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Fossil floras from the Lower Rhenish Embayment - opencast mines Hambach, Garzweiler and Inden (RWE Power AG) – a never ending story (in honour of our colleague Zlatko Kvaček, Prague)

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Summary

In this paper, we describe fossils excavated from Hambach, Garzweiler and Inden - three opencast mines of the Rhenisch Embayment - that are interesting and unique in comparison to other European finds. Although each of the three opencast mines has its own separate profile, they still correlate with the schematic profile of the whole area. Here we find fossilised fruits and seeds, leaves, rhizomes, wood, pollengrains as well as some faunistic elements, which have now been the subject of research for more than 25 years.

All types of biotopes, such as water- and reedfacies, bottomland and mesophytic forests, hilltop and swampy edaphic-floras, can be found in this area. The stratigraphical ages of the strata begin in the field with the Lower? or Middle Miocene and continue onwards from the Upper Miocene, the Lower Pliocene and the Upper Pliocene to the Lower and Upper Pleistocene.

Palaeoclimatologically, we have a nearly straight decline of temperature and rainfall from around 18°C to 12°C and 2000 mm to 800 mm respectively, as can be deduced from the floras found.

Key words: Rhenish Embayment, fossil floras, Miocene, Taphocoenoses, mesophytic forests, mastixioidean floras, swamps

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1 Introduction

1.1 Overview

In his work with browncoals, Author GREGOR's focus has been directed towards all types of tertiary deposits with study visits made to mines in the Czech Republic, England, Spain, Greece and Italy in addition to his regular visits to the rhenish opencast mines in Germany. In the case of the latter, GREGOR was first given permission to visit Frechen (1973), Zukunft-West and Eschweiler (1979) in the 1970s. Nearly 10 years later, he then set up a working group together with the authors of this paper to carry out systematic studies of the region by courtesy of Dr. B. H. WUTZLER in Hambach, who, as the operating geologist, kindly made it possible for the group of palaeophytologists and private persons to visit the open mine Hambach in 1987. From that time on, the group has been in the lower rhenanian area every year, including 2017, and next year we are proud to celebrate our 30th anniversary. The group comprises a total of about 20 people - both scientists and private collectors – and we have enjoyed incredibly good teamwork on our trips each year, when we often found rich strata. It is always inspiring to see people dig, wrap the fossils, carry them to the bus, heave the heavy rucksacks inside and make notices about the environment and profile.
This way, we were not only able to gather abundant material for the Natural History Museum in Augsburg (short NMA), but also large collections that remained in private hands. The data we collected about fossil leaves, fruits, woods, samples for pollengrains or molluscs etc. were collated in a single database (author GREGOR) and we could thus publish many data about the tertiary browncoals in the rhenish area.

Over the years, we were able to visit a great number of open mines, many of which are, however, now closed, but the most interesting ones were the opencast mines Hambach, Garzweiler and Inden, which are described here (text-fig. 1). The profiles of the last two differ from that of Hambach, but demonstrate other interesting features (text-fig. 2).

We have thus been able to collect huge amounts of plant fossils, which are housed in the NMA, and present the fruits of our work with tertiary fossils that now spans more than 25 years. Sometimes we think that the exploration of the aforementioned area has similarity with the treatment of the fossil rich strata as an orphan, because, despite the existance of a number of universities, little is done by our colleagues in the way of field work in contrast to the apparently preferred publishing of highlights only or computer models.

Digging in tertiary sediments is a dirty job, but thanks to our working group, the PBA, it has been done and the data analysed, which has provided us with an abundance of invaluable information.

1.2 Browncoal deposits and fossil floras

Geological and sedimentological studies were carried out by BOENIGK 1978, 1995, SCHNEIDER & THIELE 1965, TEICHMÜLLER 1958, HAGER 1981, GOSSMANN 1983 and SCHÄFER 1994, LITT 2007, palynological studies by BRELIE 1958, BRELIE & WOLF 1981,, BURGH & ZETTER 1998, studies on megafloras of various ages and strata by BURGH 1978, 1986, 1994, 1987a, b, 1983, 2014, BURGH & MOOSBRUGGER 1987, BELZ & MOOSBRUGGER 1994 and studies on fossil in-situ-forest by MOOSBRUGGER et al. 1994 (only a selection).

New species were published from the lignites and accompanying sediments by various taxonomic groups (see literature in Chapter 5.2):

Species	**Object**
Tilia gieskei PINGEN & GREGOR 1994	Armor-flower
Liquidambar wutzleri GREGOR 1993	Fruiting head
Betula henningii GREGOR 1992	Leaves
Liquidambar lievenii GREGOR & WINTERSCHEID 2006	Leaves
Rhizocaulon garzweilerense GREGOR, LIEVEN & WINTERSCHEID 2010	Rhizome
Rhizocaulon hambachense GREGOR & LIEVEN 2015	Rhizome
Salix gehlertii – GREGOR 2015	Fruiting spindle

Some additional new species are just in preparation or print (GREGOR et al. 2017):

Species	**Object**
Cephalanthus lievenii GREGOR	Fruiting head
Monsterites pingenae BOGNER & GREGOR	Seeds
Pulvitrix schmittii GREGOR & LIEVEN	Leaf base
Palaeocancer lignitica LIEVEN & GREGOR	Wooden Cancer
Magnoliaestrobus gossmanni GREGOR	Sterile fruiting heads
Palaeocortex koeditzii GREGOR & LIEVEN	Bark
Palaeocortex gaiplii GREGOR & LIEVEN	Bark
Palaeocortex wutzleri GREGOR & LIEVEN	Bark
Palaeocortex burghii GREGOR & LIEVEN	Bark
Palaeocortex lievenii GREGOR	Bark
Palaeocortex sericeus GREGOR & LIEVEN	Bark
Palaeocortex kvacekii GREGOR & LIEVEN	Bark
Palaeocortex gottwaldi GREGOR & LIEVEN	Bark
Palaeocortex gehlertii GREGOR & LIEVEN	Bark
Palaeogemma winterscheidii GREGOR & LIEVEN	Buds

In the following, a comparison of all the opencasts is made with regard to the special profiles that are specifically valid in only the opencast mine concerned (table 1)

Here it is necessary to take note of the names of the different opencast mines, strata and horizons in the field, because both the mines and the strata have their own separate names.
The seams are called Morken, Frimmersdorf, Garzweiler and Schophoven, while the sands and clays are called Inden-layers, Hauptkiesserie (translated main gravel layer), Rotton (Red clay), Reuver (Reuverian clay) and Tegelen (Tiglian) and finally the terraces (Pleistocene).
A simple profile shows the most important strata and horizons in the field (table 1).
Additionally we show a map with the Neogene coastlines and the distribution of the seams (text-fig. 3).

2 Opencast mine Hambach

2.1 Geology and Palaeontology

Pl. 14, fig. 1, pl. 13, fig. 4, 6, 7, 8

The oldest strata in this Hambach mine are the underlying clays of seam Frimmersdorf. To find clays here is normal (and not sands as is the case elsewhere, horizon 6B), but they occur as a special horizon up to the seam Morken, which ist not under work (not thick enough and too much basal in position). Upwards follow the seams Frimmersdorf (a and b) and Garzweiler (Ville-Formation, main seam sequence), which are in part 100 m thick. A separation of the two main seams is only made possible by the varying amounts of trace elements aluminium and iron. Very thin horizons of sand or clay separate the different seams. Overlying are the mighty fluvial and limnic clays and sands of the Inden-Formation (Upper seam group, horizon 7), in which abundant (middle to) upper Miocene leaf- and diaspore-floras are to be found. Further upwards come the Kieseloolith-Formation (horizons 8-11) with coarse gravel and sands (Hauptkies-layers, HKS, hor. 8), which belongs to the Mio-Pliocene transition. The meandering and braided river systems continue on to the Pliocene without a break – the megafloras show this varying ecosystem very clearly. The Red clay (Rotton, hor. 9) and the following Reuver-subformation (hor. 10, 11), also clays, often cannot be separated in the field. Species- and individual-rich leaf-floras in clays coincide with the abundant cones, fruits and seeds from sandy layers. At the top of the whole sequence follow the clastic sediments of the quaternary with hiatuses. The clays (Tegelen, Hor. 13) are overlain by coloured gravels of the younger main terraces (hor. 16). Here we have a lot of problems from a stratigraphical point of view: officially the Tegelen is pleistocene (according to the stratigraphical commission of Germany) as are also the following yellow sands, but the megafloras from there are typically pliocene with many exotic elements. Some small lenses of blueish clays with a poor water-flora would appear to actually belong to the pleistocene.
The following Fig. 4 shows the three small coal seams A-C with Tegelen age and subtropical elements in the flora. From the sediments, we have other results, which put the Tegelen into the pleistocene and separate the older main terraces from the younger ones. Here we need further data for a resolution of these problems.
Because a photo depicting the whole profile is not available, we have elected to show a drawing instead, which illustrates both the real and the ideal profile (text-fig. 4) as well as the top of the sequence in isolation (text-fig. 5).

2.2 Important fossil findings

2.2.1 *Quasisequoia* seam

Pl. 12, fig. 7, 8

One of the most interesting samples came from the so-called *Quasisequoia*-seam, a black browncoal clay with abundant seeds and cones of *Quasisequoia couttsiae*. The seam could not be sufficiently correlated with one of the typical seams from the Upper seam group, but was perhaps comparable to seam Schophoven (Text-fig. 6). This seam is a model for quickly changing conditions in the field and can be seen in many other short time equivalents in this large coalfield.

The flora list is typical for swampy conditions (leaves and diaspores) and yields more than 100 species:

Acer tricuspidatum, Asimina brownii, Byttneriophyllum sp.*, Carpolithus mettenii, Catalpa* sp.*, Craigia bronnii, Fagus* sp.*, Glyptostrobus europaeus, Juglans* sp.*, Lauraceae, Liquidambar magniloculata, Liquidambar wutzleri, Magnolia* sp.*, Nyssa ornithobroma, Paliurus sibiricus, Populus* sp.*, Quasisequoia couttsiae, Quercus pseudocastanea, Salvinia* sp.*, Taxodium dubium* and many more.

2.2.2 *Pinus timleri* and other pines

Pl. 1, fig. 1-6, pl. 1, fig. 6, pl. 2, fig. 5

The huge cones and scales are always a surprise when we find them. The remains are rare, but we generally find one at every excursion. The species was under research by KVACEK, LIEVEN & GREGOR 2015. A special survey about fossil pies was published by MAI 1986. *Pinus timleri* is a species, related to the extants *Pinus canariensis* (Canary Islands) and *P. roxburghiana* (Himalaya), which occurs specifically in the rhenish area (not in the molasses, for example) and is known from Pliocene times only. The accompanying flora has many fruits and seeds from well-known taxa such as *Aesculus spinosissimus, Carya angulata, Carya quadrangula, Fagus deucalionis, Juglans bergomensis, Picea latisquamosa, Styrx maximus, Torreya schulzii* – and many more (see KVACVEK et al 2014).

The rhenish sediments are famous for their rich conifer floras, especially from the sands around the Fischbach Clay. In Hambach, they come from the HKS (main gravel series) and the Red Clay sands as well as from the Reuver sands. The many species were published by KILPPER 1967, 1968a, b, c) and others.

Besides the *P. timleri*, the next important species is *Pinus spinosa*, which we find in several horizons (pl. 1, Fig. 1, 6).

2.2.3 Frimmersdorf and Garzweiler seams - palms

Pl. 4, figs. 5, 6

Abundant palm remains were found in dense browncoal. These finds mainly involved vascular bundles, but leaf scars, roots and parts of rhachis were also found (pl. 12, fig.5). The palm remains died out in the Bavarian molasse in the middle Miocene. Accompanying these palm remains are remains of strongly compressed pine cones, so that we are able to reconstruct a „Palmetto“ forest such as that found in the Southeastern United States (Florida, Bahamas, Georgia etc.). A fossil bark resembles a pine bark (pl. 12, fig. 6).

Although we found vascular bundles, rhachis, leaf scars and compressed network of fibres, the fruits of the palms were unexpectedly missing. We also never found a seed, which should be very hard, but consists of a special protein. One seed is well known from an old mine, Kreuzau, together with a rich leaf flora, but this seed is fusitized and was developed by nature as a result of coalification in this state.

2.2.4 Yellow sand-flora from the Tegelen

Pl. 14, fig . 2, 3

Despite the determination of the yellow sands and gravels as Pleistocene, we find exotic flora elements here, such as *Cyclocarya* species and other fossil plants, and we believe them to be

Uppermost Tertiary – in the old sense "Tegelen". Above the yellow sands in yellow gravels, we had for some time a clay lens with scarce findings of micromammals and some diaspores such as *Phellodendron* etc.
This opinion is in contrast to the publications of other authors, who work in palynology, but not with megafloras (LITT 2007).

2.2.5 *Rhizocaulon hambachense*
Pl. 10, fig. 6
One of the most interesting and marvellous fossil finds was the huge number of rhizomes with a radially exposed arrangement of small rootlets, looking like a tiny sun. The bulb of *Rhizocaulon hambachense* GREGOR & LIEVEN (2015) was typical for rhizomes of Cyperaceae and the species is closely related to the molassian *Rhizocaulon zenettii* from the brackish molasse in Bavaria (GREGOR 2016). This species ist quite different from the *Rh. garweilerense* from opencast mine Garzweiler (GREGOR, LIEVEN & WINTERSCHEID 2010).

2.2.6 Poor water flora at the top
Pl. 13, figs. 3, 4, 6
The newest data allow us to reflect on the border from the Pliocene to the Pleistocene. When mesophytic elements are missing and only *Menyanthes, Potamogeton* and Cyperaceae are present, we can be certain that a change from warm temperate Cfa- climate to a Cfb or D-climate had taken place. Huge water areas are typical for such environments at the beginning of the pleistocene – but as an unofficial border around 1.8 ka. The official border is 2.6 ka (see MENNING & HENDRICH 2002). The abundance of water facies at the beginning of glaciation is affirmed in the data from GÜNTHER & GREGOR 1989-2004, vol. 1).
Further data about the seeds and the facies can be found in Chapters 2.5 and 2.6 in GREGOR et al. 2015.

2.3 Palaeoambiente of the sequence
By considering the various floras, it is possible to establish an ecological and climatological record over the course of time.
Beginning in the lower strata with coals, we find a very rich "palmetto" underground (all types of palm leaves, rhachis, wood etc.) with pines in the coals. This is accompanied by swamp conditions in the clays above with *Spirematospermum* and *Nyssa, Stratiotes* and *Decodon*. The Inden strata with rich leaf-floras are dominated by *Liquidambar, Quercus, Taxodium* and many more taxa, including water plants such as *Nelumbium* and *Nymphaea*. An intercalation, the browncoal clay seam, is dominated by *Quasisequoia couttsiae* twigs, seeds and cones and other swampy species (*Glyptostrobus, Taxodium*). Moving upwards, we find leves of Quercus roburoides (pl. 17, fig. 1), conifer cones (*Picea, Pinus), Fagus, Styrax* and *Juglans, Carya,* funghi and the rare Ginkgo adiantoides (pl.17, fig. 1)(HKS, Rotton clay and Reuver sand). The Reuver Clay also yielded Charophytes, which were studied by SCHWARZ & MÖRS 2000. This is followed by the "Tegelen coals" with abundant rhizomes of *Osmunda* (pl. 2, fig. 1), fruitlets of *Cercidiphyllum* and *Glyptostrobus*, followed by *Cyclocarya* and *Phellodendron* and some herbs. Based on facies and ecology, the climate can be reconstructed

principially as an Cfa-climate sensu KÖPPEN, declining in temperature from some 16-17°C (Lower seams, Middle to upper Miocene) to about 14-12°C in the uppermost pliocene.

An overview on the fossil plants you find on pl. 2, fig. 6,7, pl. 3, fig. 1-9, pl. 4, fig. 7, pl. 9, figs. 1-3, 5, pl. 11, fig. 1, pl. 12, figs. 1, 2

3 Opencast Mine Garzweiler
3.1 Geology and palaeontology
Pl. 14, fig. 2

The lowermost strata in the mine Garzweiler are the "laying sands" (horizon 5B), which are often missing, because the following seam Morken II (Hor. 5C) is only sporadically under work. Morken sand (hor. 5D) is overlying and then seam Morken I (hor. 6A) is outcropping.
Also overlying are the Frimmersdorf sands (hor. 6B) with a short-time ingression with many ichnofossils from *Ophiomorpha nodosa* (crayfish). Seam Frimmersdorf (hor. 6C) follows with sandlenses aund erosional gullies and channels. The Neurath sands (hor. 6D) is also marine characterized.

The uppermost seam in Garzweiler is "Garzweiler" and is tectonically uplifted, thin and locally missing. The Inden-Formation is totally missing (hiatus, horizon 7) and therefore the following sediments (fluvial and limnic sands) belong to the Kieseloolith-Formation (horizons 8-11), whereby only HKS (hor. 8) and Reuver clay (hor. 11), which are in transition between Miocene and Pliocene, can be clearly separated. The whole sequence is very complicated in its build-up and the Red Clay (hor. 9) and Reuver Sand (hor. 10) are hardly to be found in the profile, because of the many disturbances of the sediments.
The most important stratum is the grayish Reuver Clay with some coaly parts, underlain by the gray Reuver Sand (both some meters thick).
The uppermost clastic sediments of the quaternary yield are ocre-coloured gravels of the older and younger main terraces (hor. 12, 16), intercalated by brownish-greenish Tegelen Clays (hor. 13). Loess and surface soil close up the sequence. The whole profile is photographed in text-fig. 7.

3.2 Important fossil findings
3.2.1 The Upper Pliocene Otzenrath-Flora
Pl. 4, figs. 1-4, pl. 5, figs. 1-7, pl. 6, figs. 1-7

More than 1000 plant fossils were found in the gray clays of the Reuverian and Upper Pliocene. The flora was named "Otzenrath" after the village that stood here before the mining began. This is, for example, equivalent to the Fischbach-flora, which is found in the fischbach clay in the opencast mine Frechen.
Here the speciesrich exotic flora yielded leaves, fruits and seeds and rhizomes.
The dominant elements were:
Oaks and beech, maple and amber, cypress and many more (LIEVEN et al. 2013):
Acer, Alnus, Ampelopsis, Berchemia, Betula, Carpinus, Fagus, Liquidambar, Parrotia, Populus, Quercus, Salix, Sassafras, Sequoia, Taxodium, Ulmus, and *Zelkova* and many more.

A new species, *Rhizocaulon garzweilerense* (see 3.2.2), the rare agaric, and a fungus completed the picture of the wonderfully preserved flora.
The importance of this flora is shown by the whole closed complex, which is younger than the Upper Miocene Fischbach-flora KRAMER (1974), thus allowing these two chronostratigraphically well defined floras to be comparable in time and space.
Ecologically the flora is shaped by many aueforest elements, which include fewer slope and swamp inhabitants and many reed- and waterfacies ones. Exclusively evergreen elements are missing and the flora can be seen as a deciduous mixed mesophytic forest like that found today in China or in the USA (SE-part). We can expect a Cfa-climate with 14-15°C and 1500 mm rainfall/year, i.e. both higher than the rainfall and temperatures experienced today. Such favourable climate conditions could be assumed also in the Pliocene with the occurrence of *Glyptostrobus* and *Stewartia* far up in the profile and a short time before the first glaciation.

3.2.2 *Rhizocaulon garzweilerense*

Pl. 6, fig. 4

One of the most interesting plant remains were the rhizome bulbs from *Rhizocaulon gerzweilerense*, which are unique for Garzweiler. The bulbs were associated with the Otzenrath flora and belong to the Upper Pliocene Reuver clay. Rhizomes principally do not directly belong to a fossil leaf- or diaspore-flora, because it is an underground object belonging to Cyperaceae. The genera *Bolboschoenus, Scirpus* and *Cyperus* have a somewhat similar shape and size within the specimens of their species.

3.2.3 A giant log

Pl. 15, figs. 1-3

2011 brought a surprise, when the largest fossil ever found in the Rhenish browncoal district was excavated from the opencast mine Garzweiler in the Frimmersdorf sand: a log of a giant tree - the famous coast redwood or mammuth tree (*Taxodioxylon germanicum*) - 9.5 m long with a diameter of about 80 cm and a browncoal weight of more than 4 tons, which had drifted in the water along the Miocene coast. There was no bark or any imprints of teredo borings. 2018, in May, another equivalent large log was found in the same horizon.

3.2.4 Other fossil plants

Pl. 1, fig. 7, pl. 7, fig. 8, pl. 9, fig. 7, pl. 11, figs. 4, 5, pl. 16, figs. 1, 4

Typical for all the Lower Rhenish Browncoal seams are fossil stems and trunks of conifers such as *Pinuxylon parryoides, Taxodioxylon gypsaceum, Taxodioxylon germanicum*, cones and needles of *Glyptostrobus europaeus* and *Sciadopitys tertiaria*. Many palm remains (*Palmoxylon* sp.), especially in Seam Garzweiler, together with diaspores of *Mastixia, Comarostaphylis globula* and *Aldrovandia praevesiculosa*, cuticules from *Laurophyllum* sp. (especially from seam Frimmersdorf, Pl. 17, figs. 2), root horizons, borings from insects and *Teredo*-borings, both in wood, complete the floras and faunas of the mine.
We must also mention the wonderfully preserved stem of *Bromeliaceophyllum rhenanum* from the seam Frimmersdorf (hor. 6C) in Garzweiler (Pl. 11, fig. 4).
This species is almost certainly not a Bromelian plant, but a clear determination is lacking – however, we would point out palms (Arecaceae) as being possible representatives. Significant thick leaf scars yield clearly visible 1-2 mm thick vascular bundle fibres, which build up the

stem. This specimen was found by a geographer student from the University of Siegen in 2011 and the fossil seems to be unique in the Rhenish browncoals (LIEVEN 2016: 38, Abb. 44).
Pleistocene mass occurrence of Characeae was astonishingly dispersed in a thin layer of Weichsel loess, the first time they were found (HARTKOPF-FRÖDER 2010).

4 Opencast Mine Inden
4.1 Geology and Palaeontology
Pl. 14, fig. 3

The lowermost layers in the mine Inden currently form the base of the Inden-Formation, the Upper Seam Group (hor. 7A). With the mine works still on-going, we can expect the Seam Garzweiler (Ville Formation, Main Seam Group) to be available in 2018.
Overlaying are three small seams from the Upper Seam Group (Friesheim, Kirchberg and Schophoven, hor. 7C, D, E). They are separated by two fluvial intercalations.
As in the other quarries, we find fluvial and limnic sediments over Seam Schophoven, the Kieseloolith-layers (hor. 8-11). They are, without any doubt, occurring in the whole field and are clearly distinguishable. The transition Mio- to Pliocene in the HKS, the main gravel series (hor. 8), is typically exposed as it is in other locations too. The Rotton layers and the Reuver-layers can be recognised by their clays (hor. 9-11).
The clastic sediments of the pleistocene follow upwards with a lot of hiatuses - the partly ocre coloured gravels of the middle terrace (hor. 18) and relics of the younger main terrace (hor. 16). As in the other two mines, we find a loose cover and dark brown silts here too (see text-fig. 8 for all layers).

4.2 Important fossil findings
4.2.1 The Mastixioidean Flora
Pl. 7, figs. 1-7, pl. 8, figs. 1-8, pl. 14, figs. 4-7, pl. 13, fig. 5

Mastixioidea floras and the accompanying elements, such as Symplocaceae, Styracaceae or other exotic elements, have long been known from Düren-, Zukunft-West- and Zülpich-mines, but in the last 20 years were only sparsely found in Hambach and now abundantly in the Inden mine at the end of 2015. The horizon of the fossils was a sandy drift layer, an intercalation between Seam Kirchberg and Schophoven (hor. 7E) with abundant twig remains, debris and thousands of fruits and seeds at the base on the first level in the outcrop. The number of specimens in the only one meter broad erosional channel was incredible and the photos show the abundance of fruits and seeds in this sandy horizon. The debris layer was about 20 cm thick and 15 cm deep and contains more than 30 litres of diaspores.

A short flora list gives an impression of the composition and the complete flora will be published separately and compared with the older and more distant floras (table 2).

The first impression of the flora, based on approximately 2000 fossils and remains larger than 5 mm, is presented in table 2. A part of the fossils have undoubtedly been gnawed by micromamals or show round holes from boring insects.
Smaller fractions were examined with the aid of binoculars, allowing us to get an impression of the flora as a whole:

Acer sp. (?), *Brasenia victoria*, *Cladium* sp., Ericaceae, *Eurya stygmosa*, *Glyptostrobus europaea*, *Homalanthus costatus*, *Ilex* sp., Lauraceae, *Myrica ceriferiformis a*nd *M. suppani*, *Pinus* sp., *Punica tertiaria*, *Rosselinites congretatus*, *Sequoia abietina*, *Symplocos* sp., *Tetrastigma lobata* and *Toddalia* sp. Conifers like *Pinus spinose* complete the list (pl. 7, Fig. 7).

Polyspora kilpperi is one of the rarest fossils from there. In 1978, this new species was described on the basis of only 2 valves of the capsule fruit found in the opencast mine Zukunft-West. Now we have the second proof of this rare species in the european tertiary. Further sampling established a lot of further mastixias and nearly three cubicmeters sand were sieved, revealing more than 250 litres of coarse material. Thus, we can expect to find more than 20,000 specimens of this wonderful flora (cones, fruits, seeds, wood) in Inden.

Many years ago, such Mastixioidean flora were found in the Rhenisch Browncoal district in the old open mines "Alfred" near Düren (1917–1940), Düren (1941–1956), "Viktor" near Zülpich (1953–1969), "Zukunft" (1910–1941) and "Zukunft-West" (1936–1987) and we have made similar findings in 1970 in Hambach in erosional deposits in the seam Frimmersdorf.

Stratigraphically, the Mastixioidean flora should belong to the Inden-Formation (Upper Seam Group, hor. 7E), the Upper Miocene, but there is some doubt about the age of the whole series. Middle Miocene (or Lower Miocene) cannot be excluded by our studies.

Now it will be possible to study the fossils again under new aspects and make comparisons with other deposits in Germany and Europe (work under progress by LIEVEN and GREGOR): Hradek-Basin (Czech Republic), Wiesa (Saxonia), Schwandorf (Upper Palatinate), Kaltennordheim (Rhön), Kreuzau (Rureifel), Arjuzanx (Southern France), Euboea (Greece) and Turow (Poland).

Most of these Floras are of Lower Miocene age, thus depending on a high subtropical climate (Cfa sensu KÖPPEN). If it can be affirmed that the Rhenish floras are really Upper Miocene, we will have to take a relic niche up to the Upper Miocene in our reflexions – or the whole sequence must be changed and revised and the Mastixias belong to older layers.

Today Mastixias live with two genera (*Mastixia* and *Diplopanax*) in India and the Malay Peninsula.

4.2.2 Other fossil plants

Pl. 9, figs. 4, 6, pl. 11, figs. 2, 3, pl. 12, figs. 3, 4

The opencast mine Inden does not have too many fossils in the different horizons, but astonishingly enough we found leaves from *Ginkgo adiantoides* some years ago (pl. 11, figs. 2, 3), a rare element in the rhenish sediments. We have also found rare specimens in Hambach (GREGOR et al. 2014: 9) and this year found a considerable number of elements of this famous Chinese tree there.

The accompanying flora showed taxa such as *Alnus, Carpinus, Liquidambar, Populus*, *Quercus, Taxodium* and *Zelkova*. The age seems to be around the Upper Miocene, i.e. Upper Inden clays.

By fortune were found some small twigs with amber, a rare finding in the sediments (pl. 16, figs. 2, 3).

5 The Rhenish Browncoals in European comparison

5.1 The ideal profile

Undoubtedly the opencast mine Hambach is the largest mine in the European tertiary and yields abundant plant fossils in the whole profile. We give a short explanation for the sequence of strata, horizons, lenses and reworked sediments from below to above. It is not possible to find the entire sequence in any one location, but every opencast mine has a part of the ideal profile, which is well known through drilling techniques (Text fig. 2 and table 1).

The text-fig. 9 tells us that the profile is tectonically strongly disturbed and therefore parts of different strata are missing, erosional lenses show destruction of profile parts and reworking seems to be a frequent problem in the field. Therefore, every opencast mine has its own profile.

5.2 Literature from the working group

Pl. 13, fig. 1, pl. 13, fig. 7

The working group (see authors) has published many papers over the years. The following Documenta naturae issues are all concerned with the fossil species and geological problems of the opencast mines Hambach, Garzweiler and Inden:

Documenta naturae, 70, München 1992
PINGEN, M.: Die Makrofloren von Kreuzau und Probleme ihrer stratigraphischen Einordnung: 1-5.
KNOBLOCH, E., KVACEK, Z. & GREGOR, H.-J.: Neue Pflanzenfossilien aus dem Niederrheinischen Tertiär VII. Pliozäne Blätter und Früchte aus dem Tagebau Hambach: 36-53, 2 Abb., 4 Taf.
Documenta naturae, 80, München 1993
GREGOR, H.-J.: Wutzlers Amberbaum - ein neues exotisches Element aus dem Obermiozän von Hambach (Rheinbraun, Köln): 1-9, 8 Abb., 1 Taf.
Documenta naturae, 84, München 1994
PINGEN, M.: *Athrotaxis couttsiae* (HEER) GARDNER - ein reiches Vorkommen in obermiozänen Kohlen des Tagebaus Hambach bei Düren (Rheinland): 24-30, 1 Tab., 1 Taf.
Documenta naturae, 89, München 1994
PINGEN, M. & GREGOR, H.-J.: Neue Pflanzenfossilien aus dem niederrheinischen Tertiär VIII. *Tilia gieskei* nov. spec. - der erste fossile Blütenfund aus dem Tagebau Hambach bei Düren: 1-8, 2 Abb., 2 Taf.
PINGEN; M.: Neue Daten und Berichtigungen zur Sand- und Tongrube von Kreuzau (früher Niederdrove): 9-19.
GREGOR, H.-J.: Neue Pflanzenfossilien aus dem niederrheinischen Tertiär IX. Die niederrheinische Braunkohle - ein literarischer Überblick und neue paläobotanische Befunde: 20-30, 2 Abb., 12 Taf.
SCHUBERT, R. & GREGOR, H.-J.: Jungtertiäre Käferreste aus dem Tagebau Hambach (Niederrheinische Braunkohle): 31-33, 1 Taf.
Documenta naturae, 104, Bd.1, München 1996
STROE, M. v.: The flora of the Miocene 7b1-Layer of Hambach, Germany: 1-18, 2 figs., 5 pls.

BUTZMANN, R.: Neue Pflanzenfossilien aus dem niederrheinischen Tertiär X. Ein Massenvorkommen von Equisetum limosellum HEER 1855 sensu novo im Tegelen (oberstes Pliozän) des Tagebaues Hambach bei Niederzier: 19-26, 2 Abb., 2 Taf.
PINGEN, M.: Neue Pflanzenfossilien aus dem niederrheinischen Tertiär XI. Erstnachweis von Eurya boveyana CHANDLER, Itea europaea MAI und Phyllanthus securinegaeformis MAI aus den obermiozänen Inden-Schichten von Hambach: 27-32, 2 Taf.
FISCHER, T. C.: Wachstumszonen an Athrotaxiszweigen aus den Inden-Schichten (Obermiozän) des Tagebaues Hambach bei Niederzier (Düren): 33-34, 2 Taf.
MAYR, CH. & FISCHER, T .C.: Eine Blattflora unter Flöz Frimmersdorf (Ville-Schichten 6B, Untermiozän) aus dem Tagebau Hambach bei Niederzier (Rheinbraun AG, Köln): 35-40, 1 Taf.
Documenta naturae, 104, Bd.2, München 1998
GREGOR, H.-J., PINGEN, M., BUTZMANN, R., FISCHER, T. C., MAYR, CH. & SCHMITT, H.: Die neogene Makrofloren-Abfolge im Tagebau Hambach der Rheinbraun AG Köln: 1-83, 142 Tab., 8 Taf.
Documenta naturae, 104, Bd.3, München 1999
GREGOR, H.-J., PINGEN, M., MAYR, CH. & SCHMITT, H.: Die neogene Makrofloren-Abfolge im Tagebau Hambach der Rheinbraun AG Köln – erste Ergänzungen: 1-81, 111 Tab., 8 Taf.
SCHMITT, H. & KVACEK, Z.: Nachweis von *Acer aegopodifolium* (Goepp.) Baik. ex Iljinskaja in den obermiozänen Indener Schichten des Tagebaues Hambach (Niederzier bei Köln) : 83-91, 16 Abb., 1 Taf.
Documenta naturae, 104, Bd.4, München 1999
GREGOR, H.-J., MAYR, CH., PINGEN, M. & SCHMITT, H.: Vorläufige paläontologische Ergebnisse und Befunde zur Plio-Pleistozän-Problematik im Tagebau Hambach (Köln, Rheinbraun AG): 1-33, 3 Abb., 5 Tab., 10 Taf.
Documenta naturae, 104, Bd.5, München 2000
GREGOR, H.-J., BURGH, J.v.d., PETERS, A. M. M. & PINGEN, M.: *Torreya schulzii* nov. spec. – eine exotische Konifere aus dem NW-europäischen Pliozän (Hambach, Liessel): 1-25, 7 Abb., 2 Tab., 4 Taf.
Documenta naturae, 138, München 2001
GREGOR, H.-J.: in honorem Bertram Wutzler, einem Freund und Förderer der Paläobotanik in Deutschland, zum Ausscheiden aus dem aktiven Dienst: I-IV, 2 Fotos
PINGEN, M., KVACEK, Z. & MANCHESTER, S. R.: Früchte und Samen von *Craigia bronnii* aus dem Obermiozän von Hambach (Niederrheinische Bucht – Deutschland) - Vorläufige Mitteilung: 1-7, 2 Taf.
BUTZMANN, R. & FISCHER, TH.: Neue Pteridophyten des Neogens aus dem Tagebau Hambach (Niederrheinische Bucht) – I. Polypodiaceae: 9-23, 1 Tab., 1 Abb., 3 Taf.,
BURGH, J. v. d.: Leaves and Cuticles from the Upper Part of the Rhenish Browncoal: 25-47, 6 Pls.
GREGOR, H.-J., PINGEN, M. & SCHMITT, H.: Eine neue Megaflora aus den basalen Inden-Schichten des Tagebaues Hambach bei Niederzier (Rheinbraun AG, Köln): 49-76, 1 Abb., 3 Tab., 2 Taf.,
THEWALT, U. & DÖRFNER, G.: Mineralogische Notizen vom Tagebau Hambach (Köln, Rheinbraun AG): 77-91, 5 Taf.,
Documenta naturae, 163, München 2007
LIEVEN, U., GÖTTLINGER, R., HORNING, G. & SENDZIK, B.: Eine unterpliozäne Makro-Flora mit Vivianit-Imprägnierung aus dem Braunkohlen-Tagebau Hambach der RWE Power AG: 15-43, 4 Abb., 3 Tab., 7 Taf.,
GREGOR, H.-J. & LIEVEN, U.: Durch Vivianit blau mineralisierte Wassernüsse aus dem Unterpliozän des Braunkohlen-Tagebaues Hambach: 45-55, 3 Taf.,

Documenta naturae, 189, München 2012
BURGH, J. v.d. : Leaves of Lauraceae in the Inden series (Miocene) from the Lower Rhenish basin, Germany (open pits Hambach and Frechen): 1-19, 4 Taf., München
Documenta naturae, 195, Teil I München 2014
Tagebau Hambach RWE Power AG - Neue Funde und Daten aus dem Jungtertiär I
J. v. d. BURGH: *Majanthemophyllyum petiolatum* WEBER in the Neogene of the Lower Rhenish Basin, opencast mine Hambach (RWE Power AG): 1-9, 1 pl.
H.-J. GREGOR: Ein miozänes Massenvorkommen von Hickorynüssen (*Carya costata* (PRESL) UNGER) in einem Baumstamm aus den Inden-Schichten im Tgb. Hambach (RWE Power AG): 9-19, 2 Abb., 3 Taf.,
Z. KVAČEK, U. LIEVEN & H.-J. GREGOR: *Pinus timleri* – ein wichtiges Element aus der pliozänen Flora des Tagebaues Hambach (RWE Power AG): 21-45, 2 Abb., 4 Taf.,
Documenta naturae, 195, Teil II München 2014
Tagebau Hambach RWE Power AG - Neue Funde und Daten aus dem Jungtertiär II
H.-J.GREGOR, R. GAIPL, W. GEHLERT, U.LIEVEN, CH. MAYR, M. PINGEN, H. SCHMITT: Neue und besondere mio-pliozäne Fossilfunde sowie geologische Beobachtungen im Tagebau Hambach (RWE-Power AG) bei Niederzier, Krs. Düren: 1-109, 7 Abb., 17 Tab., 25 Taf., Append.,
Documenta naturae, 195, Teil III München 2015
Tagebau Hambach RWE Power AG - Neue Funde und Daten aus dem Jungtertiär III
H.-J. GREGOR, W. GEHLERT, U. LIEVEN, M. PINGEN, H. SCHMITT: Neue und besondere mio-pliozäne Fossilfunde sowie geologische Beobachtungen im Tagebau Hambach (RWE-Power AG) bei Niederzier, Krs. Düren
H.-J. GREGOR, U. LIEVEN, W. GEHLERT, M. PINGEN, & H. SCHMITT: Die Quasisequoia-Kohle in der Inden-Schicht im Tgb. Hambach – Profile, Fossilinhalt, Interpretationen
H.-J. GREGOR & U. LIEVEN: *Rhizocaulon hambachense* nov. spec. im niederrheinischen Jungtertiär (Tgb. Hambach, RWE Power AG)
H.-J. GREGOR & U. LIEVEN: *Salix gehlertii nov. spec.* im niederrheinischen Braunkohlentertiär aus dem Tgb. Hambach (RWE Power AG)
Documenta naturae, 195, IV, in prep, 2017
H.-J. GREGOR, U. LIEVEN, J. BOGNER, J.V.D. BURGH, R. GAIPL (†), W. GEHLERT, R. GOSSMANN, M. PINGEN, H. SCHMITT & H. WINTERSCHEID (2017): Neue jungtertiäre Pflanzen-Arten in den Braunkohlen und Begleitsedimenten verschiedener Tagebaue der RWE Power AG (Niederrheinische Braunkohlenformation)

Some of the most important literature of other and older specialists is mentioned here, but only as a selection. Early literature comes from MENZEL 1913, followed by KILPPER 1959, 1960, 1971, KRAMER 1974 and MOOSBRUGGER et al. 1994, BELZ & MOOSBRUGGER 1994. Excellent literature was written by J.v.d. BURGH (1986, 1978, 1994, 1987a, b, 1983, 2014), who specialized in the determination of fossil woods as well as in the ecological conditions of leaf- and fruit-floras by comparing recent conditions of the related species.

5.3 Lithology and fossil content

Depending on the lithological formation, we have to wait for different floras. However, we have found the following conditions every year:

Coals: these caustobiolithic sediments belong mostly to Lower- to Middle Miocene and are a compact browncoal, often with leaves, pine cones or palm remains, especially in the Seam

Frimmersdorf. The Seam Garzweiler has much more lignites, whole stems and trunks in situ, but also palm remains.
Clays: there are abundant clays of every type, light gray to dark gray, greenish to reddish, splittable to hard-ground material, sterile to fossiliferous, mostly leaf-floras, but also tiny seeds.
Sands: in sands, we had, in part, thousands of larger fruits and seeds as flood debris, mostly picea cones, nd mesophytic elements.
Gravel: one horizon, the Main gravel series (Hauptkiesserie) yielded truncs, fossil woods of every size and also abundant diaspores of large size.

5.4 Ecological and climatological conditions

From an ecological point of view, it is necessary to distinguish between some biotopes or ecofloras:
Water flora: mostly nymphaeaceae (leaves), *Trapa* (nuts), different water plants such as *Aldrovandia and Stratiotes.*
Swamp flora: *Nyssa* (tupelo), and water pine (*Glyptostrobus)*, swampy Mammoth tree (*Quasisequoia*), *Decodon*, etc.
Bushmoor: *Decodon, Itea*.
mesophytic elements: Beech and oak (*Fagus, Quercus*), Juglandaceae.
aue forest: *Liquidambar, Populus, Platanus, Zelcova.*
hardwood bottomland flora: Amber and Ash, riparian forest (*Liquidambar* and *Fraxinus).*
softwood bottomland flora: Willow- and Poplar riparian forest (*Salix* and *Populus*).

In summary, we have a climate running through the times and the strata that is called warm-temperate and Cfa-climate (two different climate classifications). Depending on sediment and taphocenosis, we have to understand that a coal or swamp flora (autochthonous) gives a different picture of the climate than one from sands or gravels (allochthonous).
We cannot compare leaves, diaspores or palynomorphs directly, but must also consider their occurrence: autochthonous, on the one hand conservative in wet facies, on the other hand stratigraphically widespread over large distances, but bound to bottomland facies.
Allochthonous or easily distinguishable in wide areas are diaspores in sands and gravels - useful for long range correlations, these are mostly mesophytic elements.
Some modelling was done by PROSS & KLOTZ 2002, while UTESCHER et al. 1994, 1996, used a different systemic approach.

5.5 Stratigraphical problems

The whole sequence of the rhenisch browncoal profile is stratigraphically a bit uncertain, because real well-defined correlations with marine sediments or mammal, foraminiferal and palynological units are missing. Although we have data about the most striking strata, we lack good systems compared to the bavarian molasse, hessian browncoals or mediterranean deposits. Additionally, we have severe tectonic movements and attempts at a correlation often fail (text-fig. 9).

The lower strata, such as the seams Frimmersdorf and Garzweiler, seem to be correct in their age of lower to middle miocene, but there are missing correlation possibilities for the higher parts of the profile. The Inden series could be upper miocene, while the overlying main gravel series have no chance to be compared with other horizons. The lower Pliocene of the Rotton (red clay) and the upper pliocene of the Reuver sands could be well defined by comparisons with other localities of similar age. Overlaying are yellow fine gravel and sands thought to be pleistocene age. On the other hand, we have floras with exotic elements, typical for pliocene age. In Hambach, we have found really good pleistocene wet floras far above the yellow sands, which allows us to assume that the border between plio- and pleistocene is different from the official determinations.

One of the most striking problems is the so called “Pretiglian” (Prä-Tegelen), because it seems to be a problem with cooler plant remains and not a stratigraphical tool – we have not been able to find a megaflora with such a cooling trend anywhere, but only warm-temperate floras before, intra- and after this “break”. Thus, we assume that the Pre-Tiglian does not exist, especially not in the rhenish browncoals (see BOENIGK 1978, 1995). This timespan today is also called Kaltenhörn Eiszeit (LITT 2007), but cannot be found in megafloras.

5.6 Fossil faunas

Pl. 2, fig. 2, pl. 10, figs. 1-10, pl. 16, fig. 4

Some local faunas are published, especially from the opencast mine Hambach. Not only micromammals are well known from this coalfield, but also fish, turtles or birds. In the following table, we have collated the most important findings from the different layers of Hambach and the whole neogene of the Lower Rhenish Embayment:

Literature	**Animal types**	**Age**
ČERŇANSKÝ et al. 2017	Squamate faunas	Neogene
KLEIN & LIEVEN 2007	Batagurid turtle	Miocene
MÖRS 2008	Rodents	Miocene
DALSÄTT et al. 2006	Birds	Mio-Pliocene
MÖRS 2006	Rodent	Miocene
GEE et al. 2003	Rodent nut cache	Miocene
HIERHOLZER & MÖRS 2003	Fishes	Neogene
KLEIN & MÖRS 2003	Testudines	Miocene
NEMETSCHEK & MÖRS 2003	Glirids	Miocene
MÖRS 2002	Vertebrate faunas in the Lower Rhine Embayment	Neogene
MÖRS et al. 2000	First vertebrates	Miocene
ZIEGLER & MÖRS 2000	Marsupials and bats	Miocene
MÖRS et al. 1998	Rodents	Late Pliocene
SCHMIDT et al. 1958	mammal biting traces on fruits	Miocene

Also found were some newer activities of fossil mammals, as remains or traces.

One cricetid type of micromammal, a yaw, was found by colleague MAYR in the uppermost “Tiglian” lens in Hambach and some new aspects of faunal fossils were also discussed (GREGOR et al. 2014: cap. 2.15.3: 27-29, Pl. 10, fig. 2).
Only traces of small mammals were found in a wooden stem of *Picea* with many *Carya*-nuts (*Carya pusilla*) “in situ”, a so-called nut cache (GREGOR 2014).

At the proposal of author GREGOR and commissioned by RWE Power AG, the following reconstructions of the vertebrate or mammal fauna incl. vegetation pictures were painted by Uta GREGOR and her friend Heidi THIELE-PFEIFFER (†) to illustrate what they would have looked like at the time (plates 18 and 19).

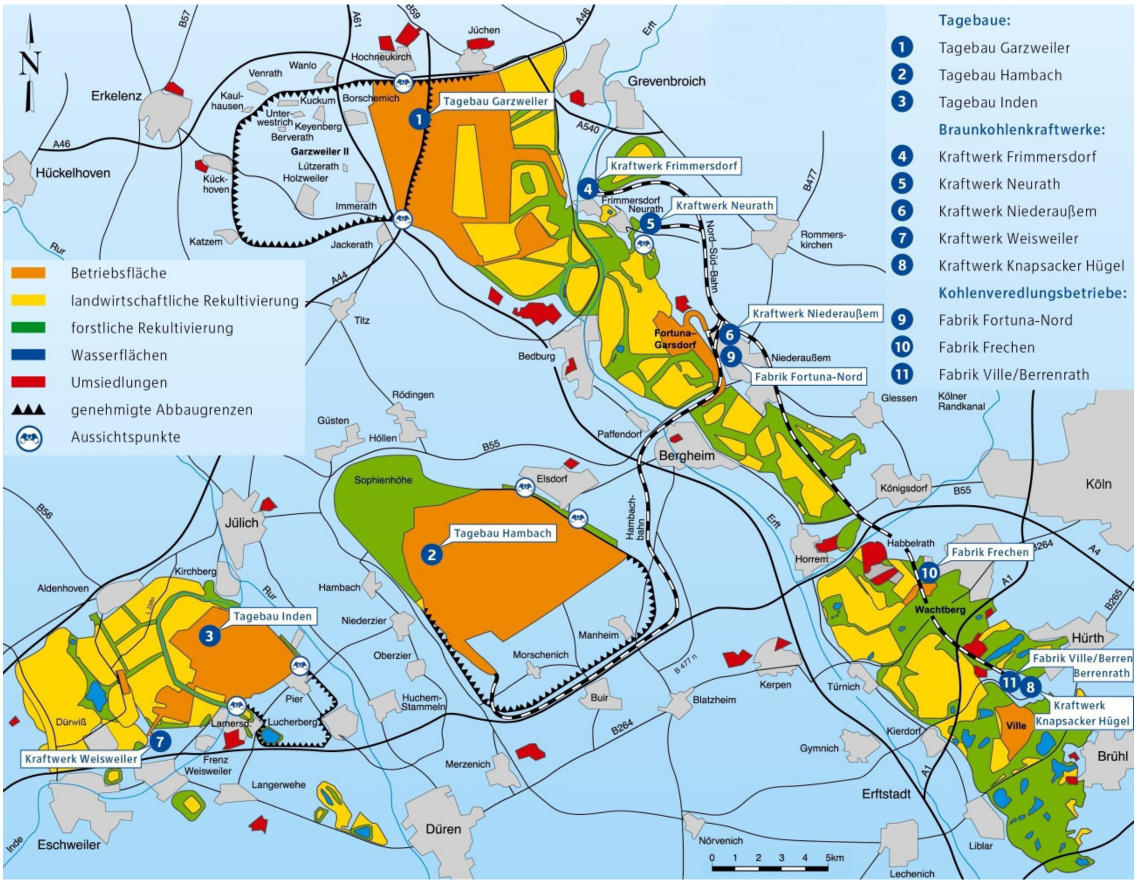
5.7 Equivalent browncoal deposits in Europe

We have abundant open mines of browncoal in Germany and middle Europe available for comparative studies. Some of the most important were the Schwandorf lignites (GREGOR 1978, 1980), the Hessian Browncoals (GREGOR & OSCHKINIS 2013), Italian lignites (GREGOR 1985, MARTINETTO 1998, 1993a, b, MARTINETTO 1994, 1995, 1996, 1998, 2015, MARTINETTO et al. 1994, 2018), Greek browncoals (GREGOR & VELITZELOS 1985,1986a, b, VELITZELOS & GREGOR 1982, 1985a, b, 1986, 1987a, b, 1990, VELITZELOS & SCHNEIDER 1977, 1979, VELITZELOS 1993, VELITZELOS et al. 1980, VELITZELOS et al. 2014, DENK et al. 2014,), or others and especially the many mines from the former German Democratic Republic (MAI 1964, 1995, MAI & WALTHER 1978, 1988, 1991, BERKNER 2004).
Thus the lower Rhenish Embayment can be compared very well with other deposits, but we must keep in mind the possibility of a certain relic niche, as also seen in the computer modelling of GÜNTHER & GREGOR (1989-2004 and 2013) and GREGOR & GÜNTHER (2001). Important is the critical analysis using the Coexistance approach by GRIMM et al. 2016).

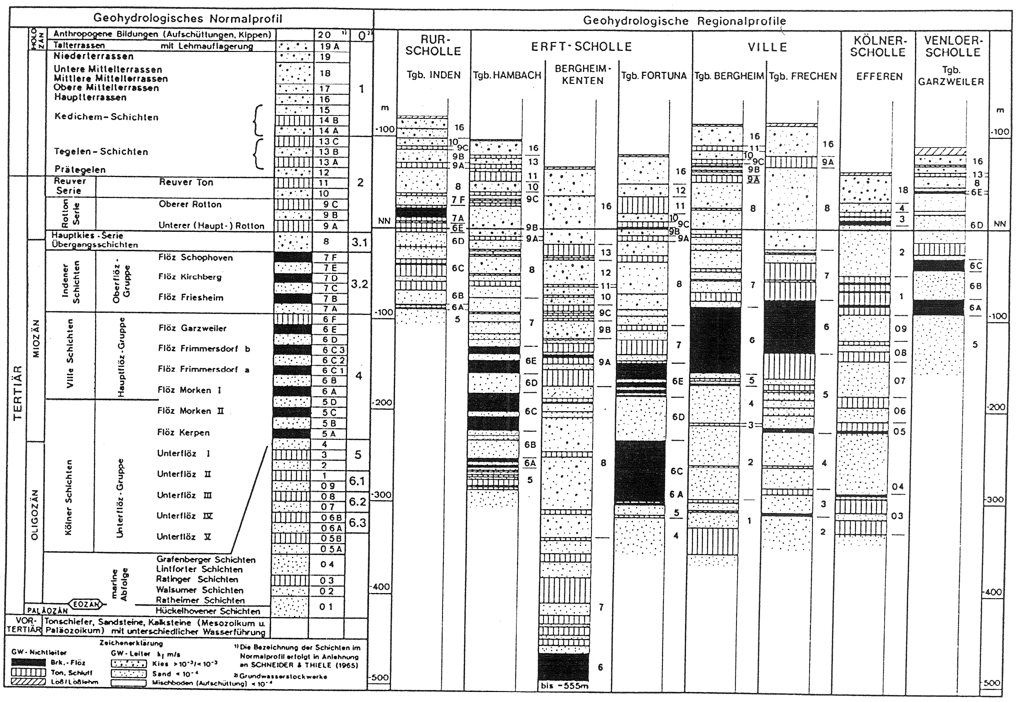
Acknowledgements

First of all we thank our old friend and colleague Zlatko Kvacek for more than 40 years of cooperation in scientific research, not only in the rhenish district, but also in Bavaria and the Alsace. Our colleague Jiri KVACEK was helpful in organising the meeting and excursions round the Tertiary in Bohemia. Mrs. GODWIN-SCHMITT was so kind to revise the English text and we aregreatly appreciated for her suggestions and comments on the manuscript. Our working group was as active and helpful as everytime in the run of the last 30 years, in which we visited the opencast mines of the RWE Power AG and where we found the fossil material, which is presented here.

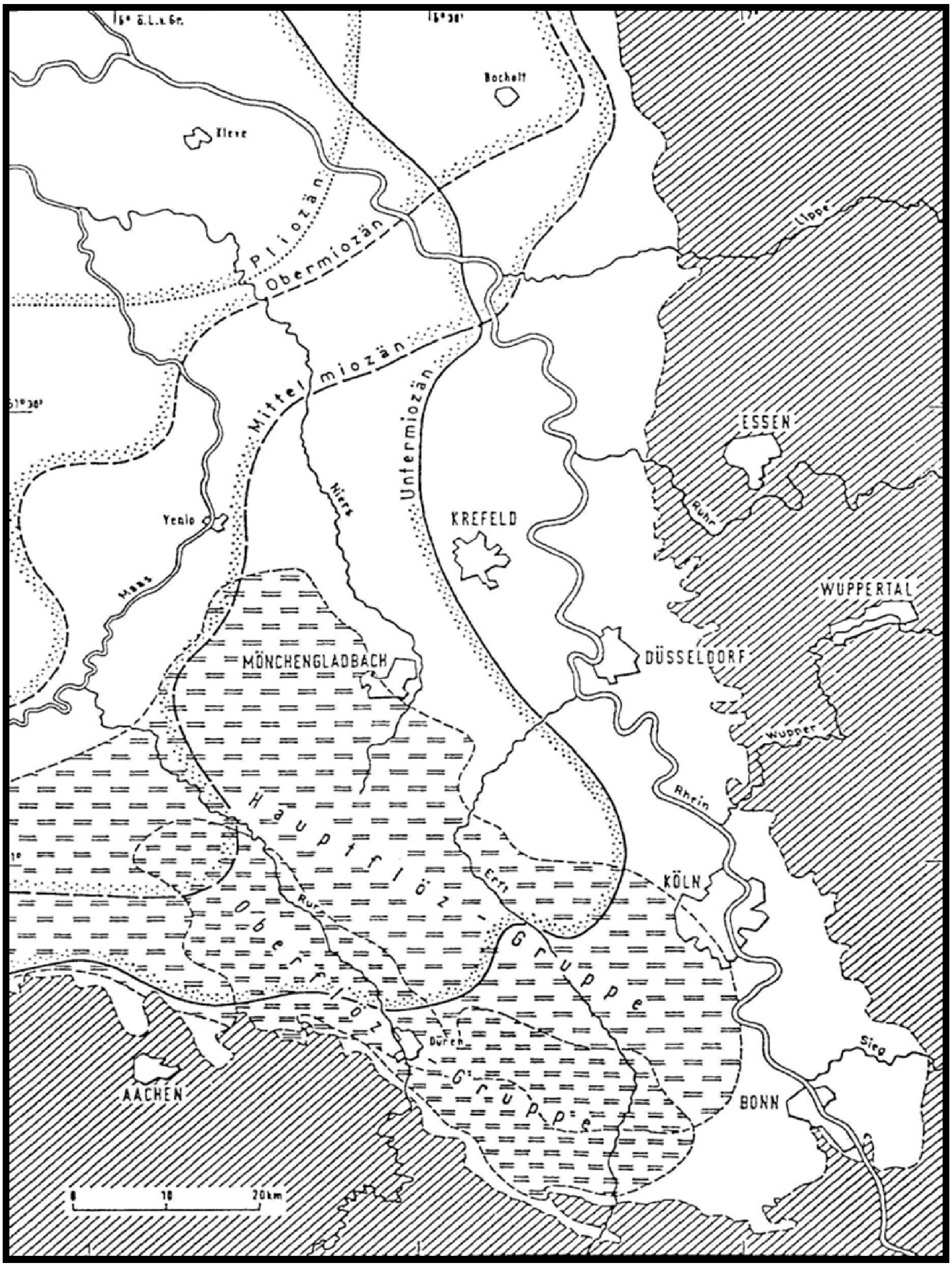
Text-Figs. and Tables



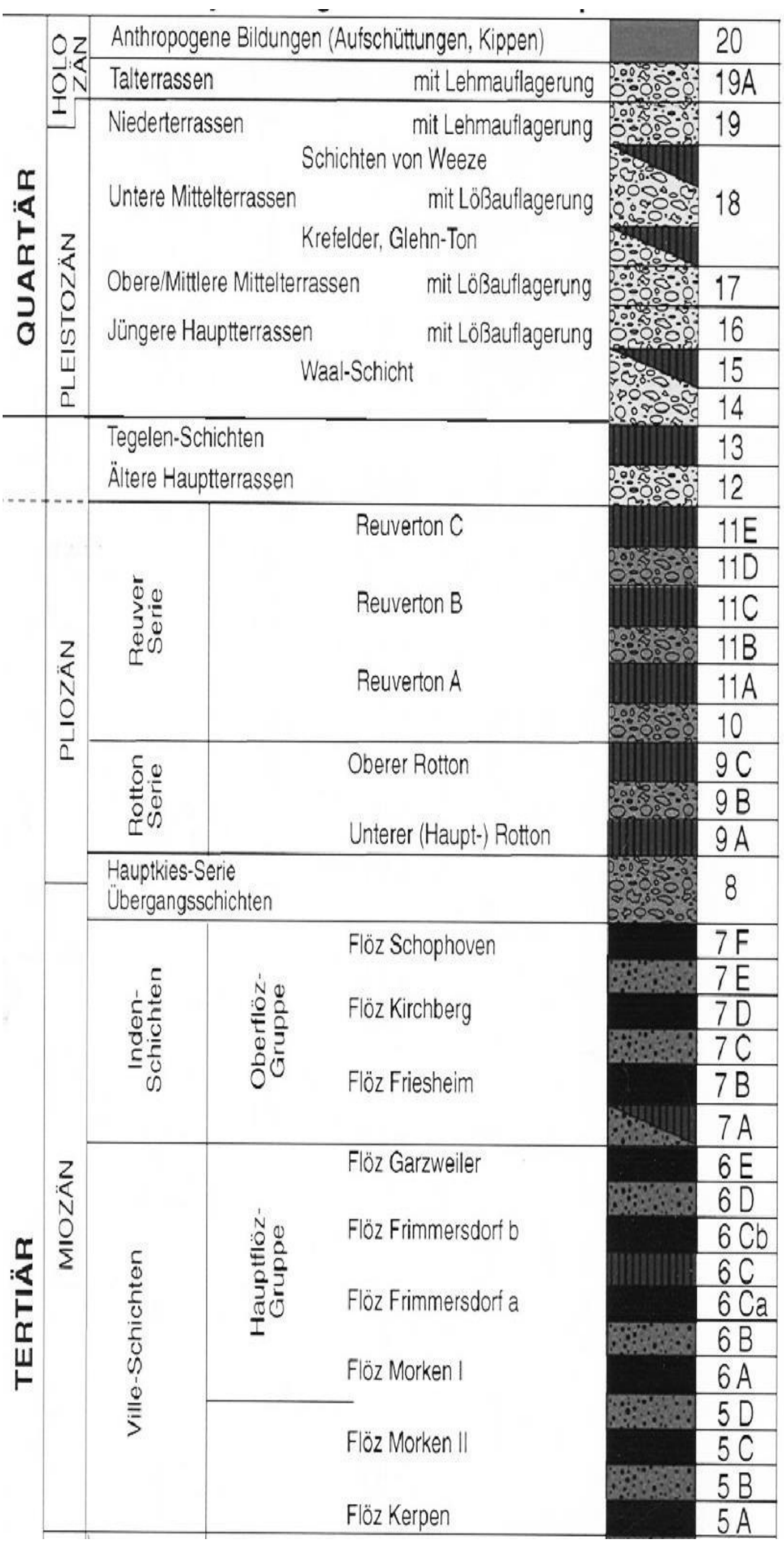
Text-fig. 1: District map of the coal fields from the Lower rhenish embayment with several opencast mines



Text-fig. 2: Profiles of every opencast mine in the browncoal district



Text-fig. 3: Lower Rhenish Embayment with Miocene and Pliocene coastlines from the North Sea with distribution of the „Hauptflözgruppe (main seam group) and „Oberflözgruppe (Upper seam group).



Real Hambach Profile

div. Sands, Clays

yellow sands and gravels with intercalated clays

Potamogeton-horizon

Cyclocarya-erosion channel
Coal C
Coal B
Coal A
Sequence of grey clays, coaly horizons, green clay, Reuver-gastropods
?
?
Without gaps
?
?
?

Sands, clays, coals
Transition Inden-HKS

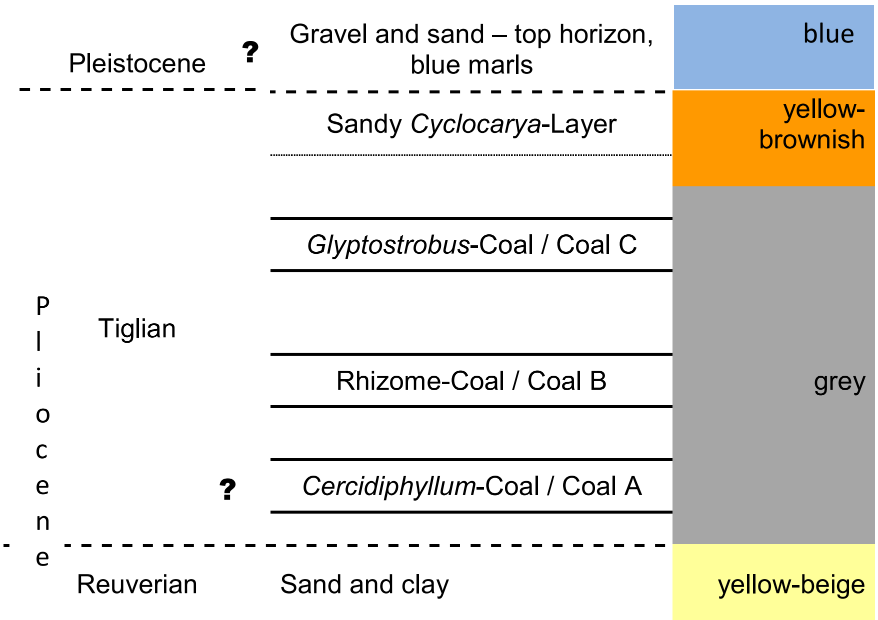
Quasisequoia-coal horizonErosional channel, Sands, clays,

No seams in the Oberflöz-Gruppe (upper seam group)
Seam Garzweiler, lumpy browncoal with more xylites

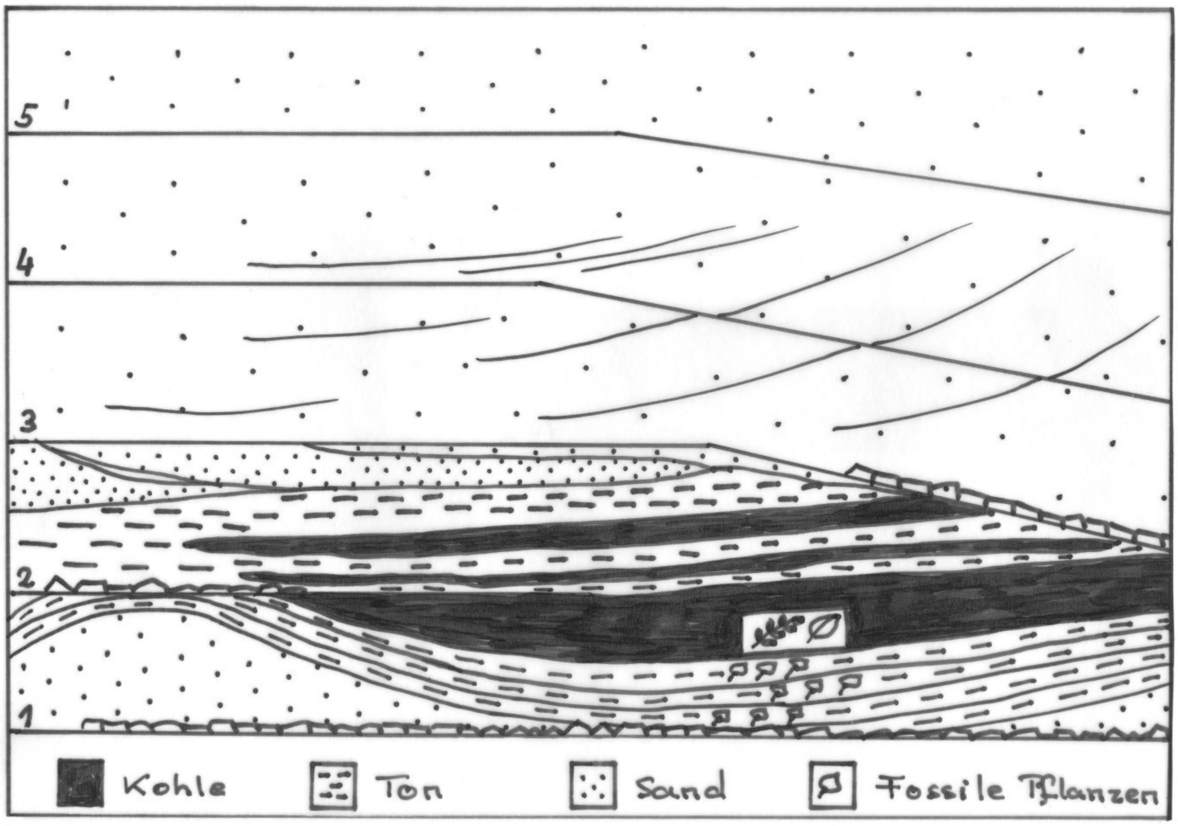
Transition to seam Frimmersdorf (no a,b),

basal clay

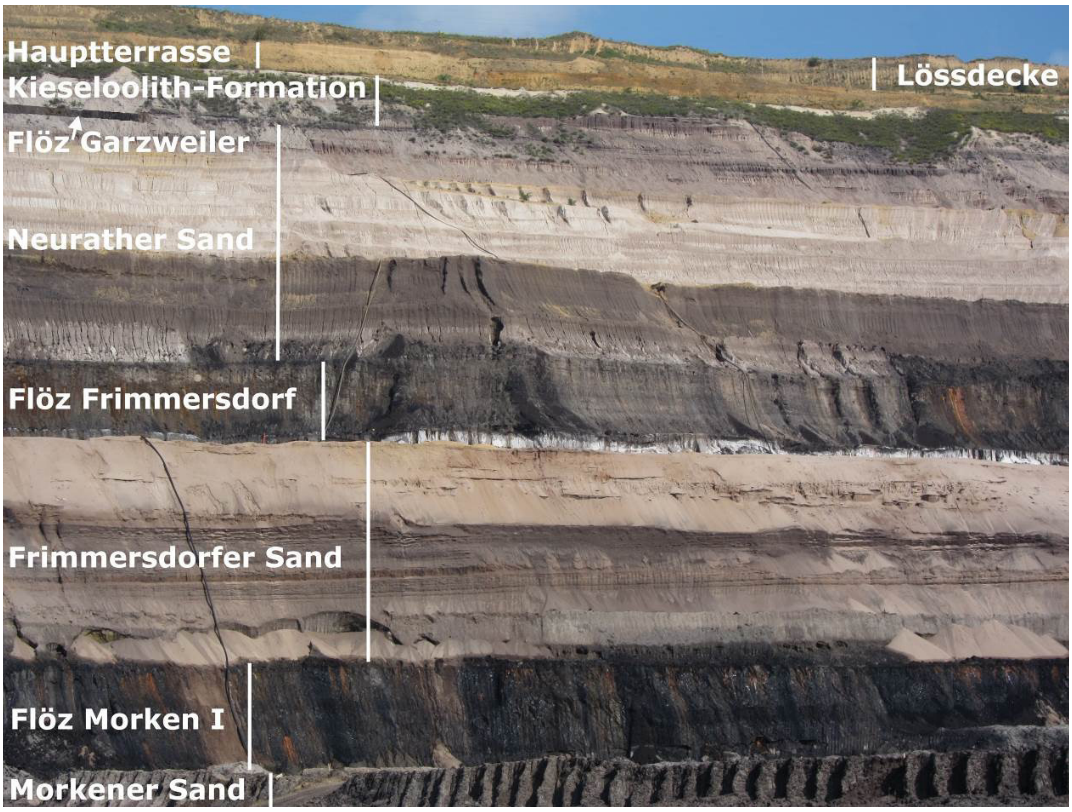
Text-fig. 4: Ideal profile after SCHNEIDER & THIELE 1965 in the opencast coal mines of the RWE and to the right with special names and remarks of the layers in opencast mine Hambach



Text-fig. 5: The uppermost top of the sequence after the Reuverian are three coal horizons, a sandy intercalation and then the poor water-flora with *Potamogeton*, upwarding the loess layer and fertile soils as a cover (Opencast mine Hambach).

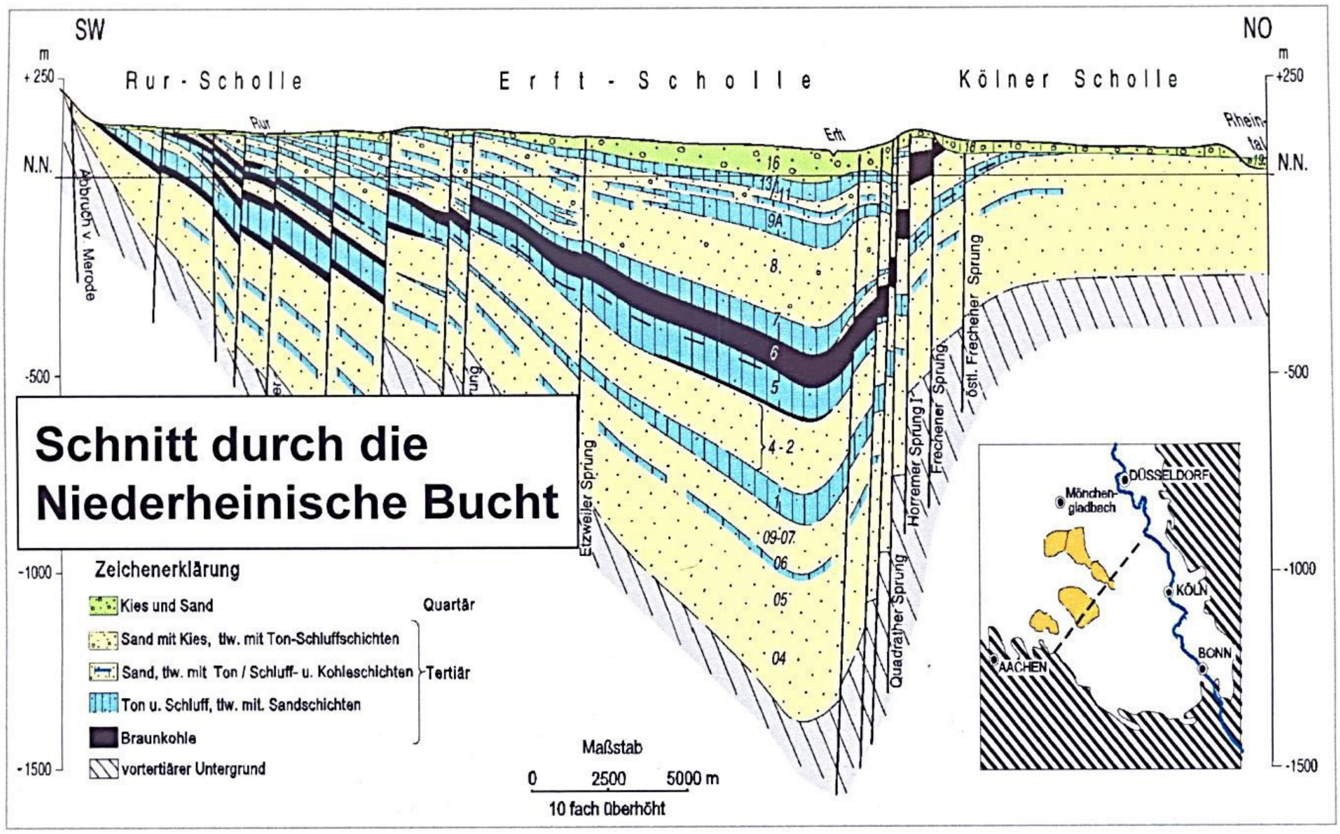


Text-fig. 6: Profile on level 4 in opencast mine Hambach (1995) with *Quasisequoia* seam



Text-fig. 7: Profile through the opencast mine Garzweiler. Layers near the Northern rim oft he field (2015). Height about 180 meters

Text-fig. 8: The northern rim oft he outcrop shows the series of layers oft he Inden opencast mine; springtime 2017. Profile about 210 m high. Depending on the standpoint and of angle the horizons 7A and seam Friesheim seem superelevated.



Text-fig. 9: Transverse cut through the Lower Rhenish Embayment with many faults and in black the tectonically disturbed coal horizons

1 Regional Stratigraphy	**2 Opencast mine Hambach**	**3 Opencast mine Garzweiler**	**4 Opencast mine Inden**	**5 Internal structure - horizon**
Pleistocene	Löss, jounger main terraces	Löss, jounger main terraces	Löss, jounger main terraces	16
Hiatus	Hiatus	Hiatus	Hiatus	14-15
Pliocene	Tegelen/terrace	Hiatus	Hiatus	13
Incorrect!Pre-Tiglian	Coal A-C (Pre-Tiglian)	Pretiglian (?)	Hiatus	12
Upper Pliocene	Reuver clay	Reuver clay	Reuver clay	11
Upper Pliocene	Reuver sand	Hiatus	Reuver sand	10
LowerPliocene	Upper red clay Sandy intercalation Lower red clay	Hiatus	Upper red clay Sandy intercalation Lower red clay	9C 9B 9A
Lower Pliocene - Upper Miocene	Main gravel series	Main gravel series	Main gravel series	8
Upper Miocene	S. Schophov.?/clay? Inden strata sand Quasisequ. S.?/clay Inden strata sand Inden strata clay/sd. Inden strata clay	Hiatus	Seam Schophoven Inden strata sand Seam Kirchberg Inden strata clay Seam Friesheim Inden strata sand	7F 7E 7D 7C 7B 7A
Upper- to Middle Miocene	Seam Garzweiler (Neurath sands) p.p. Seam Frimmersdorf **Base**	Seam Garzweiler Neurath sands Seam Frimmersdorf Frimmersdorf sand Seam Morken I	Seam Garzweiler **Base**	6E 6D 6C 6B 6A
?Middle Miocene		Morken sand Seam Morken II **Base**		5D 5C

Table 1: opencast mines Hambach, Garzweiler and Inden with their special profiles in comparison (yellow-red=Hiatus, green-red= Pretiglian problematic stage or horizon, grey-green= problematic coal seams, grey=definitely coal seams)

Species/Taxon	**Number of individuals**	**Size in mm**	**Special remarks**
Magnolia sp.	120	5–10	15 with gnawing marks
Pinus sp.	19	24–68	
Polyspora kilpperi	3	30	gnawing
Rehderodendron ehrenbergii (+)	67	14–38	
Sequoia abietina	760	6–11	ca. 80 % with galls, caused by a gall insect *Sequoiomyia kraeuseli*
Pallioporia symplocoides (+)	118	12–28	16 fruits, 102 endocarps, 1 specimen with gnawing
Sphenotheca incurva (+)	133	10–17	6 with gnawing
Mastixia sp.	553	10–25	28 with gnawing
Eomastixia menzelii (+)	220	26–57	130 fruits, 90 endocarps
Tectocarya rhenana (+)	61	26–53	fruits, 1 with gnawing

Table 2: First impression about the diaspores from opencast mine Inden, size larger 5 mm; + fruits with exocarp (endocarps without it).

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Plates 1-19

Collections, mentioned in the text for the plates, with inventory numbers following:

Natural History Museum Augsburg, NMA Inv.Nr…

Coll. Laboratory of Palaeobotany and Palynology, Utrecht,

The Netherlands: Coll. Utrecht…No.

Coll. LIEVEN, Nr. …

Coll. SCHMITT, Nr.…

Coll. PÜTTER

The excursions of the working group by H.-J. GREGOR can be found in the E-numbers

(f.e. E 800/x)

PLATE 1

Fig. 1-6: Opencast mine Hambach

Fig. 1: *Pinus spinosa,* opencast mine Hambach, 3rd level, Inden layer (7F clay), middle Miocene, (NMA Inv.Nr. 2014-1/1084), (E 726/12), length about 13 cm
Fig. 2: *Pinus timleri* in the field, opencast mine Hambach, 3rd level, transition HKS to Rotton, upper Miocene-Lower Pliocene clay,, (NMA Inv.Nr. 2014-3/1979), (E 957-12B)
Fig. 3: *Pinus timleri,* prepared specimen with large basal scales; for data, see fig. 2
Fig. 4: *Pinus timleri,* opencast mine Hambach, 3rd level, lower Rotton, (hor. 9A), Coll. H. PÜTTER (Geilenkirchen)
Fig. 5: *Pinus timleri,* magnification of scales from fig. 4
Fig. 6: *Pinus spinosa*, large cone, compressed with only resin strands remaining, opencast mine Hambach, 6th level, seam Frimmersdorf, (hor. 6C), middle Miocene, (Coll. LIEVEN, Nr. 5666)

Fig. 7: Xylite, small branch with very thin growth rings, opencast mine Garzweiler, Hauptflöz, seam Garzweiler, (hor. 6E), (Coll. LIEVEN, Nr. 5534)

PLATE 1

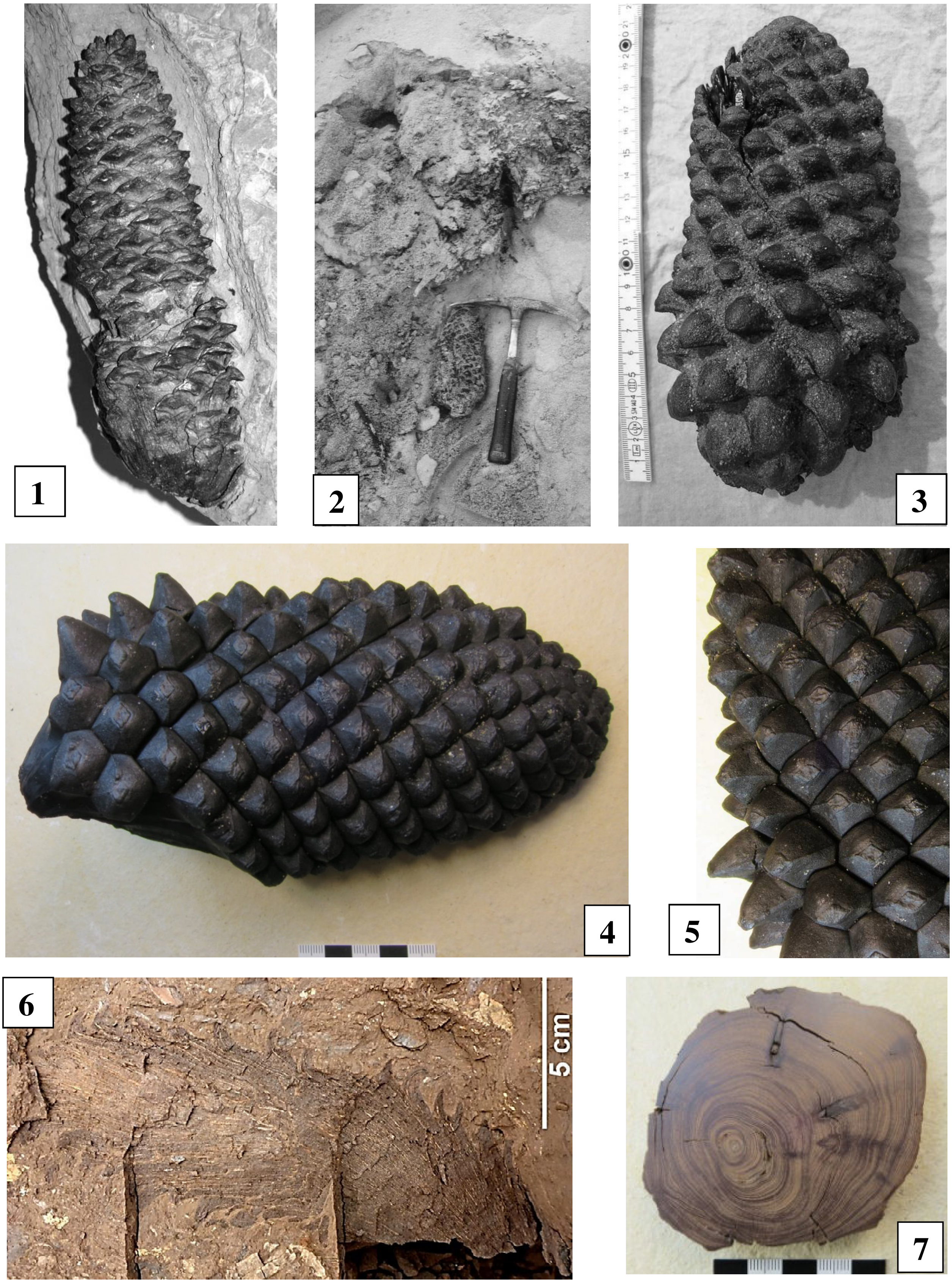

PLATE 2

Fig. 1-7: Opencast mine Hambach

Fig. 1: *Osmunda (Osmundites) dowkeri,* 2nd level, Tiglian, Rhizome-coal B, (Coll. LIEVEN Nr. 2217)
Fig. 2: Fossilized wood with borings, 3rd level, Rotton-Series, (hor. 10), (Coll. LIEVEN Nr. 3394)
Fig. 3: *Pinus* sp., mit stark destruierten Schuppen am Konus, 3rd level, sandy Reuver clay, (hor. 10), (Coll. LIEVEN Nr. 5503, 2016)
Fig. 4: *Pinus timleri,* abgerolltes Exemplar, lower Pliocene, rotton series, lower Pliocene, (hor. 9B) (Coll. LIEVEN Nr. 3394, 1994)
Fig. 5: *Pinus timleri*, 3rd level, Rotton Serie, (hor. 9B), (Coll. LIEVEN Nr. 2100)

Fig. 6: *Trapa baasii*, 3rd level, lower (main-)Rotton, (hor. 9A), (Coll. LIEVEN Nr. 2248)

Fig. 7: *Carpinus betulus* foss., 3rd level, lower (main-) Rotton-series, (hor. 9A), (Coll. LIEVEN Nr. 2238 b)

PLATE 2

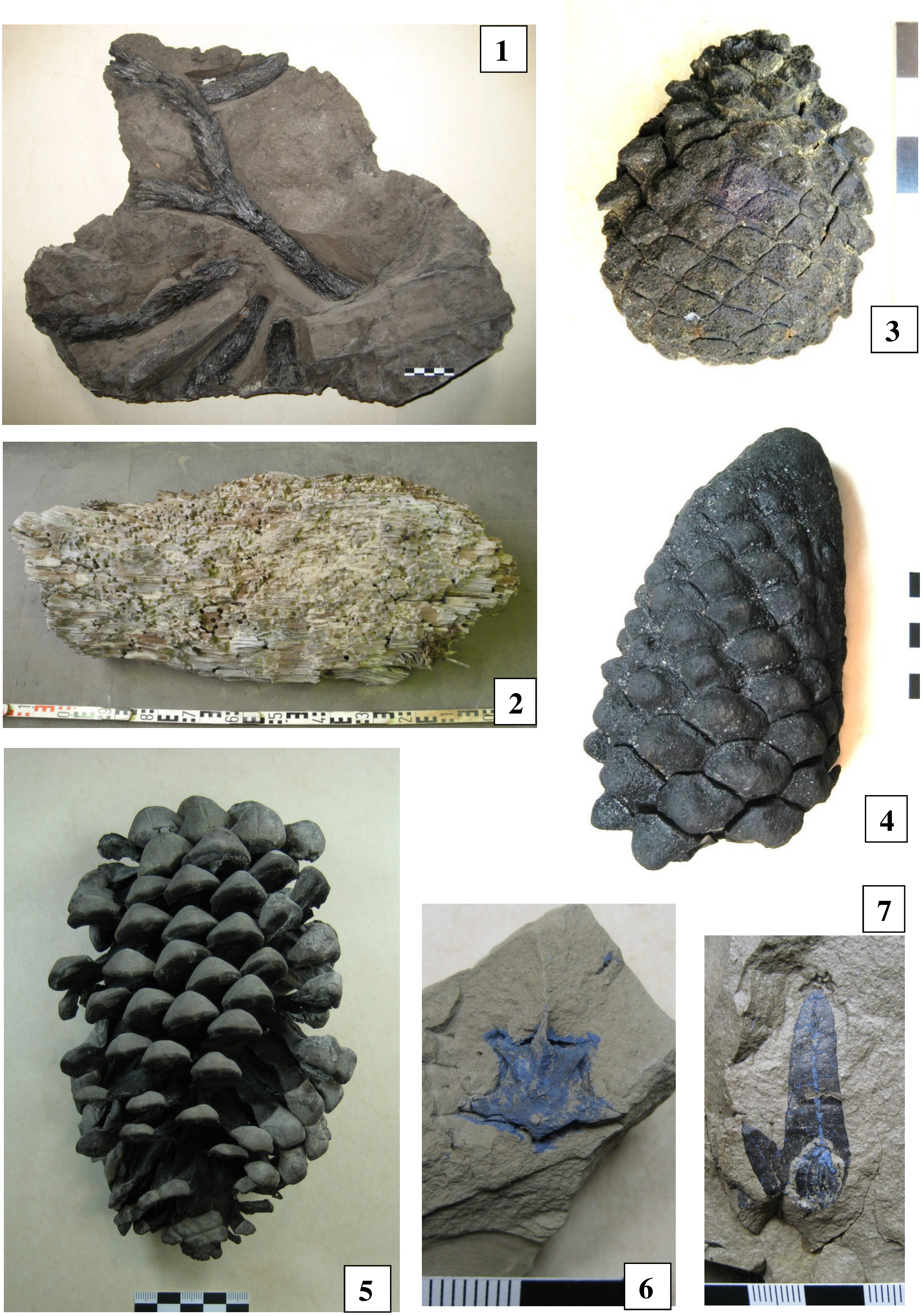

PLATE 3

Fig. 1-9: Opencast mine Hambach

Fig. 1: *Dombeyopsis lobata*, 4th level, Inden layers, Clay7, (Coll. LIEVEN Nr. 1296)

Fig. 2: *Byttneriophyllum tiliaefolium*, 4th level, Inden layers, Clay7, (Coll. LIEVEN Nr. 1299)

Fig. 3: *Fagus haidingeri*, 4th level, Inden layers, Clay7, (Coll. LIEVEN Nr. 2264)

Fig. 4: *Dombeyopsis lobata*, 5th level, Inden layers, (hor. 7A), (Coll. LIEVEN Nr. 2419)

Fig. 5: *Taxodium dubium*, 5th level, Inden layers, clay7, (Coll. LIEVEN Nr. 2137)

Fig. 6: *Parrotia pristina*, 5th level, Inden layers, (hor. 7A), (Coll. LIEVEN Nr. 2422)

Fig. 7: *Craigia bronnii*, 4th level, Inden layers, clay 7E, (Coll. LIEVEN Nr. 4700_A – positive imprint)

Fig. 8: *Craigia bronnii,* see Fig. 7, (Coll. LIEVEN Nr. 4700_B – negative imprint)

Fig. 9: *Koelreuteria macroptera,* Inden clay, (E 1141-25A), (Coll. LIEVEN, No. 4701)

PLATE 3

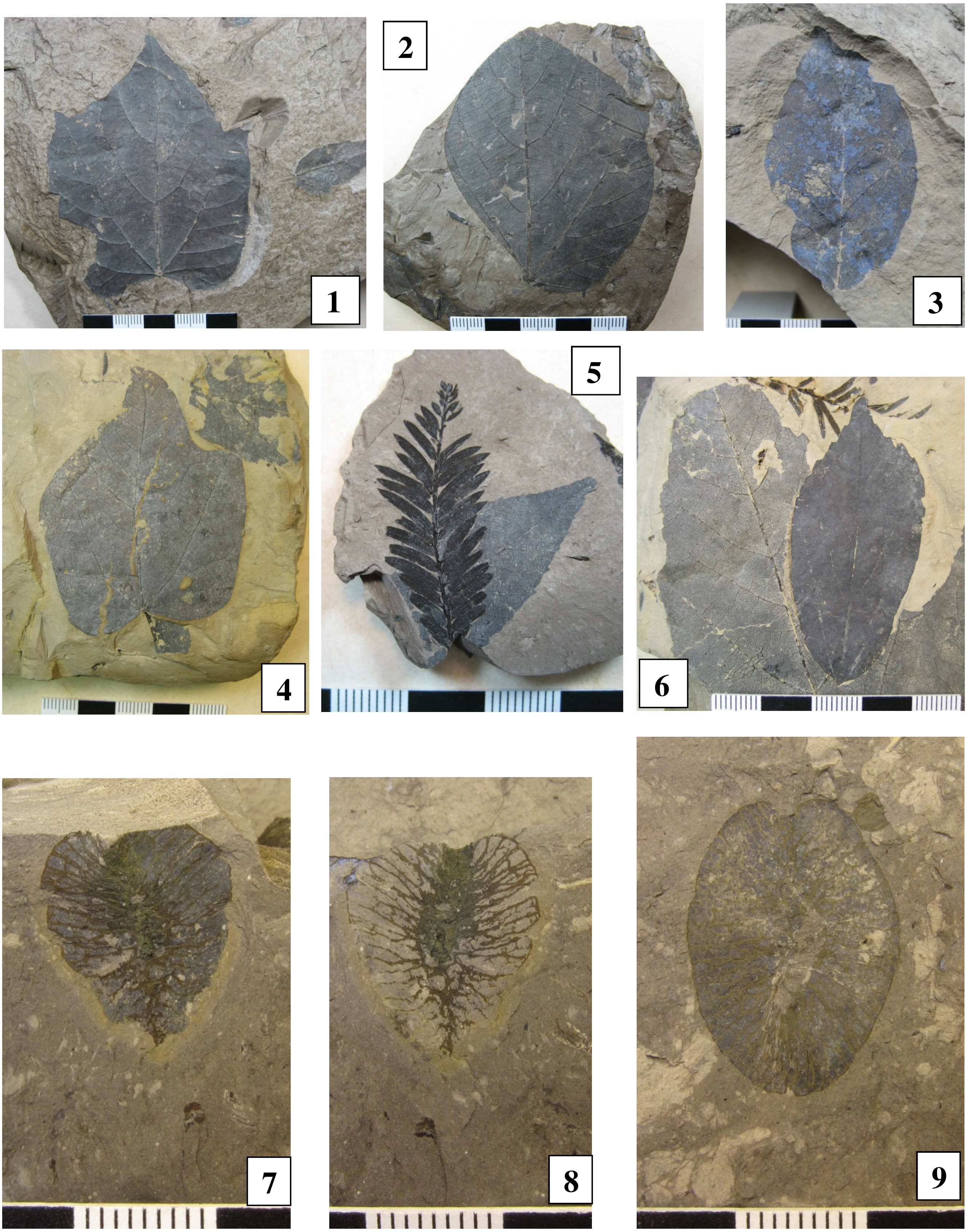

PLATE 4

Fig. 1-7: Opencast mine Hambach

Fig. 1: *Corylopsis urselensis*, capsules on a twig, 3rd level, lower (main-)Rotton, (hor. 9A) (Coll. LIEVEN Nr. 2239)

Fig. 2: Capsule of *Fagus decurrens*, 3rd level, lower (main-)Rotton, (hor. 9A) (Coll. LIEVEN Nr. 2233)

Fig. 3: Leaf of *Liriodendron procaccinii*, 5th level, Inden layers, clay 7 (Coll. LIEVEN Nr. 2125)

Fig. 4: *Daphnogene* sp., aberrant *Cinnamomum* leaf, caused by insect bite (?), 5th level, Inden layers, clay7 (Coll. LIEVEN Nr. 2151)

Fig. 5: Vascular bundles from a palm stem, opencast mine Hambach, 6th level, seam Garzweiler (E 1076-13), photo in the field

Fig. 6: Triangular leaf scars from a palm stem, opencast mine Hambach, 6th level, seam Garzweiler (E 1076-13), photo in the field

Fig. 7: Leaf composition on a clay plate, opencast mine Hambach, 6th level, over seam Garzweiler (hor. 7) (E 1121-3), photo in the field

PLATE 4

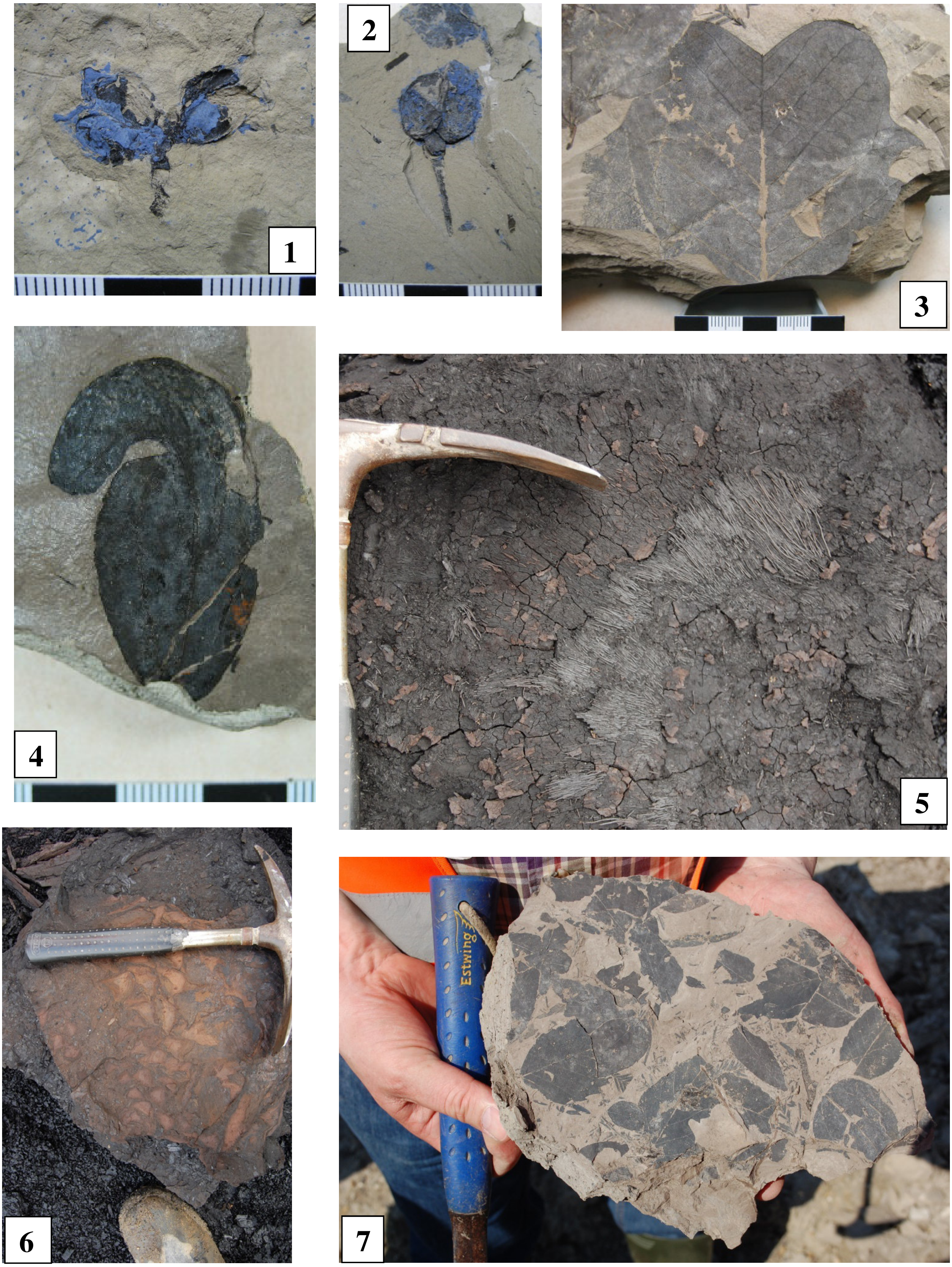

PLATE 5

Fig. 1-7: Opencast mine Garzweiler

Fig. 1: Leaf of *Fagus haidingeri,* 1st level, Reuver-Series, (hor. 11), uppermost part, Otzenrath-clay, (Coll. LIEVEN Nr. 2178b)

Fig. 2: Leaf of *Fagus haidingeri* with blue vivianite on the surface , 1st level, Reuver-Serie, (hor. 11), Otzenrath-Ton, (Coll. LIEVEN Nr. 2207 A)

Fig. 3: *Quercus roburoides*, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2178_d)

Fig. 4: *Populus crenata*, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2298)

Fig. 5: *Zelkova zelkvaefolia* with fruitlets, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2460)

Fig. 6: *Cyclocarya cyclocarpa* with round wing, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2169_a)

Fig. 7: Magnification of the fruitles of *Zelkova*, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2305 b)

PLATE 5

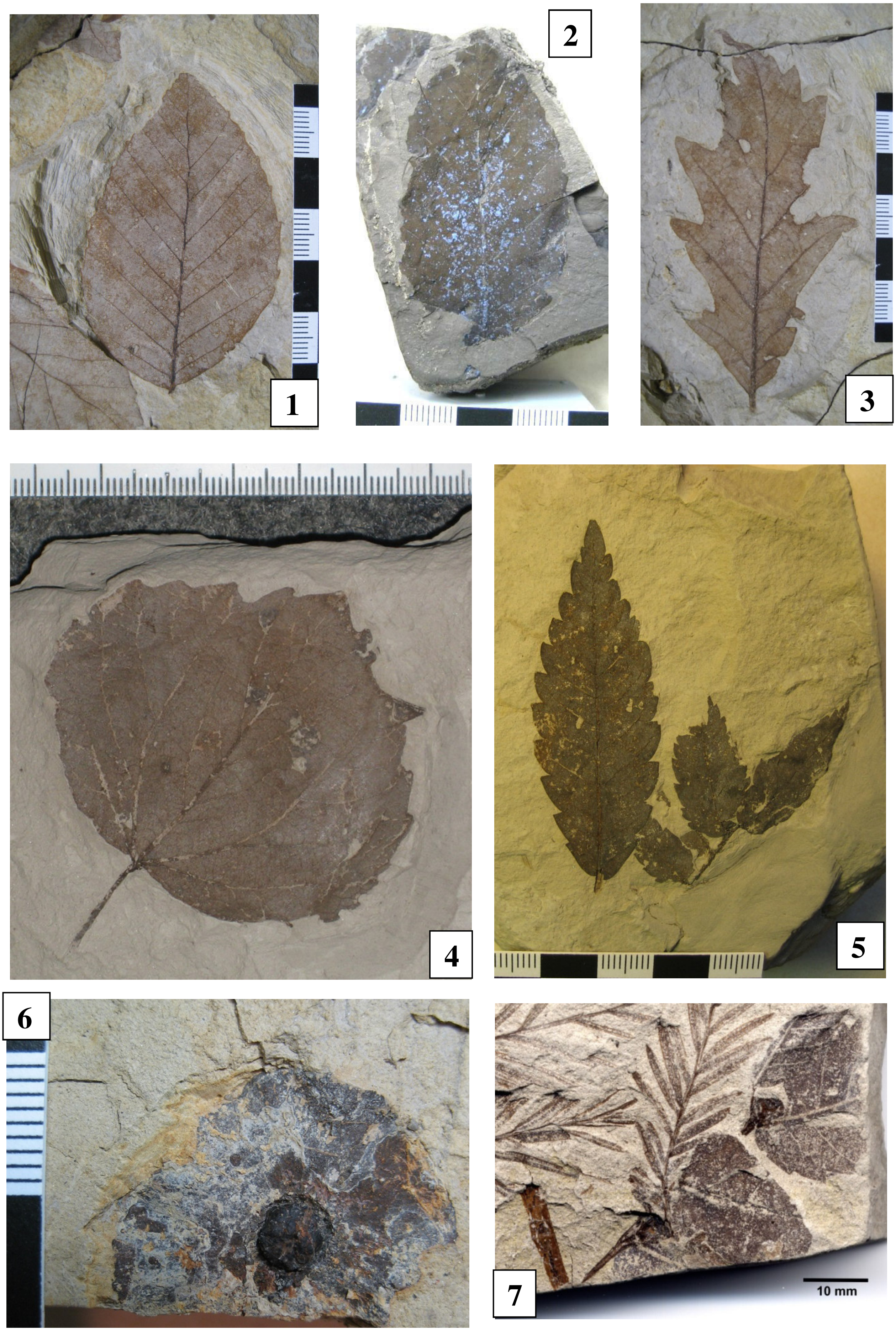

PLATE 6

Fig. 1-7: Opencast mine Garzweiler

Fig. 1: *Liquidambar lievenii*, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2294 a, holotype, NMA Inv.Nr. 2006-11/1966)

Fig. 2: *Salix* sp., 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2181 j)

Fig. 3: *Rhizocaulon garzweilerense*, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2308, Holotype)

Fig. 4: *Liquidambar lievenii,* 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-Ton, (Coll. LIEVEN Nr. 2459a)

Fig. 5: *Picea latisquamosa* in excellent preservation, 2nd level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath clay, (Coll. LIEVEN Nr. 3234)

Fig. 6: *Pterocarya* cf. *pteleaefolia*, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath clay, (Coll. LIEVEN Nr. 2183)

Fig. 7: *Glyptostrobus europaeus*, cones in compound, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath clay, (Coll. LIEVEN Nr. 2364 a)

PLATE 6

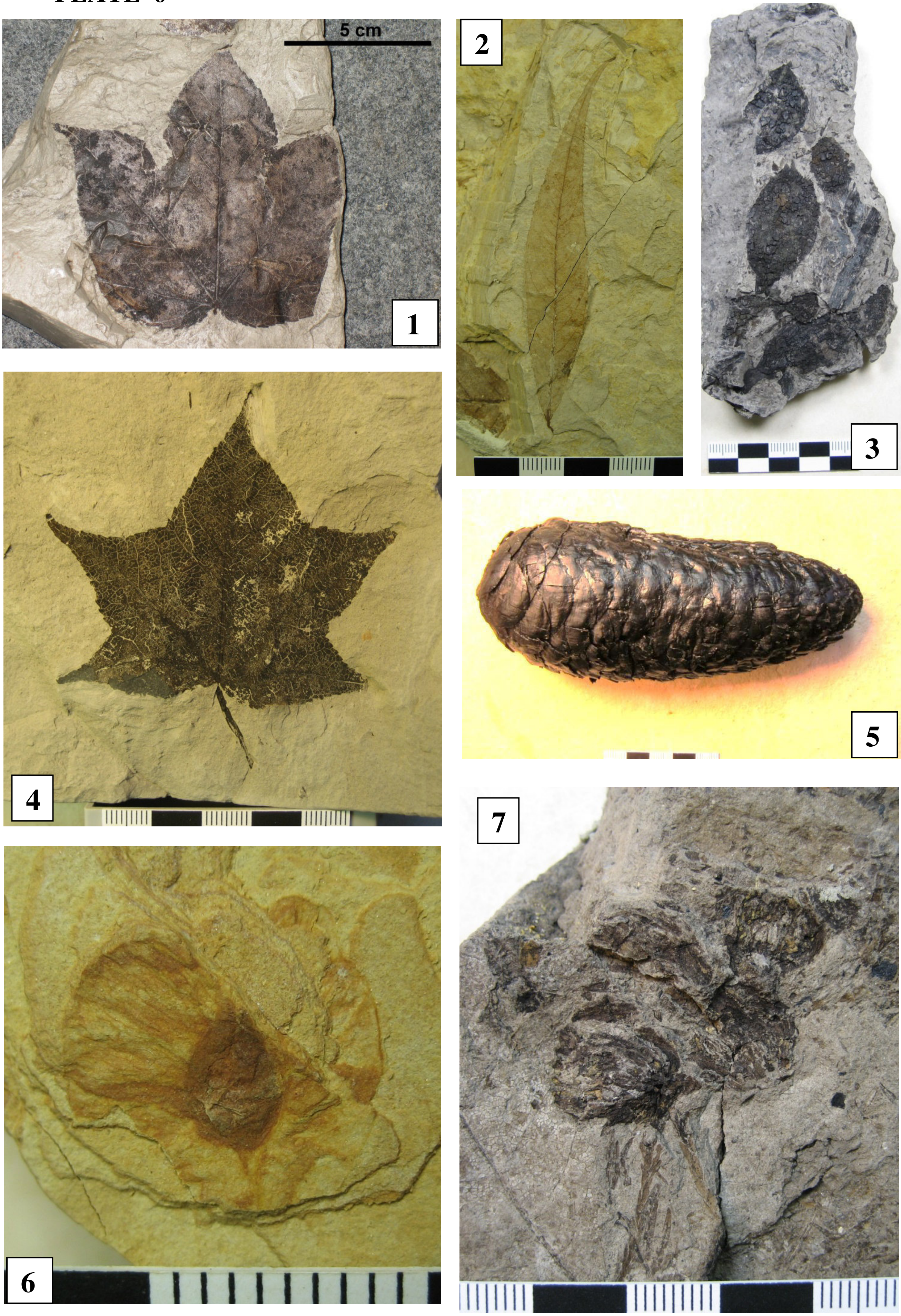

PLATE 7

Fig. 1-7: Opencast mine Inden

Fig. 1: *Eomastixia menzelii* without Endocarp, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5271)

Fig. 2: *Rhederodendron ehrenbergii*, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5275)

Fig. 3: *Tectocarya rhenana*, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5277)

Fig. 4: *Mastixia amygdalaeformis*, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5273)

Fig. 5: *Eomastixia menzelii* with Endocarp *Eomastixia menzelii*, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5270)

Fig. 6: *Sequoia abietina*, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5276)

Fig. 7: *Pinus spinosa*, opencast mine Inden, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 2904)

Fig. 8: *Liquidambar magniloculata* with Vivianite in blue, opencast mine Hambach, 3rd level, Lower (main-) Rotton, (hor. 9A), erosional channel (E 957-12), diameter about 2 cm

Plate 7

PLATE 8

Fig. 1-8: Opencast mine Inden

Fig. 1: *Polyspora kilpperi*, 5th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 4998), from side

Fig. 2: *Polyspora kilpperi*, 5th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 4998), from above

Fig. 3: *Asimina brownii*, 5th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5226)

Fig. 4: *Pinus leitzii*, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5284)

Fig. 5: *Magnoliaestrobus gossmannii*, 5th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5253/4)

Fig. 6: *Magnoliaestrobus* sp., 5th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5252)

Fig. 7: *Pinus* sp., 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5286)

Fig. 8: Composition of *Pinus leitzii*, 4th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5274)

PLATE 8

PLATE 9

Fig. 1-3, 5, 7: Opencast mine Hambach
Fig. 4, 6: Opencast mine Inden

Fig. 1: *Acer vindobonense,* opencast mine Hambach, 6th level, (hor. 7), Clay (E 1121/21), photo in the field
Fig. 2: *Majanthemumphyllum petiolatum*, opencast mine Hambach, 6th level, Inden layer, (hor. 7D), (Coll. Utrecht No. 19523)
Fig. 3: *Juglans bergomensis*, opencast mine Hambach, Rotton-clay (hor. 9A), (Coll. LIEVEN Nr. 5575)
Fig. 4: In-situ-trunk with roots upright in the clayey sediment, opencast mine Inden, 5th Level, gray clays alternating with sandy ditches, below seam Friesheim, Inden layer, (hor. 7A?), (E 1168-11)
Fig. 5: *Carya pusilla* from a nut cache (*Picea* stem), opencast mine Inden, 4th level, Inden layer, (hor. 7E/F), (E 936/5c) (NMA Inv.Nr. 2014-2 /1939B)
Fig. 6: *Quercus roburoides,* opencast mine Inden, 4th level, Inden layer, clay (E 1076/4)
Fig. 7: *Acer* sp. – winged fruit, opencast mine Hambach, lower (main-) Rotton, (hor. 9A), (E 957-12), photo in the field, length about 7 cm

PLATE 9

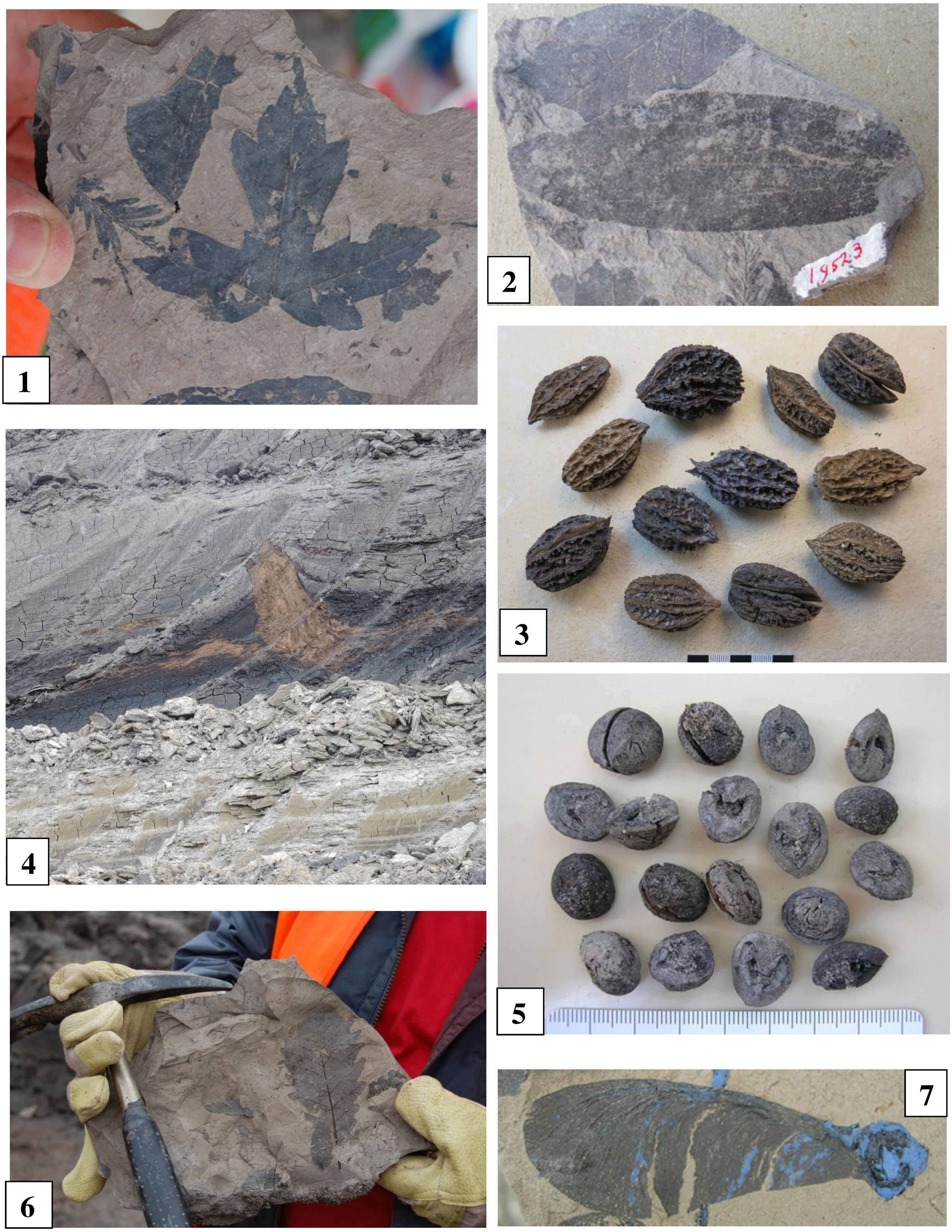

PLATE 10

Fig. 1-8: Opencast mine Hambach

Fig. 1: *Rhizocorallium* sp. (cf. *Rh. jenense*), an ichnofossil species, digging traces by Ephemeroptera larvae in sediment, opencast mine Hambach, Inden layer, photo in the field, opencast mine Hambach, clay with leaves, Inden layer, transition to HKS, (hor. 7F/8), Upper Miocene, (E 697/10B), (NMA Inv.Nr. 2014-1408/2189)

Fig. 2: Wing of a beetle in browncoal, opencast mine Hambach, seam Frimmersdorf (E 1141-19)

Fig. 3: Wood with boring traces, opencast mine Hambach, 3rd level, Reuverton sandy, (hor. 10), (Coll. LIEVEN Nr. 5502)

Fig. 4: *Mesodontopsis nehringii*, an exotic terrestrial gastropod, opencast mine Hambach, 1st level, green Reuverian clay, ((hor. 11), (Coll. Lieven, No. 4709)
Fig. 5: Pike fish *Esox* sp., tooth, opencast mine Hambach, upper clay, (Tiglian), Uppermost Pliocene, (E 836/2), (NMA Inv.Nr. 2014-1350/1780)
Fig. 6: *Rhizocaulon hambachense* rhizome bulb with rootlets, Holotype 2015-57/2206 NMA, opencast mine Hambach, 5th Level, Inden-layer, grey clay, (E 1106-17)
Fig. 7: *Trametites* sp., opencast mine Hambach, 2nd Level, (hor. 11-13) Reuverian, (E 697/6),
Fig. 8: Lower jaw of a micromammal from the upper clay, (Tiglian), Uppermost Pliocene, (E 919/10, 20, 21), (NMA Inv.Nr. 2014-1352/1780)

Fig. 9-10: Opencast mine Inden

Fig. 9: Gnawings on a *Tectocarya rhenana*, opencast mine Inden, 5th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5257)

Fig. 10: *Pallioporia symplocoides* with gnawings, opencast mine Inden, 5th level, upper seam group, Inden-layers, (hor. 7E), (Coll. LIEVEN Nr. 5255)

PLATE 10

PLATE 11

Fig. 1: *Ginkgo adiantoides* in clay, opencast mine Hambach, 4th level, Inden layer, clay, (E 1197/7)

Fig. 2: *Ginkgo adiantoides* leaf (cuticles), size: 50x32 mm, opencast mine Inden, 4th level, Inden layer, clay-sand, (E 1076/4), (Coll. SCHMITT, No. D-144-I-02-04)
Fig. 3: *Ginkgo adiantoides* leaf (cuticles), size: 17x22 mm, opencast mine Inden, 4th level, Inden layer, clay-sand, (E 1076/4), (Coll. SCHMITT, No. D-144-I-02-01A)
Fig. 4: "*Bromliaceaephyllum Bromeliaceophyllum rhenanum*, opencast mine Garzweiler, 5th level, Ville layers, seam Frimmersdorf, (hor. 6C), (Coll. LIEVEN Nr. 2620)

Fig. 5: Large plate of clay with many leafs on it, opencast mine Garzweiler, 1st level, Reuver-Serie, (hor. 11), uppermost part, Otzenrath-clay, (Coll. LIEVEN Nr. 2180)

PLATE 11

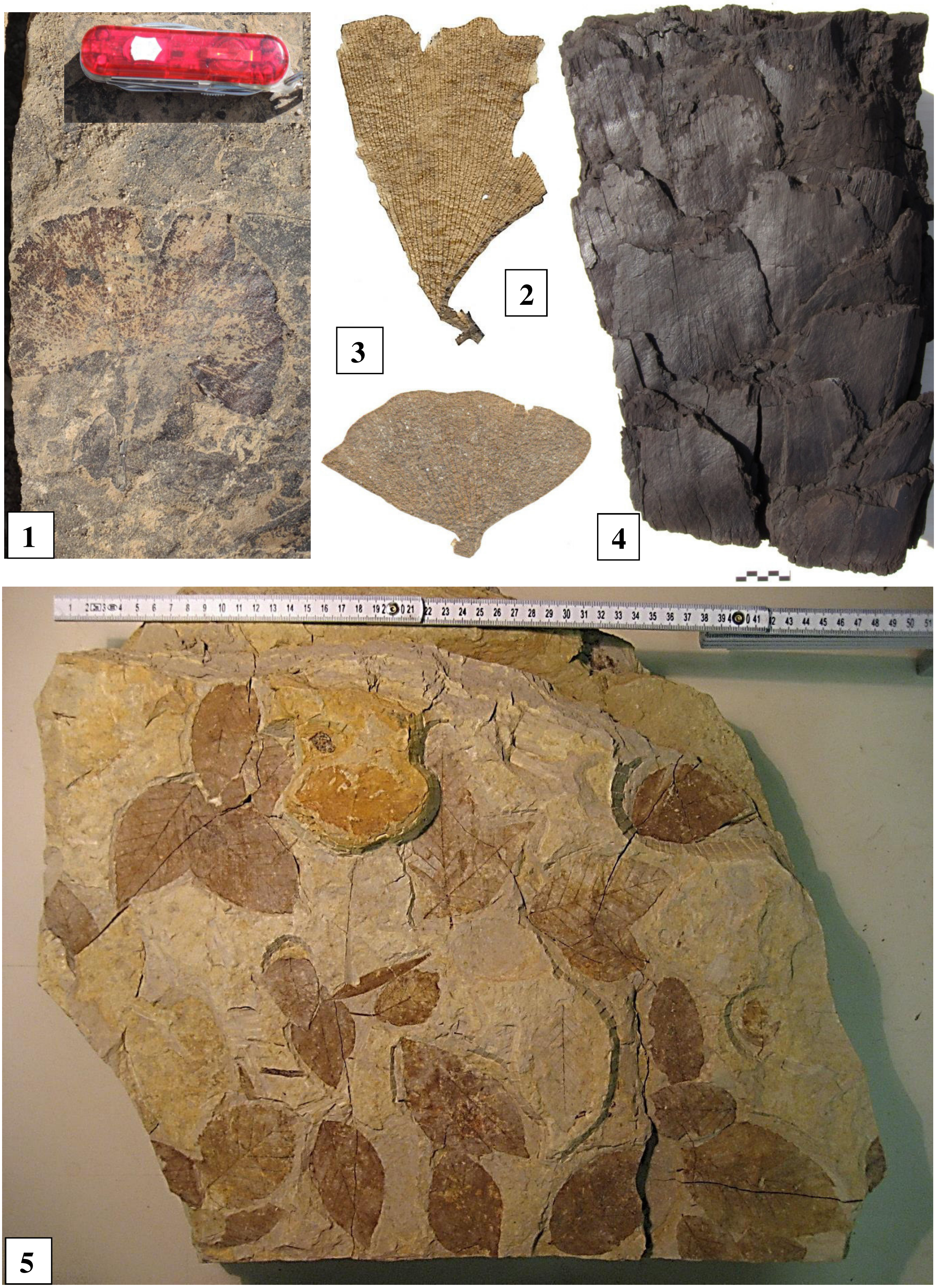

Plate 12

Fig. 1: Trunks in the HKS, opencast mine Hambach, 3rd Level, upper Miocene, (E 1173-21A)

Fig. 2: Trunk with roots in situ, cut by buckett wheel excavator, opencast mine Hambach, 6th level, seam Garzweiler, (E 1106-20B)

Fig. 3: Lignitc browncoal (Xylite) in opencast mine Inden, seam Garzweiler, 4th level, (E 1076-4)

Fig. 4: Folded wood (due to tektonic pressure) in opencast mine Inden, Inden layers-sand, 4th level, (1058-14)

Fig. 5: Palmrhachis fusitized in browncoal, opencast mine Hambach, 6th level, seam Garzweiler, (E 1121-14), photo in the field

Fig. 6: Bark with overlapping areas, *Palaeocortex lievenii* GREGOR nov. spec. (Coll. LIEVEN Nr. 4985), (NMA Inv.Nr. --/ Holotype, in progress), opencast mine Hambach, Rotton-Series, (hor. 9B), Lower Pliocene

Fig. 7: *Quasisequoia* seam, opencast mine Hambach, 4th level, Inden layer, clay, (E 772-5, 1995)

Fig. 8: *Quasisequoia couttsiae* seeds occurring very frequently in the coaly clays, Hambach seam Frimmersdorf (E 607-1 and E 566-5), (No 2015-565/2185 NMA), (cf with Fig. 7)

PLATE 12

PLATE 13

Fig. 1: Excavating crew with a bucket wheel excavator in the background, opencast mine Hambach

Fig. 2: The Tiglian clay in opencast mine Garzweiler with sampling geologist

Fig. 3: Opencast mine Hambach with the top layers and yellow terrace gravels, Plio-Pleistocene, (E 1076/23)

Fig. 4: Three coal horizons at the top in Hambach, Reuver (basal) to Tiglian, (gray-yellow transition), coal A-C, (E 1076/23-24), 1st level below point 2151, northern embankment

Fig. 5: Opencast mine Inden with sand lens, drift layers over coal seam, basal Inden layers, drifter lens with cones, fruits, wood, twigs, etc., (E 1168-11)

Fig. 6: Top of Hambach, whole sequence, transition P/Pl, see fig. 4

Fig. 7: Coal seam Frimmersdorf in opencast mine Hambach, with working group,

Fig. 8: Basal clay and coaly clay, opencast mine Hambach, channel below seam Frimmersdorf, clay, (hor. 6B), (E 1076-11)

PLATE 13

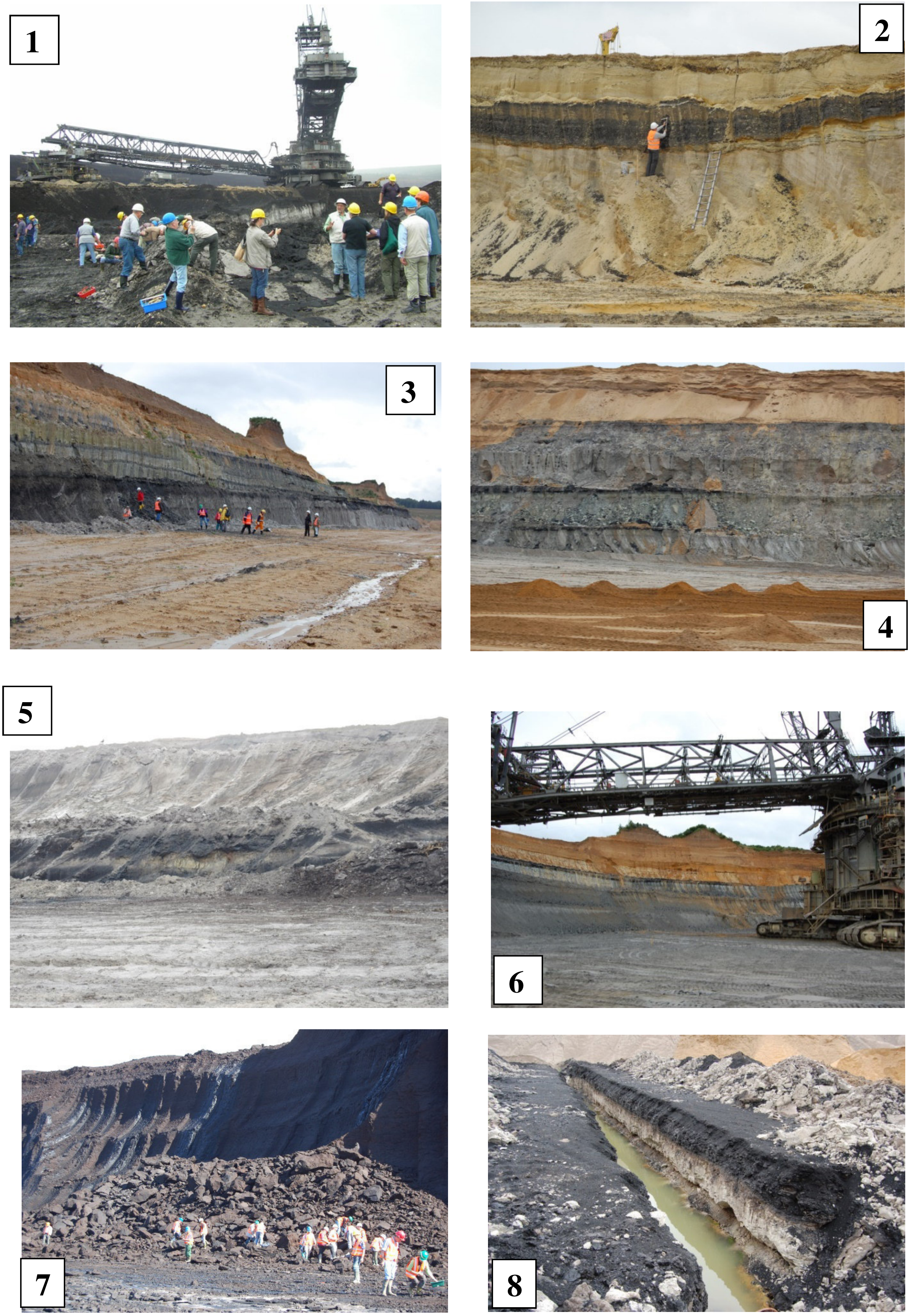

PLATE 14

Fig. 1: View on opencast mine Hambach 2017 (photo U. LIEVEN)

Fig. 2: View on opencast mine Garzweiler 2017 (photo U. LIEVEN)

Fig. 3: View on opencast mine Inden 2017 (photo U. LIEVEN)

Fig. 4-7: Opencast mine Inden, impressions of the Mastixioidean flora, Inden layers, Basal drifter lens with cones, fruits, wood, twigs, etc., (E 1168-11)

Fig. 4: Lens with fruits in the erosional horizon

Fig. 5: Magnification of the fruit layer with abundant diaspores

Fig. 6: The cone layer with sequoia-cones

Fig. 7: Sieve with hundreds of mastixias washed out

Plate 14

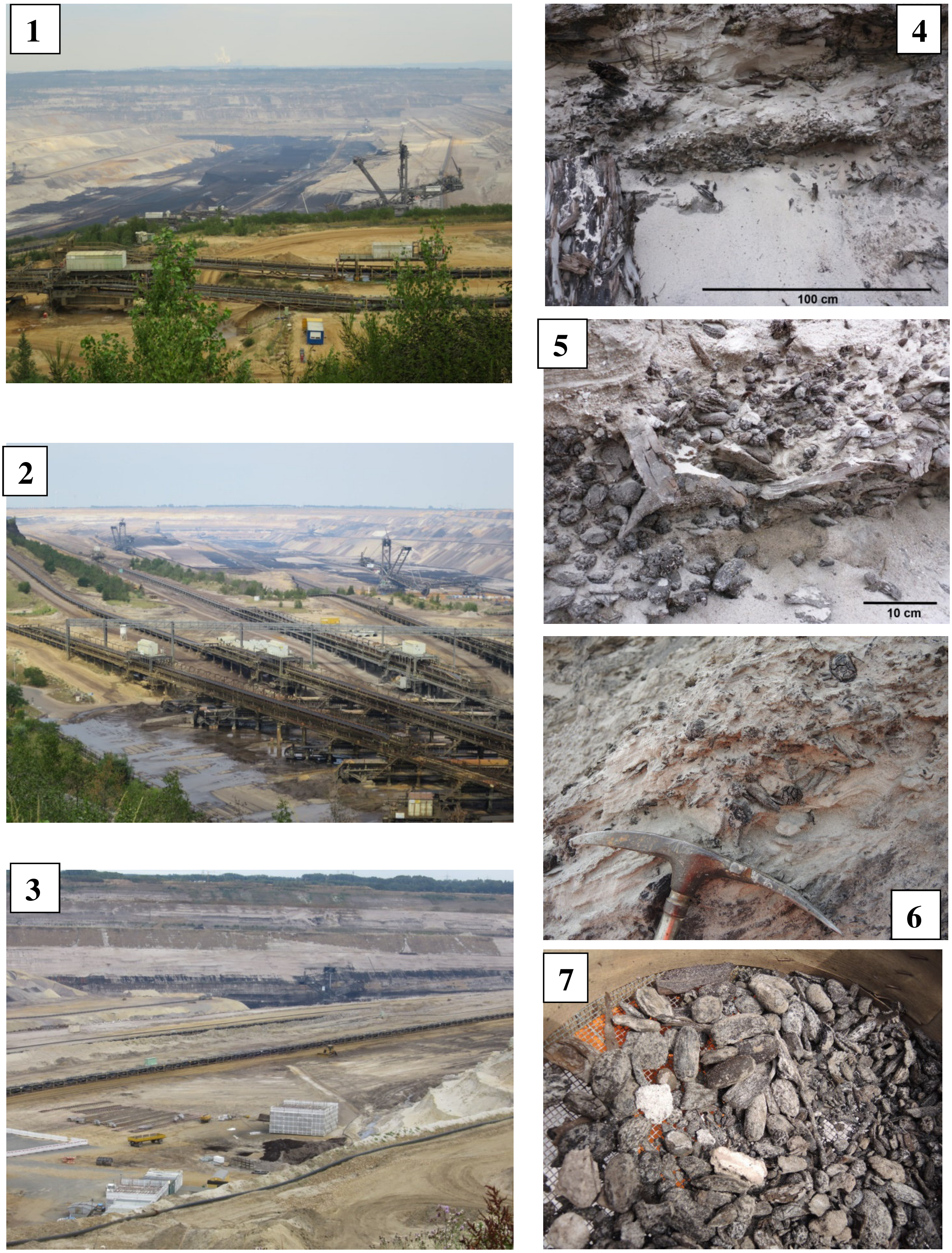

PLATE 15

Fig. 1-3: long stem of *Taxodioxylon germanicum* (9,5 m), opencast mine Garzweiler, Frimmersdorf sand, (hor. 6C), with smooth surface, in the sand layer below seam Frimmersdorf

Fig. 1: Long stem in sands of the Frimmersdorf seam

Fig. 2: Transverse section with a size comparison (diameter 80 cm) (different sections in different museums)

Fig. 3: The giant log lying in open air, waiting for transport

PLATE 15

1

2

3

PLATE 16

Fig. 1: *Pinuxylon parrioides* (left) and Cupressaceae (right), two smaller trunks in the coal of opencast mine Garzweiler, seam Garzweiler, (hor. 6E), (E 1070/11G5-left, 11G1-right)
Fig. 2: Amber on a small twig of Cupressaceae (s.l.), much gagatised (det. M. DOLEZYCH), opencast mine Inden, 5th level, 3 m above base of seam Friesheim, Oberflözgruppe, Inden layers, upper Miocene, (hor. 7B, 2013)
Fig. 3: Magnification of the amber "pearls" from fig. 2

Fig. 4: *Ophiomorpha nodosa*, opencast mine Garzweiler, 5th Level, Frimmesdorfer Sand, (photo in the field 2017, U. LIEVEN), size of a tube about 15 cm

PLATE 16

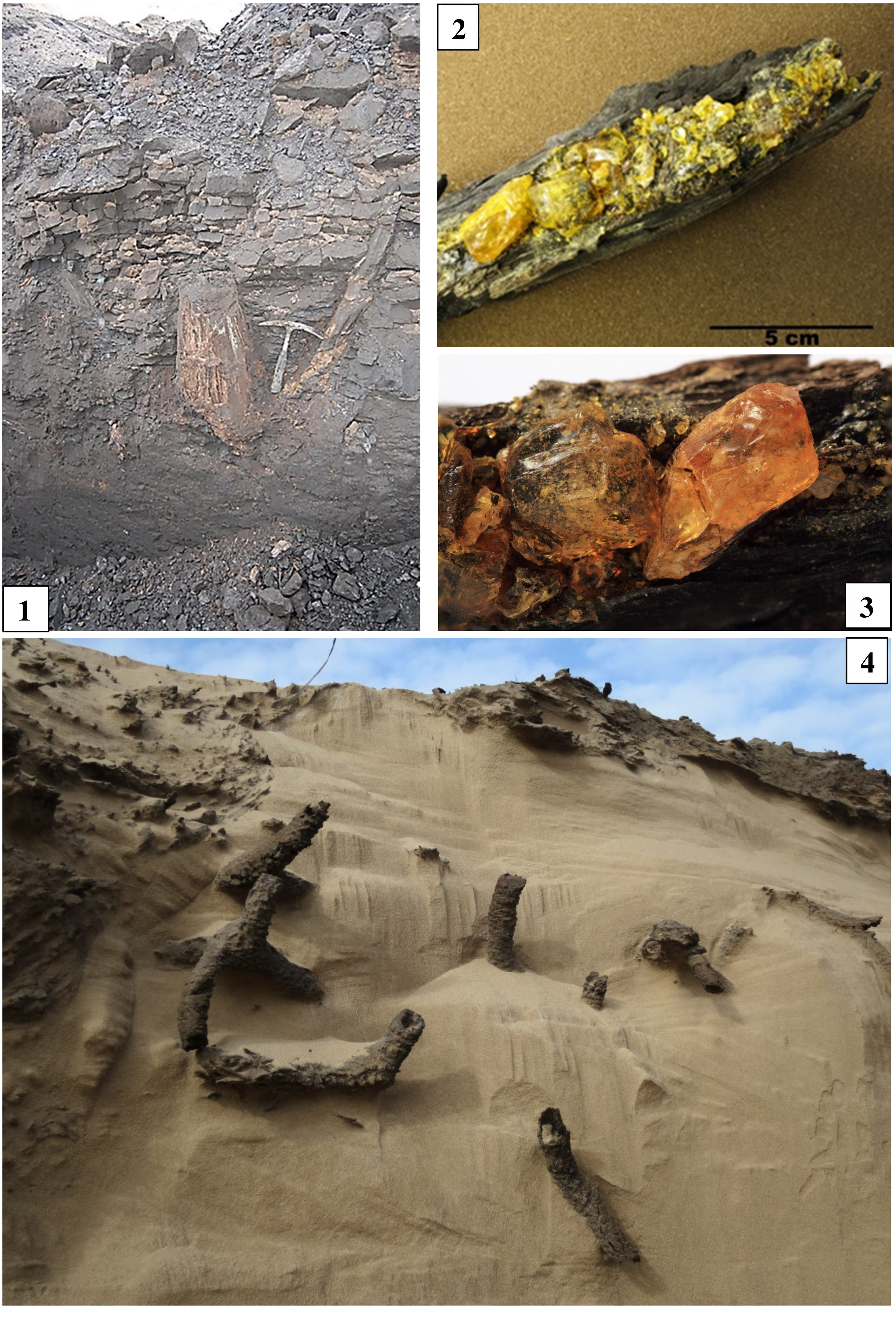

PLATE 17

Fig. 1: *Quercus roburoides* – leaves on a small twig, (Coll. KRATH-HAEGER), opencast mine Hambach, Inden layer, Upper Miocene
Fig. 2: *Ginkgo adiantoides*, well preserved leaf, opencast mine Hambach**,** HKS, (hor. 8), upper Miocene, (Coll. LIEVEN Nr. 5635)
Fig. 3: Leaf composition with *Laurophllum* sp. On a soft coal plate, opencast mine Garzweiler, 5. Level, Seam Frimmersdorf., (hor. 6C), middle Miocene, (Coll. LIEVEN Nr. 5668)

PLATE 17

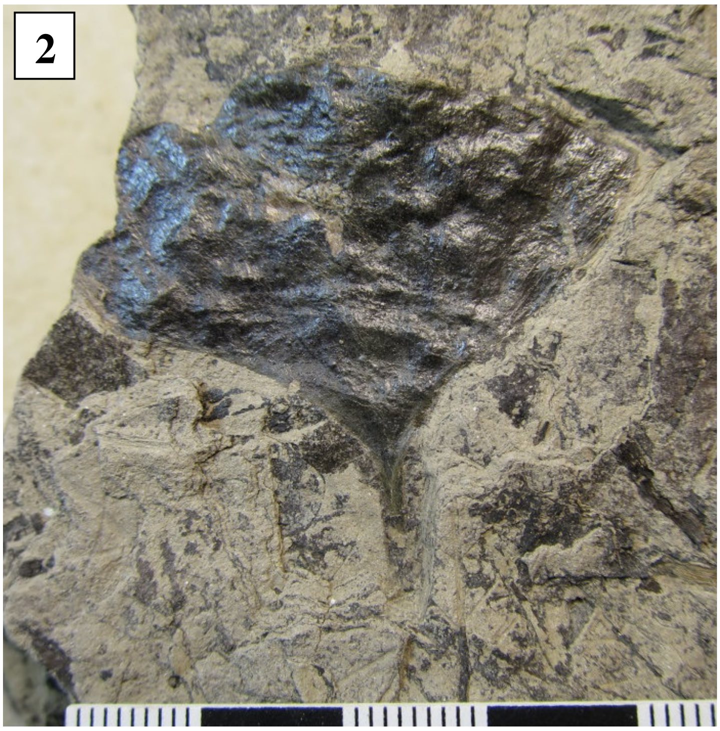

PLATE 18

Fig. 1-8: watercolour pictures from Dr. Uta GREGOR and Dr. Heidemarie THIELE-PFEIFFER (†), based on indications about the plants from author GREGOR

Fig. 1: Amphicyonid beardog in mesophytic foreste
Fig. 2: *Procervulus*- and *Hyaemoschus*-deer in a laurel forest
Fig. 3: Amphibian *Andrias* (Japanese giant salamander) and squirrel on a small brook
Fig. 4: Beaver-dam, otter and frog in a wet and riveraine biotope
Fig. 5: Snapping turtle on a trunk (*Chelidropsis*), with *Glyptostrobus* trees and a giant *Testudo* in the swampy water
Fig. 6: *Pliopithecus* monkeys in the tree canopy
Fig. 7: Dead dolphin stranded on a sandbank with a crocodile on the carcass
Fig. 8: Some *Gomphotherium*, 4-tusk-elephants near the shore of a pond in dense forest

PLATE 17

PLATE 19

Fig. 1-5: Watercolour pictures from Dr. Uta GREGOR, special single plants from left to right, after indications about the animals and vegetation units or biotopes from author GREGOR

Fig. 1: Pine forest on the top of a hilly landscape (Pines, *Picea, Pinus timleri, Pinus leitzii, Cupressoconus, Tetraclinis*)

Fig. 2: Mixed mesophytic forest with exotic elements and others (*Acer tricuspidatum, Mastixia* div.*, Toddalia, Quercus, Magnolia)*

Fig. 3: Sequoia forest near a swamp (many conifers, *Taxodium dubium, Glyptostrobus, Stratiotes, Cathaya, Cephalotaxus, Sciadopitys, Taxodioxylon, Quasisequoia, Tsuga*)

Fig. 4: Pocosin-like area, burnt, with new vegetation and pioneers (*Nyssa, Pterocarya, Taxodium, Alnus, Glyptostrobus*)

Fig. 5: Aue forest with high water level up to 9 months per year (*Pterocarya, Liquidambar, Ulmus, Populus*)

PLATE 19