995) or possibly in mesophytic forests too. Herbaceous aquatic plants are missing, except for a few specimens of *Ceratophyllum* and *Stratiotes*. The other herbaceous plants may have grown as undergrowth on the forest floor (*Selaginella*, Polypodiaceae, Apiaceae) and/or indicate reed-like habitats (*Sparganium* and Cyperaceae).

One sample, still under investigation, yielded diaspores and pollen but no leaf remains. The composition differs from the other samples in the higher percentages of herbaceous plants. The diaspore spectrum in this sample is characterized by numerous remains of *Potamogeton*, a water plant, which has not been found in Oberdorf before.

Assemblages of Clayey Lignites and Lignitic Clays from the Seam (Table 2)

These samples, ranging in composition from lignitic clays to clayey lignites have been distinguished according to their stratigraphic position in the seam; some originated from the lower or upper seam level, others from the undivided seam. The diaspore spectra of these samples are species poor and dominated by *Glyptostrobus europaeus*, which is also the best represented species in the whole opencast mine. This may indicate that *Glyptostrobus* has been a peat-forming element.

Numerous samples from clayey lignites to lignitic clays of the S and SE part of the western subbasin could not be exactly correlated with any particular part of the seam. The diaspore spectra of five of these samples are examples (Table 2: 1st column) of the floristic composition of these layers. The spectra are characterized by the dominance of *Glyptostrobus* diaspores, associated with numerous specimens of *Sequoia, Myrica*, and *Sparganium*. Diaspores of *Nyssa, Salix, Pterocarya, Viscum* vel *Loranthus, Prunus*, and *Cercidiphyllum* also occur abundantly.

These assemblages may reflect swamp forests, boggy swamps and only sometimes flooded riverside forests. *Sequoia* could have grown in the neighbourhood of these habitats too. The occurrence of *Sparganium*, Araceae, and *Carex* may indicate reed-like as well as undergrowth habitats of swamp forests.

Diaspore-bearing samples that can be exactly correlated with the lower seam level are rare (Table 2: 2nd column). Two samples from the western subbasin contain only a few seeds of *Glyptostrobus, Sequoia*, and Vitaceae. Samples recovered from the core of borehole 304 in the

eastern subbasin, which reached down into the lower seam level, contain numerous diaspores, in spite of the small core diameter and the small sediment quantities. They represent azonal habitats only. These diaspore spectra are species poor, characterized by the dominance of *Sparganium* and the high percentage of herbaceous elements (Ranunculaceae, *Saururus, Decodon* [sometimes woody], *Carex*, Araceae). However, these and the few woody elements (*Sequoia, Glyptostrobus, Rubus, Magnolia, Symplocos salzhausensis*, cf. *Poliothyrsis*) are less abundant than *Sparganium*. The proposed habitats of the herbaceous plants may have been undergrowth of wetland forests or reed-like

Table 1.
Floristic composition of the diaspore assemblages from the top of the footwall and base of the seam.
(Taxa, which have been added to the previous species lists [MELLER, 1995; MELLER et al., in press] are marked with * in Table 1–3, 5. The species are listed according to their frequencies within the Gymnospermae, Dicotyledoneae and Monocotyledoneae in Table 1-4).

diaspores from the top of the footwall							
families	taxa	nr.	%	families	taxa	nr.	%
Bryophyta and Pteridophyta				Ceratophyllaceae	*Ceratophyllum* spp.	4	0,12
Selaginellaceae	*Selaginella* spp. (megaspores)	19	0,55	Symplocaceae	*Symplocos* cf. *pseudogregaria*	4	0,12
Selaginellaceae	*Selaginella* sp. 1	3	0,09	Symplocaceae	*Symplocos* spp.	4	0,12
Selaginellaceae	*Selaginella* sp. 2	2	0,06	Vitaceae	*Vitis globosa*	4	0,12
Polypodiaceae	gen. et sp. indet. (sporangium)	1	0,03	? Actinidiaceae	? *Actinidia* sp.	3	0,09
Gymnospermae				Magnoliaceae	*Manglietia germanica*	3	0,09
Taxodiaceae	*Sequoia abietina* (seeds)	1255	36,4	Rutaceae	*Zanthoxylum giganteum*	3	0,09
Taxodiaceae	*Sequoia abietina* (young cones)	114	3,31	Ulmaceae	*Gironniera verrucata*	3	0,09
Taxodiaceae	*Sequoia abietina* (cones)	25	0,73	Ulmaceae	*Gironniera neglecta*	3	0,09
Taxodiaceae	*Glyptostrobus europaea* (seeds)	259	7,52	Vitaceae	*Ampelopsis* spp.	3	0,09
Taxodiaceae	*Glyptostrobus europaea* (cones)	4	0,12	Juglandaceae	? *Cyclocarya* sp.	3	0,09
Cephalotaxaceae	*Cephalotaxus miocenica*	3	0,09	cf. Saururaceae	cf. *Saururus* sp.*	2	0,06
Cupressaceae	*Tetraclinis salicornioides*	1	0,03	Hamamelidaceae	*Liquidambar* sp.	2	0,06
Angiospermae-Dicotyledoneae				Lauraceae	? *Cinnamomum* sp.	2	0,06
Theaceae	*Eurya stigmosa*	395	11,4	Lythraceae	*Decodon* sp. (ex gr. *globosus)*	2	0,06
Fagaceae	*Trigonobalanopsis exacantha*	211	6,12	Symplocaceae	*Symplocos poppeana*	2	0,06
Symplocaceae	*Symplocos salzhausensis*	185	5,36	Ulmaceae	*Zelkova* sp.	2	0,06
Rosaceae	*Rubus* spp.	167	4,84	Sabiaceae	*Meliosma wetteraviensis*	2	0,06
Myricaceae	*Myrica boveyana* et/vel *M.ceriferiform.*	77	2,23	Ericaceae	gen. et sp. indet. type A*	1	0,03
Symplocaceae	*Symplocos lignitarum*	59	1,71	Apiaceae	gen. et sp. indet.	1	0,03
Magnoliaceae	*Magnolia burseracea*	54	1,57	Aquifoliaceae	*Ilex* sp.	1	0,03
Juglandaceae	*Carya ventricosa*	46	1,33	Chenopodiaceae	gen. et sp. indet.	1	0,03
Lauraceae	*Cinnamomum* s.l.sp.	40	1,16	Cornaceae	*Cornus* vel *Swida* sp.	1	0,03
Flacourtiaceae	*Poliothyrsis eurorimosa*	26	0,75	Loranthaceae s.l.	*Viscum* vel *Loranthus* sp.	1	0,03
Myricaceae	*Myrica* cf. *boveyana*	25	0,72	Mastixiaceae	*Eomastixia holzapfelii* vel *E. saxonica*	1	0,03
Juglandaceae	*Pterocarya* sp.	24	0,7	Menispermaceae	*Sinomenium militzeri**	1	0,03
Hamamelidaceae	gen. et sp.indet.	21	0,61	Rutaceae	*Toddalia latisiliquata*	1	0,03
Theaceae	cf. *Eurya* sp.	20	0,58	Rutaceae	cf. *Toddalia* sp.	1	0,03
Moraceae	*Morus et* /vel *Moroidea* et/vel *Ficus* spp.	19	0,55	Sabiaceae	*Meliosma pliocaenica*	1	0,03
Aquifoliaceae	*Ilex saxonica*	19	0,55	Staphyleaceae	*Turpinia ettingshausenii*	1	0,03
Caprifoliaceae	*Sambucus sp.*	17	0,49	Staphyleaceae	*Staphylea* sp.	1	0,03
Symplocaceae	*Symplocos* cf. *schereri*	16	0,46	Ulmaceae	cf. *Gironniera* sp.	1	0,03
Vitaceae	*Ampelopsis malvaeformis*	15	0,43	Vitaceae	*Tetrastigma* cf.*chandleri*	1	0,03
Mastixiaceae	*Mastixia amygdalaeformis*	13	0,38	Vitaceae	*Tetrastigma* sp.	1	0,03
Nyssaceae	*Nyssa ornithobroma*	12	0,35	**Angiospermae-Monocotyledoneae**			
Vitaceae	*Parthenocissus britannica**	10	0,29	Sparganiaceae	*Sparganium* spp.	80	2,32
Rutaceae	*? Fagaropsis koeflachensis*	10	0,29	Sparganiaceae	*Sparganium* cf. *camenzianum*	14	0,41
Lauraceae	*"Litsea" sonntagii*	8	0,23	Araceae	*Urospathites dalgasii*	11	0,32
Actinidiaceae	*Actinidia* sp.	7	0,2	Cyperaceae	gen. et sp. indet.	10	0,29
Araliaceae	*Pentapanax tertiarius*	7	0,2	Cyperaceae	*Carex* type 3	6	0,17
Cercidiphyllaceae	*Cercidiphyllum helveticum*	7	0,2	Sparganiaceae	*Sparganium* cf. *elongatum-neglectum*	6	0,17
Hamamelidaceae	*Distylium uralensis*	7	0,2	Cyperaceae	*Carex* type 2	5	0,14
? Ulmaceae	gen. et sp. indet.	7	0,2	Hydrocharitaceae	*Stratiotes* sp.	1	0,03
Theaceae	*Ternstroemia reniformis*	6	0,17	Cyperaceae	*Scirpus* sp.1	1	0,03
Aceraceae	*Acer* spp.	5	0,14	Cyperaceae	*Scirpus* sp.2	1	0,03
Lythraceae	*Decodon gibbosus*	5	0,14	Cyperaceae	*Carex* type 1	1	0,03
Solanaceae	cf. *Hyoscyamus* spp.	5	0,14	Cyperaceae	*Carex* vel *Scirpus* sp.	1	0,03
Vitaceae	*Tetrastigma* cf. *lobata*	5	0,14				
Vitaceae	*Vitis sp.*	5	0,14			3445	99,9

Table 2.
Floristic composition of selected diaspore assemblages from the seam.
Samples from the undivded seam of the western subbasin: ME-Ob-89-6a, 6b; ME-Ob-89-28,29,30; samples from the lower seam of the western subbasin: ME-Ob-89-4, ME-Ob-90-54; samples from the lower seam of the eastern subbasin: 9 samples from the drill core of borehole 304; samples from the upper seam of the western subbasin: KOV-Ob-82-8, KOV-Ob-83-28; Me-Ob-89-64; samples from the upper seam of the eastern subbasin OEE-Pb-E1, OENE-Pb-M6, OENE-Pb-M7.

diaspores from the seam		seam undivid.	lower seam	upper seam			
families	taxa	western		western	eastern	summ	%
Pteridopphyta		nr.	nr.	nr.	nr.		
Osmundaceae	*Osmunda* sp. (sporangia)			5		5	0,11
Gymnospermae							
Taxodiaceae	*Glyptostrobus europaea* (seeds)	690	2	884	116	1692	38,52
Taxodiaceae	*Glyptostrobus europaea* (cones)	182		65	25	272	6,19
Taxodiaceae	*Sequoia abietina* (seeds)	205	44	80	285	614	13,98
Taxodiaceae	*Sequoia abietina* (cones)	78	4	2	55	139	3,16
Angiospermae-Dicotyledoneae							
Myricaceae	*Myrica boveyana et/* vel *M. ceriferiformoides*	111		270		381	8,67
Rosaceae	*Rubus* spp.	54	13	15	100	182	4,14
Nyssaceae	*Nyssa ornithobroma*	71		17	42	130	2,96
Myricaceae	*Myrica* cf. *ceriferiformoides*	46		8		54	1,23
Salicaceae	*Salix* sp.	53				53	1,21
Juglandaceae	*Pterocarya* s.l.spp.	51				51	1,16
Loranthaceae s.l.	*Viscum* vel *Loranthus* sp.	48				48	1,09
Amygdalaceae	*Prunus* spp.*	32		3		35	0,80
Cercidiphyllaceae	*Cercidiphyllum helveticum*	10		11	7	28	0,64
Magnoliaceae	*Magnolia burseracea*	4		4	14	22	0,50
cf. Ranunculaceae	cf. *Ranunculus* sp.*		15			15	0,34
Vitaceae	*Ampelopsis* cf. *malvaeformis*	6	1	6		13	0,30
Lauraceae	*"Litsea" sonntagii**	8			4	12	0,27
Betulaceae	*Alnus* sp. (strobiles)				7	7	0,16
Vitaceae	gen. et sp. indet.		1	2	3	6	0,14
Lauraceae	cf. *"Litsea" sonntagii**	1			4	5	0,11
cf. Saururaceae	cf. *Saururus* sp.*	1	4			5	0,11
Myricaceae	*Myrica* sp.			1	3	4	0,09
Theaceae	? *Cleyera boveyana*	1		4		5	0,11
? Actinidiaceae	? *Actinidia* sp.	3				3	0,07
Theaceae	*Eurya stigmosa*				3	3	0,07
Aceraceae	*Acer* spp.	2				2	0,05
Actinidiaceae	*Actinidia* sp. (aff. *polygama fossilis*)	1			1	2	0,05
Sabiaceae	*Meliosma wetteraviensis*			2		2	0,05
Aceraceae	*Acer* sp.B	1				1	0,02
Aceraceae	*Acer* sp.			1		1	0,02
Ericaceae	Ericaceae gen. et sp. indet. B*	1				1	0,02
Juglandaceae	*Carya ventricosa*				1	1	0,02
Lythraceae	Decodon gibbosus		1			1	0,02
Magnoliaceae	*Magnolia* sp.		1			1	0,02
Magnoliaceae	*Magnolia* sp. (cf. *cor*)			1		1	0,02
Sabiaceae	*Meliosma pliocaenica*			1		1	0,02
Symplocaceae	*Symplocos salzhausensis*		1			1	0,02
Symplocaceae	*Symplocos* sp.				1	1	0,02
Theaceae	*Ternstroemia reniformis**	1				1	0,02
Vitaceae	*Ampelopsis* cf. *rotundata*	1				1	0,02
Vitaceae	*Vitis* cf. *globosa*	1				1	0,02
Lauraceae vel Ulmaceae	gen. et sp. indet.*			1		1	0,02
cf. Aquifoliaceae	cf. *Ilex* sp.*	1				1	0,02
cf. Fagaceae	cf. *Castanopsis* sp.*			1		1	0,02
cf. Flacourtiaceae	cf. *Poliothyrsis* sp.*		1			1	0,02
cf. Solanaceae	gen. et sp. indet.*	1				1	0,02
Angiospermae-Monocotyledoneae							
Sparganiaceae	*Sparganium* spp.	15	324	9	1	349	7,95
Sparganiaceae	*Sparganium haentzschelii*	85	4	48		137	3,12
Araceae	*Urospathites* cf. *visimense*	16		43		59	1,34
Cyperaceae	*Carex* sp.(Utriculae)*	3	4		9	16	0,36
Cyperaceae	cf. *Carex* sp.		7			7	0,16
Araceae	*Urospathites* sp.		6	1	1	8	0,18
Sparganiaceae	*Sparganium cf. camenzianum*		3			3	0,07
cf. Typhaceae	cf. *Typha* sp.*		2			2	0,05
Cyperaceae	gen. et sp. indet.				2	2	0,05
Araceae	*Urospathites* cf. dalgasii		1			1	0,02
		1784	439	1485	684	4392	100,00

associations. The coal petrological and palynological results of the cored lignites and intercalations indicate a strong influence of zonal mesophytic forests in the lower seam (KOLCON & SACHSENHOFER, Fig. 2 and 6, this volume). However, the diaspore spectra from the small sediment quantities of the core allow only very restricted conclusions about azonal habitats while the pollen spectra reflect zonal and azonal vegetation.

Some diaspore-bearing samples have been found in lignitic clays and clayey intercalations of the upper seam level (Table 2: 3rd column) of the western as well as of the eastern subbasin. The drill core of borehole 304 contains only a few diaspores of *Rubus* sp. and *Sparganium* spp. from this level.

The diaspore spectra of the samples from the western subbasin are characterized by *Glyptostrobus, Sequoia*, and *Myrica*, all together associated with *Sparganium, Urospathites, Cercidiphyllum*, and *Rubus*. These assemblages probably reflect different azonal habitats, such as shrubby bogs, swamp forests, riverside forests, undergrowth of wetland forests and/or reed-like vegetation. The leaf spectrum of one of these samples is characterized by a species poor assemblage (*Glyptostrobus, Quercus, Myrica, Fraxinus*) (KOVAR-EDER, 1996). Both spectra complement each other. The genera *Glyptostrobus* and *Myrica* are represented by leaves and diaspores.

The samples from the eastern margin of the eastern subbasin contain *Glyptostrobus, Rubus, Sequoia, Nyssa, Magnolia, Cercidiphyllum, Alnus*, and only a few remains of *Carex* and *Sparganium*. The alders, which are rarely represented by well identifiable diaspores in the opencast mine, are preserved as strobiles or catkins. These assemblages may represent riverside and swamp forests. Unambiguous evidence for reed-like or undergrowth habitats has not been found here.

diaspores from the main parting of the western subbasin			
families	taxa	nr.	%
Gymnospermae			
Cephalotaxaceae	*Cephalotaxus miocenica*	45	8,12
Taxodiaceae	*Glyptostrobus europaea* (seeds)	40	7,22
Taxodiaceae	*Sequoia abietina* (seeds)	33	5,96
Pinaceae	Pinaceae gen. et sp. indet	2	0,36
Taxodiaceae	*Glyptostrobus europaea* (cones)	1	0,18
Angiospermae-Dicotyledoneae			
Betulaceae	*Alnus* sp. (strobiles)*	98	17,69
Juglandaceae	*Pterocarya* s.l. spp.	96	17,33
Amygdalaceae	*Prunus* spp.*	55	9,93
Theaceae	*Eurya stigmosa*	23	4,15
Actinidiaceae	*Actinidia* sp. (aff. *polygama fossilis*)	20	3,61
Juglandaceae	cf. *Engelhardia* sp.*	20	3,61
Ulmaceae	*Gironniera verrucata**	20	3,61
Caprifoliaceae	*Sambucus* sp.	13	2,35
Juglandaceae	*Carya ventricosa*	10	1,81
Symplocaceae	*Symplocos* spp.	9	1,62
Hamamelidaceae	gen. et sp. indet.*	6	1,08
Lythraceae	*Decodon* spp.*	5	0,90
Magnoliaceae	*Magnolia burseracea*	5	0,90
Symplocaceae	*Symplocos lignitarum*	5	0,90
Saururaceae	*Saururus* sp.*	4	0,72
Sabiaceae	*Meliosma pliocaenica**	4	0,72
Vitaceae	gen. et sp. indet.	4	0,72
Symplocaceae	*Symplocos salzhausensis*	4	0,72
Nyssaceae	*Nyssa ornithobroma*	4	0,72
Rosaceae	*Rubus* sp.	3	0,54
Vitaceae	*Ampelopsis* cf. *malvaeformis*	3	0,54
Mastixiaceae	*Mastixia amygdalaeformis*	2	0,36
cf. Rutaceae	cf. *Zanthoxylum giganteum**	1	0,18
Chenopodiaceae	gen. et sp. indet.*	1	0,18
cf. Aquifoliaceae	cf. *Ilex* sp.*	1	0,18
Fagaceae	*Fagus* sp.	1	0,18
Angiospermae-Monocotyledoneae			
Sparganiaceae	*Sparganium* spp.	12	2,17
Araceae	*Urospathites* cf. *visimense*	3	0,54
Araceae	*Urospathites* sp.	1	0,18
		554	100

Table 3.
Floristic composition of selected diaspore assemblages of the main seam parting of the western subbasin.
Samples ME-Ob-89-3,8,12-17; ME-Ob-90-25-36.

Assemblages from the Main Seam Parting of the Western Subbasin (Table 3)

The diaspores from the coarse-grained clastic sediments of the western subbasin have been discovered in lenses or small horizons with a high amount of plant detritus. They are often poorly preserved, which hinders a systematic identification. The characteristics are the dominance of woody deciduous taxa, such as *Alnus* sp., *Pterocarya* sp., *Prunus* sp., *Cephalotaxus miocenica* (KRÄUSEL) GREGOR, *Sambucus* sp., *Actinidia* sp., *Carya ventricosa* (STERNBERG) UNGER, associated with a few evergreen genera, such as *Eurya, Gironniera, Mastixia*, and *Symplocos*. These assemblages may reflect riverside forests, which have been occasionally flooded and/or mesophytic forests. Some of these genera may not have been restricted to only one habitat. The records of *Glyptostrobus europaeus, Nyssa ornithobroma* UNGER, *Eurya stigmosa, Symplocos salzhausensis* may indicate swamp forests. The herbaceous elements (*Sparganium* spp., *Urospathites* sp., *Decodon* sp. [sometimes woody], *Saururus* sp.) are represented by few specimens only. The occurrence of poorly preserved Pinaceae cones is remarkable. These are rare elements in the whole diaspore spectra in Oberdorf, in contrast to their abundant occurrence in the pollen spectra (ZETTER, this volume).

Assemblages from the Main Seam Parting of the Eastern Subbasin (Table 4)

Diaspore-bearing horizons have rarely been discovered in the fine-grained clastic sediments of the main seam parting. The diaspore spectra are characterized

Table 4.
Floristic composition of the diaspore assemblages of the main parting of the eastern subbasin.
Samples OEE-ZWIM-PB-E4, OEE-ZWIM-Pb-E5 [= ZWIM-B-IV-2.35-2.45], OEE-ZWIM-A-V-4.2-4.3; these samples are still under investigation and the results have not been published before.

diaspores from the main parting of the eastern subbasin			
families	taxa	nr.	%
Bryophyta			
Selaginellaceae	*Selaginella* sp. (megaspore)	1	0,08
Gymnospermae			
Taxodiaceae	*Sequoia abietina* (seeds)	530	41,77
Taxodiaceae	*Sequoia abietina* (young cones)	150	11,82
Taxodiaceae	*Glyptostrobus europaea* (seeds)	20	1,58
Taxodiaceae	*Sequoia abietina* (cones)	17	1,34
Cephalotaxaceae	*Cephalotaxus miocenica*	1	0,08
Angiospermae-Dicotyledoneae			
Nyssaceae	*Nyssa ornithobroma*	43	3,39
Rosaceae	*Rubus* sp.	41	3,23
Saururaceae	*Saururus sp.*	36	2,84
Cercidiphyllaceae	*Cercidiphyllum helveticum*	19	1,50
cf. Moraceae	cf. *Moraceae*	17	1,34
Ranunculaceae	*Ranunculus* sp.	14	1,10
Actinidiaceae	*Actinidia* sp.*(aff. polygama fossilis)*	6	0,47
Flacourtiaceae	*Poliothyrsis* sp.	5	0,39
Amygdalaceae	*Prunus* sp.	3	0,24
Magnoliaceae	*Magnolia* sp.	3	0,24
Theaceae	*Eurya stigmosa*	3	0,24
cf. Aquifoliaceae	cf. *Ilex* sp.	2	0,16
Chenopodiaceae	gen. et sp. indet.	2	0,16
Juglandaceae	*Pterocarya* sp.	2	0,16
? Lauraceae	gen. et sp. indet.	2	0,16
Caprifoliaceae	*Sambucus* sp.	1	0,08
cf. Hamamelidaceae	gen. et sp. indet.	1	0,08
cf. Staphyleaceae	cf. *Turpinia*	1	0,08
Loranthaceae s.l.	*Viscum* vel *Loranthus* sp.	1	0,08
Lythraceae	*Decodon* sp.	1	0,08
Menispermaceae	cf. *Sinomenium* sp.	1	0,08
Sabiaceae	*Meliosma pliocaenica*	1	0,08
Vitaceae	cf. *Tetrastigma* sp.	1	0,08
Vitaceae	gen. et sp. indet.	1	0,08
Angiospermae-Monocotyledoneae			
Sparganiaceae	*Sparganium* spp.	310	24,43
Cyperaceae	gen. et sp. indet.	11	0,87
Araceae	*Urospathites* spp.	22	1,73
		1269	100

by the dominance of *Sequoia* seeds and small young cones, rarely mature, and by a high percentage of herbaceous plants (*Sparganium*, Araceae, Cyperaceae, Ranunculaceae and probably *Saururus*). *Nyssa* and *Cercidiphyllum* also occur abundantly. These spectra may reflect riverside forests and undergrowth of wetland forests or reed-like vegetation. A fluviatile-lacustrine environment has been inferred from the sedimentary analysis of this main parting (HAAS, this volume).

Assemblages from the Hanging Wall Sediments (Table 5)

The hanging wall sediments consist of coarse- to medium-grained sands, marls, silty clays to marls, clayey lignites and lignites. They are rich in diaspore assemblages. Many plant-bearing horizons have been discovered in the hanging wall sequence, where thin coaly layers and one divided seam are developed. As case examples, a few characteristic samples have been selected.

The thin hanging wall seam contains species poor diaspore assemblages (Table 5: 5th column). The samples have been taken from the base, the thin seam intercalation, the lignite itself and from the top of the seam. A vertebrate assemblage, rich in mammals, has been found at the base of this seam (DAXNER-HÖCK, this volume). The petrology of the coal (KOLCON & SACHSENHOFER, this volume) indicates "neutral or even slightly basic pH-conditions", suitable for the preservation of vertebrate bones and oogonia of Charophyceae, too. The Charophyceae, here represented by numerous oogonia of *Lychnothamnus* sp., are extremely rare in the whole lignite-bearing sequence. *Lychnothamnus*, today a monospecific genus, grows, as do other Charophyceae, in permanent ponds or lakes of up to 5 m water depth (det. and comm. J.-P. BERGER). Furthermore, the diaspore spectra are characterized by herbaceous plants (*Umbelliferopsis, Decodon*), woody taxa (*Glyptostrobus, Sequoia, Myrica, Celtis*, ? *Cleyera*) or lianas (*Rubus*). Besides the occurrence of *Lychnothamnus* and *Umbelliferopsis*, the diaspore spectra include the same taxa as other silty horizons from the hanging wall sequence.

Sample 90-5 (Table 5: 1st column) has been taken from silty sediments. The diaspore spectra is characterized by the dominance of *Myrica*, which represents more than 60 % of all diaspores in this sample. *Decodon, Rubus* and ? *Cleyera* occur with numerous specimens too. *Potamogeton* is represented only by few specimens. The growth habits represented are shrubs or small trees, together with lianas and herbaceous, sometimes woody plants, such as *Decodon*.

The diaspore spectrum of sample St2 (Table 5: 2nd column), which originated from silty clays near to a tree stump, is species poor too. It is characterized by the lack of a dominating element and the high percentage of herbaceous plants, which represent 50% of all specimens. The floristic composition with *Glyptostrobus, Decodon, Sequoia, Potamogeton, Myrica*, and *Sparganium*, could indicate swampy or riverside forests, undergrowth or reed-like habitats (*Sparganium, Saururus* and perhaps *Decodon*), and lacustrine habitats (*Potamogeton*).

Samples 90-5-1 and 89-54 were taken from coarse-grained sandy layers; the former contain a species rich assemblage, the latter a poorer one. The characteris-

diaspores from the hanging wall		90-5	St2	90-5-1	89-54	hanging wall seam
		Si	Si-C	Sa	Sa	C-L
families	taxa	n=1426	n=411	n=487	n=138	n=133
Charophyta						
Charophyceae	*Lychnothamnus* sp.(oogonia)					37,6
Gymnospermae						
Cephalotaxaceae	*Cephalotaxus miocenica*	0,1		6,1	19,5	
Taxodiaceae	*Glyptostrobus europaea* (cones)		1			
Taxodiaceae	*Glyptostrobus europaea* (seeds)		28		60,1	9
Taxodiaceae	*Sequoia abietina* (cones)	1,4	0,5	13,35		1,5
Taxodiaceae	*Sequoia abietina* (seeds)	3,5	18,2			14,3
Pinaceae	gen. et sp. indet.			3,2		
Angiospermae-Dicotyledoneae						
? Actinidiaceae	? *Actinidia* sp.	0,2	0,3			
Actinidiaceae	*Actinidia* sp.(aff. *polygama fossilis)*			0,4	2,2	
Amygdalaeae	*Prunus* sp.	0,2		0,2		
Apiaceae	*Umbelliferopsis* sp.*					15
Betulaceae	*Alnus* sp.			6,6		
Caprifoliaceae	*Sambucus* sp.			0,2		
Cercidiphyllaceae	*Cercidiphyllum helveticum*	0,7				
Fagaceae	*Fagus* cf. *deucalionis*			3,7		
Fagaceae	*Fagus* spp.			43,3		
Hamamelidaceae	gen. et sp. indet.			0,2		
Hamamelidaceae	*Liquidambar sp.*			0,2		
Juglandaceae	*Carya ventricosa*	0,1		0,6		
Juglandaceae	*Pterocarya* s.l. spp.			4,7		
Lythraceae	*Decodon gibbosus*	10,5	28			3,8
Magnoliaceae	*Magnolia burseracea*	0,2		3,9	2,9	
Magnoliaceae	*Magnolia* sp. (cf. cor)			0,4		
Mastixiaceae	*Mastixia amygdalaeformis*			8,1	6,5	
Mastixiaceae	*Mastixia cf. lusatica*			0,6		
Myricaceae	*Myrica* cf. *boveyana*	66,3	0,7			8,3
Myricaceae	*Myrica* cf. *cerifériformoides*	0,3				0,8
Rosaceae	*Rubus* sp.	8,8				0,8
Rutaceae	*Toddalia latisiliquata*			0,2	0,7	
Sabiaceae	*Meliosma wetteraviensis*					
Sabiaceae	*Sabia europaea*				0,7	
Saururaceae	*Saururus* sp.*		3,2			
Symplocaceae	*Symplocos lignitarum*			0,2		
Symplocaceae	*Symplocos salzhausensis*			0,4		
Theaceae	*Eurya stigmosa*	0,1		0,6	1,5	
Theaceae	? *Cleyera boveyana*	6,3				0,8
Ulmaceae	*Celtis lacunosa*					8,3
Vitaceae	*Tetrastigma cf. lobata*			0,2		
Vitaceae	gen. et sp. indet.		0,5	0,2		
Vitaceae	*Vitis* cf. *globosa*			1,4	2,9	
Vitaceae	*Vitis cf. teutonica*			0,2	1,5	
? Lauraceae	gen. et sp. indet.		0,3			
cf. Cornaceae	gen. et sp. indet.	0,1		0,2		
Angiospermae-Monocotyledoneae						
Sparganiaceae	*Sparganium* spp.	1,3	4,9			
Potamogetonaceae	*Potamogeton* sp.*	0,3	14,6			

Table 5.
Floristic composition of the diaspore assemblages of selected samples from the hanging wall.
Samples of the hanging wall seam level are combined: ME-Ob-89-33-1-3, 90-8, HÖCK-O4, 97-2; taxa listed in alphabetical order of the families within the Gymnospermae, Dicotyledoneae and Monocotyledoneae.
Sa = sand; Si = silt; C = clay; L = lignite.

ic elements of sample 89-54 (Table 5: 4th column) are *Glyptostrobus, Cephalotaxus, Mastixia, Magnolia*, and *Vitis*. The diaspore spectrum of sample 90-5-1 (Table 5: 3rd column) is dominated by *Fagus* cupules. All the other elements, such as *Sequoia, Mastixia, Pterocarya, Magnolia* are less abundant. Sample 90-5-1 contains some poorly preserved cones of Pinaceae. No remains of Monocotyledoneae have been found in either sample. The supposed habitats may have been riverside forests as well as mesophytic forests. The numerous seeds of *Glyptostrobus* indicate swamp forests too.

A few samples from clayey to silty horizons of the hanging wall have not as yet been fully analysed. They contain diaspore spectra with numerous deciduous woody elements, such as *Alnus* sp., *Acer* sp., *Cercidiphyllum helveticum, Fraxinus* sp., *Meliosma wetteraviensis, Nyssa ornithobroma, Prunus* sp., and *Viscum* vel *Loranthus* sp.

The different diaspore assemblages of the hanging wall sequence indicate variable and changing habitats during the deposition of these sediments.

4. Conclusions

There are no significant changes in the floristic composition of the samples from the different stratigraphic levels. The occurrence or lack of species depend primarily on the habitats and the kind of sediment. Similar environments could have existed during the time of deposition in the surrounding areas. The floristic compositions indicate different habitats, such as swamp forests, bogs, variable riverside forests, and mesophytic forests too. The occurrence of *Glyptostrobus* in nearly all samples and its dominance in the lignitic clays within the seam indicate that *Glyptostrobus* has been an important peat-forming element. Many of the preserved genera are not restricted to one habitat only, but may have occurred in wetland forests as well as in mesophytic ones. Herbaceous plants indicating undergrowth or reed-like habitats occur abundantly only in few samples; extensive reed-like vegetation cannot be assumed. The lack of Monocotyledoneae leaves (KOVAR-EDER, this volume) support this conclusion. Furthermore, aquatic plants are exceptionally rare elements in most samples. The numerous specimens of the water plant *Potamogeton*, which have been found in two of the more than 200 samples examined, seem to be an outstanding exception. Herbaceous Dicotyledoneae plants are better preserved in the pollen spectra (ZETTER, this volume).

Today, many of the represented genera are distributed in evergreen broad-leaved forests and mixed mesophytic forests of E and SE Asia under subtropical climatic conditions (MELLER, 1998; MELLER et al., in press). Therefore, similar climatic conditions may be proposed for the time of the deposition.

The stratigraphic range of the represented species in Central Europe is variable. However, some species (e.g. *Litsea sonntagii* GREGOR, *Gironniera verrucata* MAI, *Manglietia germanica* MAI) are restricted to the Early to Middle Miocene, others occur still in Late Miocene or Pliocene localities in S or SE Europe (MELLER, 1998; MELLER et al., in press).

Acknowledgements

These investigations are supported financially by the Austrian Science Foundation (FWF), Project-Nr. 10337-Geo and could be accomplished by the courtesy of the Graz-Köflacher Eisenbahn- und Bergbaugesellschaft (GKB).

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Manuskript bei der Schriftleitung eingelangt
am 19. Dezember 1997