

## World Heritage Sites

### Protected Areas and World Heritage



## MESSEL PIT FOSSIL SITE GERMANY

*Messel Pit is the richest site in the world for understanding the living environment of the Eocene of 48 million years ago. It provides unique information about the early stages of the evolution of mammals including a herd of primitive horses and includes exceptionally well-preserved fossils from fully articulated skeletons to hair, feathers, wing membranes and stomach contents.*

### COUNTRY

Germany

### NAME

Messel Pit Fossil Site

### NATURAL WORLD HERITAGE SITE

1995: Inscribed on the World Heritage List under Natural Criterion viii.

### STATEMENT OF OUTSTANDING UNIVERSAL VALUE [pending]

### IUCN MANAGEMENT CATEGORY

Not applicable

### BIOGEOGRAPHICAL PROVINCE

Middle European Forest (2.11.05)

### GEOGRAPHICAL LOCATION

Located in the northern foothills of the Odenwald, 35 km southeast of Frankfurt am Main, near Darmstadt at 8°46' E by 49°55' N.

### DATES AND HISTORY OF ESTABLISHMENT

1884-1971: The site was actively mined for bituminous oil shale;

1875: Discovery of a fossil crocodile; 1919: Formal excavation began;

1966-1975: Systematic excavations carried out to pre-empt amateurs digging for profit;

1991: The Hessian government bought the site for scientific use to replace a proposed refuse dump; it was designated a cultural monument under the Hessian Heritage Protection Act of 1974;

1992: Declared a public monument under two Agreements: the Conduct of Palaeontological Excavations in Messel Pit with the Senckenberg Society for Nature Research, and the Scientific and Cultural Use of the Messel Pit Fossil Site with the Society for the Preservation of the Messel Pit Fossil Site.

### LAND TENURE

Public: the property of Land Hesse in Darmstadt Administrative District.

### AREA

70 ha

## ALTITUDE

~200m at ground level. The pit is 60m deep.

## PHYSICAL FEATURES

The pit is a former open-cast bituminous oil-shale mine approximately 1,000m north-south by 700m east-west, now 60m deep, though the accompanying sediments extend some 120-130m deeper. The site is the remains of 48 million year old Middle Eocene lakebed sediments (the Messel formation) which lie over 270-290 million-year old Permian Old Red Sandstone. The lake basin, small but deep, formed in a granite fault-bounded graben following tectonic activity. Over a long period the accumulation under anoxic conditions of lakebed muds, clays, dead vegetation and algae slowly subsided, and immense deposits were laid down which became shale. The slow subsidence and lack of bioturbation preserved the fossil layers over millennia; by contrast, the watercourses that fed the lake were completely eroded. Only part of the structure is stratigraphically intact with the strata in chronological sequence; outcrops of older Eocene seams found on the slopes of the pit are partly distorted by landslides.

The great richness of the deposits, which started life in a dense subtropical jungle, may be due to stratification of the water column which left the ooze on the lake bottom little disturbed and anoxic. Corpses sank, undisturbed by scavengers. Seasonal overturn of this water, local volcanic activity or intermittent earth movements, may have periodically released gases such as carbon dioxide, hydrogen sulphide and ammonia into the lake and the surrounding atmosphere, killing any organisms in and around it which were then preserved in unusually good condition by the very slow rate of deposition. This could account for the many non-aquatic fossils found such as of bats, birds and terrestrial animals (Riley, 2003). Today parts of the pit slopes are forested. In its eastern section there is a small lake (Mayer, 1994). It is bounded by a railway line to the north, industrial and commercial estates to the south and west and forestry land to the east.

## CLIMATE

The Eocene Lake Messel lay 10 degrees south of its present latitude when it had a subtropical climate (Schaal & Ziegler, 1992). The present climate at ground level is temperate.

## VEGETATION

Eocene Lake Messel was surrounded by dense subtropical rainforest, shown by the preserved plant material, including preserved palm leaves, fruits, wood, pollen and some water plants. The presence in millions of the green algae *Tetraedron minimum* and *Botryococcus* sp. during seasonal blooms, consumed much of the lake's oxygen and the decay resulted in a rich production of oil (Riley, 2003). Over 31 types of plant fossils have been identified although most are described only at the family level: club mosses Selaginellaceae, royal fern Osmundaceae, curly grass fern Schizaeaceae, cypress Cupressaceae, plum yew Cephalotaxaceae, swamp cypress Taxodiaceae, walnut Juglandaceae, water lilies Nymphaeaceae and grapevine Vitaceae.

## FAUNA

The first animal remains discovered were those of a crocodile in 1875. By 2004 subsequent excavations have led to the identification of 132 vertebrate species including ten extinct orders (Morlo *et al*, 2004). Most are insects and fishes, mammals making up only 2% of the faunal remains. But the best known fossils are those of the primeval Messel pygmy horses *Propalaeotherium parvulum* 30-35 cm high and *P. hassiacum* 55-60cm high, of which over 70 have been found including pregnant mares and foals. Overall, the deposits partly due to the action of bacterial imprintation, have preserved even the hair, feathers, 'skin shadows', wing membranes, stomach and intestinal contents of some species and even insect scale colouring, providing evidence for the feeding habits, ecology and environment of the Eocene flora and fauna (Schaal & Ziegler, 1992; Riley, 2003).

The mammal fauna totals 45 species (Storch, 2004). It includes 4 marsupial opossums such as *Peradectes* sp. and *Amphiperatherium* spp.; 3 hedgehog-like omnivores *Macrocranion tenerum*, *M. tupaiodon*, and scaly-tailed *Pholidocercus hassiacus*; 8 bats, one the large *Archaeonycteris pollex*, and another, *Tachypteron franzeni* which resembled the present-day *Taphosus*. 3 lemur-like primates *Europolemur kelleri*, *E. koenigswaldi*, and a lemur-like monkey *Godinotia neglecta*; the unique scaleless anteater-like pangolin *Eurotamandua joresi*; 2 primitive pangolins: *Eomanis krebsi*, and *E. waldi*; 4 rodents, one the large *Ailuravus macrurus*; 2 carnivores: the arboreal fossa-like *Paroodectes feisti*, and *Messelogale kessleri*, 5 species of odd-toed ungulates: the horse-like *Hallensia matthesi*, a primeval tapir *Hyrachyus minimus*, the primitive leaf-eating horses *Propalaeotherium hassiacum*, *P.*

*parvulum* and the bulky now extinct *Lophiodon*; and 3 even-toed ungulates, an early tapir *Masillabune martini*, *Messelobunodon schaeferi* and *Aumelasia cf. gabineaadi* (Morlo *et al.*, 2004).

Bird fossils are abundant: 43 species in 23 families have been found. Preservation is extremely good, with bacteria mapping even single barbules on feathers. Feather pigmentation is also possibly preserved in a specimen of Araeotrogoridae. Since in the Eocene epoch there were no large predatory mammals large birds took their place (Riley, 2003). At the top of the food chain was the giant flightless bird *Diatryma*. There were also a proto-ostrich *Palaeotis weigelti*, the Messel rail *Messelornis cristata* a sun-bittern relative which formed 60% of the bird fossils, the flamingo-like *Juncitarsus merkei*, a primitive falcon, *Massillaraptor*, owl-like *Messelasturidae* and *Palaeoglaux sp.*, a freshwater booby *Masillastega*, the crane-like *Idiornis*, swift-like *Aegialornis szarskii*, an early humming bird *Paragornis*, hoopoe-like *Messelirrisor* and birds resembling parrots, woodpeckers, rollers, mousebirds and frogmouths.

31 species of reptiles in 12 families have been found, including 7 crocodiles, 3 being aquatic: the large *Asiatosuchus* and *Allognathosuchus* and an alligator *Diplocynodon*; also 20 snake, lizard, monitor and skink species and 5 turtles. Amphibians of 5 species in 4 families included frogs and salamanders. Many specimens are whole and articulated compared with the many broken specimens from other Tertiary fossil localities, because the deep bottom was so undisturbed.

Over 10,000 fossil fishes of 8 species in 6 families have been found at Messel, a hundred times the numbers of birds and reptiles, mostly from high in the water which indicates that the water column was stratified. All the species are so-called Osteichthyes, where the skeleton is partly composed of true bone. These include ray-finned fish Actinopterygii, 'new-finned' fish Neopterygii, Messel garfish *Atractosteus trausi*, Messel bowfin *Cyclurus kehleri*, archaic knife-fish *Thaumaturus intermedius*, Messel eel *Anguilla ignota*, high-backed predatory Messel perch *Amphiperca multifformes*, and double-finned Messel perch *Palaeoperca proxima*.

The thousands of aquatic and terrestrial insects are the most numerous invertebrates found on site, several specimens having very well preserved structure and metallic colouring (the cuticle colour coming from refracted light not organic pigments). Flying insects are superabundant probably having been like the bats and birds poisoned by the atmosphere over the lake. A notable insect was the 5.5cm Messel giant ant *Formicium giganteum* with a wingspan of 13cm. The most frequent finds are beetles: click beetles Elateridae (15.8%), weevil Curculionidae (12.8%), jewel beetles Buprestidae (8.4%), dung beetles Scarabaeidae (3.9%), stag beetles Lucanidae (1.7%), ground beetles Carabidae (1.4%), water beetles Dascillidae (1.4%), longhorn beetles Cerambycidae (0.5%), and rove beetles Staphylinidae (0.26%).

## CONSERVATION VALUE

Messel is the only major site to provide evidence of such unmatched quality of the explosive evolution of mammals in the Eocene. It is an essential conservation *Lagerstätte* (storage site) of exceptional fossils. Its complete skeletons of many middle Eocene species plus fragile structures in great detail, are unique in their diversity, types and quality and quantity of preservation. The site has provided thousands of fossil specimens and identifications of carnivores, fish, birds, insects, vascular plants, bacteria and organic molecular structures; and also documentation of their environment. These provide many clues for research concerning palaeontological and palaeoecological methods, and enable palaeobiological processes to be reconstructed (Mayer, 1994).

## CULTURAL HERITAGE

The pit's oil shale as a historical mineral resource is considered part of the cultural heritage of Hesse, as defined in the Hessian *Heritage Protection Act* (Mayer, 1994).

## LOCAL HUMAN POPULATION

No-one lives in the pit but it is bordered by industrial and commercial land uses.

## VISITOR AND VISITOR FACILITIES

The Cultural Advisory Council manages the public presentation of the site and runs guided tours. There is a viewing platform at the edge of the pit with information displays to explain the significance of the site to visitors but there is no nearby exhibition for lack of parking. Entrance to the pit is by pre-arranged tour. However, there are three museums in the region: the Messel Museum of Fossils and Local History in the town, the Hessian Regional Museum in Darmstadt and the Senckenberg Museum

of Natural History in Frankfurt, all of which have information and permanent exhibits on the Messel site discoveries.

## **SCIENTIFIC RESEARCH AND FACILITIES**

Although the first sample was identified in 1875, the first formal agreement to recover salvage finds between the Regional Museum in Darmstadt and the mining company was in 1912. Formal excavations started in 1919. Systematic excavations took place in 1966, 1971, and periodically to the end of 1974. Before the use of modern methods in the 1960s, preservation and examination of the fossils was difficult because they disintegrated on exposure. In 1974, the frequency of fossil finds increased and the high prices paid for rare finds led to invasion of the pit by private excavators and fossil merchants. By 1975, under the threat of the use of the area as a refuse dump, the Senckenberg Natural History Museum and Research Institute was granted permission to join the Hessian Regional Museum in excavating and salvaging finds and the Senckenberg Society for Nature Research bought a building close to the Pit as a field research station. Excavations are kept within the framework prescribed for archaeological properties by the 1989 Charter for the Protection and Management of the Archaeological Heritage. Thousands of fossils are now preserved in the Senckenberg Museum. In addition to the wealth of complete and detailed fossils of organic life forms, complex chemical compounds found in the oil shale preserved unaltered in the rock as 'chemical fossils' provide many clues for palaeontological and palaeoecological research, and enable palaeobiological processes to be reconstructed (Mayer, 1994).

Since 1975 a number of scientific research projects have been initiated, recorded in Schaal & Ziegler, (1992) and Mayer (1994). Other institutions have obtained permission to excavate and conduct research: the Natural History Museum Dortmund, the Institute for Geology and Palaeontology, University of Hamburg, in 1975, Johannes Gutenberg University, Mainz, 1976, the Regional Natural History Collection, Karlsruhe, 1979, the Belgian Royal Institute of Natural Sciences in 1983, and the University of Tübingen Institute for Geology and Palaeontology in 1987. In 1991, the second International Messel Symposium was held at Darmstadt with over 100 participants from 21 countries (Schaal & Ziegler, 1992). In 2001 the fossil site acquired a private collection of very rare Messel fossils, including the primeval anteater, tapir and horse fossils, which travelled the country in 2007.

## **MANAGEMENT**

Responsibility for the care, preservation, and operation of the site was assigned to the Senckenberg Society for Nature Research on 1 July 1992. Under German mining law, the Society is the operator of the Messel Pit. The site has been categorised into five geo-scientific priority areas to ensure that scientific excavations are kept within reasonable limits and that particular care is taken with the more valuable strata. Excavation of the strata is determined by two factors: the available quantity of a deposit and its accessibility. Category I excavations are those permitted only within very strict limits; Category II are excavations permitted on condition of minimal disturbance to the property; Category III is in the non-stratified Eocene succession where excavations must be preceded by probes to determine which rock to assign to Category I or II; Category IV is the non-stratified Eocene succession covered by other layers and therefore inaccessible; and Category V is outside the Eocene succession and of no research value.

On the instructions of the Hessian Ministry of Science and Arts, an operational plan was drawn up to establish permanent statutory safeguards for palaeontological research. The plan aimed to set out all necessary future operations, including revegetation of the site. It is overseen by a full-time manager advised by the Senckenberg Research Institute which engages individual engineering or planning agencies to carry out the specific work required for preservation and maintenance of the site. A fenced perimeter is kept under surveillance by foot patrols to prevent trespassing. A measurement system has been established for the pit and surrounding area to monitor the stability of the slopes. Water that gathers on the pit floor is pumped away in order to stabilize the slopes of the pit. All activities are discussed with experts and other interested parties of the Cultural Advisory and Scientific Advisory Councils for the Messel Pit (Mayer, 1994).

## **MANAGEMENT CONSTRAINTS**

The site lies in a highly urbanized and densely populated area and was badly degraded by mining. There has also been considerable controversy over the importance of the fossil resources and protection of the site. A refuse dump planned on adjoining forestry land was prevented in 1990 by citizen protests. Strict monitoring, regulation and guarding has stopped commercial exploitation.

## STAFF

The pit has a full-time manager and there are six full-time positions at the Senckenberg Society for Nature Research.

## BUDGET

2.8 million Deutschmarks per annum (US\$1.9million) in 1995 plus financial support from the Senckenberg Museum of Natural History and the Senckenberg Research Institute.

## LOCAL ADDRESSES

Hessian Office for the Preservation of Monuments, Schloss Biebrich, 65203 Wiesbaden, Germany.

Scientific Advisory Council for the Messel Pit, Senckenberg Research Institute, Senckenberg Society for Nature Research, Senckenberganlage 25, 60325 Frankfurt am Main, Germany.

Cultural Advisory Council for Messel Pit, Hessian Ministry of Science and the Arts, Rheinstrasse 23-25, 65185 Wiesbaden, Germany.

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## DATE

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