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THE NUSPLINGEN LITHOGRAPHIC LIMESTONE - A "FOSSIL LAGERSTAETTE" OF LATE KIMMERIDGIAN AGE FROM THE SWABIAN ALB (GERMANY)

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Abstract. A short overview is given on the actual excavations within a fossiliferous lithographic limestone site near Nusplingen (western Swabian Alb, SW Germany). In contrast to the better known Early Tithonian Solnhofen Lithographic Limestone, it is much richer in fossils and 0.5 my older (Late Kimmeridgian, Beckeri Zone, Ulmense Subzone). Many of the fossils exhibit an excellent preservation, sometimes even of the organic matter. More than 7.000 specimens have been recorded belonging to almost 300 taxa (plants, microfossils, invertebrates, ichnofossils, and vertebrates).

Riassunto. Viene fornita una breve rassegna degli attuali scavi in un sito di calcare litografico fossilifero vicino a Nusplingen (Alb Svevo occidentale, Germania sudoccidentale). In contrasto con il più noto Calcare Litografico di Solnhofen del Tithoniano inferiore, questo è molto più ricco di fossili, ed è più vecchio di 0.5 milioni di anni (Kimmeridgiano superiore, Zona a Beckeri, Sottozona ad Ulmense). Molti fossili mostrano una conservazione eccellente, a volte perfino della materia organica. Sono stati documentati più di 7000 esemplari appartenenti a quasi 300 taxa (piante, microfossili, invertebrati, icnofossili e vertebrati).

Introduction

The Nusplingen Lithographic Limestone is a fossil lagerstaette similar to the famous Tithonian Solnhofen Lithographic Limestone of southern Franconia in Bavaria. It is located in the western part of the Swabian Alb, few kilometers north of the Upper Danube Valley (SW Germany) (Fig. 1). The first fossils from the Nusplingen Lithographic Limestone were reported since the middle of the 19th century (O. Fraas 1855; Quenstedt 1843, 1855; Dietl et al. 2000). Several excavation campaigns took place, at first with commercial aspects, prospecting for limestones to be used for lithography or for roofs, but later restricted to scientific interests. A bibliography on the Nusplingen Lithographic Limestone with all references until 1997 was published by Schweigert (1997).

In contrast to Solnhofen, the Nusplingen Lithographic Limestone is of Late Kimmeridgian age (Fig. 2). It represents a stratigraphical equivalent to the "Liegende Bankkalk" Formation which belongs to the Ulmense Subzone, Beckeri Zone (Fig. 3), thus about 0.5 my older than

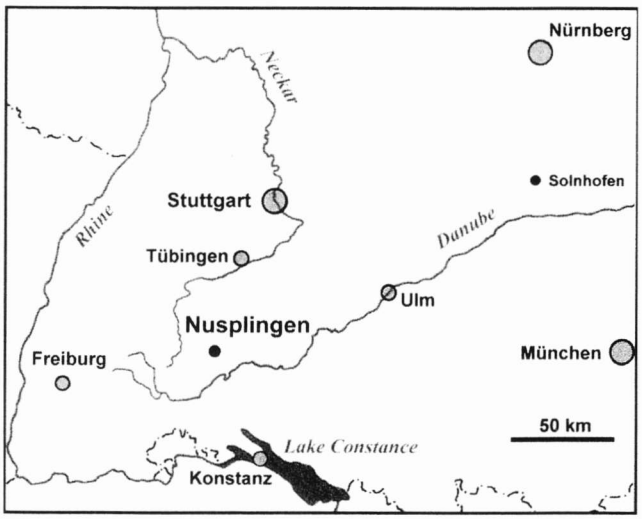

Fig. 1 - Map showing the location of the fossil site Nusplingen, a few km N of the River Danube, SW Germany.

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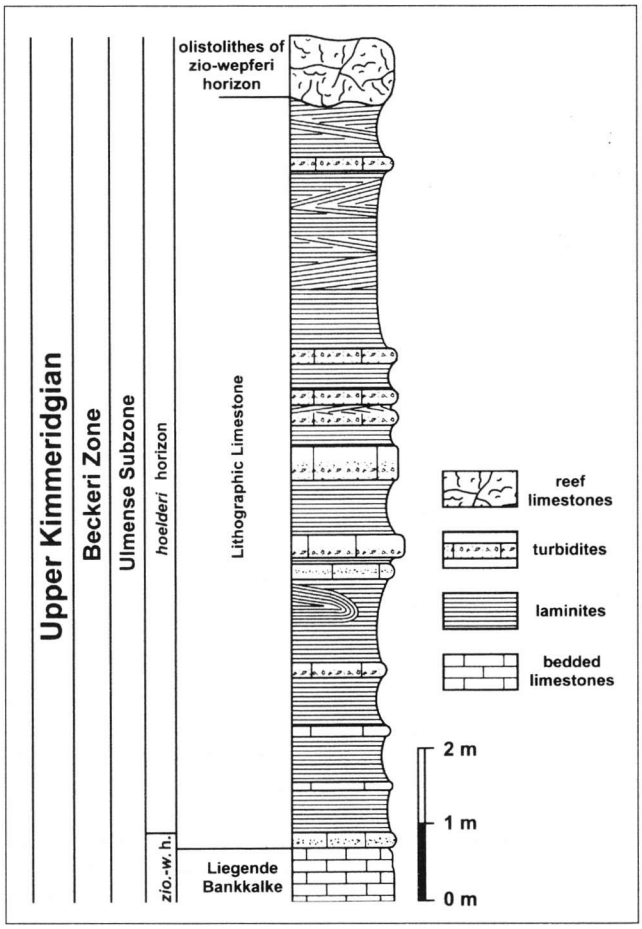


Fig. 2 - Detailed section of the Nusplingen Lithographic Limestone and its stratigraphical position within the Upper Kimmeridgian. The thickness of the Nusplingen Lithographic Limestone in the figured section is of about 10.5 m.

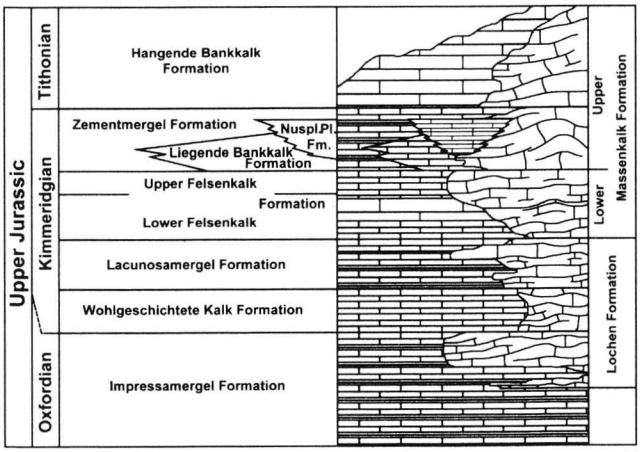


Fig. 3 - The general stratigraphical position of the Nusplingen Lithographic Limestone (Nusp. Pl. Fm.) within the Upper Jurassic of the southwestern Swabian Alb/SW Germany.

the Solnhofen Lithographic Limestone famous for the oldest bird, *Archaeopteryx*. This is confirmed by the ammonite fauna, which allows a high resolution biostratigraphy (Schweigert 1998b; Schweigert & Zeiss 1999).Today, the outcrop of the Nusplingen Lithographic Limestone is not larger than 1.5 km²; its thickness reaches a maximum of 17 m. Several sections from drillings, from two small quarries and from natural outcrops were reported by Dietl et al. (1998) and by Bantel et al. (1999). Since 1983 the whole area has become a Protected Excavation Area ("Grabungsschutzgebiet") by the Monument Protection Law (see Bloos, this volume) of the "Land" Baden-Wuerttemberg because of its extraordinary fossils. The Nusplingen Lithographic Limestone is actually exposed in two small quarries. For the public it is not allowed to excavate or to take away fossils from the two quarries or from everywhere in the protected area. To visitors local instructions about the importance of this fossil site and about the above mentioned prohibitions are given directly at the quarries. Visitors and excursions can visit at any time the quarries of the Nusplingen Lithographic Limestone.

Environment

The laminated limestones were deposited in a more or less anoxic environment of a lagoon surrounded by sponge/microbial bioherms, some of them partly tectonically uplifted over the sea level as small islands (Fig. 4). The minimum depth of the lagoon was approximately 80-100 m. At the seafloor of the lagoon living conditions were unfavourable for most organisms apart from very few exclusions. Hence, an exceptional preservation was possible which is normally prevented by bioturbation. Within the succession of laminated limestones, several turbidites with graded bedding ("allodapic limestones") and few thicker bioturbated beds indicating a better oxygenation are intercalated. The turbidites comprise angular lithoclasts and other components like calcareous ooids, sponge spicules, and even some fragments of hermatypic corals from shallow areas surrounding the lagoon. It is possible to correlate the outcrops in the quarries with the help of these thicker beds. Besides, some silica layers also occur throughout the basin. The deposition of laminated limestones ended abruptly. From the nearby sponge/microbial reefs, a lot of boulders had been broken off, gliding into the central parts of the lagoon, where they were deposited directly above the laminated limestones with a thickness of several meters. The allochthonous nature of these boulders is indicated by geopetal fillings in hollow fossils and several finds of ammonites significantly older in age than the underlying laminites. Below the boulder beds, the original stratification of the laminites is strongly disturbed, with folding, boudinage, lateral compression, and repetition by stapling. We presume that a strong seaquake was the reason for this dramatic event. No data are available from the younger Upper Jurassic in the closer area because of Cenozoic erosion.

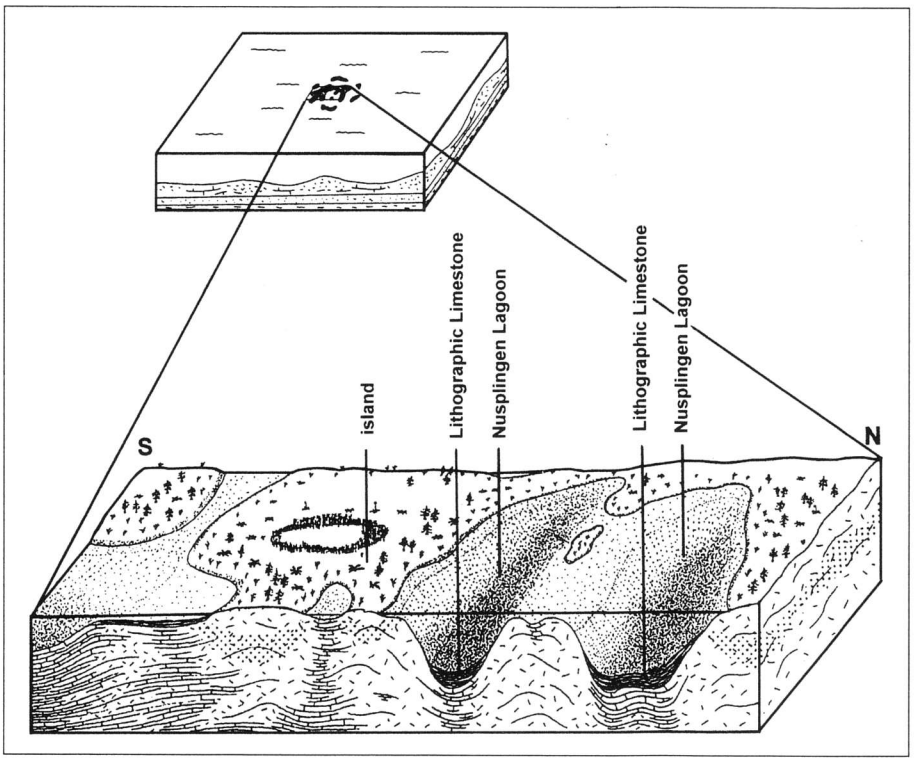


Fig. 4 - Reconstruction and palaeogeographic setting of the Nusplingen lagoon, without scale.

The fossils from the Nusplingen Lithographic Limestone

New excavations by the Natural History Museum of Stuttgart (SMNS) in two small quarries accompanied by several drillings proliferate new data on the sedimentology, palaeoecology, taphonomy, biostratinomy, and especially the fossil content of the Nusplingen Lithographic Limestone (Dietl & Schweigert 1999b, 2001). Since 1993 more than 7.000 fossils were recovered and are going to be registered in an electronic database. They belong to almost 300 taxa, many of them new. Some of the fossils which are embedded in bituminous layers occurring in the upper part of the succession exhibit an extraordinary preservation of organic matter. They tell us interesting stories about sea life in or around the Nusplingen lagoon and in the surrounding shallow sea of the Upper Jurassic in SW Germany, far away from larger continental islands like the Ardennian and Bohemian Massifs in the north and in the north-east.

Microfossils

The Nusplingen Lithographic Limestone yields a significant amount of debris from the nearby reefs and from the water column. A high percentage is made up of coccolithophorids and their debris characterizes the laminites as marine alginites (Bantel et al. 1999). Surface structures of some bedding plains point to a temporary development of microbial mats. More than 60 species of radiolarians were identified in thin sections or by dissolving the limestone with acid (Zügel et al. 1998; Bantel et al. 1999). Together with the ammonites, the radiolarians allow an integrated biostratigraphical approach in the latest Kimmeridgian. Other common microfossils are *Saccocoma* skeleton elements and various sponge spicules, namely of the *Rhax* type.

Plants

In bituminous strata occurring in the higher part of the succession land plants (Pl. 1, fig. 1) (e.g. *Cycadopteris*, *Brachyphyllum*, *Zamites*, and *Baiera*), which are derived from nearby uplifted islands, are still preserved with their organic tissue showing finest details like cell-structures and stomata. Recently, we were even able to identify amber (Schweigert & Dietl 2003). This amber occurs still in situ within the resin vessels of some araucariacean cone scales. Marine algae are restricted to bituminous layers. They closely resemble recent brown algae like *Cystoseira*. Calcareous algae have not been recorded at all.

Invertebrates

Completely preserved specimens of non-rigid sponges like the *Rhax*-bearing *Codites* (formerly often misidentified as brown algae and better known as "*Phyllothallus*") are rather common (Pl. 2, fig. 1). Bivalves are mostly documented by different species of pectinids, limids, and oysters. Apart from a single layer with small nuculids, all bivalves are allochthonous. They were brought into the laminated facies by predators or passively living on drifting ammonites before they finally sank to the sea floor. The most frequent and typical macrofossils of the Nusplingen Lithographic Limestone are ammonites and aptychi. The ammonite fauna comprises *Lithacoceras ulmense* (Oppel), *Silicisphinctes hoelderi* (Sapunov), *Silicisphinctes russi* (Schweigert), *Hybonoticeras* sp., *Physodoceras nattheimense* Schweigert, *Sutneria* cf. *rebholzi* Berckhemer, *Ochetoceras zio* (Oppel), *Glochiceras lens* Berckhemer, *Lingulaticeras pseudopercevali* Schweigert etc., characteristic of the *hoelderi* faunal horizon of the Ulmense Subzone, Late Kimmeridgian (Schweigert 1998b; Schweigert & Zeiss 1999). Some ammonites are very spectacular because they are preserved with their complete jaw apparatus and stomach content (Schweigert & Dietl 1999a, 2001). The lower jaw is represented by the calcitic Aptychus, whereas the upper jaw which was originally chitineous is preserved in carbon. Also nautilids (*Pseudaganides*) have been found with both jaws (rhyncolithes = upper jaw and conchorhynchus = lower jaw) still in the body chamber, together with stomach-contents consisting of decapod or ophiuran remains (Dietl & Schweigert 1999a) (Pl. 2, fig. 3). Belemnites occur frequently in all ontogenetic stages of a single species, *Hibolithes semisulcatus* (Münster) (Schweigert 1999). The guards are very often bitten by predators. Teuthids (*Trachyteuthis*, *Plesioteuthis*, *Leptotheuthis* etc.) are also mostly bitten but often preserved with their inksacs.

Among the arthropods, marine polychaetes sometimes exhibit a soft-part preservation (Schweigert & Dietl 2000). A very well known fossil of Upper Jurassic lithographic limestones is the limulid *Mesolimulus walchi* (Desmarest), but in the Nusplingen Lithographic Limestone it is quite rare. The newly excavated fossils include the first record of a centipede, *Eogeophilus jurassicus* Schweigert & Dietl, from the Jurassic (Schweigert & Dietl 1997). Other remarkable fossils are several insects such as beetles and dragonflies (*Urogomphus*, *Stenophlebia*, *Aeschnidium*, *Cymatophlebia*) (Pl. 1, fig. 2). They are also partly preserved in organic matter (Schweigert et al. 1996; Bechly 1998). Many well-preserved decapods are typical of the Nusplingen Lithographic Limestone and more than 20 taxa have been recorded: *Antrimpos*, *Cycleryon*, *Hefriga*, *Aeger*, *Bylgia*, *Dusa*, *Coleia*, *Eryma*, *Glyphea*, *Palaeopentacheles*, *Pustulina* etc. (Schweigert et al. 2000; Schweigert 2001b) (Pl. 2, fig. 2). *Coleia longipes*

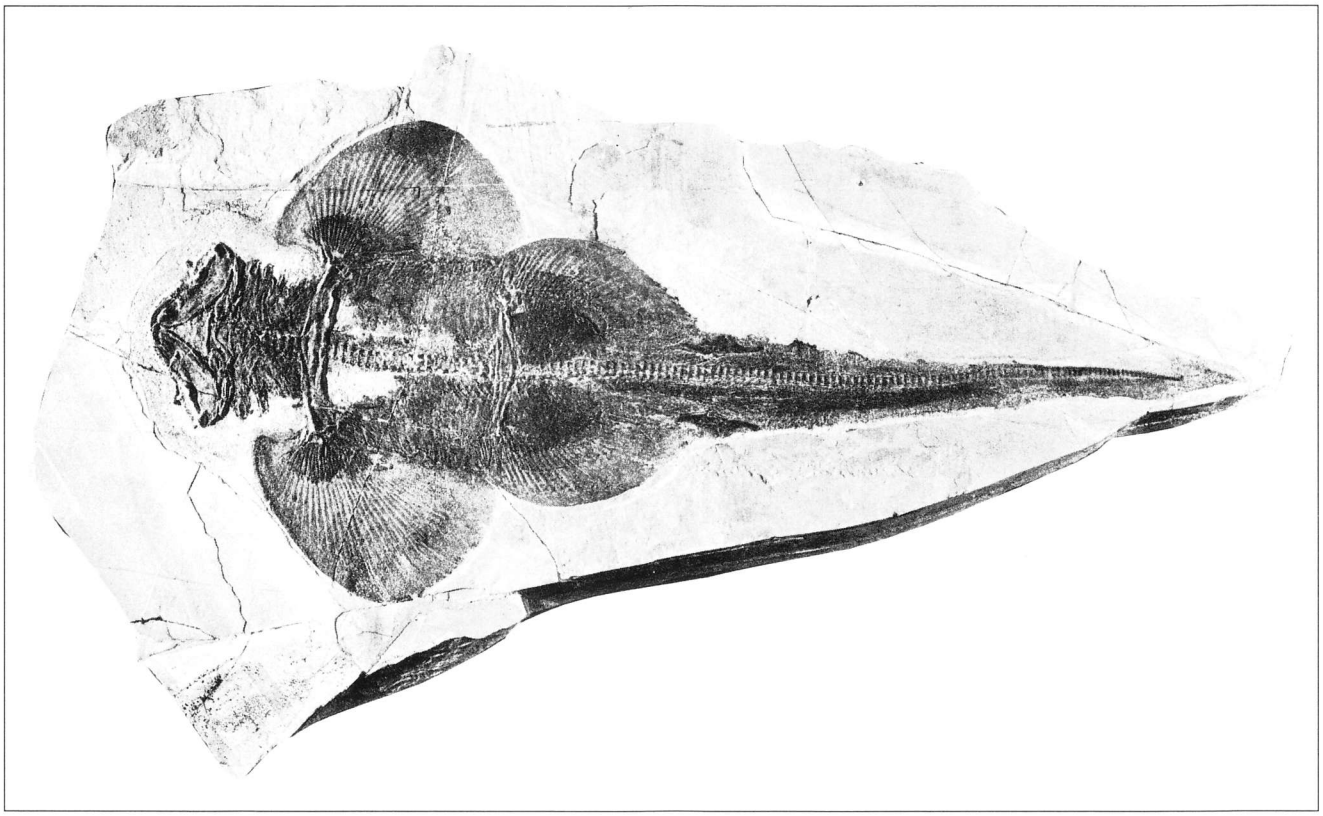


Fig. 5 - Angel shark - *Squatina acanthoderma* O. Fraas, ♂, Nusplingen Lithographic Limestone, Nusplingen quarry, length 113 cm, SMNS 80431/20.

(O. Fraas), a primitive eryonid, only known from Nusplingen, still shows its compound eyes (Schweigert & Dietl 1999b) (Pl. 2, fig.4).

Brachiopods are present with rare specimens of the genera *Cheirothyris*, *Lacunosella*, *Ornithella*, and *Torquirhynchia* (Dietl & Schweigert 2000). Other benthic organisms such as echinoids (*Stomechinus*, *Rhabdocidaris*, *Polycidaris*, *Plegiocidaris*, *Paracidaris*, *Nenoticidaris*, *Diplopodia*, and *Diplocidaris*), ophiurans (*Sinosura*), and crinoids (*Pterocoma*, *Solanocrinites*, and *Plicatocrinus*) also occur only sporadically (Grawe-Baumeister et al. 2000). In contrast, the planctonic crinoid *Saccocoma tenella* (Goldfuss) is rather frequent on some bedding planes, but much less conspicuous than in the Tithonian of Solnhofen.

Vertebrates

Among the vertebrate fauna the fishes are predominant. They are represented by elasmobranchii (*Squatina*, *Eonotidanus*, *Heterodontus*, *Sphenodus* etc.) (Schweizer 1964; Böttcher & Duffin 2000), holocephali (*Ischyodus*, *Elasmodectes*) (Heimberg 1949; Schweizer 1964), crossopterygii (*Coccoderma*, *Undina*), and numerous actinopterygii like *Allothrissops*, *Anaethalion*, *Aspidorhynchus*, *Caturus*, *Eurycormus*, *Furo*, *Gyrodus*, *Leptolepides*, *Ophiopsis*, *Siemensichthys*, *Solnhofenamia*, *Tharsis* etc (Heineke 1906). The most typical fish of the Nusplingen fossil site, however, is the angel shark *Squatina acanthoderma* (Fig. 5), typically preserved with its complete skeleton and skin outline. During the new excavations, 10 well preserved specimens, juveniles, males, and females, were discovered.

Reptiles rarely occur, but this may be due to the small size of the excavations. They are represented by marine crocodiles (*Geosaurus*, *Dacosaurus*) (E. Fraas 1902) and 3 genera of pterosaurs, *Pterodactylus*, *Gallodactylus*, and *Rhamphorhynchus* (Quenstedt 1855; Plieninger 1907). During the new excavations, only several isolated bones and teeth were found.

Ichnofossils

In contrast to the typical Lithographic Limestones of the Solnhofen area, the ichnofauna of the Nusplingen Lithographic Limestone is much more diverse, although restricted to specific layers. Its comprises feeding burrows like *Chondrites*, *Haentzschelinia*, *Parahaentzschelinia*, *Rhizocorallium*, and moving trails such as *Serpentichnoides*, *Telsonichnus*, *Undichna* (Schweigert 1998a; 2001a). Coprolites are generally frequent in the laminites indicating that there was marine life in the water column above the anoxic sea floor. Some phosphoritic ones are attributed to fishes and reptiles, whereas the very common *Lumbricaria* is interpreted as the faeces of aspidoceratid ammonites (Dietl & Schweigert 2001).

Remarks

Both the diversity of the fossil fauna and flora and its exceptional preservation make the Upper Jurassic Nusplingen Lithographic Limestone an outstanding fossil lagerstaette which opens a window into the past of the earth. Some interesting parts of the section, however, have been exploited only for few m², which provides hardly any statistical database. Thus, we hope the excavations can be continued successfully in the following years.

Acknowledgements. The enormously enlarged knowledge on this fossil lagerstaette would have been impossible without the engaged work of our technicians, namely M. Kapitzke, M. Rieter, O. Maass (all SMNS), and of our enthusiastic volunteers R. Hugger (Albstadt-Onstmettingen), B. Russ (Nusplingen) and O. Dietl (Stuttgart). The excavations and the contemporaneous scientific work were generously funded by the Deutsche Forschungsgemeinschaft (DI 680/1). Many thanks should also go to all others who engaged themselves in our project. We are grateful to K. Page and U. Nicosia for their comments and suggestions.

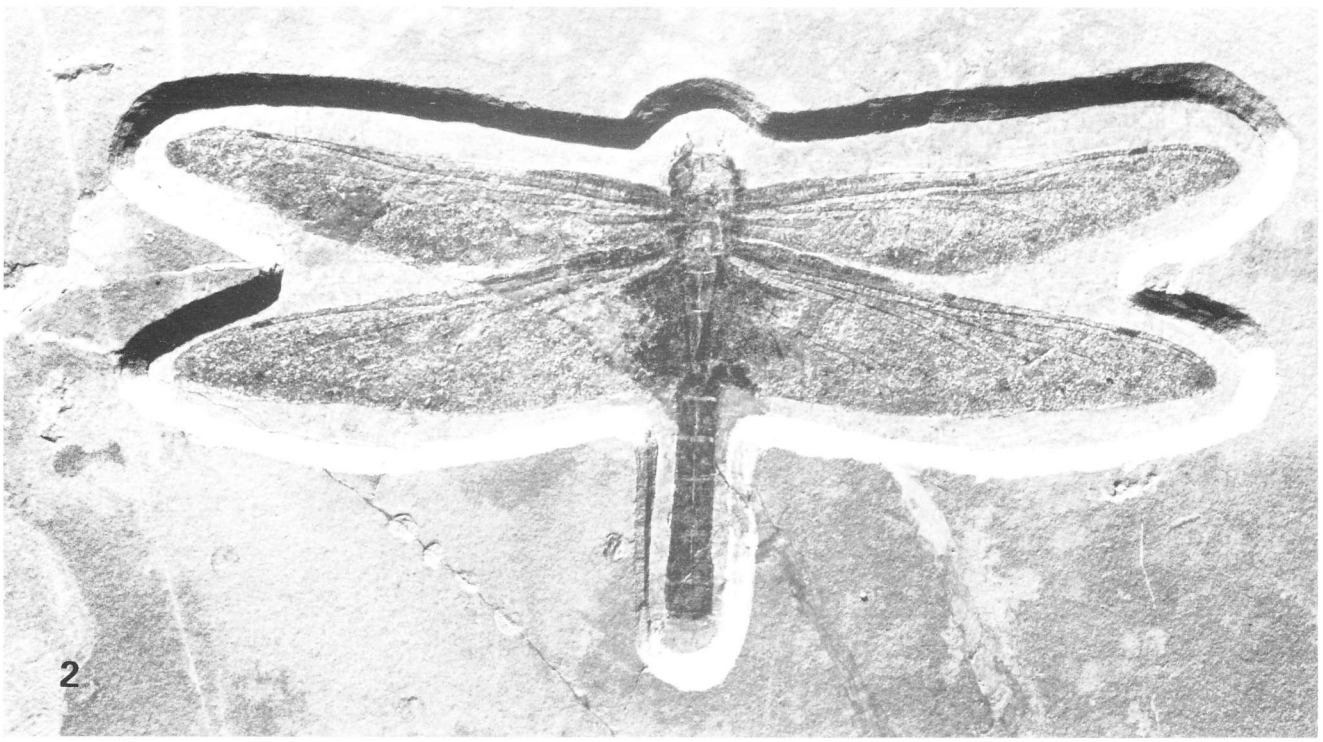
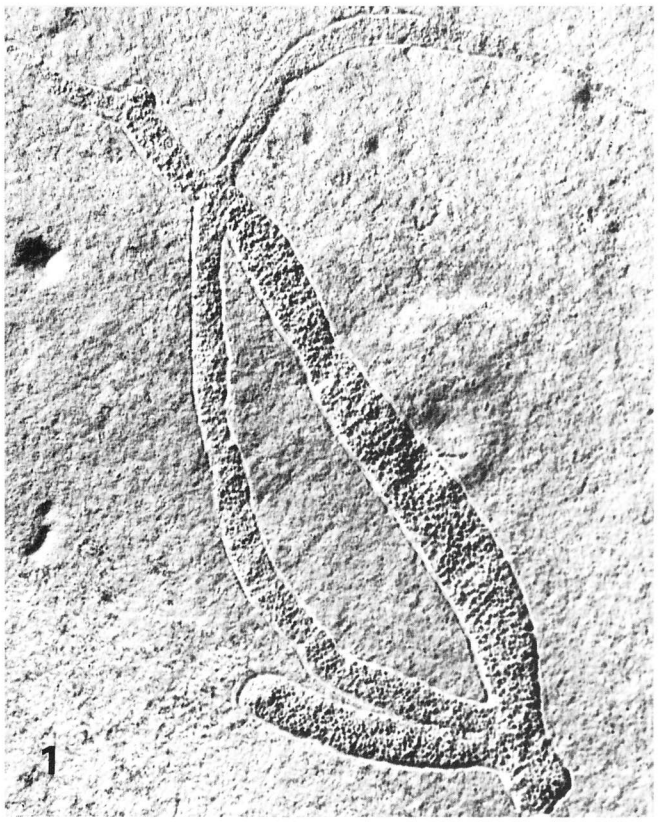
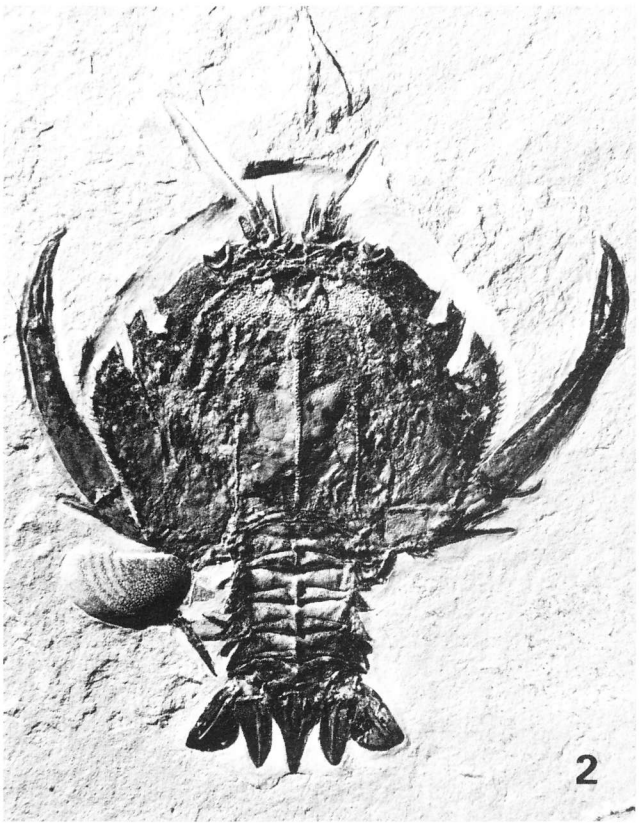


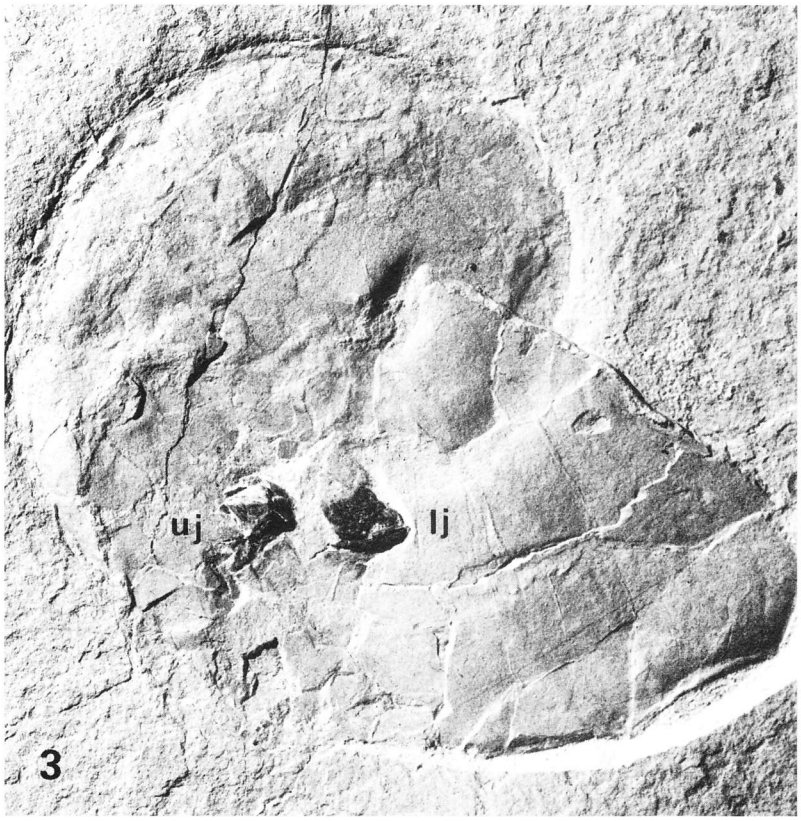
PLATE 1

Fig. 1 - Pteridosperm - *Cycadopteris jurensis* (Kurr) Hirmer, Nusplingen Lithographic Limestone (from bituminous bed), Nusplingen quarry, length 40 cm, SMNS P1875.

Fig. 2 - Dragonfly - *Urogomphus nusplingensis* Bechly, Nusplingen Lithographic Limestone (from bituminous bed), Nusplingen quarry, span of wings 15.5 cm, SMNS 62602.







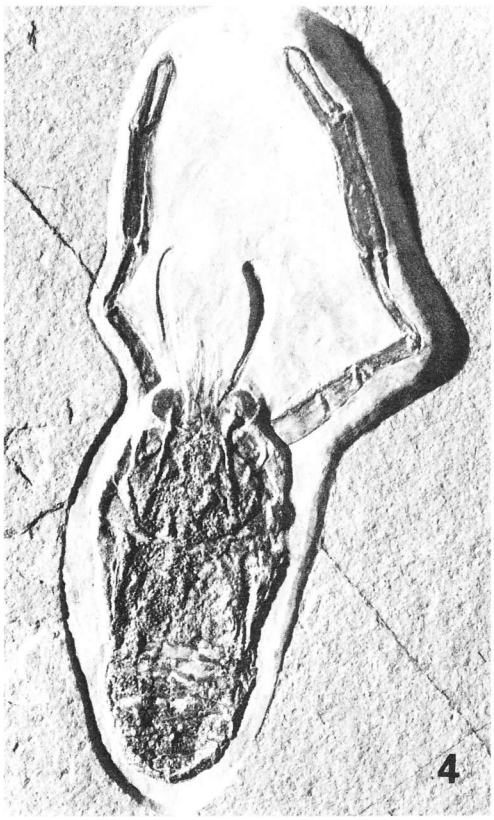


PLATE 2

Fig. 1 - Non-rigid sponge – *Codites serpentinum* (Sternberg), Nusplingen Lithographic Limestone, Nusplingen quarry, height 11 cm, SMNS 64402.

Fig. 2 - Eryonid decapod – *Cycleryon propinquus* (Schlotheim) ♀ (= *spinimanus* Germar), Nusplingen Lithographic Limestone, Nusplingen quarry, length 8 cm, SMNS 64368.

Fig. 3 - Nautilid – *Pseudaganides* sp. with both jaws in situ (upper jaw = uj, lower jaw = lj), Nusplingen Lithographic Limestone, Nusplingen quarry, diameter 13.8 cm, SMNS 63272.

Fig. 4 - Eryonid decapod – *Coleia longipes* (O. Fraas), Nusplingen Lithographic Limestone, Nusplingen quarry, length 9.5 cm, SMNS 63744.

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