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# Abu Ballas Formation (Tithonian/Berriasian; Southwestern Desert, Egypt) a significant lithostratigraphic unit of the former 'Nubian Series'

By K. Werner Barthel and Ronald Boettcher*)

With 6 text figures and plates 11—12


## Abstract

E. Klitzsch recently succeeded in subdividing the socalled 'Nubian Series'. One of these rock units is a very striking claystone, averaging 25 to 30 ms in thickness. It can be traced over several hundered kms. Bottom and cover consist of white to purplish sandstones with root horizons. — The claystone mostly yields *Lingula* in the lower part of the section while *Neomiodon*-like pelecypods, *Corbula*, and others are frequent near midsection. Rare echinoderm remains scales and skull bones of the holostean fish *Pholidophorus* also come from this level. Toward the top the claystones hold numerous plants e. g. *Hausmannia*, *Weichselia* and 40 ms above the formation *Araucaria*, *Brachyphyllum*, *Frenelopsis* and *Stiehleria* (?). The former are accompanied by the isopod *Archaeoniscus* and insects. Ichnofossils are found throughout the section. — An environmental shift from terrestrial to marine and back to terrestrial is evidenced in depositional history. Fauna and flora are closely comparable to those of the European Purbeckian. Accordingly Abu Ballas Formation is thought to be of Late Jurassic/Early Cretaceous (Late Tithonian/Berriasian) age.



## Kurzfassung

Die bisher ungegliederte sog. „Nubische Serie" der Südwestlichen Wüste Ägyptens konnte jetzt durch E. Klitzsch grob unterteilt werden. Eine durchschnittlich 25—30 m mächtige rote und grüne Tonsteinfolge, die über mehrere hundert km verfolgbar ist, wird hier als Abu Ballas Formation bezeichnet. Die Formation liegt zwischen weißlichen und violetten Sandsteinen mit Wurzelhorizonten. — In den Tonsteinen finden sich unten vor allem *Lingula*, gegen die Mitte *Neomiodon*-artige Muscheln, sowie *Corbula*. Aus diesem Bereich stammen auch seltene Funde von Echinodermen-Resten und Schuppen des Holosteers *Pholidophorus*. Die höheren


*) Prof. Dr. K. W. Barthel, Dipl.-Geol. R. Boettcher; Institut für Geologie und Paläontologie der Techn. Univ. Berlin, Hardenbergstr. 42, D-1000 Berlin 12.

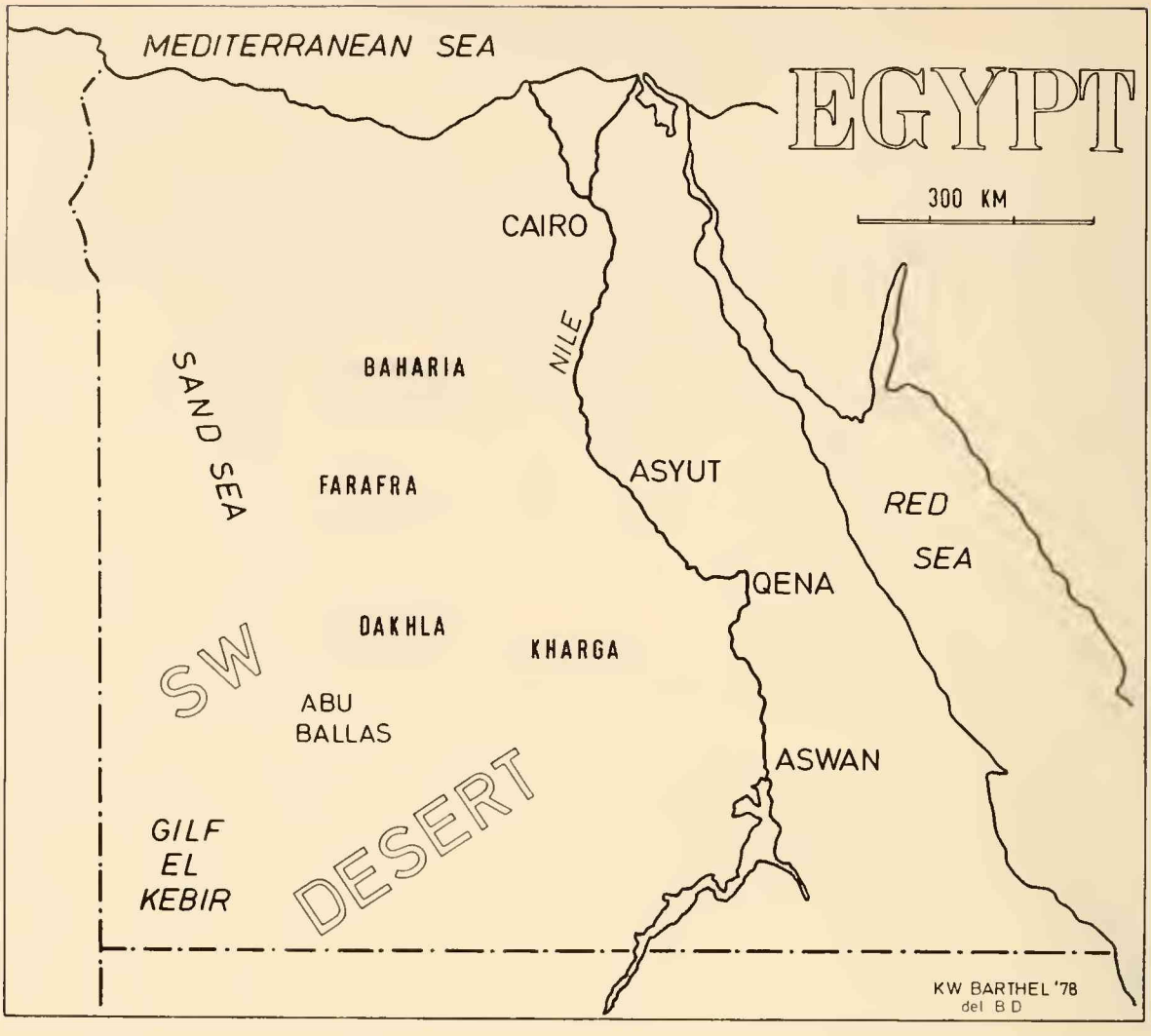


Fig. 1: Outline of major geographic features in the area of investigations.

Lagen liefern zahlreiche Pflanzenreste wie *Hausmannia* und *Weichselia* und ca. 40 m über der Formation *Stiehleria (?) Araucaria, Brachyphyllum* und *Frenelopsis.* In den obersten Tonen kommen auch Insekten und der Isopode *Archaeoniscus* vor. Ichnofossilien sind im ganzen Profil häufig. Diese Lebewelt kann zeitlich wie faziell mit dem europäischen Purbeck verglichen werden. Die Sedimente der Abu Ballas Formation wurden demnach um die Wende Jura/Kreide, spät im Tithon oder im Berrias gebildet.

## Introduction

The extensive sandstone series of the Southwestern Desert of Egypt (text-fig. 1) have resisted stratigraphic subdivision for almost a centennium (Pomeyrol 1968, Klitzsch 1978). Limited research in isolated areas fostered the term "Nubian Sandstone" for these seemingly uniform deposits. A recent gridlike field survey permitted to separate several rock units (Klitzsch 1978). Text-fig. 2 and the following 'petit' paragraph outline the lithostratigraphy recognized.

This brief listing gives names, authors, general lithology, and coordinates of reference areas, in that sequence.

"Quseir" Formation; Youssef 1957; also known as Variegated Shales (Said 1962, p. 130); up to 100 ms. "Quseir" Formation has been put in quotation marks because correlation with the reference area near the Red Sea is still tentative.

Taref Formation; Awad & Ghobrial 1966; also known as Taref Sandstone; few ms to more than 100 ms.

Kharga Formation; new; Klitzsch herein; claystones alternating with sandstones, both rich in plant remains, hence Klitzsch's field term 'Plant Beds'; up to 200 ms; reference area in foothills below Abu Tartur phosphate mine, about 45 kms W of Kharga; longit. 29°37′ E, latit. 25°21′ N).

Sabaya Formation; new; Klitzsch herein; rosé to whitish sandstones with some soil horizons and occasional plant remains; Klitzsch's field term 'Desert Rose Sandstone' was based on locally frequent gypsum rosettes which, however, occur also in sandstones below and abbove Sabaya Formation; several 100 ms thick; reference area about 90 kms W of Kharga on the road to Dakhla at Gebel Qulû el Sabaya, (longit. 29°43′ E, latit. 25°14′ N).

Abu Ballas Formation; new; Barthel & Boettcher herein; claystone, for description see below; Klitsch's field term: *Lingula* shales; named after cliffs near Abu Ballas, about 300 kms SW of Kharga; reference area location see below.

Six Hills Formation; new; Klitzsch herein; sandstones with soil horizons; several 100 ms; Klitzsch's field term: 'Basal Clastics'. Reference area Six Hills about 200 kms SW of Kharga; (longit. 29°14′E, latit. 24°21′N).

Gilf el Kebir Formation; Klitzsch 1978, original term; sandstones and siltstones intercalating toward the E with Six Hills, Abu Ballas, and Sabaya Formations; up to several 100 ms; reference area: W side of Gilf el Kebir, (longit. 25°51′E, latit. 23°2′N).

With the lithostratigraphy essentially standing (text-fig. 3), there still remains the problem of a more precise biostratigraphic levelling.

The formation most likely to yield good stratigraphical and paleontological evidence, therefore, was given preference by the authors. We here present the first results. A monographic treatment by Boettcher will follow later.

We are dealing with a formation that consists almost entirely of claystone. Its thickness is approximately 30 ms. Exposures are found along the scarps between the Abu Tartur and the Gilf el Kebir plateaus. Further outcrops have been located in the desert S and E of these scarps (text-fig. 4). Sections are best accessible and almost completely exposed in the scarps near Abu Ballas. Accordingly we here name the new rock unit Abu Ballas Formation with a reference site at longit. 27°33′ E and latit. 24°18′ N.

## Outline of lithology of Abu Ballas Formation

As indicated, Abu Ballas Formation essentially consists of claystone. The dominant colors of the sediment are red and pale green. To a lesser degree purple, gray, and ochre colored clays occur also and locally may prevail in parts of some sections.

Thin seams of siltstone and silty ironstone frequently are intercalated in the claystone sequence. Usually but millimeters in thickness, they may reach up to 10 centimeters. Thick seams easily weather out and residual slabs then cover exten-

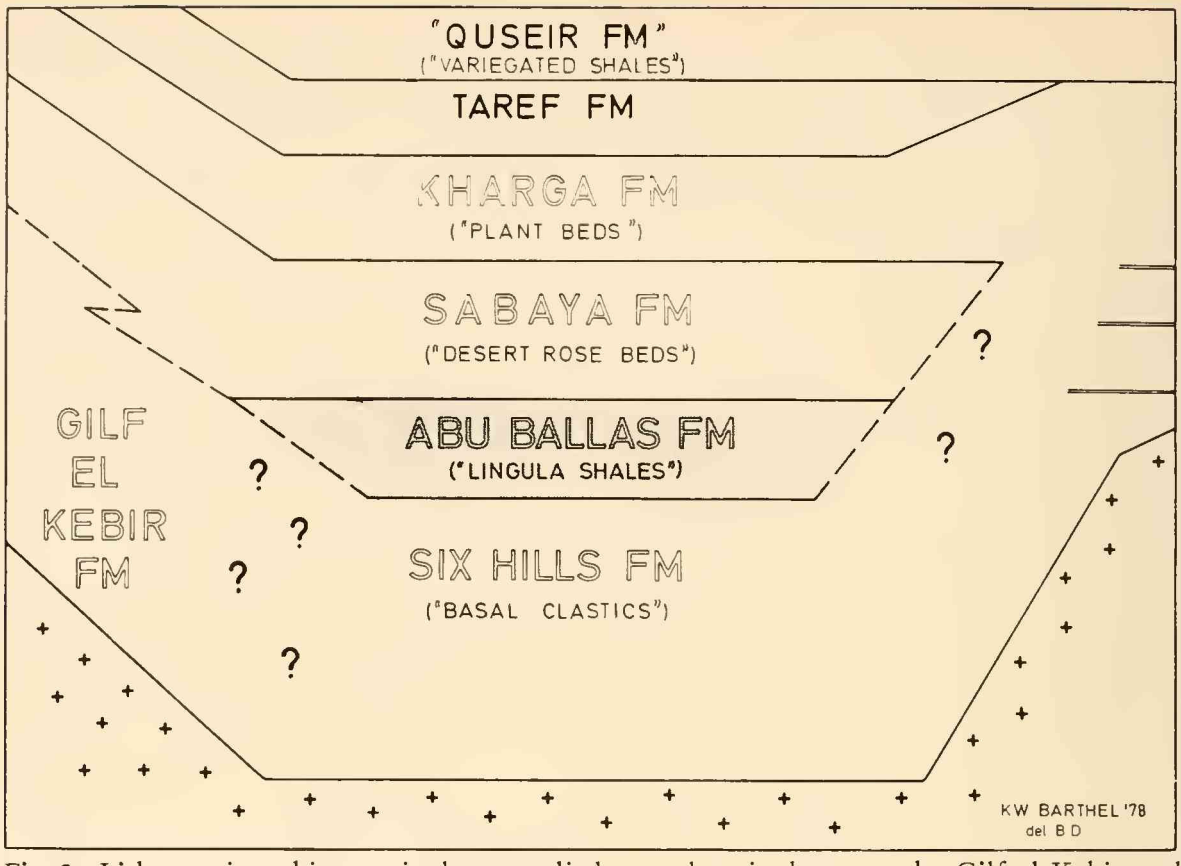


Fig. 2: Lithostratigraphic terminology applied to rock units between the Gilf el Kebir and the Kharga Oases. For a briefing on the new formations see p. 154.

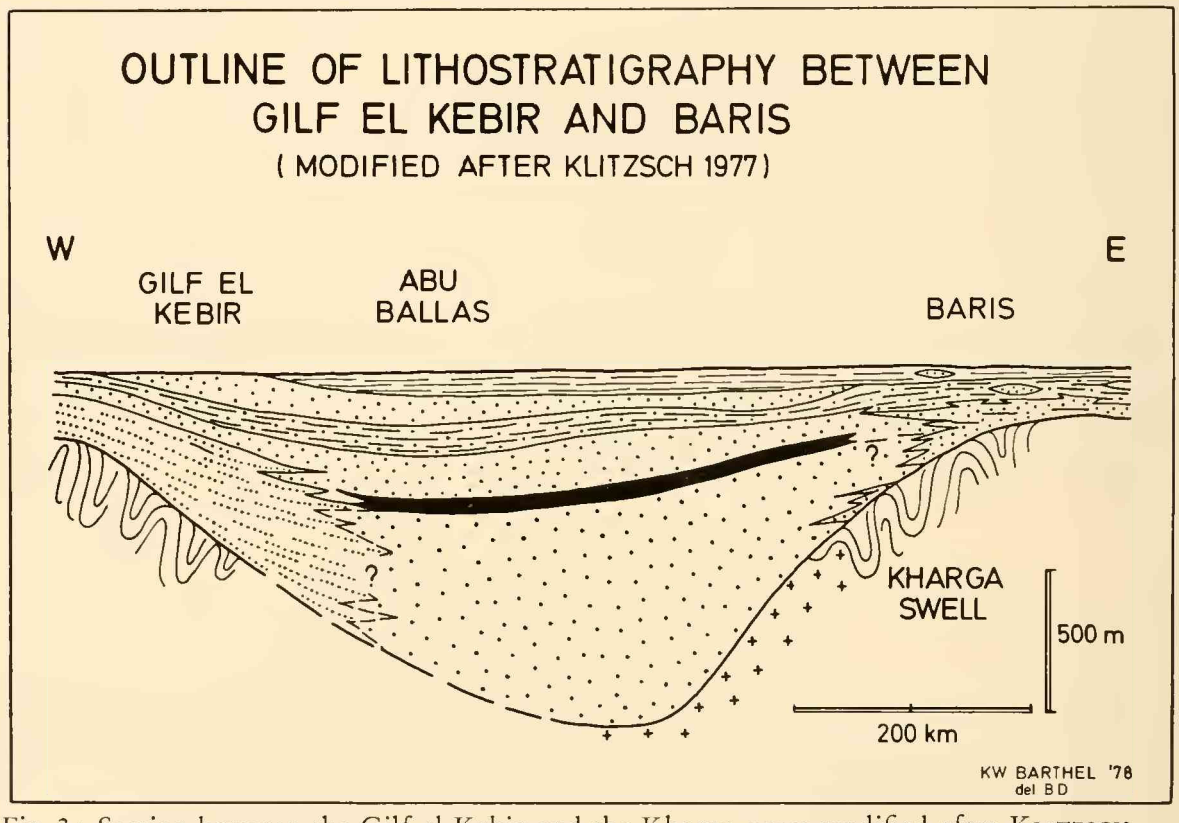


Fig. 3: Section between the Gilf el Kebir and the Kharga oases modified after KLITZSCH. — Abu Ballas Formation shaded. Vertical scale greatly exaggerated: maximum thickness of sedimentary cover in center of depression approximately 1500 ms.

sive surface areas. Slab fields are good indicators for Abu Ballas Formation sites. Surfaces of slabs often abound with imprints and cores of invertebrate fossils. Some of the more persistent siltstone seams are associated wih small phosphatic pebbles and occasional vertebrate remains. Other seams indicate local high salinity by primary intra-sedimentary gypsum crystals.

The top bed of Abu Ballas Formation is very striking in appearance. 50—100 cms of closely packed siltstone seams, rippled and laminated, show considerable bioturbation which occasionally nearly obscures original beddig structures. The top bed is encountered all over the area of distribution with the only exceptions to be mentioned below. A hard red seam, thought to be fossil soil crust, terminates the top bed.

River channels cut into Abu Ballas Formation are restricted to a region in the NE according to present knowledge (text-fig. 5). Some of them are overlain by the top bed and thus are intra-Abu-Ballas features. In other instances, however, the channel fills uninteruptedly grade into the capping formation. The fills exhibit a variety of sediments, e. g.:

1. Occasional sandstone channels, in gray claystones with numerous remains of various ferns in Sabaya Basin W (longit. 29°43′ E, latit. 25°12′N)
2. Claystones, intergrading with narrow parallel sandstone channels and seams of moderately to fine grained conglomerates that hold phosphatic components including rare vertebrate remains, near Plant Hill (longit. 29°41′E, latit. 25°5′ N). Inintermittent sandstone fills are transitional to the formation above in that area.

The almost ubiquitous presence of the top bed and its final crust suggests an abrupt and contemporaneous stop of clay deposition.

Above and below Abu Ballas Formation whitish to purplish sand- and siltstones with root horizons are present throughout, except where river sediments grade into the capping formation.

Laterally Abu Ballas Formation is interfingering with standstones of the Gilf el Kebir Formation in the SW. The pinch-out in the NE and E, except for the area around longit. 30°5′ E, latit. 24°25′ N, is still unknown.

## Fossil content

Abu Ballas Formation is generally rich in fossils which are in most cases concentrated at certain levels. Determination of these fossils, however, poses some problems because nearly all carbonate and carbonaceous materials have been destroyed in the course of diagenesis. In addition, crushing and distortion becomes a major handicap with fossils preserved in claystones. Continued research thus may bring about some changes in the floral and faunal lists presented below but this will certainly not upset the general conclusion reached here.

### a. Plant fossils

Plant debris can be found in most parts of the sections but good specimens have been extracted only from levels near the top (text-fig. 5). These horizons were probably deposited in freshwater or slightly brackish waters.

Among the plant remains identified so far are ferns like *Hausmannia* and

*Weichselia* (pl. 12, figs. 2, 3), and frequent elongate parallelveined leaves possibly belonging to the enigmatic genus *Stiehleria* (= *Algacites*[?]). Furthermore these beds hold numerous fruits (pl. 12, fig. 4) of unknown provenience.

Plant parts initially thought to belong to *Nathorstiana* or a related form, on closer inspection show side rootlets. Hence *Nathorstiana* is ruled out. The remains probably are fragments of rhizomes belonging to a monocotyledonous water plant (pl. 12, fig. 6).

Since the investigations runnig strengthen the above findings, we apparently are dealing with a Neocomian flora as described from Nothern Germany (MÄGDEFRAU 1968). Our interpretation of the paleoenvironment, though, is differing. While originally these plants were thought to have grown on dunes, we believe they must have lived near river channels mouthing into a wadden area. The climate presumably was hot and seasonal.

In an intra-Abu-Ballas river channel in Sabaya Basin W (text-fig. 5; near the Dakhla-Kharga road) we discovered fragments of crushed stems and leaves of tree-ferns. This is the only locality where some carbonaceous matter has been preserved.

About 40 ms above Abu Ballas Formation, Sabaya Formation yielded a "Solnhofen" flora in several places: *Araucaria, Brachyphyllum* (pl. 12, figs. 1, 5; W. Jung 1974), and *Frenelopsis*. Here again we encounter the elongate leaves mentioned.

At another locality (Plant Hill, longit. 29°41′ E, latit. 25°5′ N) channelled sandstone just a few ms above the top bed yielded an angiosperm flora with leaves of the Potomac type.

b. Invertebrate fossils

Numerous bedding planes in Abu Ballas claystones are covered with invertebrate fossils in various states of deformation. Uncrushed specimens in form of semi-cores are abundant on the surfaces of siltstone intercalations. Only fossils possessing chitino-phosphatic hard parts have their shells more or less well preserved.

Microfossils:

Excluding tiny molluscs, none have been preserved.

Brachiopoda:

*Lingula* sp. (pl. 12, fig. 10) is the only representative of the group. Shells of this inarticulate are distributed almost throughout the section but are fairly abundant in the lower half only.

Lamellibranchiata:

Palaeotaxodonta:

*Nuculana* sp. (pl. 11, fig. 3) is occasionally found with other bivalves in midparts of sections.

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Fig. 5: Simplified sections of Abu Ballas Formation between the Abu Ballas area and the Kharga-Dakhla road, about 100 kms W of Kharga. Average thickness 25—30 ms. — Capping and underlying sandstones stippled; river channels white; major plant occurences indicated by "leaf" sign.

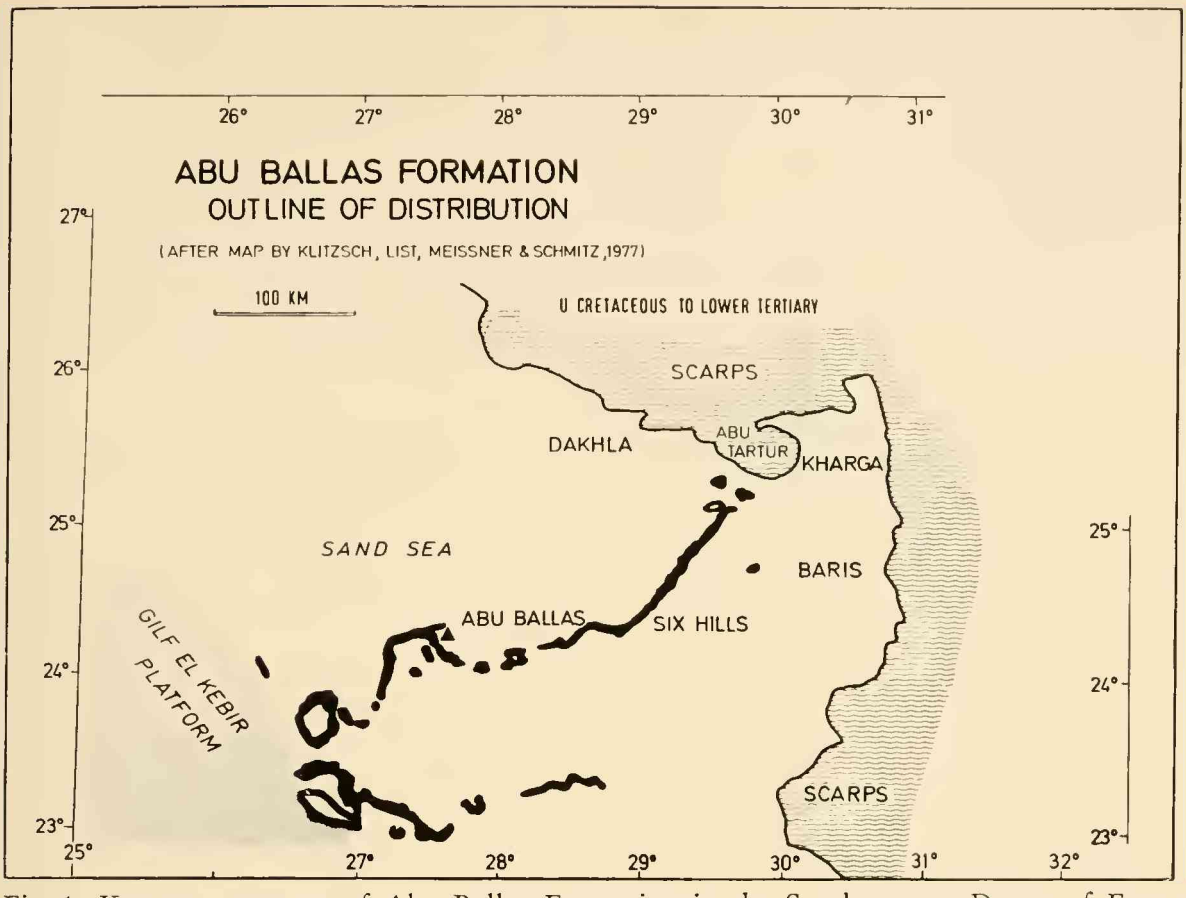
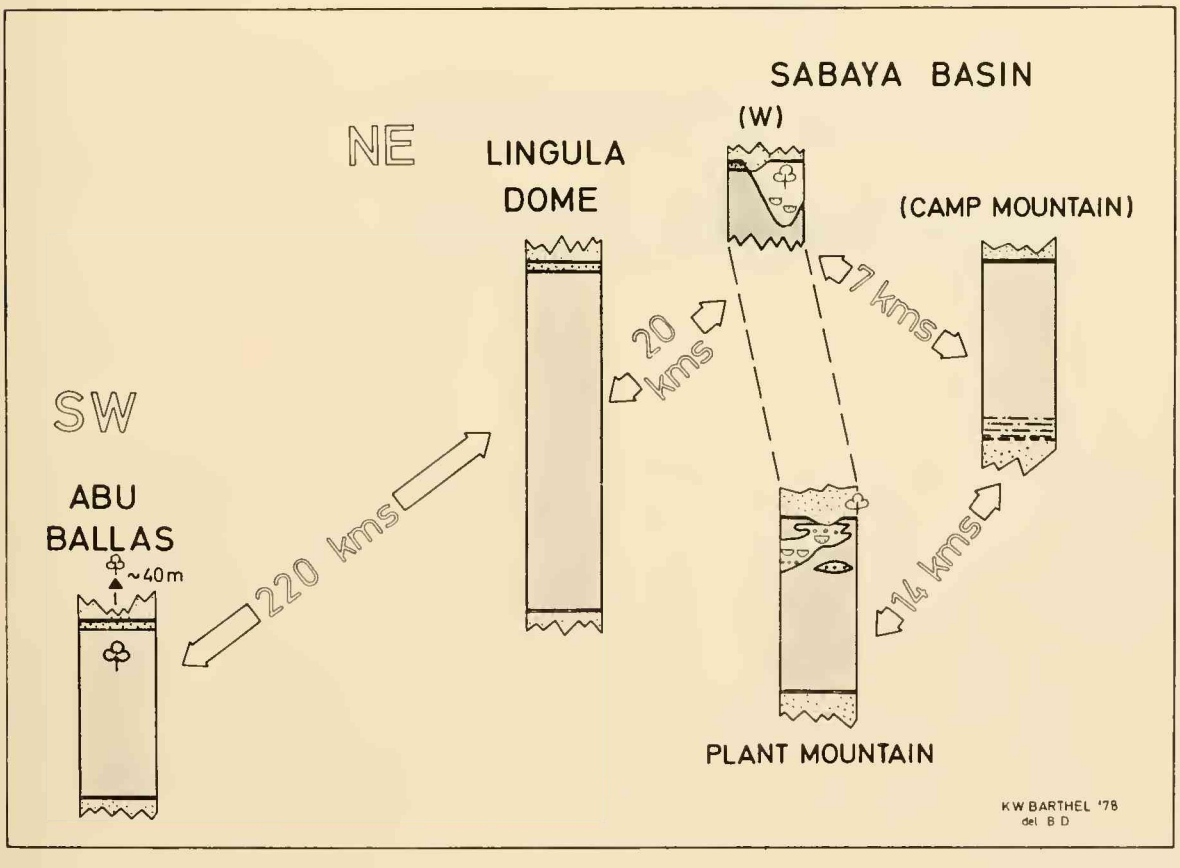



Fig. 4: Known exposures of Abu Ballas Formation in the Southwestern Desert of Egypt after KLITZSCH et al. (1977, unpublished).



Pteriomorphia:

*Grammatodon* sp., rare, in claystone.

*Bositra*(?) sp., so far from claystones only.

*Ostrea* (s. l.) sp., small specimens, on siltstone and claystone, not very frequent.

Palaeoheterodonta:

*Unio*(?) sp., a single specimen from intermediate claystone levels may be attributed to this or a closely related genus.

Heterodonta:

*Protocardia* sp., fairly rare

*Astarte* sp., fairly rare

*Eomiodon* sp., fairly rare

*Neomiodon*(?) sp. (pl. 11, figs. 7, 10). Most of the bivalves on siltstone surfaces probably belong to this genus, well known from the European Purbeckian.

*Corbula* sp., moderately abundant on siltstones. Numerous in the European Purbeckian.

Gastropoda:

At least three smallsized genera have been discerned (cf. pl. 11, fig. 6).

Arthropoda:

All from the plant bearing upper claystone levels.

Crustacea:

Decapoda(?) indet., abdominal segment; a single specimen.

*Archaeoniscus brodiei* Milne-Edwards, Isopoda, fairly abundant (pl. 12, fig. 13).

Insecta:

Coleoptera indet., elytra, rare (pl. 12, fig. 8).

Heteroptera(?) indet., single specimen (pl. 12, figs. 11 a, b)

Echinodermata:

Rare on siltstone surfaces, signalling a marine peak low in midsection.

Asterozoa:

*Asteriacites* sp., an imprint (pl. 11, fig. 9)

Echinoidea:

coronal fragments, generically as yet undetermined (pl. 12, fig. 9)

c. Vertebrate fossils

Teeth, scales, vertebrae and skull plates are occasionally found on midsection siltstone slabs.

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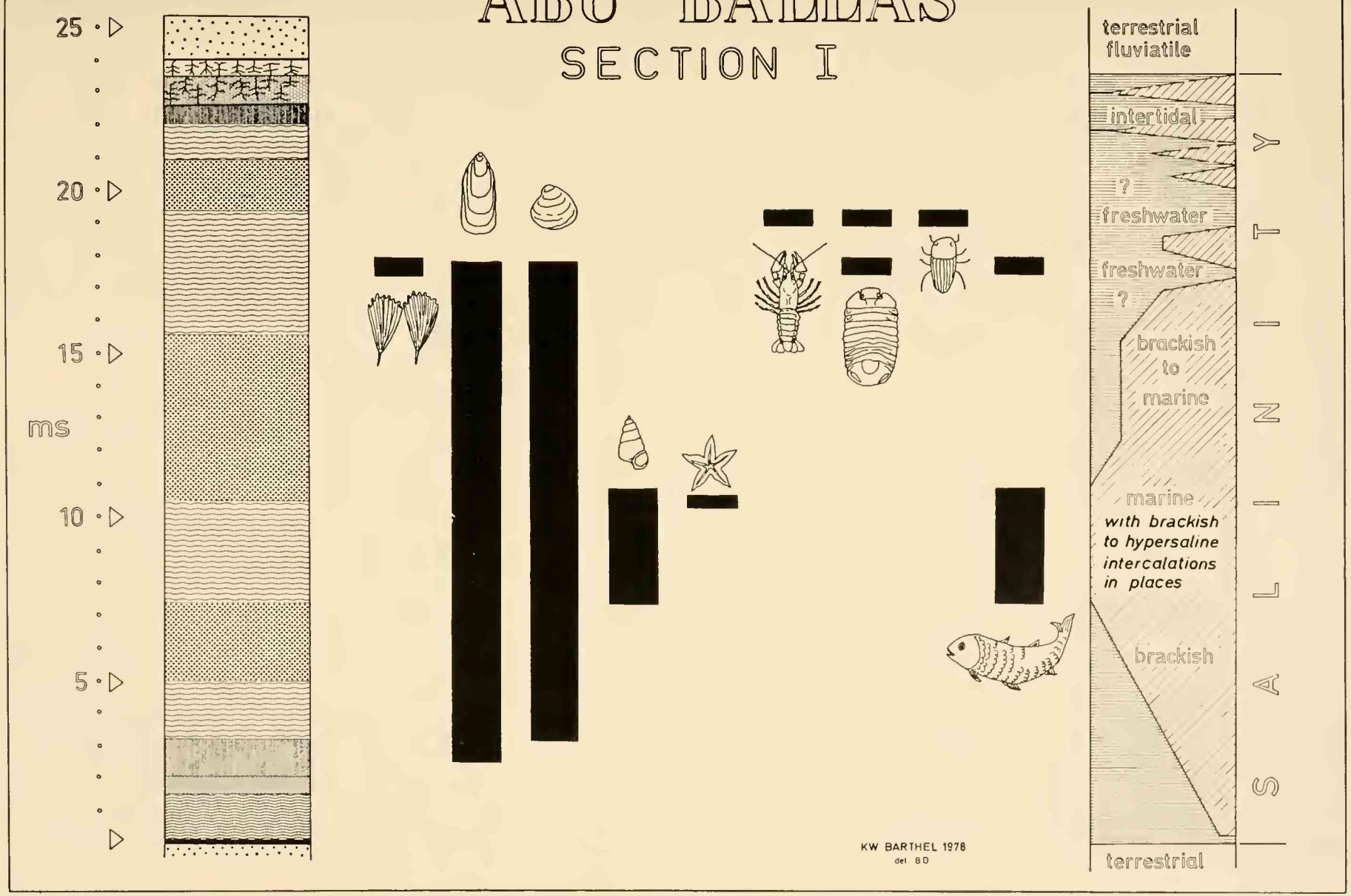
Fig. 6: Simplified reference section (left column), stratigraphic distribution of important fossils (represented by symbols, middle), and assumed environmental conditions (right column) near Abu Ballas. — Stippling in left columnn indicates topping sandstone; top of claystone with symbols for burrowing; shadings represent different colors of claystone, from top to bottom: purple, ochre, pale — green and red in repeated sequences, and at the bottom ochre, gray, and red. Thickness of section 25 ms.



*Pholidophorus* ex gr. *granulatus* EGERTON, scales and a skull roof, very similar in size and surface morphology to the British Purbeckian species (pl. 12 figs. 7 a, b)

d. Trace fossils

They are abundant and have their maximum development in siltstones, in the claystone below the top bed, and in the top bed itself.

Marks:

Scratch- and impact marks caused by transport of shells sometimes cover siltstone surfaces.

Trails, tracks, and other ichnia:

Worms and other animals were roving over the surfaces, leaving countless trails in rippled siltstones throughout the sections. Best specimens, however, are collected from the top bed of Abu Ballas Formation. Zig-zag trails like *Belorhaphe* (pl. 11, fig. 1) and arthropod tracks (pl. 11, fig. 2) have been observed sporadically. The cubichnium of a starfish, *Asteriacites* (see above) is very scarce.

Burrows:

Small burrows of the *Chondrites* (pl. 11, fig. 8) type and simple tubes are richly represented on many of the siltstone intercalations. *Gyrochorte* (pl. 11, fig. 4) supposedly caused by an arthropod, is found between siltstone beds.

Burrows of the callianassid type (shaft diameter about 1 cm) are restricted to the top bed and the claystone immediately below.

All trace fossils registered point to a shallow marine environment with occasional intertidal and freshwater phases (see text-fig. 6, right side). Except for the apparent absence of tidal channels the sediments of Abu Ballas rather resemble those of a wadden area.

## The age

Since preservational and environmental conditions have been too adverse for presence or conservation of index fossils such as ammonites, ostracods, and pollen, we must rely on general floral and faunal aspects for age determination of Abu Ballas Formation.

Until now dating of the "Nubian Series" of the Southwestern Desert was entirely dependent on various plant species indicating ages from Uppermost Triassic to Mid-Cretaceous (see A NICOL-LÉJAL in KLITZSCH 1978).

If we consider the most striking plant genera recovered during our field trips, as mentioned above, we find the range of

*Hausmannia:* Jurassic to Lower Cretaceous

*Weichselia* (incl. *Paradoxopteris):* Lower Cretaceous

*Araucaria* extending from Upper Jurassic to Recent

*Brachyphyllum* extending from Upper Jurassic to late Lower Cretaceous. *B.* has also been recorded from Lower Cretaceous beds of Africa (MÄGDEFRAU 1968).

*Frenelopsis* known from the Lower Cretaceous only.

*Stiehleria:* Hauterivian to Barremian of N Germany; "*Algacites*" from the Tithonian.

Averaging these ranges, an early Lower Cretaceous age for Abu Ballas and lower Sabaya Formations is considered acceptable.

The general faunal picture given above (text-fig. 6) is closely comparable to that of the European Purbeckian. The Purbeckian is a lithostratigraphic unit, straddling the Jurassic/Cretaceous boundary. In the reference area (Swanage, S Great Britain) the lower Purbeck beds are included in the Tithonian whereas middle and upper Purbeck beds represent the Berriasian.

Among the fossils from Abu Ballas Formation two genera deserve special interest as both are readily identifiable and both occur in Europe as well as in Northern Africa:

1. The discovery of numerous specimens of the isopod *Archaeoniscus brodiei* (p. 160) in levels near the top of Abu Ballas Formation was most surprising. This genus is rather trilobite-like in appearance and, at present, has been registered only from the British Lower to Middle Purbeckian and the NW German Serpulite. Thus, a corresponding age for the Egyptian form, i. e. late Upper Jurassic to early Lower Cretaceous, is assumed.

The trilobite-like shape of *Archaeoniscus* initiates associations with some fossils reported from between the crystalline rocks and the Cenomanian series in the well Baharia 1. On grounds of 'trilobite fragments' and *Lingula* (Said 1962, 84, 302) these basal sediments are thought to be Cambrian. Such deposits, however, seem to be rather isolated in that area. Now, if we assume the 'trilobite fragments' to be remains of *Archaeoniscus,* the presence of *Lingula* would match equally well, but the age would be that of Abu Ballas Formation. This suggestion forwarded by Barthel will be checked on as soon as we have located the depository of the Baharia specimens.

2. The scales and the skull roof of the holostean *Pholidophorus* ex gr. *granulatus* again link Abu Ballas Formation with the British Middle Purbeckian where these fishes occur in fairly complete specimens.

Evaluating flora and fauna of Abu Ballas Formation as age indicators we do not hesitate to time its origin with the Jurassic/Cretaceous transition. Further studies and additional fossils may possibly shift the age somewhat, but not significantly, in either way.

## The environmental conditions

The distribution of Abu Ballas claystones shown in text-fig. 4 suggests a large embayment that extended between the Gilf el Kebir and the Kharga oases ("Kharga swell"; text-fig. 3). From the underlaying and the capping sandstones a general south to north direction of sediment transport has been determined (Harms 1977).

Preliminary studies of sediments and fossils lead us to assume estuarine conditions for the embayment area. The situation must have been rather similar to that of the European Purbeckian, except for a negligible carbonate deposition. Consequently, we have to reckon with changes in salinity, occasional freshening and local exposure. An initial brackish stage is indicated by a high count of *Lingula* specimens and few other faunal elements. From trace fossils and sediments we also can derive that the marine realm was shallow and resembling to a wadden sea.

The uniform thickness (text-figs. 3, 5) of Abu Ballas Formation over such vast an expanse must have been due to a very low relief. Start and termination of sedimentation were rather abrupt events.

Finegrained sediments document sluggish rivers, filling channels which had been cut into the estuarine deposits during late Abu Ballas time. Numerous remains of tree ferns (*Weichselia* leaves and long stems of the *Paradoxopteris* type) and other plants are preserved in the river beds. This indicates a lush growth of vegetation along the small steams.

Toward the end of clay deposition an increase of plant fossils suggests increasing freshwater influence. Co-occurence *of Archaeoniscus* (cf. HAACK, 1918; 1921) seems contradictory but this isopod possibly was able to stand strong salinity changes. On the other hand, under the environmental conditions prevailing, freshwater and saline ponds might have existed side by side. Mixing should have occurred frequently during floods and tides.

After another short marine interlude, during the deposition of the Abu Ballas top bed, sedimentation swung back to the terrestrial realm. The white sand- and siltstones covering the formation contain root horizons, silicified trees, and plants that grew on an enormous alluvial plain in a climate of seasonal rainfall. The inverse sequence is observed at the base of Abu Ballas Formation. In areas of tectonic disturbance the basal white and purplish sandstones are easily mistaken for those on top.

In the lower and middle part of the "Nubian Series" the Abu Ballas claystone is the most significant and consistent Formation. It also marks the most conspicuous marine ingression. Minor marine ingressions occured throughout the series.

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Miss B. DUNKER did the line drawings, B. KLEEBERG prepared the photographs.

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# Tafelerklärungen

## Plate 11

Fig. 1: *Belorhaphe* on siltstone. Scarp about 170 kms E of Gilf el Kebir
Fig. 2: Arthropod tracks on siltstone, presumably of *Archaeoniscus*. Lingula Dome N.
Fig. 3: Siltstone with microripples and *Nuculana*. Camp Hill, about 100 kms W of Kharga.
Fig. 4: Oscillation ripples in siltstone with *Gyrochorte* trails. Sabaya Basin W.
Fig. 5: *Lingula* coquina, siltstone. Abu Ballas. Bar = 10 mms.
Fig. 6: Gastropod debris in mineralized siltstone. Gilf el Kebir E. Bar = 1 mm.
Fig. 7: Omission surface paved with *Neomiodon* (?) valves. Claystone. 10 kms E of Lingula Dome.
Fig. 8: *Chondrites* burrows in siltstone. Abu Ballas.
Fig. 9: *Asteriacites* in siltstone. Abu Ballas. Bar = 5 mms.
Fig. 10: *Neomiodon* (?). Claystone. Abu Ballas. Bar = 5 mms.

All specimens are from Abu Ballas Formation.
Depository: Bayer. Staatsslg. Paläont. hist. Geol., Munich, N°. 1978 XIII.

## Plate 12

Fig. 1: *Araucaria* in sandstone; silicone cast, whitened. Abu Ballas. Bar = 10 mms.
Fig. 2: *Hausmannia*, a dipteridacean fern. Claystone. Abu Ballas. Bar = 10 mms.
Fig. 3: *Weichselia*, fragment of leaf. Claystone fill of river channel. Sabaya Basin W. Bar = 10 mms.
Fig. 4: Fruits of unknown provenience, Claystone. Abu Ballas.
Fig. 5: *Brachyphyllum*, silicone cast, whitened. Sandstone. Abu Ballas. Bar = 10 mms.
Fig. 6: Rhizome fragment of (monocotyledonous ?) aquatic plant. Claystone. Abu Ballas. Bar = 10 mms.
Fig. 7: *Pholidophorus ex gr. granulatus* EGERTON. a: skull roof, Lingula Dome N; bar 10 mms. b: scale, Abu Ballas. Bar = 2 mms.
Fig. 8: Elytra of a beetle. Claystone. Abu Ballas. Bar = 1 mm.
Fig. 9: Coronal fragment of an echinoid. Plate boundaries largely obliterated by phosphoritic (?) vernier. Sandstone with bioclasts. Lingula Dome N. Bar 1 mm.
Fig. 10: *Lingula* sp. Claystone. Abu Ballas. Bar 10 mms.
Fig. 11: Heteropteran (?) insect. a, b: slab and counter-slab. Claystone. Abu Ballas. Bar = 2 mms.
Fig. 12: Abdominal segment of a decapod (?). Claystone. Abu Ballas. Bar = 1 mm.
Fig. 13: *Archaeoniscus brodiei* MILNE-EDWARDS. Claystone. Abu Ballas. Bar = 5 mms.

Specimens of figs. 1 and 5 from Sabaya Formation, about 40 ms above the Abu Ballas claystones. All others from Abu Ballas Formation.
Depository: Bayer. Staatsslg. Paläont. hist. Geol., Munich, N°. 1978 XIII.