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The "White" (Upper) Jurassic in Southern Germany

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With 11 plates and 42 figures

1. Introduction

The upper part of the Jurassic sequence in southern Germany is named the "White Jurassic" due to the light colour of its rocks. It does not correspond exactly to the Upper Jurassic as defined by the International Colloquium on the Jurassic System in Luxembourg (1962), because the lower Oxfordian is included in the "Brown Jurassic", and because the upper Tithonian is missing.

The White Jurassic covers more than 10 000 square kilometers between the upper Main river near Staffelstein in northern Bavaria and the Swiss border west of the lake of Konstanz. It builds up the Swabian and the Franconian Alb. Because the upper Jurassic consists mainly of light limestones and calcareous marls which are more resistent to the erosion than the clays and marls of the underlying Brown (middle) Jurassic it forms a steep escarpment directed to the west and northwest. To the south the White Jurassic dips below the Tertiary beds of the Molasse trough.

2. Lithostratigraphy

2.1. The Swabian Alb

The lithostratigraphical sequence of the upper part of the Jurassic in southern Germany was first studied in detail in the Swabian Alb by F. A. Quenstedt (1843). He introduced symbols (α to ζ) for six main lithostratigraphic units which are still in use.

The so-called White Jurassic α is a rather marly formation. Its lower part is defined by a series of about ten grey limestone beds ("Grenzbank" of O. Fraas

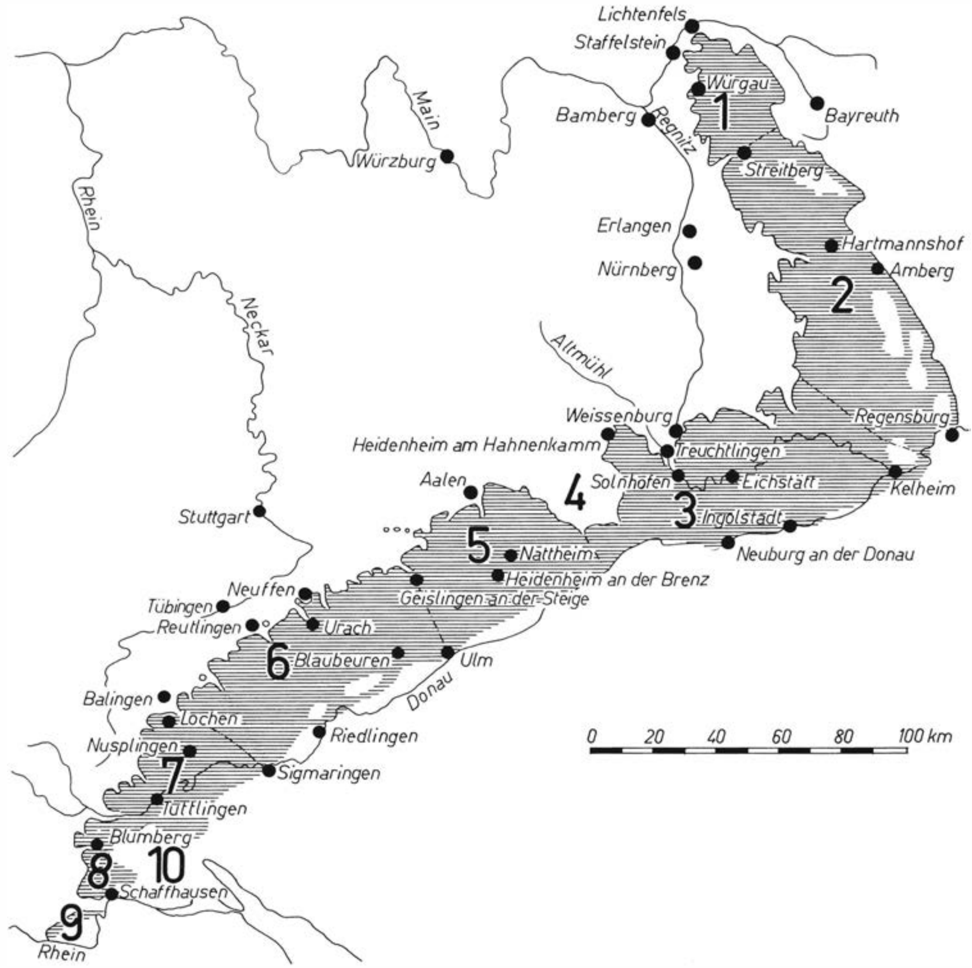


Fig. 1. Schematic map of the distribution of the "White" (upper) Jurassic in southern Germany.
1: northern Franconian Alb, 2: central Franconian Alb,
3: southern Franconian Alb, 4: Ries, 5: eastern Swabian Alb,
6: central Swabian Alb, 7: southwestern Swabian Alb,
8: Randen, 9: Klettgau, 10: Hegau.

1882, p. 124; see also F. A. QUENSTEDT 1858, p. 574, G. WUNDT 1883, p. 151, and A. J. A. ZAKRZEWSKI 1887, p. 95). In the southwesternmost part of the Swabian Alb (near Blumberg) these beds are replaced by sponge biostromes. Marls and clays immediately below the limestones and biostromes contain fossils of the lower Oxfordian. They are included into the White Jurassic by A. ZEISS (1957, p. 197) and subsequent authors. Here they are classified as uppermost Brown Jurassic ζ according to the original usage.

The basal limestones of the White Jurassic α are followed by grey marls. Except for the lowermost part they are characterized by weathered ferrugineous (originally

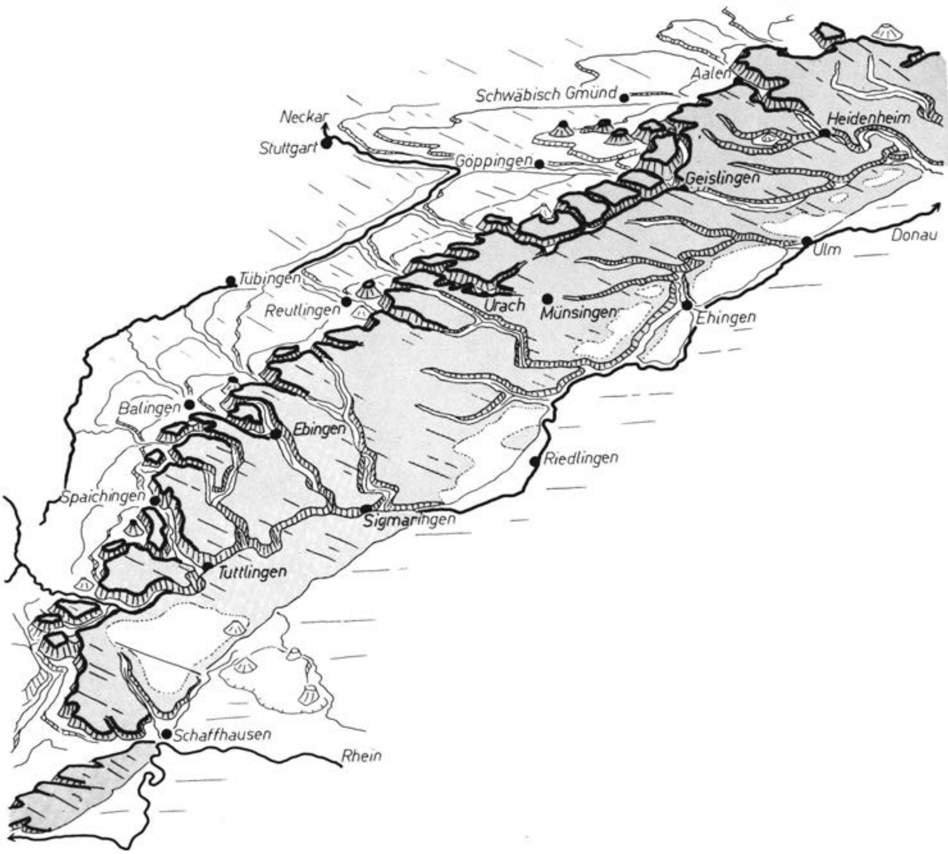


Fig. 2. The tableland of the Swabian Alb (shaded: "White" Jurassic) and its erosional slope in the north and northwest. View from the south. After A. Koch in G. Wagner (1960).

pyritic) small nodules. The upper part of the White Jurassic α is built up by marls and limestones which are replaced in the southwestern part of the Swabian Alb by sponge biostromes and bioherms named the Lochen beds. The total thickness of the White Jurassic α varies between 25 m (in the southwest) and 100 m (in the central and eastern parts of the Swabian Alb).

The White Jurassic β was named by F. A. Quenstedt the "well bedded limestones". It is a rather uniform series of limestone beds separated by thin layers of marl. As it was shown by E. Seibold (1950, p. 294) in the upper part of the formation individual beds can be correlated over large distances. In some places sponge bioherms are intercalated in this sequence. In the southwestern part of the Swabian Alb biostromes and bioherms are the predominant representations of this formation. The thickness of the White Jurassic β is about 30 m in the central and eastern parts of the Swabian Alb. It reaches up to 100 m in the southwest.

The White Jurassic γ is once more a rather marly formation. Its lithostratigraphic subdivision was studied by H. Aldinger (1945, p. 112, 143) and O. F.

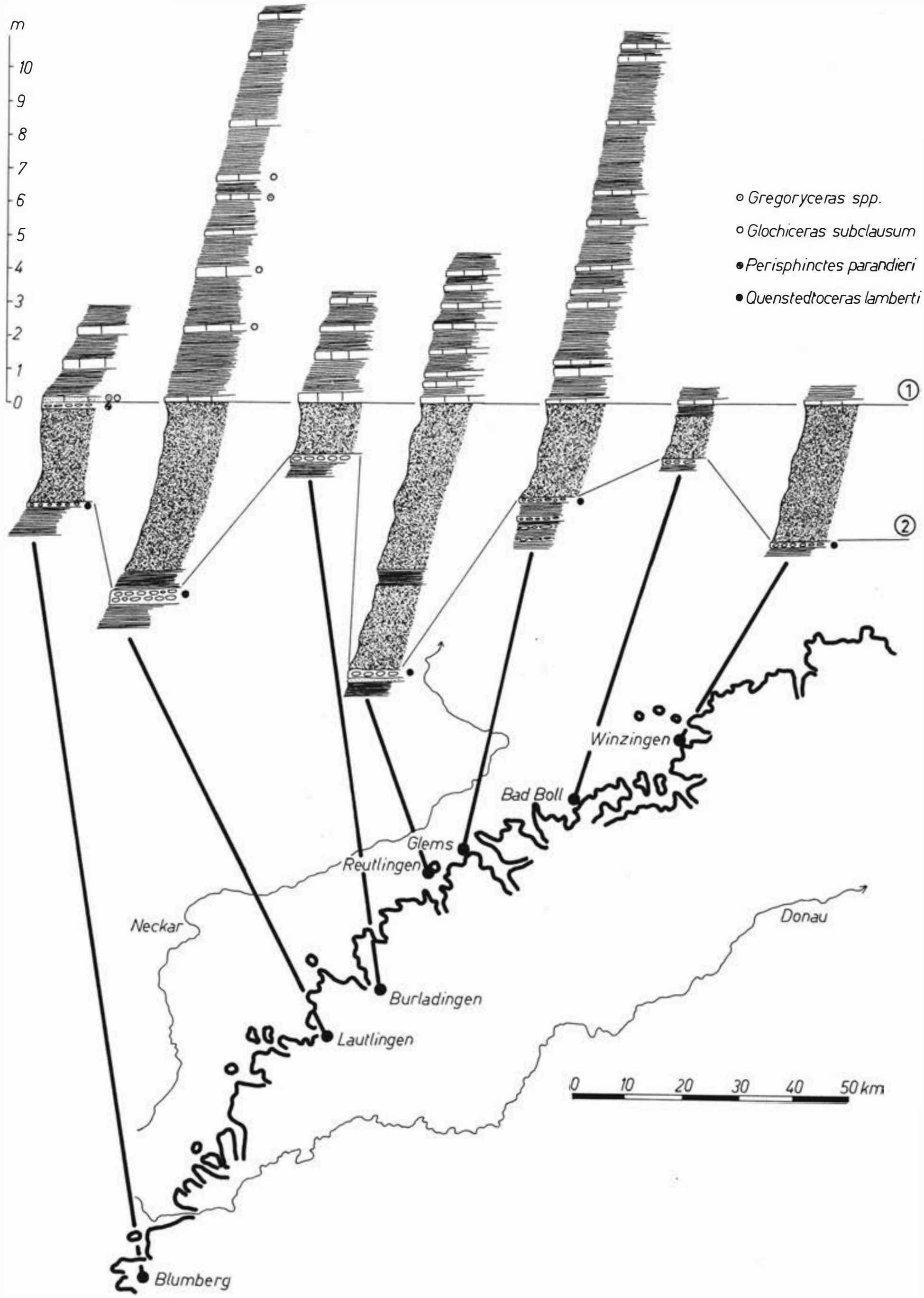


Fig. 3. The sequence at the limit "Brown" / "White" Jurassic in the central and southwestern parts of the Swabian Alb.

1: Base of the "White" Jurassic according to F. A. QUENSTEDT, O. FRAAS, G. WUNDT, and A. J. A. ZAKRZEWSKI.

GEYER (1961a, p. 105). More calcareous beds are intercalated few meters above the base of the formation, at the base of its upper part, and within the upper part. These calcareous members can be traced as a whole, but not as individual beds, from the southwest to the east all over the Swabian Alb. As in the White Jurassic β in some localities small sponge bioherms occur within the sequence. Especially the calcareous horizon at the base of the upper part of the White Jurassic γ is often represented by sponge limestones. The thickness of the White Jurassic γ is largest in the central part of the Swabian Alb (55 to 65 m). Towards the east (Aalen: 35 m) and the southwest (Tuttlingen: 20 m) the thickness is considerably less.

The White Jurassic δ is represented by bedded limestones. The lithostratigraphical subdivision was established by H. ALDINGER (1945, p. 112) and refined by B. ZIEGLER (1955, p. 40). As in the White Jurassic β individual beds can be traced over large distances (B. ZIEGLER 1958a, p. 266). The lowermost meters of the formation are rather thin bedded. Then a more marly sequence follows. The middle part is once more rather thin bedded whilst the upper part of the formation is built up by thick bedded limestones without layers of marl. A marker bed (Glauconite marker bed) separates the middle from the upper part of the White Jurassic δ. Approximately at the same horizon the sponge limestones spread over most parts of the Swabian Alb. The mean thickness of the White Jurassic δ is in the central part of the Swabian Alb about 50 meters, in the east and the southwest somewhat less.

The White Jurassic ε was originally established by F. A. QUENSTEDT (1843, p. 447) for unbedded limestones and dolomites of the upper White Jurassic. In addition he thought silifications to be characteristic of this formation. In the meantime it became clear that the massive limestones are of rather different ages. They range from the White Jurassic β to the White Jurassic ζ and originated in the extensive growth of algal-sponge bioherms. Silification, too, is not of stratigraphic value. The existence of bedded limestones contemporaneous to the massive limestones was first dicovered by TH. SCHMIERER (1902, p. 542) and studied in detail by F. BERCKHEMER (1922) and A. ROLL (1931). They are characterized by a light, somewhat brownish colour and are usually thin bedded. Marly layers are missing. A correlation of individual beds over large distances is not possible. Although the bulk of the unbedded limestones starts with the upper part of the White Jurassic δ the White Jurassic ε is now restricted to parts of these rocks and to its bedded equivalents. The mean thickness of the White Jurassic ε in the revised sense is about 20 to 30 meters.

The White Jurassic ζ comprises the more marly sediments above the pure limestones of the White Jurassic ε in the Swabian Alb. Their lithostratigraphic sub-

2: Base of the "White" Jurassic, according to A. ZEISS, H. HÖLDER, and O. F. GEYER & M. P. GWINNER.

Section Blumberg after A. ZEISS (1955), G. HAUERSTEIN (1966), and R. GYGI (1969). Section Lautlingen after A. J. A, ZAKRZEWSKI (1887). Section Burladingen after W. HAHN & U. KOERNER (1971). Section Reutlingen after K. SCHÄDEL in H. HÖLDER (1964). Section Glems after A. TERZIDIS (1966). Section Bad Boll after H. SÖLL (1954). Section Winzingen after G. STAHLECKER (1934).

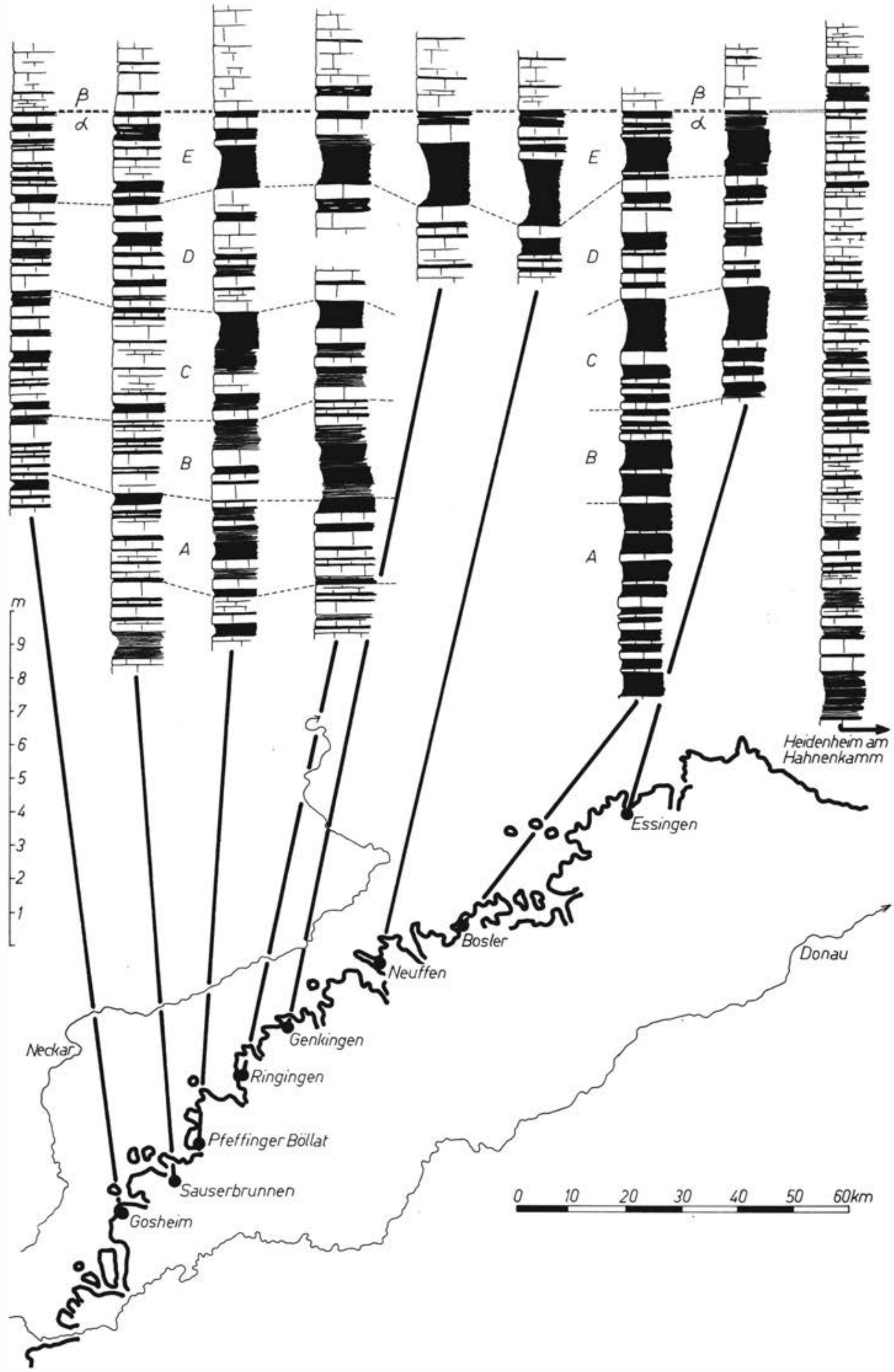


Fig. 4. The lithostratigraphy of the uppermost part of the White Jurassic α.
Sections Gosheim, Sauserbrunnen, Pfeffinger Böllat, Ringingen, and Genkingen after U. KOERNER (1963). Section Neuffen after E. & I. SEIBOLD (1953). Sections Bosler, Essingen, and Heidenheim am Hahnenkamm after H. SCHMIDT-KALER (1962 b).

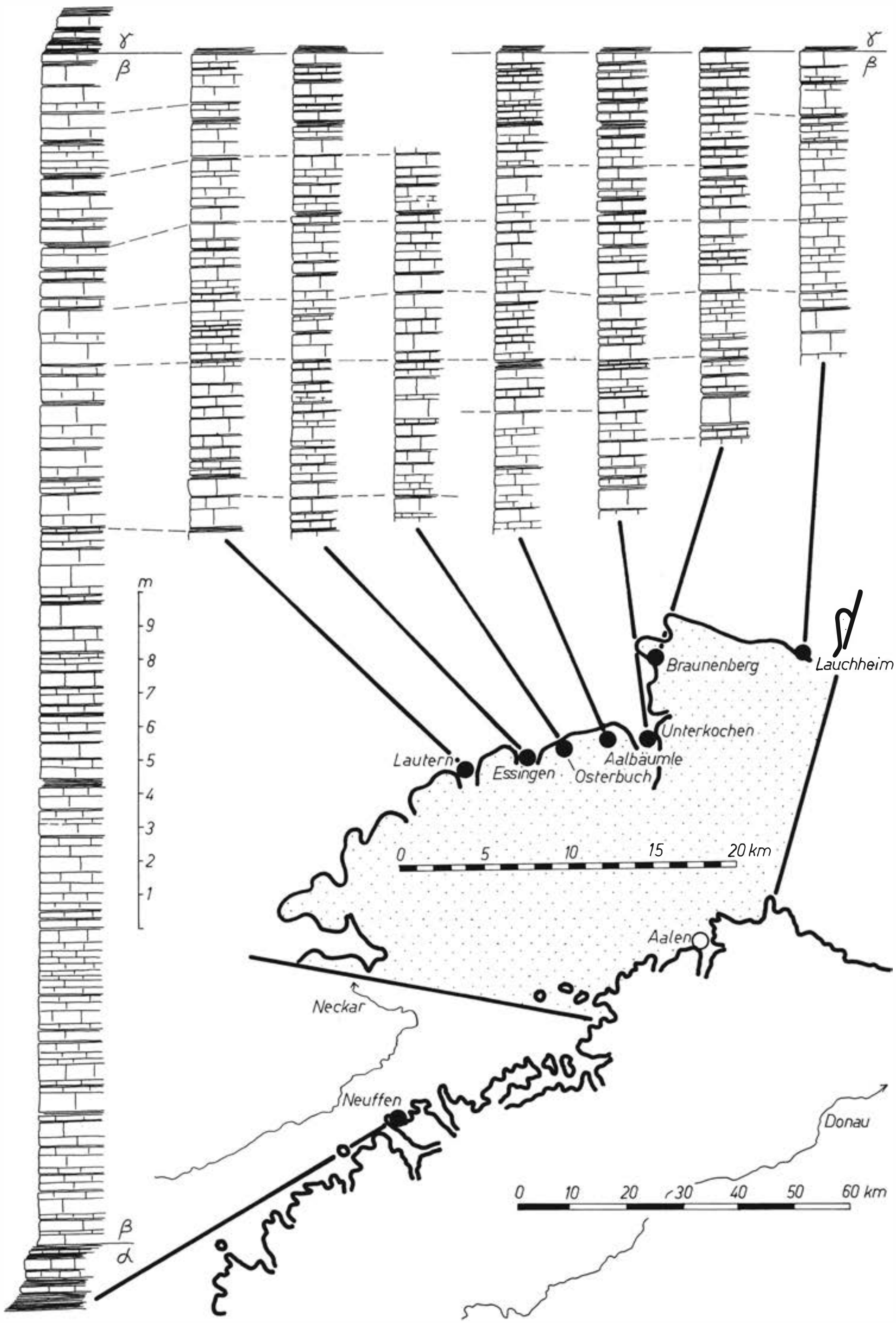


Fig. 5. The lithostratigraphy of the White Jurassic β at the section of Neuffen (after E. & I. SEIBOLD 1953), and the correlation of individual beds in the eastern Swabian Alb (after E. SEIBOLD 1950).

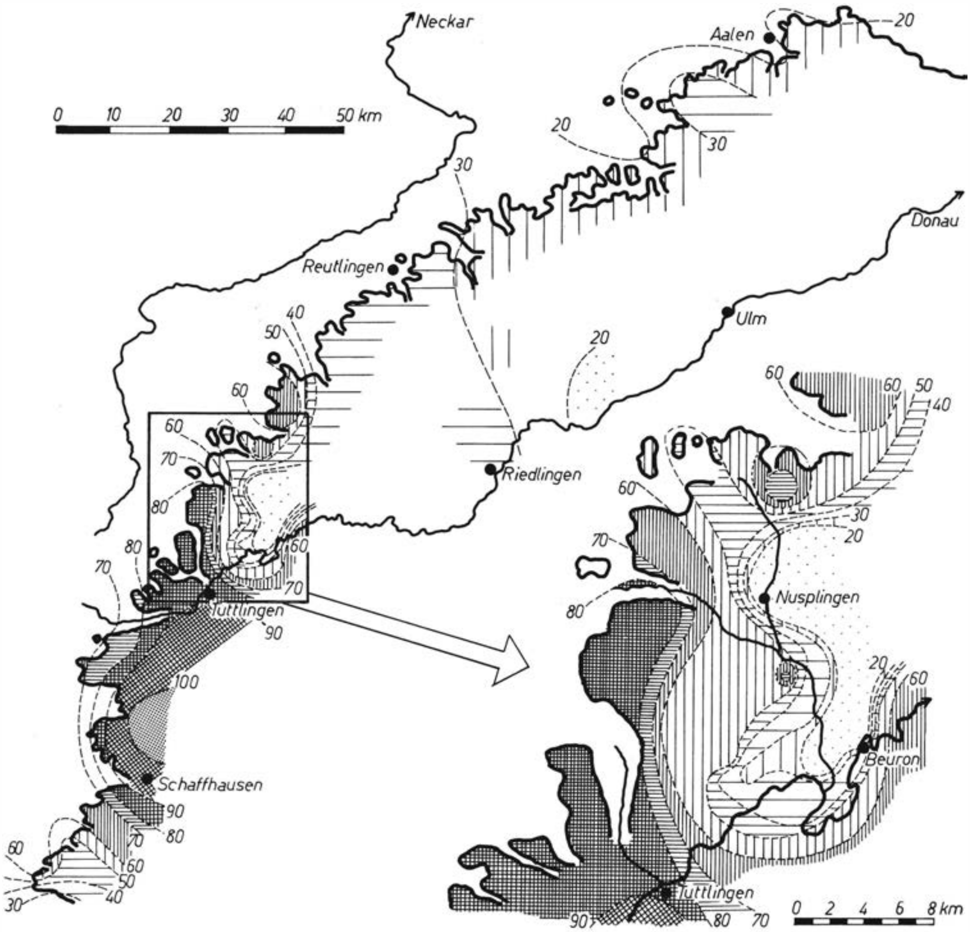


Fig. 6. The thickness of the White Jurassic β in the Swabian Alb.
Isopachs after E. DIETERICH (1940), modified after R. GYGI (1969) for Klettgau, Randen, and southwesternmost Swabian Alb, D. ELWERT (1963), H. GEBERT (1964), and G. HAFNER (1969) for the southwestern part of the Swabian Alb, E. WIRTH (1958; 1960) for the boreholes Buttenhausen, Upflamör, and Ehingen, and E. SEIBOLD (1950), M. BEURER (1963), and W. SCHALL (1964) for the eastern part of the Swabian Alb.

division was established by A. ROLL (1931). In the bedded facies it starts with irregularly bedded limestones alternating with marly layers. This member is named the "Liegende Bankkalke" and reaches a thickness of about 30 to 50 meters (in the eastern part of the Swabian Alb up to 100 m). At some localities in the central and southwestern Swabian Alb the limestones pass laterally into calcareous shales (e. g. Nusplingen). The "Liegende Bankkalke" are followed in some restricted areas by the Cement marls which attain a thickness up to 120 meters. The uppermost unit in the Swabian Alb is named the "Hangende Bankkalke". They are represented by an alternation of irregularly bedded limestones and marly layers. Because they are

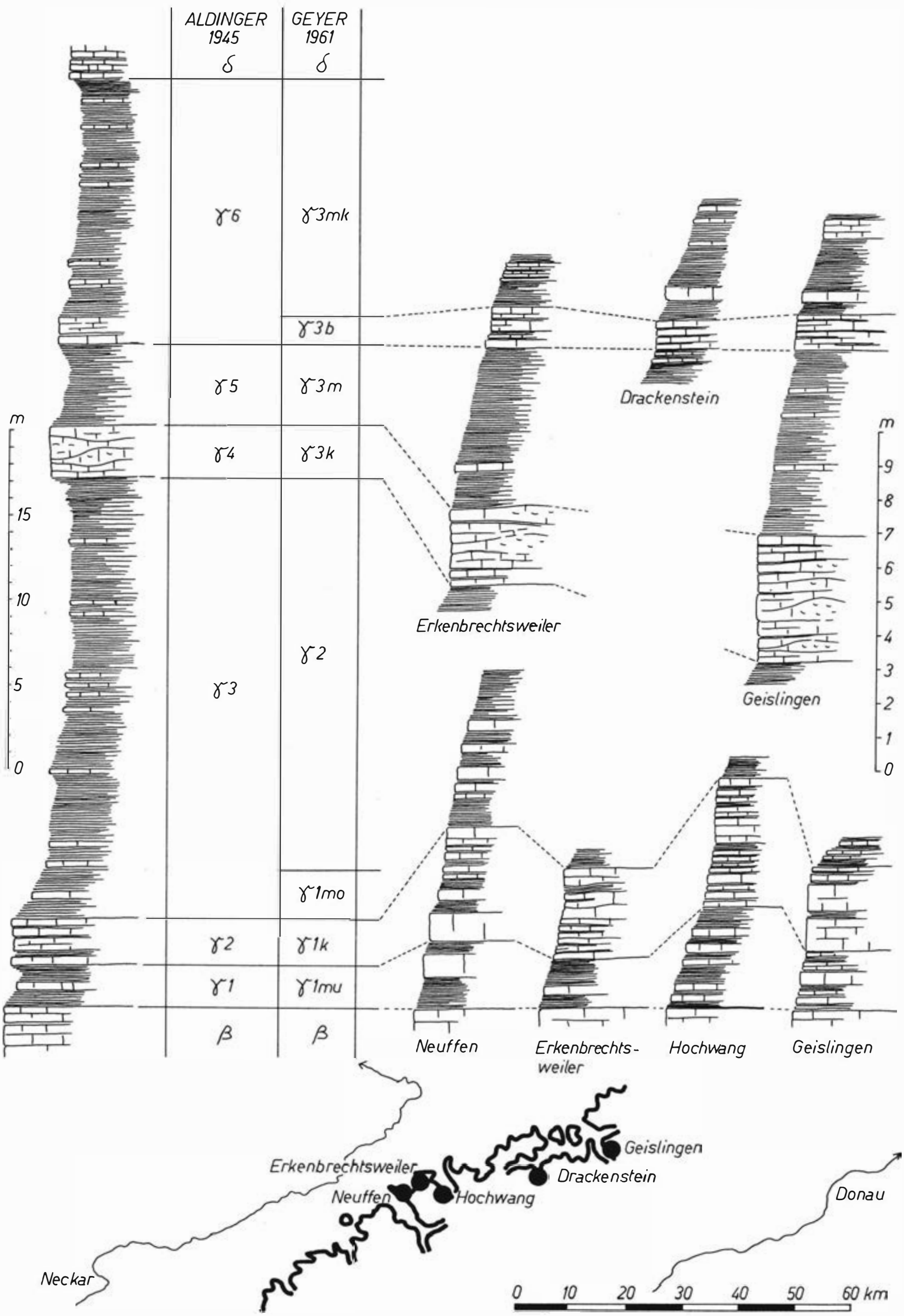


Fig. 7. The lithostratigraphy of the White Jurassic γ in the central part of the Swabian Alb. After H. ALDINGER (1945) and O. F. GEYER (1961 a).

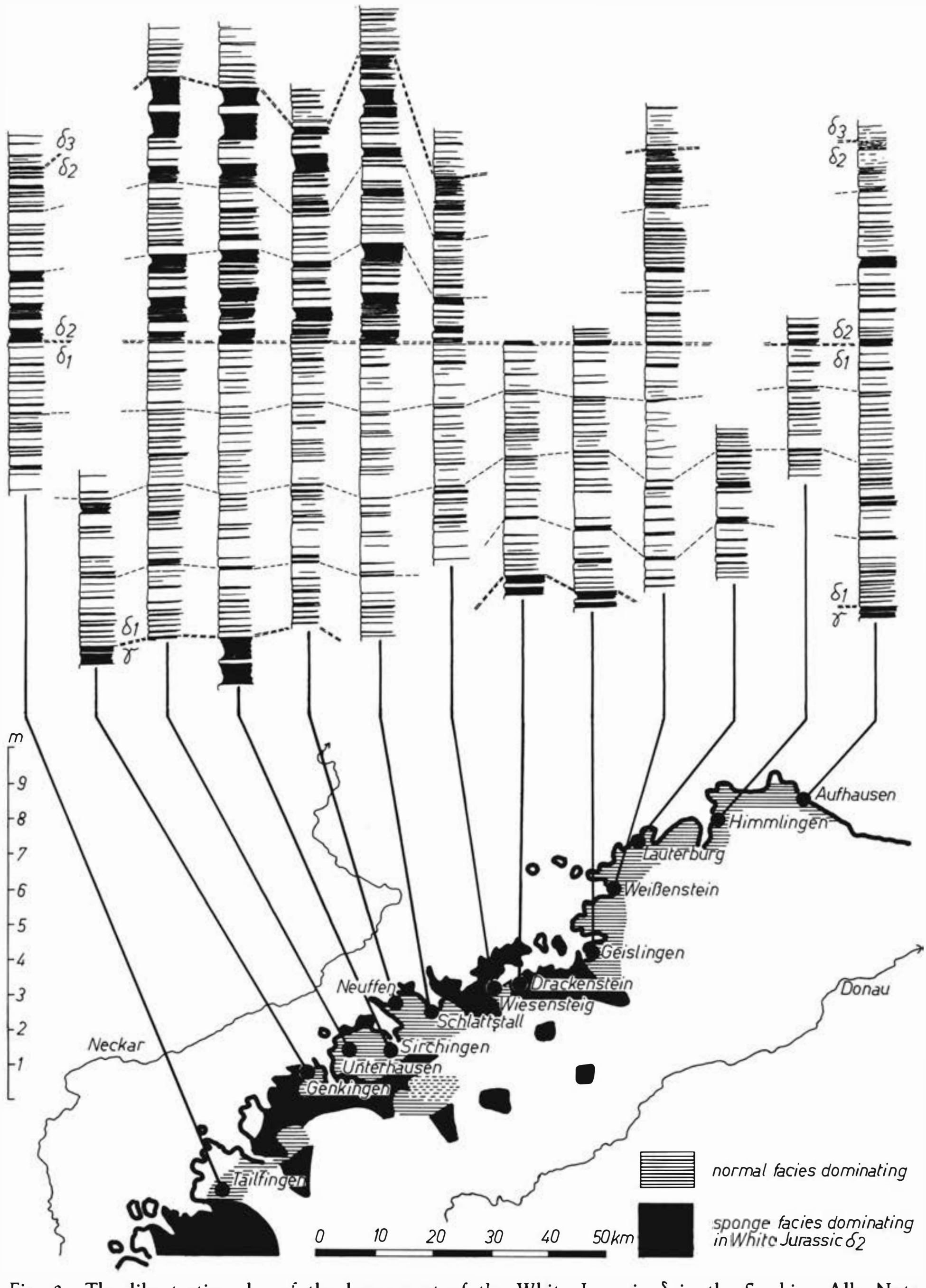


Fig. 8. The lihostratigraphy of the lower part of the White Jurassic δ in the Swabian Alb. Note the more marly sequence of the White Jurassic δ 2 in the Urach region (sections Unterhausen, Sirchingen, Neuffen, and Schlattstall). After B. ZIEGLER (1955; 1959).

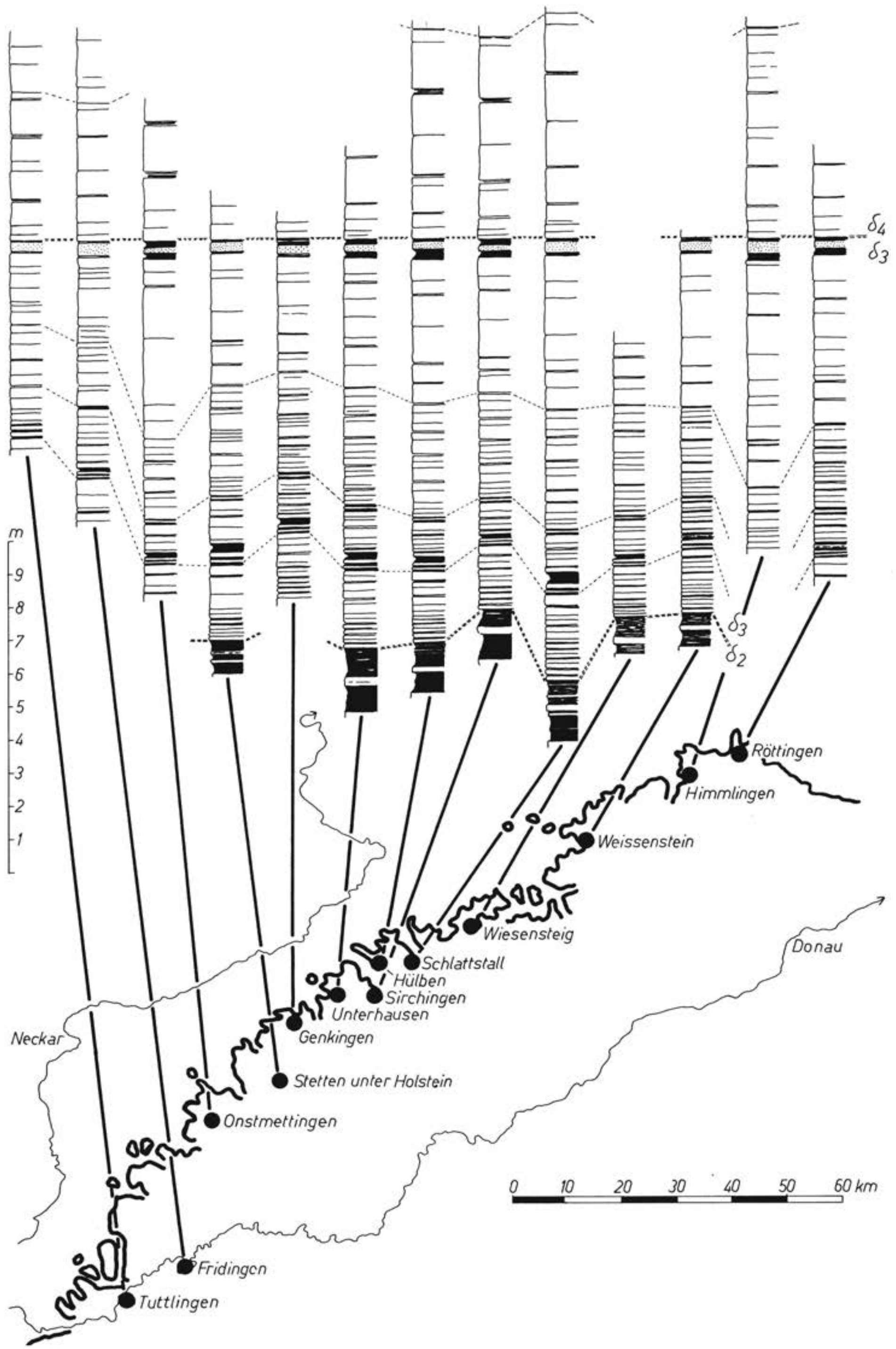


Fig. 9. The lithostratigraphy of the middle part of the White Jurassic δ in the Swabian Alb. After B. ZIEGLER (1955; 1958 a; 1959).

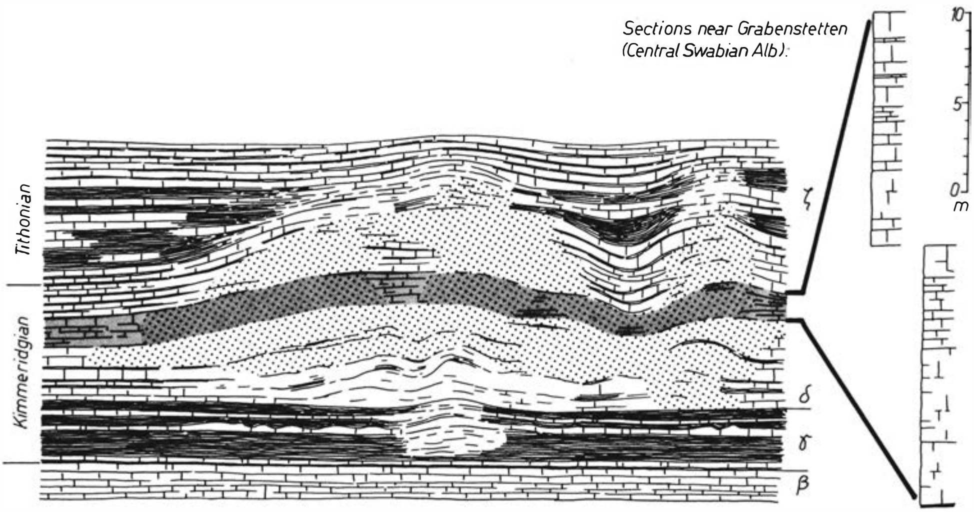


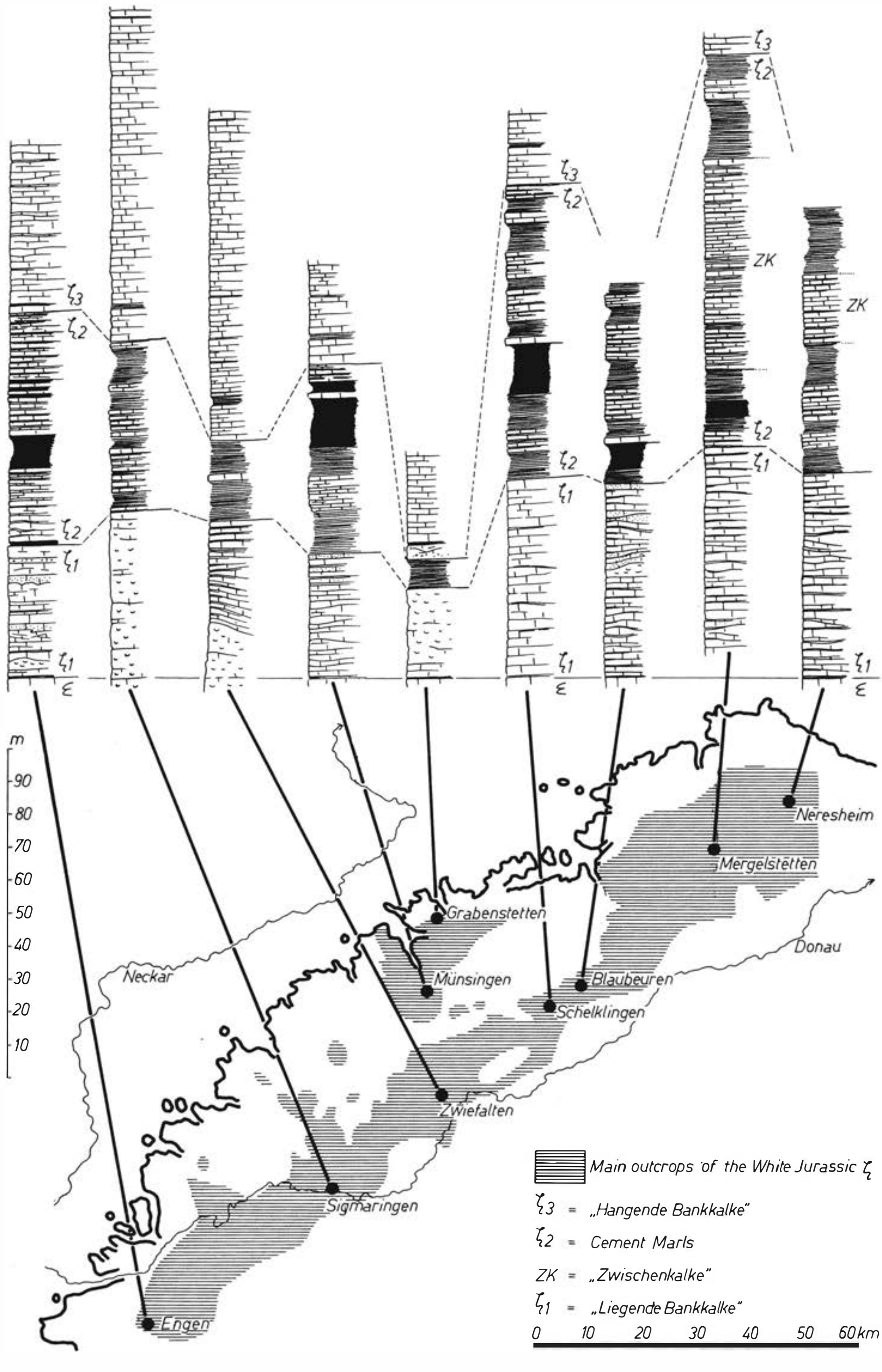
Fig. 10. The different interpretations of the White Jurassic ε. Stippled: The White Jurassic ε according to F. A. QUENSTEDT. Shaded: The White Jurassic ε as the term is used today. After O. F. GEYER & M. P. GWINNER (1961). Section Grabenstetten after F. BERCKHEMER & H. HÖLDER (1959).

eroded more or less their original thickness is not known but must have exceeded 100 meters. All these beds are locally replaced by biostromes and bioherms, mostly built up by sponges, sometimes — in the "Liegende Bankkalke" and the Cement marls — by corals. The lithostratigraphic relationships of the White Jurassic ζ are best summarized by M. P. GWINNER (1976, p. 17).

2.2. The Franconian Alb

The upper Jurassic sequence in the Franconian Alb resembles that of the Swabian Alb. In the lower and middle part of the upper Jurassic — corresponding to the Swabian White Jurassic α to δ — three basins with minor differences in sedimentation are recognized (A. ZEISS 1968a). The basins are separated by algal-sponge bioherms. In the northernmost basin the greatest affinities to the sedimentation of the Swabian Alb are present. In the other basins the sediments are more calcareous,

Fig. 11. The lithostratigraphy of the White Jurassic ζ.
Section Engen after A. SCHREINER (1961). Section Sigmaringen (combined section) after A. ROLL (1931) and J. SCHNEIDER (1957). Section Zwiefalten after H. W. HAAG (1960) and J. SCHNEIDER (1957). Sections Grabenstetten and Münsingen after J. SCHNEIDER (1957). Sections Schelklingen and Blaubeuren after W. LILLICH (1962) and J. SCHNEIDER (1957). Sections Mergelstetten and Neresheim after M. BEURER (1963), K. KNOBLICH (1963), W. REIFF (1958), and J. SCHNEIDER (1957).


ζ3
ζ2
ζ1
ε
ZK
m
90
80
70
60
50
40
30
20
10
Neckar
Donau
Grabenstetten
Münsingen
Neresheim
Mergelstetten
Blaubeuren
Schelklingen
Zwiefalten
Sigmaringen
Engen
Main outcrops of the White Jurassic ζ
ζ3 = „Hangende Bankkalke"
ζ2 = Cement Marls
ZK = „Zwischenkalke"
ζ1 = „Liegende Bankkalke"
0 10 20 30 40 50 60km

especially in the more marly formations. Correlation of individual beds is possible within each basin (B. v. FREYBERG 1966) but difficult between different basins.

Pecularities in the Franconian Alb are the Treuchtlingen "marble", a thick bedded calcareous formation restricted to the Southern Franconian Alb and equivalent approximately to the Swabian White Jurassic δ, and the "Franken-Dolomit". This latter formation is built up by sometimes massive, sometimes stratified dolomites which correspond to the massive limestones of the Swabian White Jurassic ε and uppermost δ but sometimes apparently include even lower strata. Thus the "Franken-Dolomit" especially in the southern Franconian Alb partly overlies and partly is equivalent to the Treuchtlingen "marble" (U. BANTZ 1970; R. MEYER 1972; 1974; 1977).

It is the upper part of the upper Jurassic for which especially the southern Franconian Alb is famous. A summary was given by B. v. FREYBERG (1968) and A. ZEISS (1968a, p. 103; 1968b, p. 17). The sequence above the Treuchtlingen "marble" and the "Franken-Dolomit", respectively, starts with pure, bedded limestones. Locally silifications are frequent. These series, which are named the Torleite beds and the Geisental beds, are followed by the well known Solnhofen calcareous shales and by the Mörnsheim beds which resemble the Solnhofen shales but contain much more silica. The sequence continues with the Usseltal formation (bedded limestones and calcareous shales) and the Rennertshofen formation. All these strata together attain a maximum thickness of about 400 meters, that is more than twice the thickness of all the formations corresponding to the Swabian White Jurassic α to δ.

In a very restricted area near Neuburg an der Donau the youngest sediments of the Franconian Jurassic are exposed. This Neuburg formation contains white, somewhat marly limestones and is about 45 meters thick (K. W. BARTHEL 1962; 1969).

Between Regensburg and Passau small outcrops of upper Jurassic sediments are known (L. v. AMMON 1875). However, they will not be mentioned further. For references on the upper Jurassic in Franconia see B. v. FREYBERG (1974), E. FLÜGEL (edit., 1975, p. 154, 212), and A. ZEISS (1977).

2.3. The Upper Rhine Valley

In the Upper Rhine Valley between Basel and Freiburg some outcrops of tectonically isolated upper Jurassic rocks are known. Because they belong to the so-called rauracic facies belt they will not be treated in this context.

3. Biostratigraphy

The biostratigraphy of the White Jurassic sequence in southern Germany is based mainly on ammonites. Other macrofossils and foraminifera are of less value. Ostracods are not yet studied. Ammonites are rather frequent and a great variety of genera and species is present. It has been found that perisphinctids and aspidoceratids are the best index fossils, the range of haploceratids in most cases being much larger.

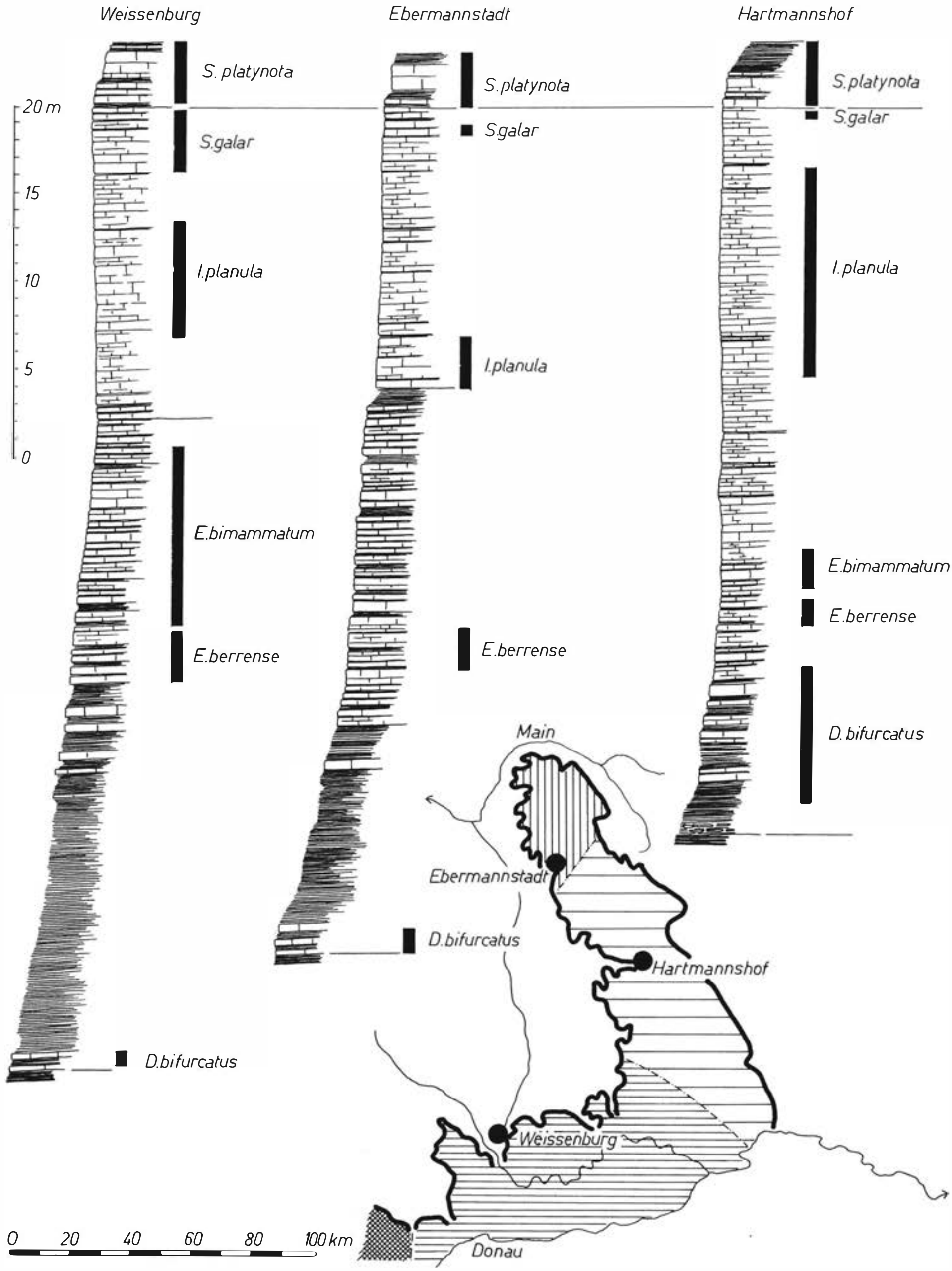


Fig. 12. The three sedimentary basins in the lower Malm of the Franconian Alb and sections characteristic for them.
Ebermannstadt: northern Franconian Alb; Hartmannshof: central Franconian Alb; Weissenburg: southern Franconian Alb. Cross-hached: eastern Swabian Alb. After B. v. FREYBERG (1966) and A. ZEISS (1968 a).

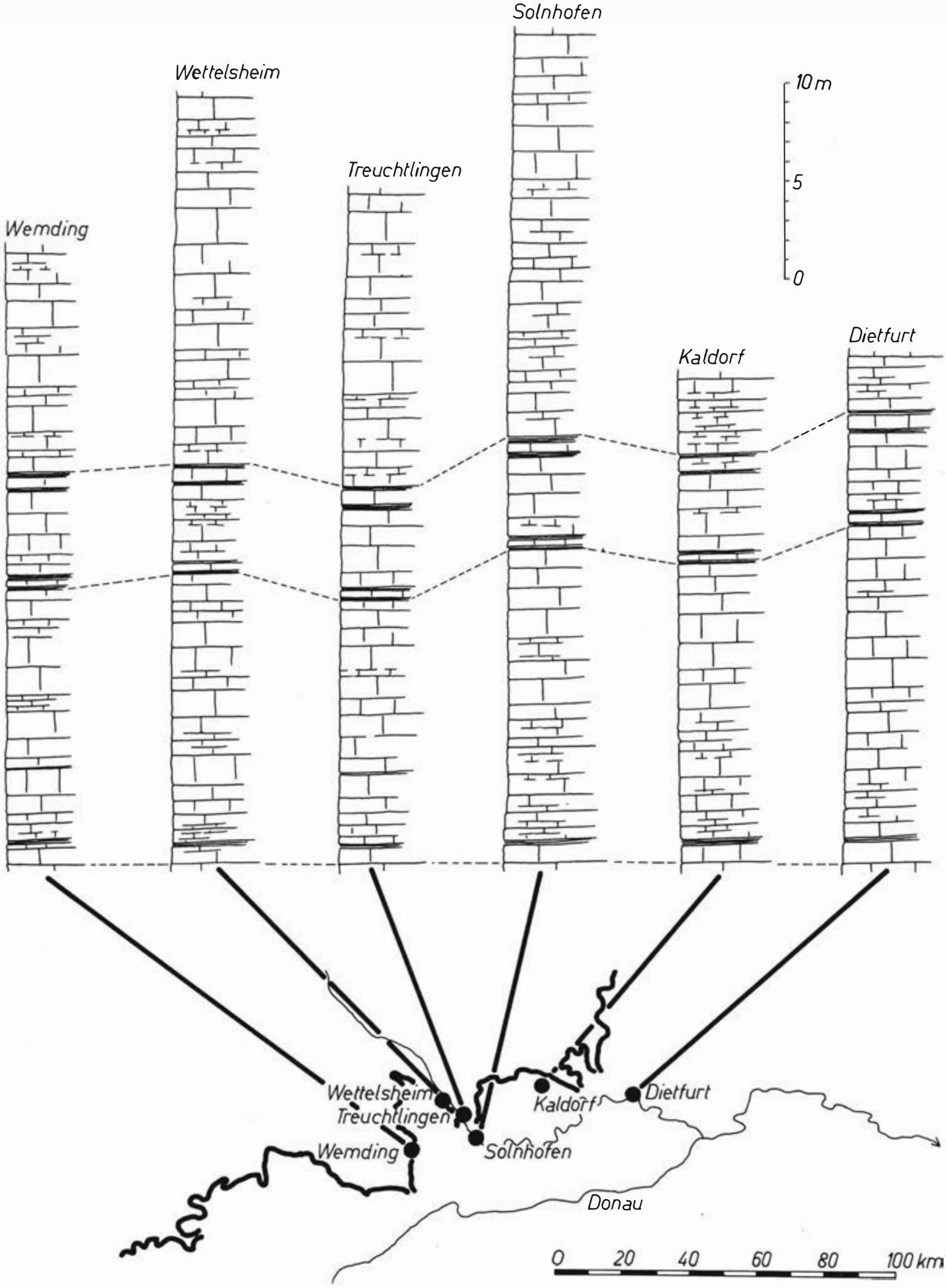


Fig. 13. The correlation of individual beds in the Treuchtlingen "marble", according to H. SCHMIDT-KALER (1962 b, and personal communication).

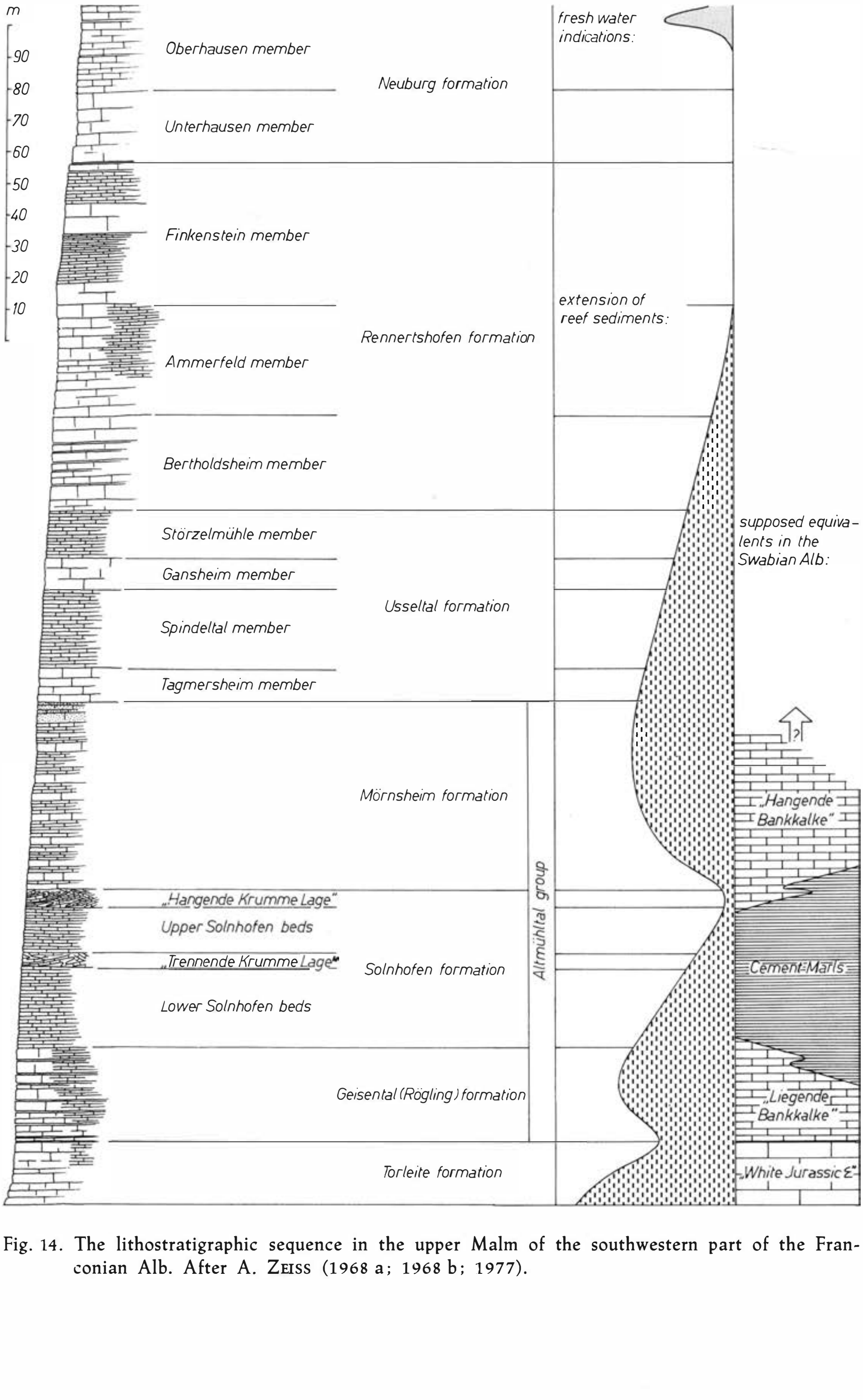


Fig. 14. The lithostratigraphic sequence in the upper Malm of the southwestern part of the Franconian Alb. After A. ZEISS (1968 a; 1968 b; 1977).

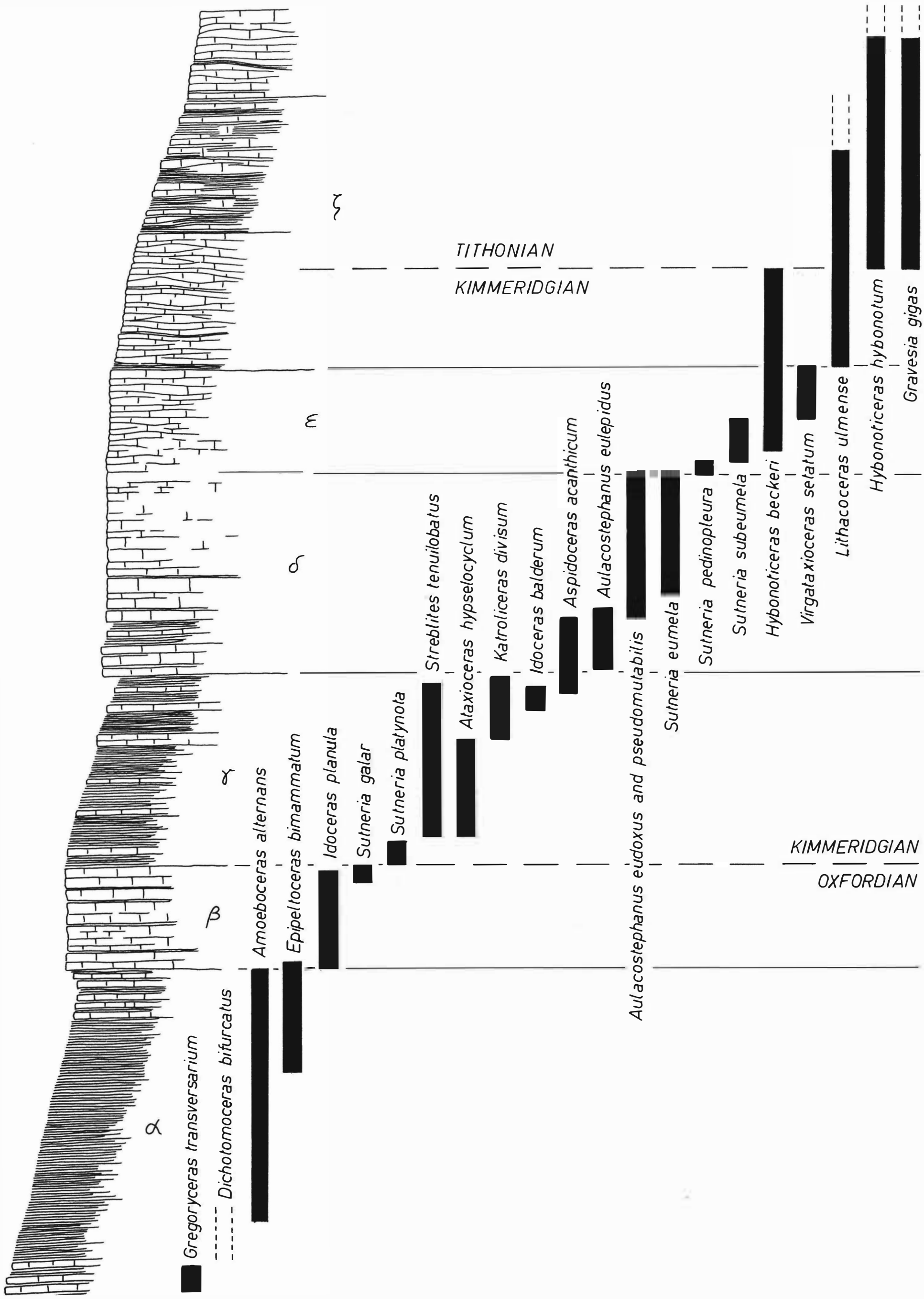


Fig. 15. Main index fossils of the White Jurassic of the Swabian Alb. After I. G. SAPUNOV & B. ZIEGLER (1976).

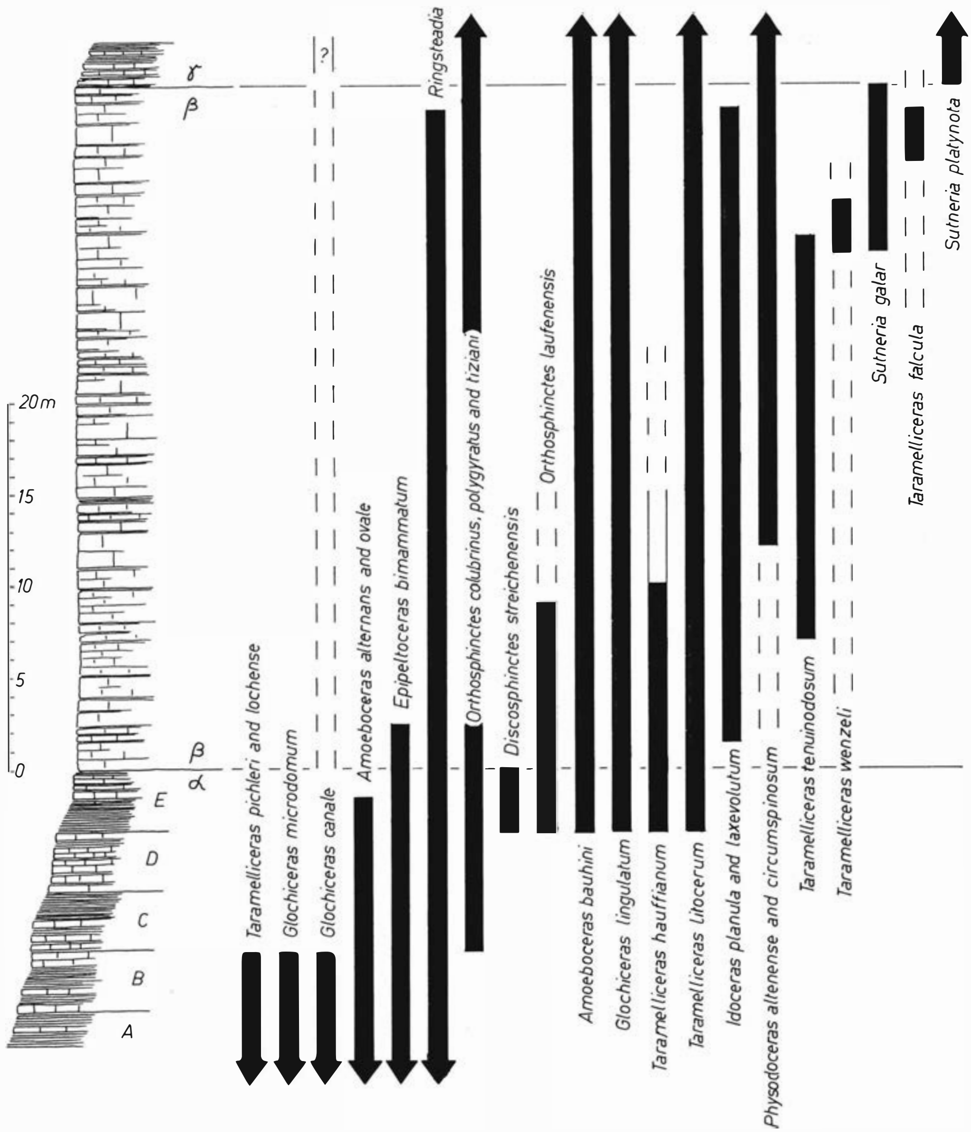


Fig. 16. Ranges of some ammonites in the uppermost White Jurassic α and in the White Jurassic β in the Swabian Alb. Mainly after E. DIETERICH (1940) and U. KOERNER (1963).

3.1. The Swabian Alb

In the Swabian Alb the base of the White Jurassic α is characterized by *Gregoryceras transversarium* and *G. toucasianum.* Unfortunately both species are very rare. However, *Glochiceras subclausum, Ochetoceras canaliculatum,* and *O. hispidum* are valuable substitutes. Somewhat above follows a horizon with *Dichotomoceras bifurcatus.* This zone is proven only at very few localities, owing to difficulties in preservation. In the marls of the middle White Jurassic *α* no ammonite species restricted to these beds is known, but the brachiopod species *Aulacothyris impressa* is a useful marker. *Amoeboceras alternans* is used as index fossil. It occurs, however, in the upper part of the White Jurassic *α* and in the Lochen beds, too. In the upper part of the White Jurassic *α* *Epipeltoceras bimammatum* occurs, but is very rare. More frequent species characteristic for these beds are *Glochiceras canale, G. microdomum*, and *Taramelliceras pichleri*. *Ringsteadia* is proven but is not very frequent.

The White Jurassic *β* is characterized by *Idoceras planula* and its relatives. *Idoceras* is known to start with the lowermost layers of the formation and *Epipeltoceras bimammatum* is said to occur still in the same beds. Thus, their ranges seem to overlap for a short interval. Within the White Jurassic *β* E. DIETERICH (1940, p. 8) established a refined biostratigraphy using small species of *Taramelliceras*. In practice, however, there are great difficulties in the application of these species. In the uppermost few meters of the White Jurassic *β* *I. planula* is said still to occur. More important as an index fossil for these beds is *Sutneria galar*. It is accompanied by species of *Physodoceras (P. altenense* and *P. circumspinosum)* which, however, are found in the overlying strata, too. *Ringsteadia* is proven throughout the White Jurassic *β*, but is rare.

Immediately above the boundary between the White Jurassic *β* and *γ* *Sutneria platynota* sets in. In this zone *Ataxioceras* makes its appearance. Somewhat above the limestones of the lower White Jurassic *γ* *S. platynota* is replaced by *S. cyclodorsata*. Only few meters higher *Streblites tenuilobatus* and *Creniceras dentatum* occur for the first time, and *Ataxioceras* (subgenus *Parataxioceras)* reaches its climax. *Ataxioceras* (subgenus *Ataxioceras)* has its greatest development in the upper region of the middle part of the White Jurassic *γ*. Other species characteristic for the middle part of the White Jurassic *γ* are *Taramelliceras (Metahaploceras) strombecki* and *Aspidoceras binodum*. *Rasenia* is not rare. The upper White Jurassic *γ* is characterized by *"Katroliceras" divisum* and related species and by *Aspidoceras uhlandi. Streblites tenuilobatus, Creniceras dentatum*, and *Rasenia* still are present. Another characteristic species in these beds is *Taramelliceras trachinotum*. *Nebrodites*, although present much earlier, becomes rather frequent. *Idoceras balderum* is an excellent marker for a group of limestone beds within the upper part of the White Jurassic *γ*. For full details on the zonation of the formation see O. F. GEYER 1961 a, p. 107).

The uppermost beds of the White Jurassic *γ* and the lowest part of the White Jurassic *δ* contain *Lithacoceras ribeiroi*. *Aulacostephanus eulepidus* is characteristic of the lower limestones and calcareous marls of the White Jurassic *δ*. The species is missing in the lowermost beds of the formation, but is still present in the lowest parts of the thin bedded limestones of the middle White Jurassic *δ*. *A. mutabilis* is known from the same beds as *A. eulepidus* but is very rare. *Aspidoceras acanthicum* which is found already in the uppermost beds of the White Jurassic *γ* is another index fossil for the lower part of the White Jurassic *δ*. *Streblites tenuilobatus* is replaced by *S. levipictus*. *Creniceras dentatum* and *Sutneria cyclodorsata* are still present. *Nebrodites* is rather frequent, too. In the middle and upper part of the White Jurassic *δ* *Aulacostephanus eudoxus* and *A. pseudomutabilis* are characteristic. In

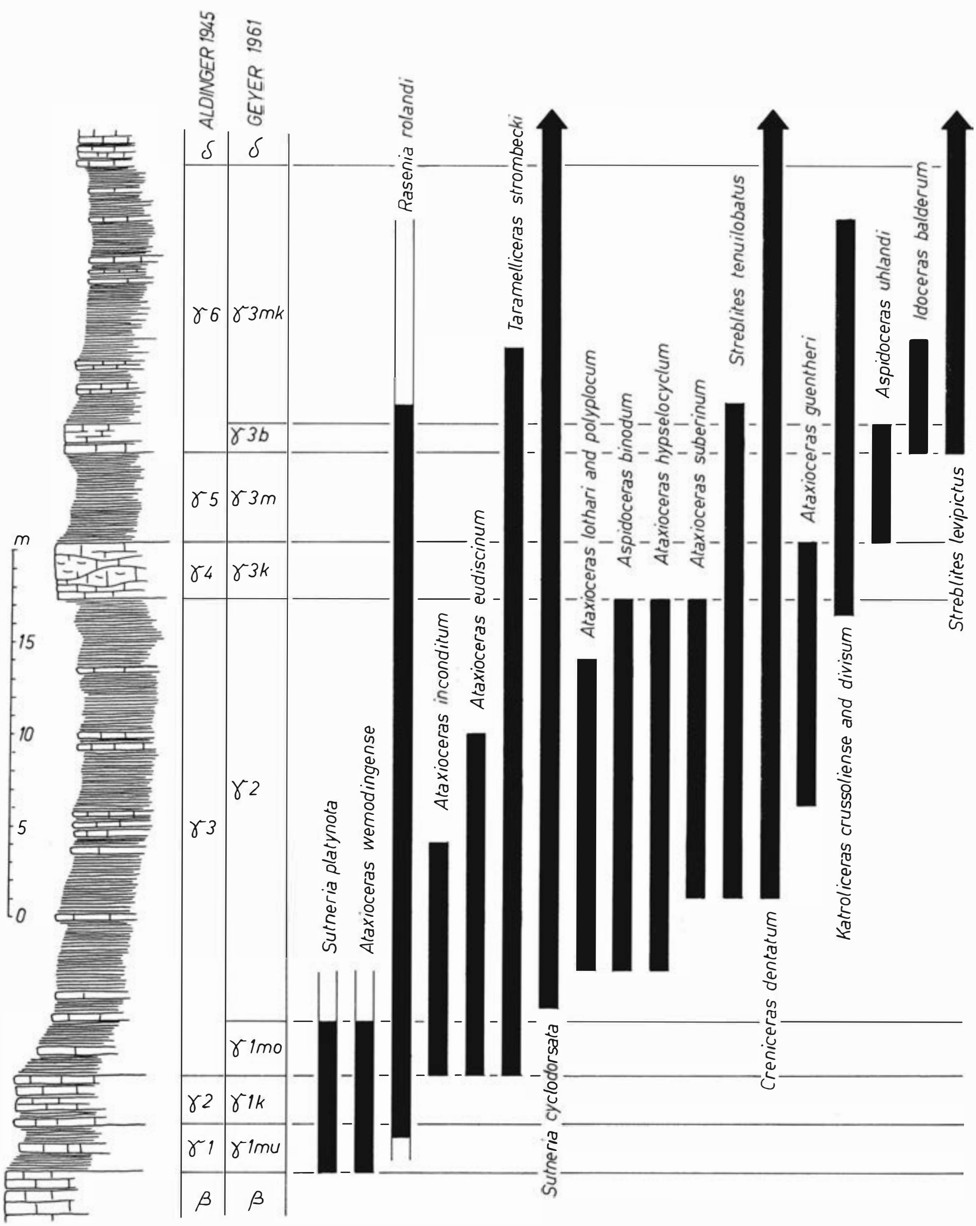


Fig. 17. Ranges of some ammonites in the White Jurassic γ in the Swabian Alb. Mainly after O. F. GEYER (1961 a; 1961 b).

the lower part of their ranges *Streblites levipictus*, *Creniceras dentatum*, and *Sutneria cyclodorsata* still occur. The same beds are characterized by *Orthaspidoceras* (*O. liparum* and *O. schilleri*). All these species suddenly disappear few meters below the

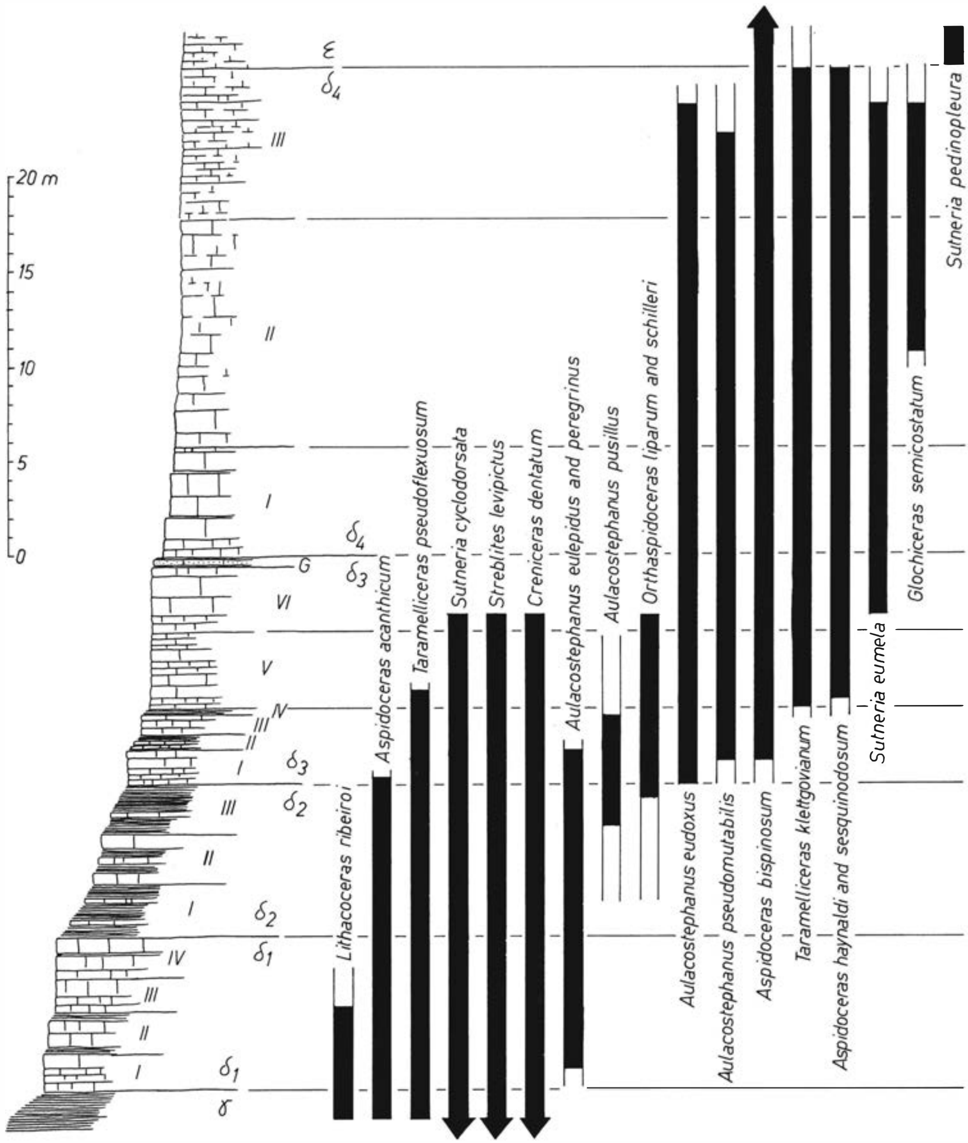


Fig. 18. Ranges of some ammonites in the White Jurassic δ in the Swabian Alb. Mainly after B. ZIEGLER (1958 b; 1962).

glauconite marker bed. *Sutneria cyclodorsata* is replaced by *S. eumela* which is restricted to the upper part of the range of *Aulacostephanus eudoxus.*

At the limit between the White Jurassic δ and ε *A. eudoxus* and *A. pseudomutabilis* disappear. New species are *Sutneria pedinopleura* and *Hybonoticeras pressulum.* Both are recorded only from very few localities (see D. SEEGER 1961, p. 57), and are followed only few meters higher by *S. subeumela* and *H. beckeri. Aspidoceras hermanni* is characteristic of the range of *Sutneria subeumela.* The index fossil

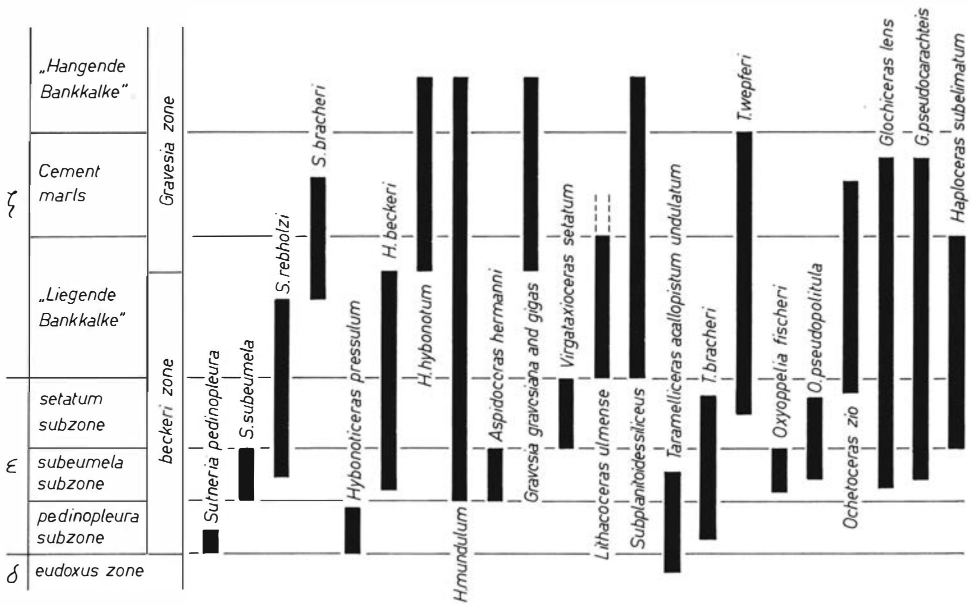


Fig. 19. Ranges of some ammonites in the White Jurassic ε and ζ in the Swabian Alb. Mainly after F. BERCKHEMER & H. HÖLDER (1959) and D. SEEGER (1961), slightly modified.

for the upper part of the White Jurassic ε is *Virgataxioceras setatum*. This species is accompanied by *Taramelliceras wepferi* and *Hybonoticeras beckeri*. However, both species still occur in the lower part of the White Jurassic ζ.

The biostratigraphy of the White Jurassic ζ, summarized by F. BERCKHEMER & H. HÖLDER (1959, p. 114), is very uncertain, owing to the scarcity of ammonites except uncharacteristic species of *Glochiceras* and *Taramelliceras*. For the "Liegende Bankkalke" *Lithacoceras ulmense* and *Subplanitoides siliceus* are used as index fossils. Their ranges are, however, not well defined. *Hybonoticeras beckeri* is said to be found in rather young beds of the "Liegende Bankkalke". From the upper part of this member and from the "Hangende Bankkalke" *H. hybonotum* and *Gravesia* are recorded.

3.2. The Franconian Alb

In the lower and middle part of the upper Jurassic sequence the differences in biostratigraphy between Swabia and Franconia are unimportant. Between *Gregoryceras transversarium* and *Epipeltoceras bimammatum* in Franconia beds with *Euaspidoceras hypselum* and a zone with *Epipeltoceras berrense* can be distinguished. Contrary to the relationships in Swabia in Franconia *Orthaspidoceras liparum* is already known from the strata with *Aulacostephanus eulepidus*. *A. mutabilis* is not known from Franconia (H. SCHMIDT-KALER 1962 a; 1962 b).

The biostratigraphy of the uppermost Jurassic in Franconia is known very well and shows much more details than in Swabia. It has been summarized by A. ZEISS

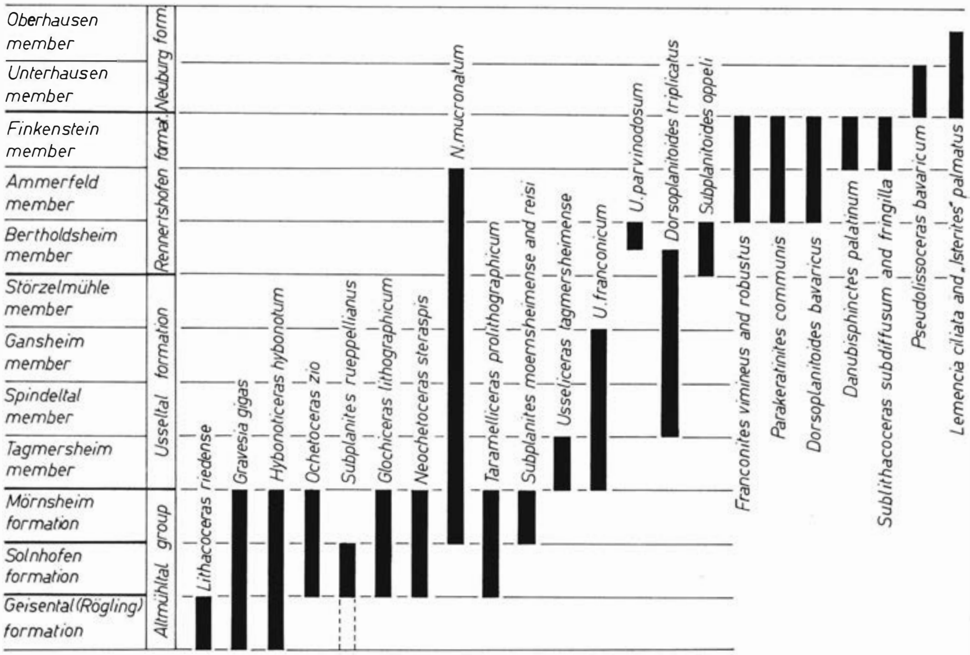


Fig. 20. Ranges of some ammonites in the upper Malm of the southern Franconian Alb. Mainly after K. W. BARTHEL (1962; 1969) and A. ZEISS (1968 b).

(1968 b, p. 133). According to this author *Hybonoticeras beckeri* is restricted to the Torleite beds. The subdivision of this formation *(Sutneria pedinopleura — S. subeumela — Virgataxioceras setatum)* is identical with the relationships in the Swabian Alb.

From the Geisental beds to the Mörnsheim beds *Hybonoticeras hybonotum* and *Gravesia* are recorded. The index species of the Geisental beds is *Lithacoceras riedense.* In the Solnhofen shales *Subplanites rueppellianus* is characteristic. In the Mörnsheim beds *S. moernsheimensis* occurs. *Neochetoceras steraspis* and *Glochiceras lithographicum* are known from the Solnhofen shales but are much more frequent in the Mörnsheim beds.

The zonal sequence in the Usseltal and Rennertshofen formations is based on relatively few specimens and depends largely on apparently endemic species of the Perisphinctidae. Only *Franconites vimineus* is known in somewhat greater number. It occurs in the middle (and more rarely in the upper) part of the Rennertshofen formation. *Neochetoceras mucronatum* is characteristic of the uppermost Mörnsheim beds, the Usseltal formation, and the lower Rennertshofen formation.

In the Neuburg formation the exact distribution of the Perisphinctidae is not yet published. *Lemencia ciliata* and *"Isterites" palmatus* are characteristic of the formation as a whole except of the uppermost part. Additional ammonites are *Pseudolissoceras bavaricum, Protancyloceras, Simoceras,* and *Virgatosimoceras.* The topmost beds of the Neuburg formation contain the calpionellid *Crassicollaria.*

4. Chronology

Owing to the great number of ammonite species the correlation of the local range zones with the international standard scheme is well established.

The base of the White Jurassic, that is the zone of *Gregoryceras transversarium*, is interpreted by J. H. CALLOMON (1964, p. 289) to be contemporaneous with the base of the upper Oxfordian *(cautisnigrae* zone). However, R. GYGI (1966, p. 941) showed that the *transversarium* beds represent the uppermost part of the *plicatilis* zone *(parandieri* subzone) and sometimes even include the *antecedens* subzone. A. ZEISS (1966, p. 110), too, puts the *transversarium* zone into the middle Oxfordian. As is indicated by the occurrence of *Ringsteadia* in the ranges of *Epipeltoceras bimammatum* and *Idoceras planula* these zones seem to be contemporaneous with the *pseudocordata* zone. Thus the marls with *Aulacothyris impressa* may be an equivalent of the *decipiens* zone, their lowermost parts perhaps even of the *cautisnigrae* zone.

The limit between the White Jurassic β and γ seems to be the limit between the Oxfordian and the Kimmeridgian, as is shown by the distribution of *Ringsteadia*. Unfortunately no true *Pictonia* and no *Pachypictonia* identical with those of north-western Europe are known in southwestern Germany. Moreover, *Rasenia* is found in the Swabian Alb already in the White Jurassic β, that means in true equivalents of the *pseudocordata* zone. Because *Rasenia* reaches its climax in southern Germany in the *tenuilobatus* zone (middle and upper part of the White Jurassic γ) there are good reasons to interpret this period to be an equivalent of the *cymodoce* zone. If so the zone of *Sutneria platynota* is contemporaneous with the *baylei* zone. This is confirmed by few findings of *Pictonia* in the northern Franconian Alb.

Common index fossils in the White Jurassic δ prove that this formation belongs to the *mutabilis* and *eudoxus* zones. The zones of *Sutneria subeumela* and *Virgataxioceras setatum* were named by E. HENNIG (1943, p. 84) the new stage „Suebium" owing to their very peculiar and endemic faunas. It can be shown, however, that the White Jurassic ε and large parts of the "Liegende Bankkalke" (that means the range of *Hybonoticeras beckeri*) are the local equivalents of the *autissiodorensis* zone and therefore the youngest Kimmeridgian s. str. (B. ZIEGLER 1962, p. 26; 1964, p. 351).

The limit between the Kimmeridgian s. str. and the lower Tithonian falls between the ranges of *Hybonoticeras beckeri* and *H. hybonotum*, that means it falls into the upper part of the "Liegende Bankkalke" in Swabia and into the Geisental beds in Franconia, respectively. In the Swabian Alb only the uppermost "Liegende Bankkalke", the Cement marls, and the "Hangende Bankkalke" are of Tithonian age. All these strata belong to the *Gravesia* zone.

In southern Franconia the lower Tithonian is much more complete. It contains a considerable number of zones. Therefore, the name "Danubian" for this substage may be used. All strata younger than the Mörnsheim beds have no equivalents in the Swabian Alb.

The Neuburg formation represents the middle Tithonian as it was shown by K. W. BARTHEL (1962, p. 23) and K. W. BARTHEL & J. R. GEYSSANT (1973, p. 33) when studying the occurrence of *Pseudolissoceras*, *Virgatosimoceras*, and other ammonite genera. The uppermost part of the Neuburg formation is already upper Tithonian in age as is indicated by the occurrence of the calpionellid *Crassicollaria* (K. W. BARTHEL 1969, p. 150). In the Franconian Alb no marine transition from the Jurassic into the Cretaceous is known.

5. The normal facies

5.1. Lithology

The sediments of the White Jurassic in southern Germany consist of two rather different units: The so-called normal facies and the sediments of recifal or organic origin. The sedimentological features of both have been described in detail by M. P. GWINNER (1976). He, too, refers to the modern literature.

For the normal facies bedded limestones and calcareous marls are characteristic. The carbonates are lutites. Among the clayey components kaolinite and illite predominate (W. BAUSCH 1971, p. 333). The sequence is built up by limestone beds of different thicknesses alternating with more marly layers. As it was shown by E. SEIBOLD (1952) and H. WEILER (1957) in the more calcareous formations the amount of carbonate exceeds 90 % in the limestone beds and varies between 70 % and 90 % in the marly layers. In the marly formations the limestone beds sometimes contain only 70—75 % carbonate, the marly horizons being still less calcareous. That means that the appearance of an individual bed as a limestone or as a marl does not depend on the absolute but on the relative content of carbonate and that it is the result of weathering.

In the calcareous formations of the White Jurassic β (*planula* zone) and δ (*acanthicum* and lower *eudoxus* zones) individual beds can be traced over large distances. This is possible because the carbonate content is constant over large areas, and each change of sedimentation to more or less carbonate took place simultaneously. Moreover, the quantity of precipitated lime and clay is approximately the same at very different localities. Apparently the oceanographic conditions were very uniform during these times. The ocean floor was deep enough so that it was not disturbed by currents, waves or storms.

In the upper part of the White Jurassic δ (upper *eudoxus* zone) and in the White Jurassic ε (lower and middle *beckeri* zone) the limestones are very rich in carbonate (partly more than 99 %). Marly layers are missing. Apparently the influx of clay minerals that continued during the upper Oxfordian and most parts of the Kimmeridgian was interrupted. Many limestone beds contain stylolites, often the surface of beds is covered with stylolites. Therefore it seems that solution has diminished the original thickness of the sediments to some degree. Owing to the absence of marly layers and to the stylolitic structure a correlation of individual beds is impossible.

The limestones of the upper White Jurassic in the Swabian Alb (upper *beckeri* zone and *Gravesia* zone) are bedded rather irregularly. A correlation of individual beds over considerable distances is impossible. Sometimes the sedimentation is disturbed by slumping or other unconformities. It seems that the sedimentation took

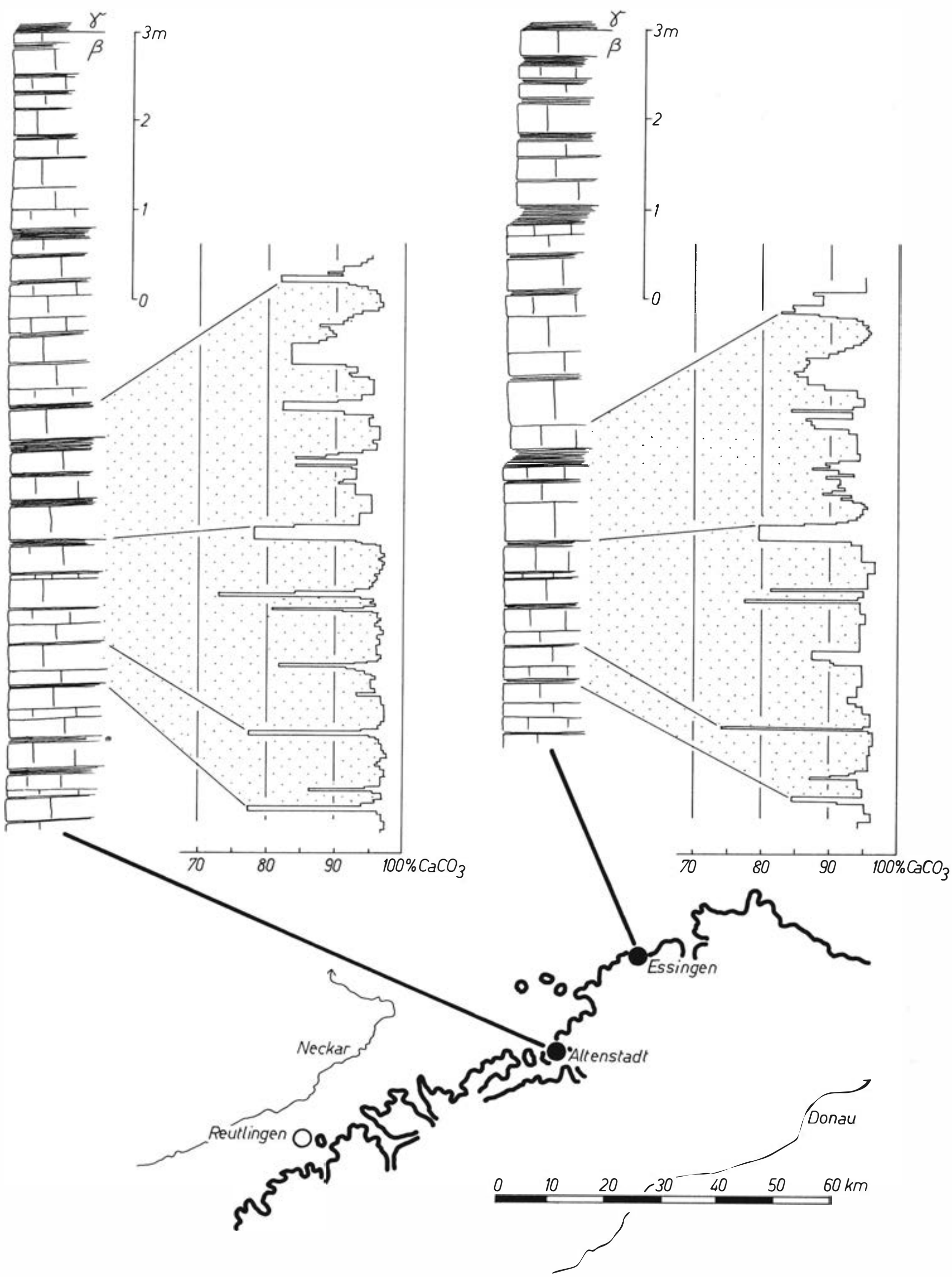


Fig. 21. Correlation of individual limestone beds over a distance of about 25 km in connection with the content of calcium carbonate. Upper part of the White Jurassic β of the eastern Swabian Alb. After H. WEILER (1957).

place under a regime of higher energy compared with older beds. Apparently the sea was shallower.

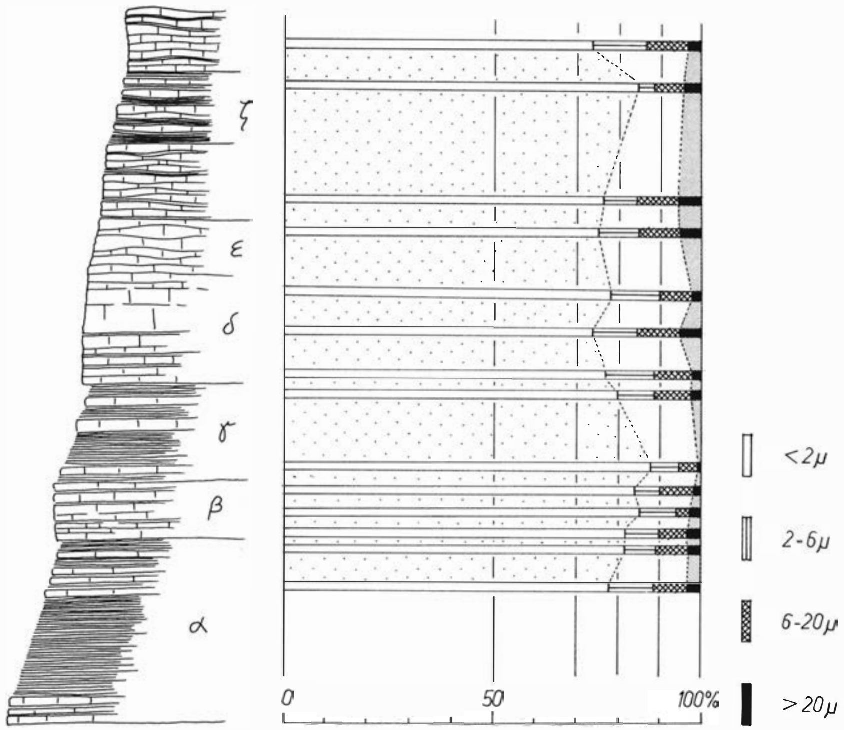
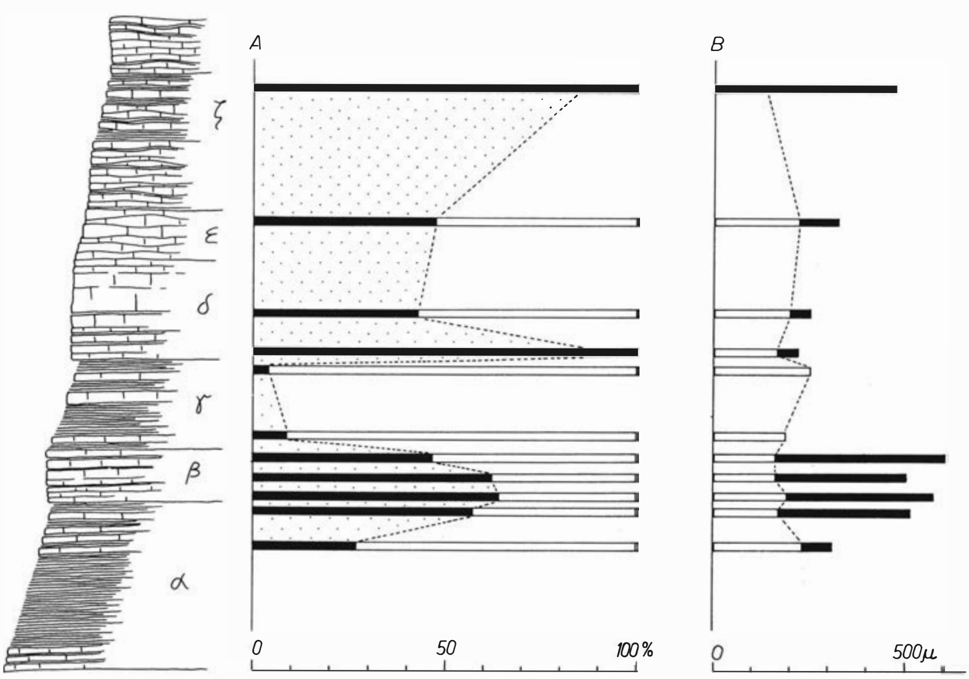


Fig. 22. The unsoluble residues in some samples of the Swabian White Jurassic and the sizes of the grains. After G. KNOBLAUCH (1963).



The so-called "Treuchtlingen marble" which is characteristic in the *acanthicum* and *eudoxus* zones of southern Franconia shows a special type of sedimentation. The beds are rather thick and contain a considerable amount of calcified siliceous sponges. The sponges are covered by calcareous crusts (see page 33) apparently of algal origin and by sessile miliolid foraminifera. Algal crusts and miliolid foraminifera point to sedimentation of the "Treuchtlingen marble" in rather shallow waters. On the other hand B. v. FREYBERG (1966), H. SCHMIDT-KALER (1962 b), and W. STREIM 1960; 1961) have shown that the correlation of individual beds is possible over large distances, so that the sea floor must have been situated below the influence of currents, storms and waves.

In addition to the carbonates and the clayey components a certain amount (0,2—2 %) of heavy minerals is present within the rocks (G. KNOBLAUCH 1963). In most cases the heavy minerals are authigenous, for instance pyrite, haematite, limonite, apatite, baryte, phosphorite, and others. Other heavy minerals, especially zirkone, turmaline, and others seem to be terrigenous. Magnetite, pyroxene, and amphibole are interpreted as to be of volcanic origin. These volcanic minerals — although present only in very small quantities — are much more frequent and of larger size in the Oxfordian and the upper parts of the Kimmeridgian (s. str.) than in the lower Kimmeridgian. Apparently they are wind-blown tuffs.

5.2. The fossils

Macrofossils are abundant throughout most parts of the White Jurassic in southern Germany. The most frequent group are the ammonites. In the Swabian Alb the Perisphinctaceae are represented by a large number of genera (however, the distinction between genera, subgenera, and synonyma being highly subjective). The Haploceratacea are present with only about one third of the taxonomic units shown by the Perisphinctaceae. The number of individuals, however, is much larger in the Haploceratacea than in the Perisphinctaceae. Only in parts of the Kimmeridgian (*hypselocyclum* and *divisum* zones) in some localities of the normal facies Perisphinctaceae predominate over the Haploceratacea. Phylloceratids and lytoceratids are known only with very few specimens. The Stephanocerataceae are represented by the amoeboceratids which are rare, however, in the normal facies. No amoeboceratid is known in southern Germany in strata younger than the upper *eudoxus* zone.

The most frequent ammonite genera and genus groups in the upper Oxfordian of the Swabian Alb are the following: Perisphinctids of various generic (or subgeneric) affinities, mostly microconchs, *Taramelliceras*, and *Glochiceras*. Frequent but restricted to parts of the upper Oxfordian are *Idoceras* and *Trimarginites*. Less frequent are *Amoeboceras*, *Ochetoceras*, *Epipeltoceras*, euaspidoceratids, *Physodoceras*, *Sutneria*, *Rasenia*, and *Ringsteadia*. Some other genera are known but are extremely rare.

In the Kimmeridgian of the Swabian Alb the most frequent ammonites belong to the following genera which, however, in several cases are restricted to parts of

Fig. 23. Heavy minerals in the White Jurassic of the Swabian Alb.
A: Percentage of grains of volcanic material > 60 μ (black). Authigenous minerals and magnetite omitted.
B: Maximal diameter of grains. Volcanic material in black.
After G. KNOBLAUCH (1963).

the stage: *Progeronia, Orthosphinctes, Ataxioceras, Aspidoceras, Taramelliceras, Glochiceras, Creniceras,* and *Streblites.* Less frequent are *Amoeboceras, Lithacoceras, Katroliceras, Rasenia, Aulacostephanus, Sutneria, Nebrodites, Idoceras, Virgataxioceras, Subplanitoides, Physodoceras, Orthaspidoceras, Ochetoceras, Haploceras,* and *Oxyoppelia.* All other genera are extremely rare.

The lower Tithonian of the Swabian Alb is very poor in ammonites.

Other macrofossils than ammonites are present with different groups in the normal facies of the Swabian White Jurassic. They are, however, much less frequent than the ammonites. The brachiopods are playing a major role. They are represented by Terebratulida and Rhynchonellida of different generic affinities. The most frequent genera are *Aulacothyris* (in the upper Oxfordian), *Loboidothyris,* and *Lacunosella. Terebratulina* and other genera of the Terebratulida are well represented, too. Because brachiopods are a consistent element in the recifal facies and because they may be allochthonous in some cases it is often difficult to attribute them to the normal facies with certainty.

Belemnites range throughout the White Jurassic, being not frequent, however. In the lower Tithonian they become still more scarce. Nautiloids are always rare, too. The pelecypods are still scarcer than brachiopods or belemnites, except for some strata in the lower Tithonian where astartids are rather abundant and for a few horizons in the *divisum* zone (Kimmeridgian) which are built up locally nearly completely by the shells of *Meleagrinella.* In the pelecypod epifaunas single valves of *Liostrea roemeri* and *Velata velata* are known from many localities pointing to formerly attached animals. Limids are present, too. Other epifaunal pelecypods are scarce. In the infaunal groups *Pholadomya acuminata* is a characteristic species. Other species are very scarce.

The gastropods are represented especially by rare specimens of *Bathrotomaria.* Crustaceans are scarce except for some parts of the lower Tithonian which are known as "Krebsscheren-Kalke" (that means limestones with crustacean chelipeds). *Prosopon* is an often cited genus in these beds. Crinoids are recorded in the normal facies from different horizons and localities, their skeletons, however, are mostly totally disintegrated. The most frequent genus seems to be *Balanocrinus.* Echinids are scarce in the normal facies except for a few localities where *Collyrites, Holectypus,* and some other genera are present.

Even vertebrates are known, but they are very rare. Mostly only single bones or teeth of fishes and ichthyosaurians occur. The most important discovery is a skeleton of *Machimosaurus* in the *hypselocyclum* zone (Kimmeridgian).

Trace fossils are present in the normal facies of the Swabian White Jurassic but are predominantly restricted to few horizons and otherwise rare. The most important beds with trace fossils (especially *Chondrites)* occur in the uppermost part of the *bimammatum* zone and in some parts of the lower Tithonian.

In Franconia the macrofossils of the normal facies of the upper Oxfordian and the Kimmeridgian belong to the same groups and genera as in Swabia. In the ammonites, however, the Perisphinctaceae seem to predominate the Haplocerataceae not only in the number of taxa but also in the number of specimens. In the lower Tithonian the differences between Franconia and Swabia became much more obvious being related, however, to the development of the recifal facies. Therefore the macrofossils of the Franconian lower Tithonian will be treated in the chapter on the recifal facies.

Among the microfossils of the upper Jurassic in southern Germany several groups are rather well studied, the knowledge about other taxa being still incomplete. Coccolithophorida are proven (E. Flügel & H. E. Franz 1967, H. Keupp 1976), but detailed investigations for most parts of the upper Jurassic are still missing. The dinoflagellates are published by K. W. Klement (1960). Radiolarians are extremely rare.

Foraminifera are frequent but difficult to extract from the limestones and therefore better known in the marly formations. E. & I. Seibold (1960), J. Th. Groiss (1966a, 1966b, 1967, 1970) and B. Winter (1970) record a majority of Nodosariacea (especially of the genus *Lenticulina*), followed by Lituolacea. Furthermore, representatives of the Ammodiscacea, Miliolacea, Involutinidae, and Epistominidae are present. Some of the species are restricted to a certain amount of carbonate (E. & I. Seibold 1960, p. 408), others show some variation in their morphology during their ranges (J. Th. Groiss 1966 b, 1970).

Sponges are characteristic of the recifal facies. In some localities, however, isolated spicules occur pointing to the existence of siliceous sponges of choristid type in the normal facies, too.

The ostracod fauna of the upper Jurassic in southern Germany is much less known than the foraminifers. Especially in the limestones the fossils are difficult to extract and often badly preserved. In the Oxfordian (H. Glashoff 1964, p. 55) and in the middle Tithonian (H. Oertli 1965, p. 127) rather poor ostracod faunas are described. The ostracods of the Kimmeridgian still are not investigated in detail.

6. The recifal and related facies

6.1. The sponge-algal bioherms

In the White Jurassic of southern Germany large areas are covered by the famous sponge-algal bioherms ("Schwamm-Stotzen"). Their sedimentology was described in much detail by M. P. Gwinner (1976). Therefore here only the general relationships will be treated.

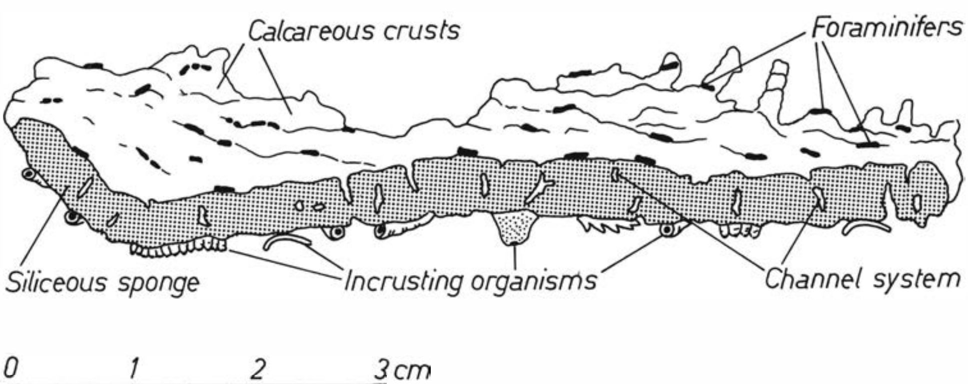


Fig. 24. Cross section through a siliceous sponge (dotted) covered by calcareous crusts and settled on its lower surface by sessile organisms. After G. K. Fritz (1958).

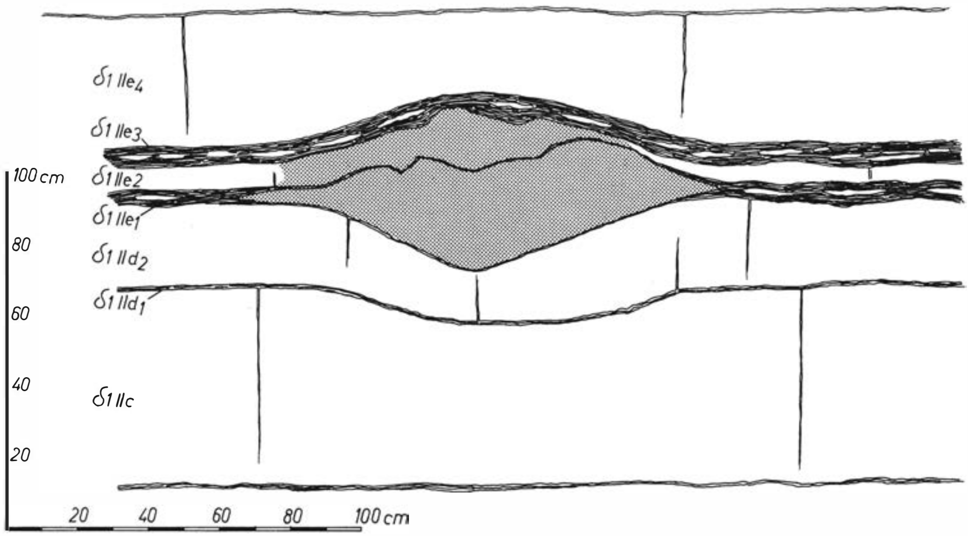


Fig. 25. A small sponge-algal bioherm (shaded) evolving during the deposition of a calcareous marl. White Jurassic δ 1 I I e 1, Sirchingen near Urach (central Swabian Alb). Note the enlarged thickness of the bioherm and its being sunken into the underlying bed. After B. ZIEGLER (1955).

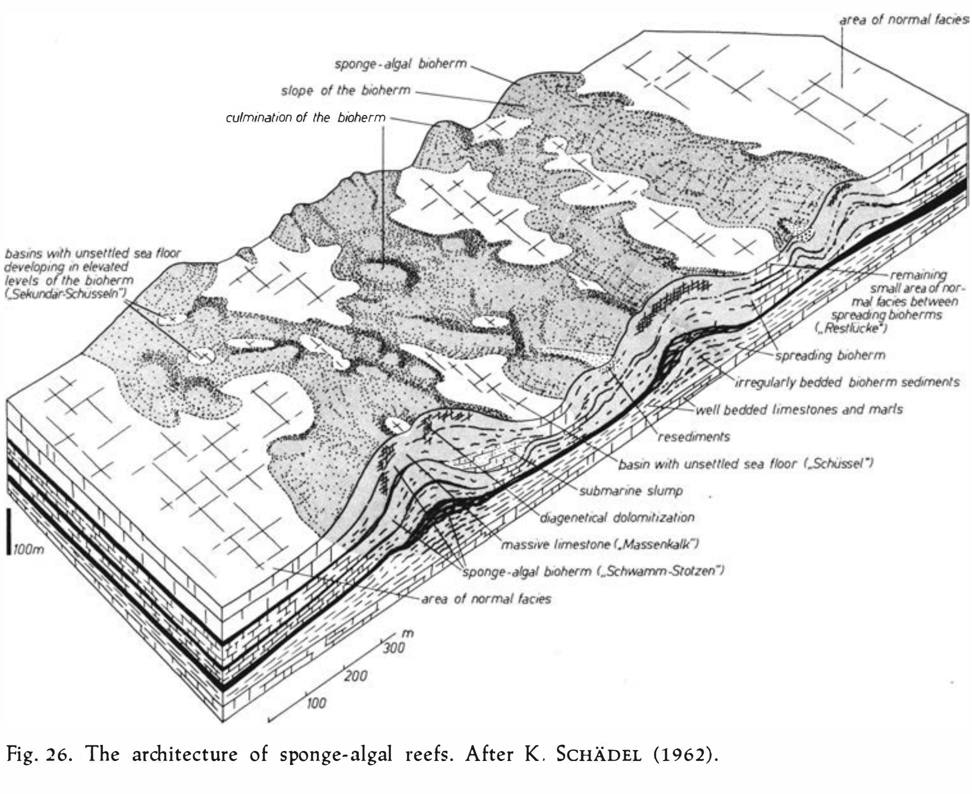


Fig. 26. The architecture of sponge-algal reefs. After K. SCHÄDEL (1962).

The framework of the sponge-algal bioherms is formed by siliceous sponges. In the Oxfordian and Kimmeridgian Hexactinellida are dominating; in the lower Tithonian the Demospongea became more frequent. The spicular skeletons of these sponges are covered on their upper surfaces by calcareous crusts which are thought to be of algal origin (K. HILLER 1964, p. 156; K. & H. J. BEHR 1976). In the calcareous formations of the upper Kimmeridgian the crusts are replaced by stromatolites. The calcareous crusts are settled by a variety of benthic animals, especially by sessile worms (serpulids) and forminifera *(Nubeculinella)*. The lower surfaces of the sponges are overgrown in many cases by serpulids, bryozoans *(Berenicea* and *Stomatopora* being most frequent), sessile brachiopods (Thecideidae, Craniidae), and other sessile animals.

During the growth of the sponge-algal bioherms the normal lutitic sedimentation continued. It was supplemented by the material of the sponges, of the crusts, and of

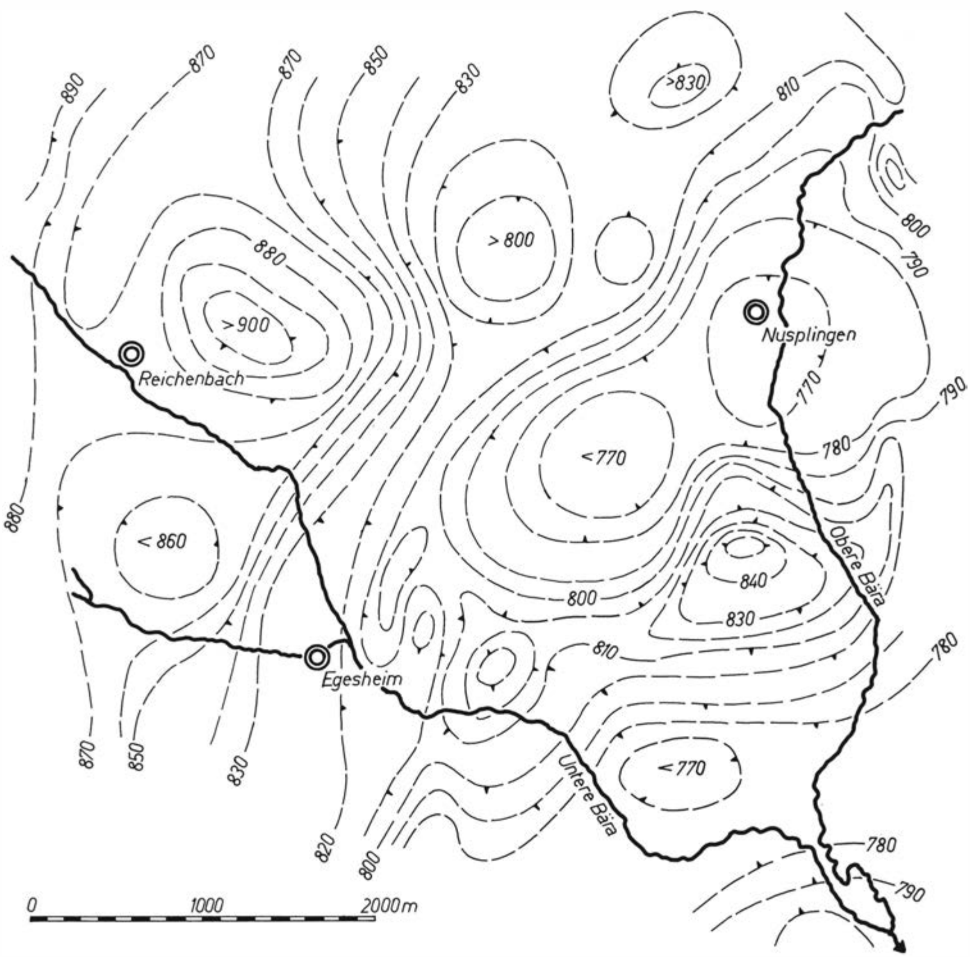


Fig. 27. The relief of the sponge-algal bioherms at the boundary between the White Jurassic β and γ (boundary Oxfordian/Kimmeridgian) near Nusplingen (southwestern Swabian Alb). Lines of equal elevation above sea level (in meters). After K. SCHÄDEL in B. ZIEGLER (1958 a).

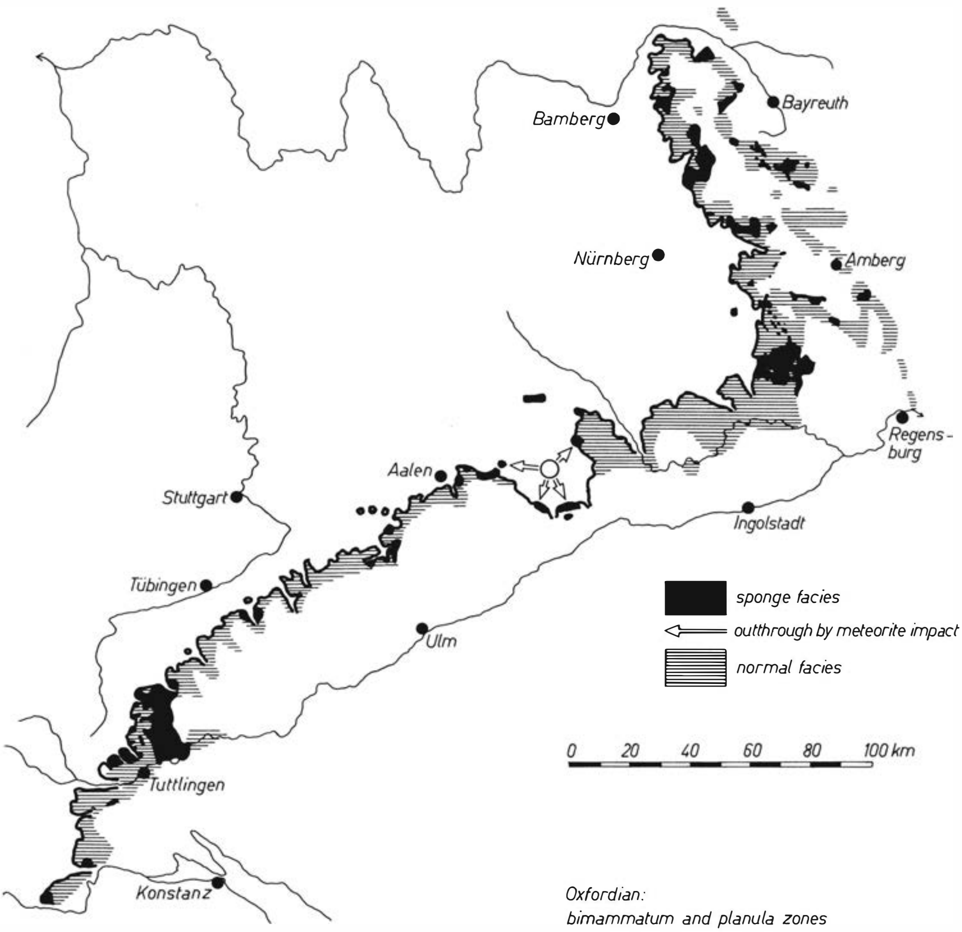


Fig. 28. The extension of the sponge facies in the upper Oxfordian (*bimammatum* and *planula* zones). Mainly after E. Dieterich in G. Wagner (1960), B. v. Freyberg (1966), R. Gygi (1969), and K. Hiller (1964).

other sessile organisms. Therefore in the areas of sponge growth usually the thickness of the sediment is much greater than in the normal facies. Especially in the more marly formations the sponge-algal buildings grew up considerably above the unsettled sea floor. This primary relief sometimes attained 120 meters. The basins without sponge-algal growth are named "Schüsseln".

In southern Germany the first sponge settlements are known from the *transversarium* zone of the southwesternmost part of the Swabian Alb (Blumberg). Contemporaneous bioherms are widespread in northern Switzerland (Birmenstorf beds). In the *bimammatum* zone large parts of the southwestern Swabian Alb and some regions in the Franconian Alb were covered by sponge-algal bioherms. In the uppermost Oxfordian and lower Kimmeridgian (*planula* to *hypselocyclum* zones) of the Swabian Alb the distribution of the sponge-algal facies did not change remarkably, whereas in Franconia a spread of sponge reefs locally occurred already in the upper

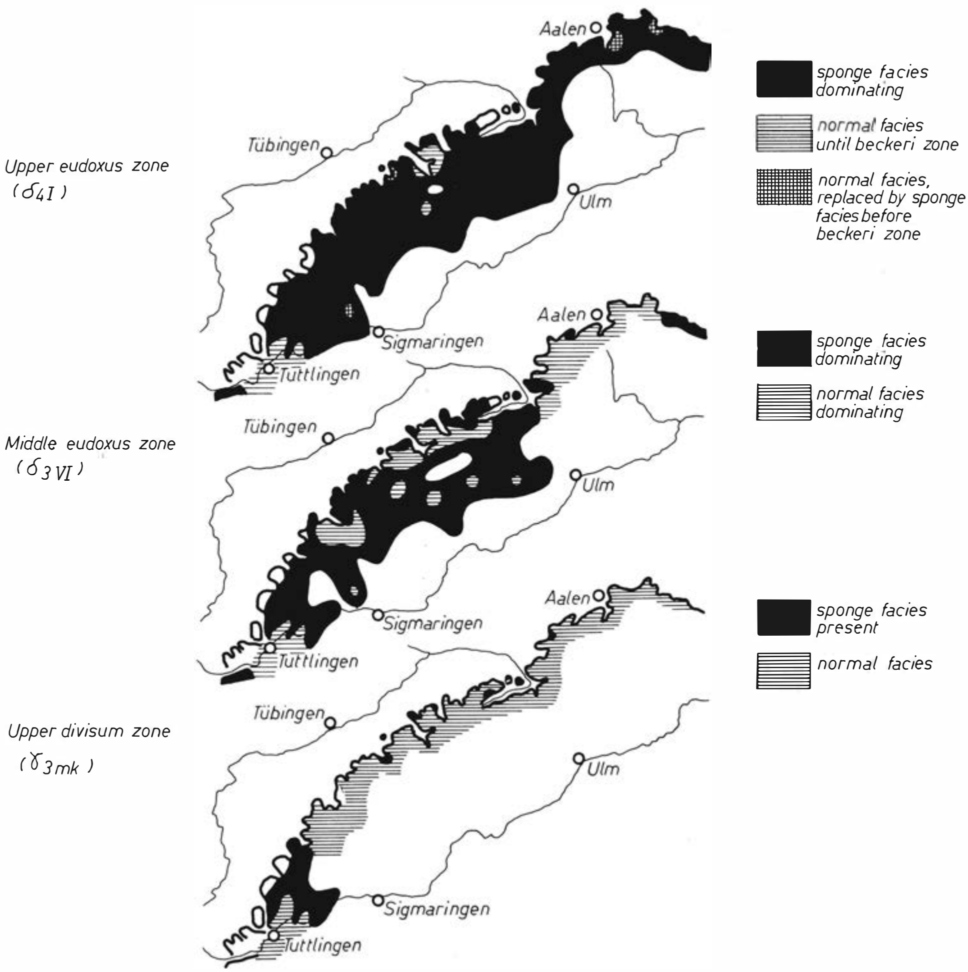


Fig. 29. The extension of the sponge facies in the Kimmeridgian of the Swabian Alb. Mainly after K. Hiller (1964), B. Ziegler (1955; 1967), and M. P. Gwinner (1976).

Oxfordian. Starting with the *divisum* zone, however, a rapid spread of the sponge-algal bioherms began. They reached their maximum distribution in the upper *eudoxus* zone. In this period only small areas of normal facies (so-called "Restlücken") were left. In the latest Kimmeridgian and in the lower Tithonian the distribution of sponge-algal bioherms was less extensive. It is still unknown when the sponge growth finally stopped.

The most striking feature in the fauna of the sponge-algal facies is the wealth of siliceous sponges. A. Schrammen (1936) noted 136 species, some of which, however, being possibly only ecological variations. 84 species belong to the Hexactinellida, this group, however, being more frequent in the Oxfordian and Kimmeridgian than in the Tithonian. 25 species belong to the rhizomorine Demospongea, which are represented throughout the stratigraphic column in rather uniform frequency.

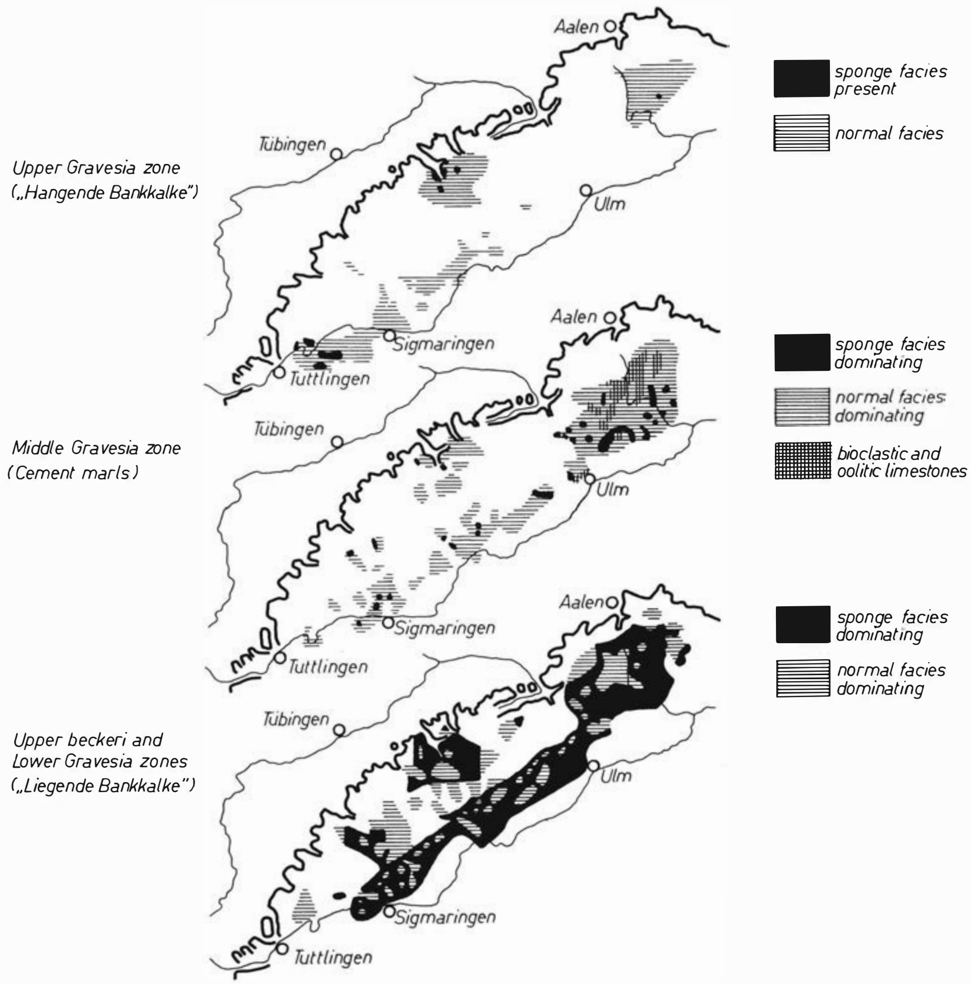


Fig. 30. The extension of the sponge facies in the upper White Jurassic of the Swabian Alb. Mainly after K. HILLER (1964) and M. P. GWINNER (1976).

18 species belong to the tetracladine Demospongea, which are frequent only in the uppermost Kimmeridgian and in the lower Tithonian.

Although the siliceous sponges are often the most conspicuous fossils they are not always the most frequent ones. The percentage of individuals represented by siliceous sponges varies to a high degree. P. WAGENPLAST (1972, p. 31, 39) mentions 8 %. If the epizoans of the siliceous sponges, such as serpulids, calcareous sponges, thecideans, and bryozoans, are omitted, about 20 % of the individuals are sponges. This number can be compared rather well with the relationships in the *transversarium* zone of northern Switzerland where B. KREBS (1967, p. 695) showed the sponges to represent 22 % of the specimens. On the other hand in other collections of different localities about 40 % of the individuals are sponges.

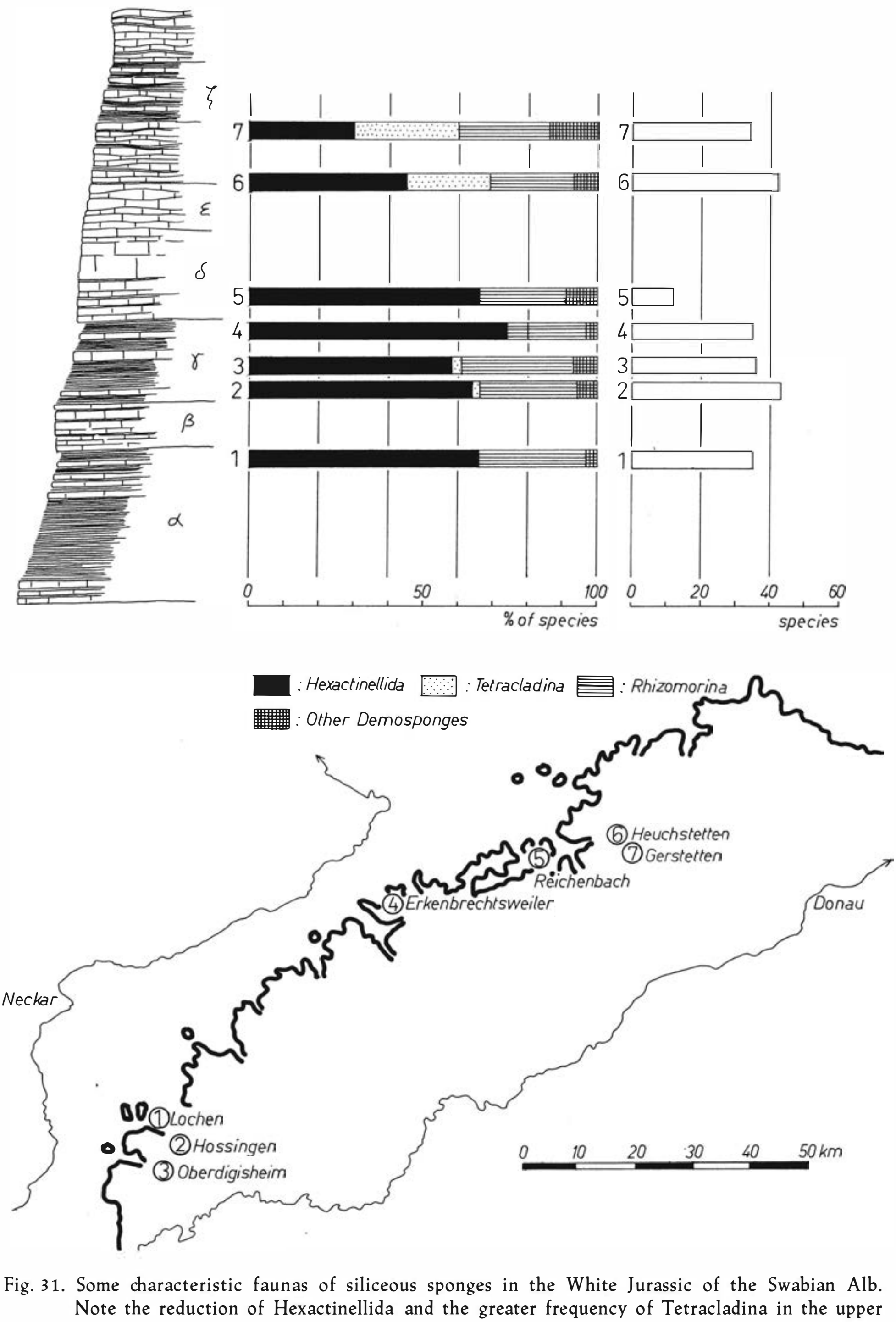


Fig. 31. Some characteristic faunas of siliceous sponges in the White Jurassic of the Swabian Alb. Note the reduction of Hexactinellida and the greater frequency of Tetracladina in the upper White Jurassic. After A. SCHRAMMEN (1936) and M. P. GWINNER (1962)

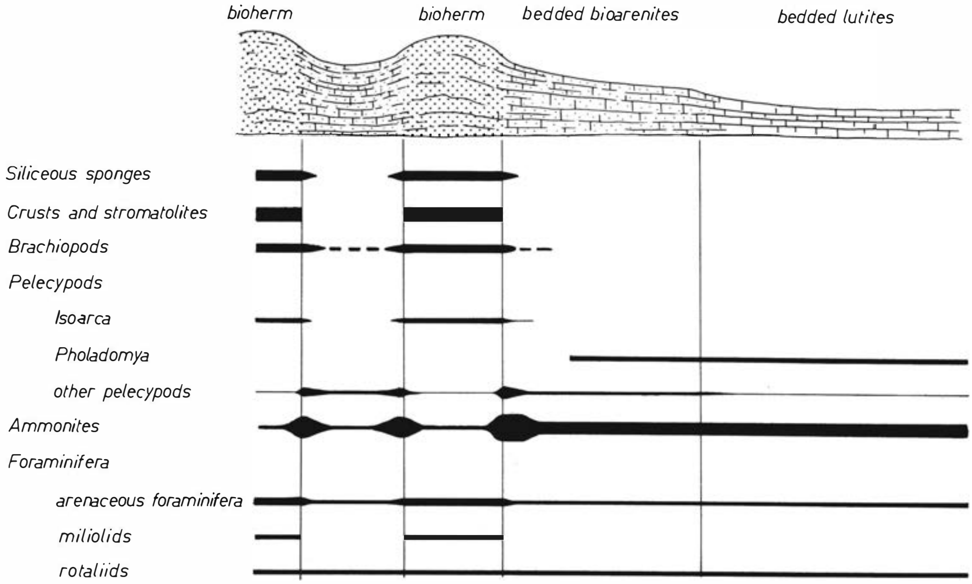


Fig. 32. The ecological distribution of the most frequent fossils in the sponge-algal facies and in the normal facies. After G. NITZOPOULOS (1974).

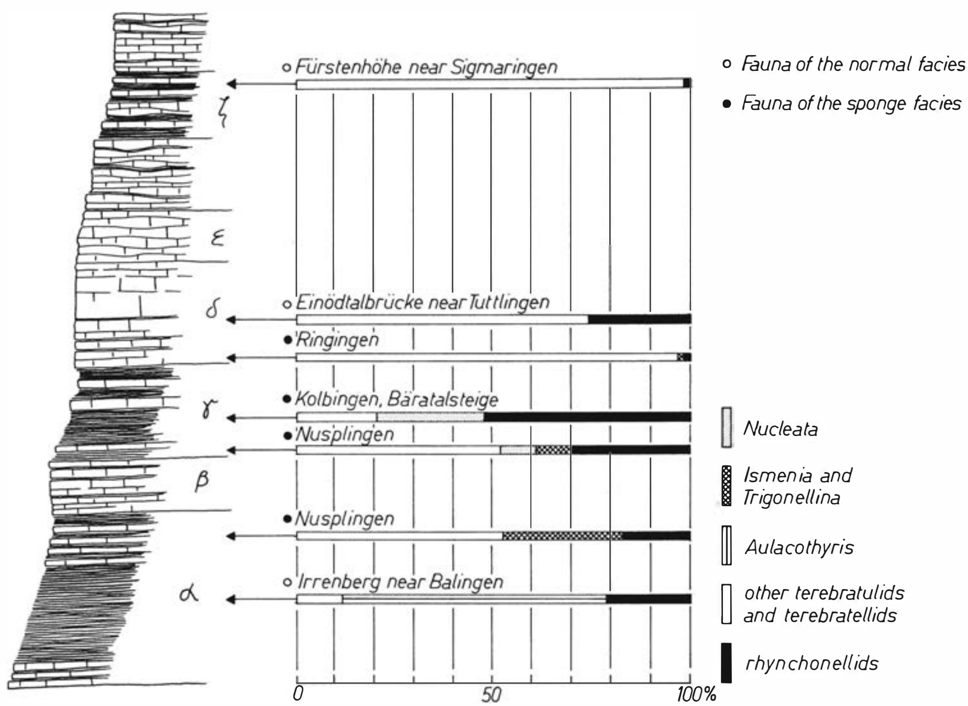


Fig. 33. Brachiopod faunas in the Swabian White Jurassic and their composition (according to individuals) of the most important groups.

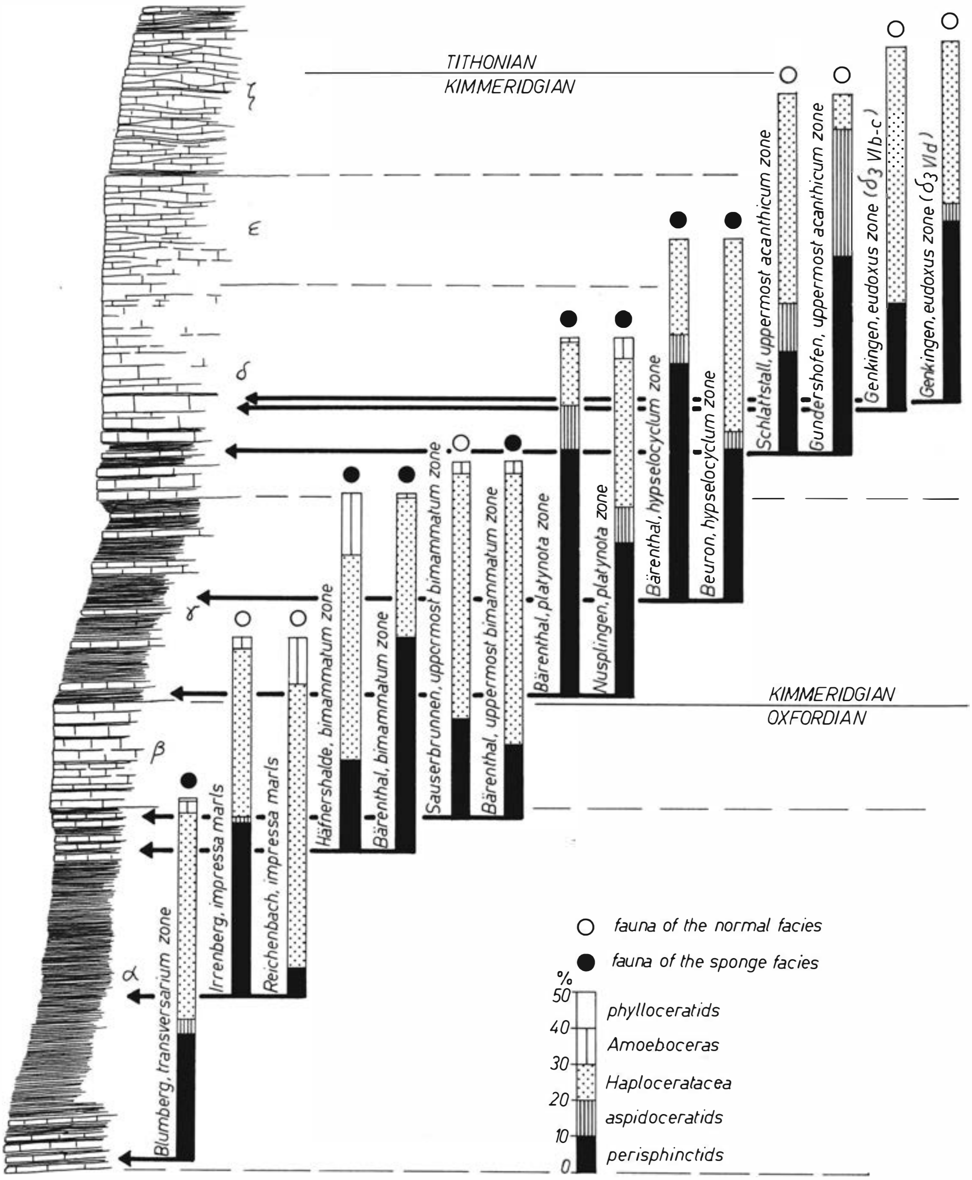


Fig. 34. Ammonite faunas in the Swabian White Jurassic and their composition (according to individuals) of the major ammonite groups.

Owing to their considerable sizes the siliceous sponges sometimes form more than 50 % of the sediment. Especially in the more marly formations they often are the constructive element of the rock. In the more calcareous formations, however, they may occur rather scattered (compare R. MEYER 1975, p. 158).

The brachiopods are another characteristic group of the sponge-algal facies. They represent often more than 20 % of the specimens. The most abundant genera

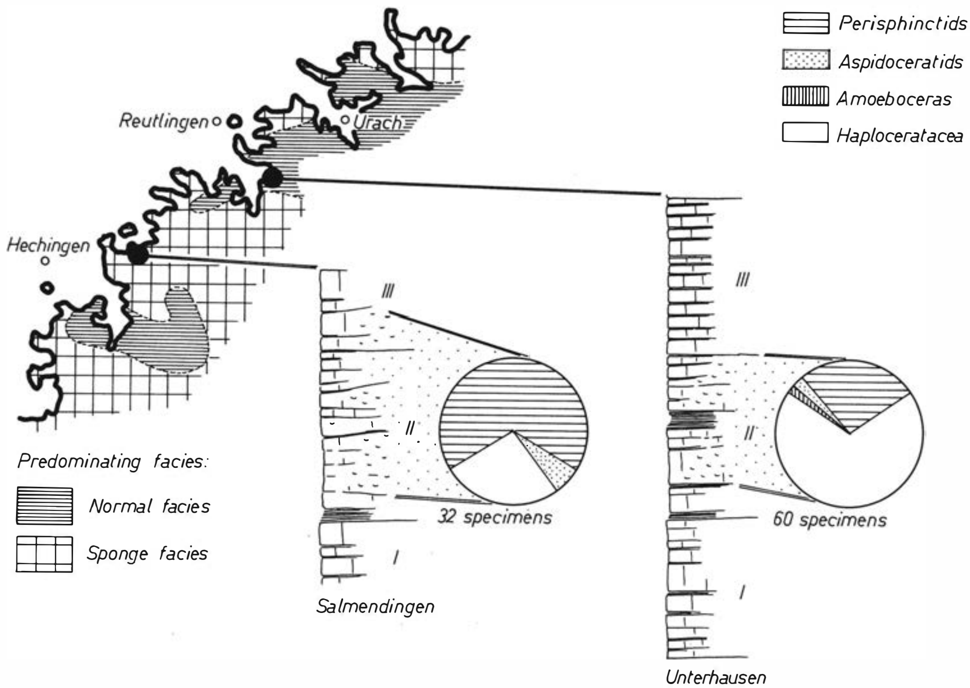


Fig. 35. The composition (according to individuals) of two ammonite faunas of the major ammonite groups. White Jurassic δ 1 (lower *acanthicum* zone) of the central Swabian Alb.
Salmendingen: Section with sponge-algal limestones within a region of predominant sponge facies.
Unterhausen: Section with some sponge-algal limestones within a region of predominant normal facies.

are *Lacunosella* (especially in the lower part of the *divisum* zone where this genus sometimes forms the majority of the organisms in small bioherms) and *Loboidothyris*. *Terebratulina* and other small terebratulids and terebratellids are frequent only in certain parts of the sponge-algal facies (p. 43). Craniids and thecideans occur as epizoans especially on the sponges.

In life the ammonites did not belong to the community of the sponge-algal bioherms. However, they are deposited rather frequent in the sponge-algal facies and it seems that they lived near the sea floor. Sometimes they are represented by more than 60 % of the specimens, in other cases they are much more rare. Some genera or species (e. g. *Amoeboceras, Creniceras dentatum, Glochiceras canale)* are much more abundant near or in the sponge-algal facies than in the normal facies. The relative abundance of genus groups is highly variable. It seems that in general the Haplocerataceae are more frequent in marginal parts of the sponge-algal bioherms than in the normal facies but that in the central parts of the reefs often the Perisphinctaceae become more frequent. In addition differences during time can be shown. Therefore no general rule can be established.

Macroscopical Echinodermata are found in the sponge-algal bioherms rather scattered, being mostly represented by regular echinids and their spines. Pelecypods

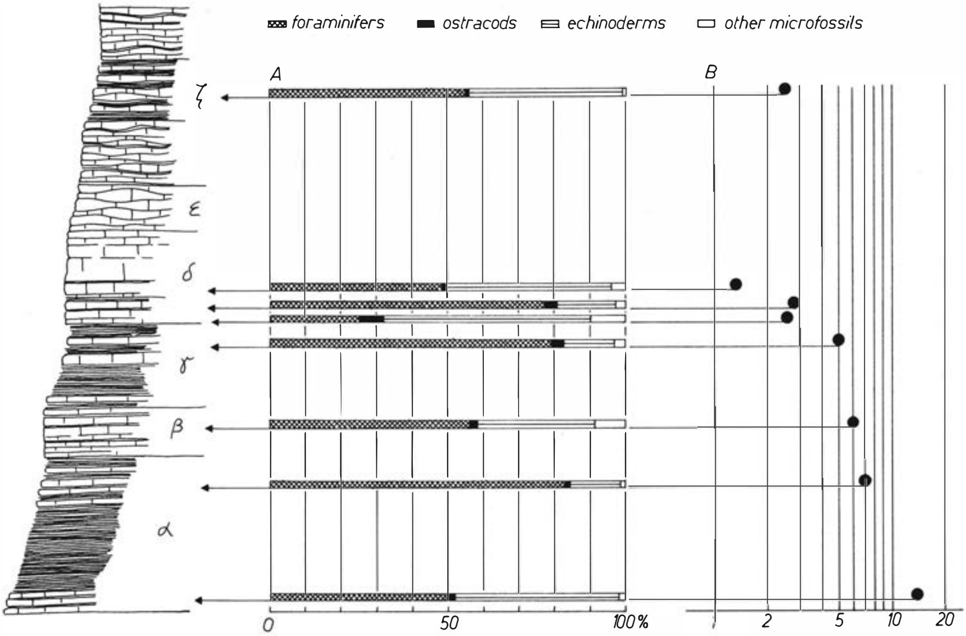


Fig. 36. The microfauna of marly sponge-algal sediments in the Swabian White Jurassic. After P. WAGENPLAST (1972).
A: Percentage of individuals in the most important groups.
B: Number of individuals (in thousands) in samples of 110 g.

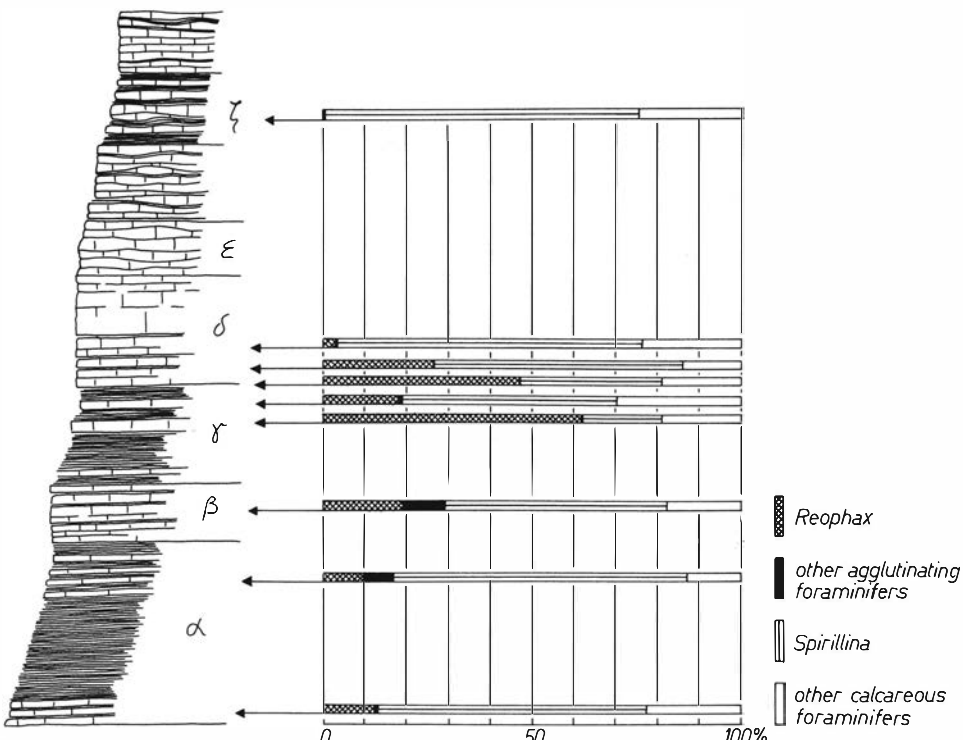


Fig. 37. Percentage of individuals of the most important foraminifera in some samples from marly sponge-algal sediments in the Swabian White Jurassic. After P. WAGENPLAST (1972).

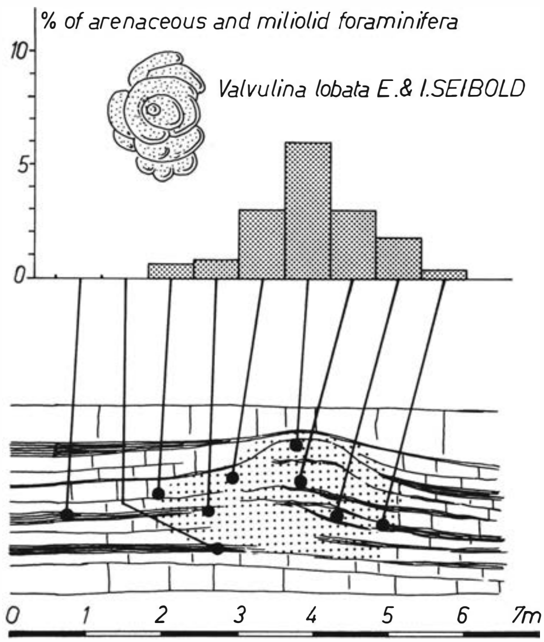


Fig. 38. The arenaceous foraminifer *Valvulina lobata* E. & I. SEIBOLD and its restriction to sponge-algal sediments (stippled). After E. & I. SEIBOLD (1960).

are rare; their majority consists of the valves of fixosessile spondylids which grew on sponges.

The microfauna of the sponge-algal bioherms is dominated by foraminifera. As could be shown by E. & I. SEIBOLD (1960, p. 395) a variety of species and genera is much more frequent in the sponge-algal facies than in the normal facies. The most important companions of the sponge-algal reefs are *Spirillina, Rheophax, Lenticulina,* and *Paalzowella* (P. WAGENPLAST 1972, p. 14). A quite peculiar microfauna occurs in the channel-systems of the siliceous sponges. However, owing to the mode of preparation, only the agglutinating foraminifera are known. *Subbdelloidina, Trochammina, Thurammina,* and *Tolypammina* are the most frequent genera (P. WAGENPLAST 1972, p. 20).

Ostracods are rare. The echinoderms are the second major group in the microfossils. Most frequent are the skeletal elements of ophiuroids, followed by those of crinoids and asteroids.

Parts of the sponge-algal facies, especially those with high carbonate content, were altered during diagenesis. Thus large areas now are covered by dolomites and saccharoidal limestones which are interpreted as the result of dedolomitization (H. B. LANG 1964). At some localities in the Swabian Alb and widespread in the Franconian Alb the dolomites are not restricted to the bioherms but have penetrated into the normal facies, too (R. MEYER 1972; 1974).

6.2. The Lochen facies

In the marly formations of the upper Oxfordian and of the lower Kimmeridgian especially (but by no means exclusively) marginal parts of the sponge-algal bioherms show quite peculiar relationships. They are crowded with small, sometimes dwarfed fossils. This facies, which is named the Lochen facies after the Lochen beds of the *bimammatum* zone, is intimately linked with the common sponge-algal facies. No sharp boundary can be drawn.

The most striking feature of the Lochen facies is the high percentage of small individuals in the fauna. Even in the siliceous sponges many small specimens occur, belonging mostly to *Sporadopyle* or *Trochobolus*. The brachiopods are represented to a large degree by genera and species otherwise missing. Characteristic forms are *Nucleata, Zittelina, Trigonellina, Ismenia, Terebratulina,* and other small Terebratulida and Terebratellida. Normal sized *Lacunosella* and *Loboidothyris* are present, too. It appears that the majority of the small brachiopods is fully grown (cf. K. VOGEL 1959, p. 124).

Ammonites are often abundant. Although the bulk of the specimens seems to be adult, juveniles are present, too. Some ammonite species and genera are much more frequent in the Lochen facies than elsewhere in the Swabian Alb (e. g. *Amoeboceras, Epipeltoceras).* Others apparently are totally restricted to this facies (e. g. *"Euaspidoceras" bidentosum).* The most characteristic species in the Lochen facies of the *bimammatum* zone are *Taramelliceras lochense, T. pichleri,* and *Glochiceras canale.*

In the Echinodermata small representatives of crinoids and echinids are common. The most frequent crinoids are *Balanocrinus* and *Eugeniacrinites.* Characteristic echinids are cidaroids and *Pseudodiadema.* Whether the small echinids are dwarfed specimens or juveniles is unknown. As in the brachiopods the small species are accompanied by normal sized cidaroids. In addition to crinoids and echinids skeletal plates of asteroids occur.

6.3. Basins with calcareous shales

In the topmost Kimmeridgian (uppermost *beckeri* zone) in some deep basins ("Schüsseln") between the elevated culminations of the sponge-algal bioherms the deposition of calcareous shales took place. The original thickness of the sediment was much higher as it appears now; during diagenesis the rocks were compressed to about one tenth of the former state. Fossils are very rare but the extensive quarrying has yealded a very interesting fauna and flora in a considerable number of specimens. Apparently the water near the sea floor in the basins was very poor in oxygen. Therefore benthic life was extremely scarce, but allochthonous, mostly nectic or planctic fossils were preserved extraordinary well.

In the southwestern part of the Swabian Alb basins with deposition of calcareous shales existed in the uppermost *beckeri* and the lowermost *Gravesia* zones. Best known is the basin of Nusplingen which yealded ammonites, crustaceans, fishes, even some reptiles, and plants. However, the fossils are very scarce. Other basins existed near Kolbingen and Tiergarten (H. TEMMLER 1964).

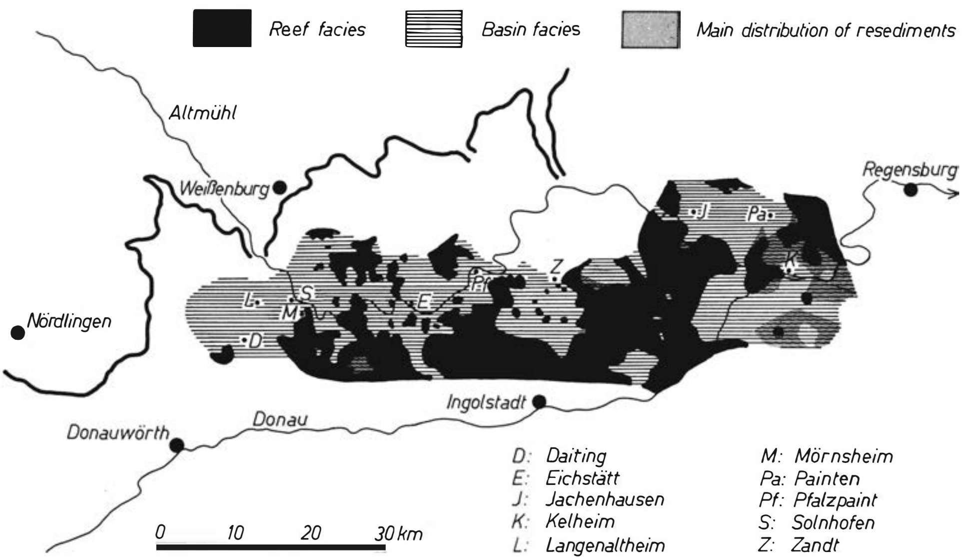


Fig. 39. The distribution of the basin facies (mainly lithographic calcareous shales) within the upper Solnhofen formation (lower Tithonian) in the southern Franconian Alb. After B. v. FREYBERG (1968).

By far more important are the calcareous shales in the southern Franconian Alb. They are somewhat younger and belong mainly to the *Gravesia* zone. However, deposition of the calcareous shales started in the Torleite beds (*beckeri* zone) and continued locally until the Rennertshofen formation (*vimineus* zone). The most famous outcrops are situated in the region of Solnhofen and Moernsheim, in the surroundings of Eichstätt, and near Pfalzpaint, Zandt, Daiting, and Painten. The beds are known as the Solnhofen lithographic shales (cf. K. W. BARTHEL 1970; 1972).

The most frequent fossils in these shales are the free swimming crinoid *Saccocoma* and the ammonite genus *Glochiceras*. Both are rather common findings. All other fossils are rare. However, due to the extensive exploitation of the rocks now large materials are known. Best represented are small fishes (especially *Leptolepis*) and decapod crustaceans.

In total about 700 species of macrofossils have been described from the Solnhofen shales, the taxonomic validity of some being disputable, however. Many species are represented only by one or few specimens. The taxonomic diversity is largest in insects (about 180 species), followed by fishes (about 150 species), crustaceans (about 60 species), and reptiles (about 60 species). For literature on the fauna and flora of the Solnhofen shales see O. KUHN (1961; 1963).

The most outstanding findings in the Solnhofen lithographic shales are the five skeletons of *Archaeopteryx*. Whereas these birds were fossilized far outside their biotope, the pterosaurians apparently lived near or on the sea. They are represented by several genera belonging to the long-tailed Rhamphorhynchoidea and to the short-tailed Pterodactyloidea as well. Some specimens still show the contents of the

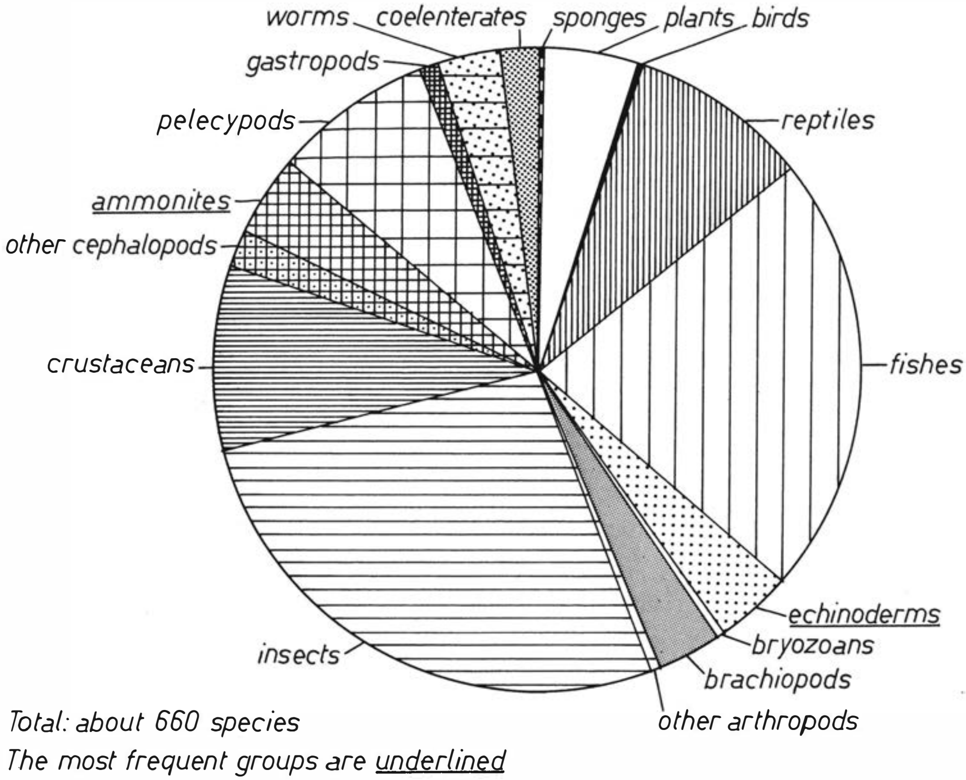


Fig. 40. The composition (according to species) of the macrofauna of the calcareous shales of the Altmühltal group (lower Tithonian) in the southern Franconian Alb. After O. KUHN (1963).

stomach (remains of fishes and crinoids). The aquatic saurians such as ichthyosaurians, plesiosaurians, turtles, and crocodilians are very rare. More frequent are representatives of the Rhynchocephalia, especially *Homoeosaurus*, which occurs preferably in the easternmost localities. *Homoeosaurus* apparently had amphibic life habits. True terrestrial reptiles occur with but a unique specimen *(Compsognathus)*.

Fishes are known in all states of preservation. A biostratinomical survey of this group reveals that in many cases drifting dead bodies were disintegrated. Parts fell down to the sea floor and were embedded isolatedly. On the other hand, decay of dead bodies on the sea floor is proven, too. Finally, in more exceptional cases complete skeletons are preserved. Apparently all these processes went on under permanent covering by sea water. An occasional draining of the sedimentary basin as it was postulated by O. ABEL (1927, p. 580) and F. X. MAYR (1967) is not proven (K. W. BARTHEL 1970; 1972).

Soft-bodied animals are preserved in the Solnhofen shales very rarely but in an extremely good manner. Jelly-fishes, worms, and cuttle-fishes are known with excellent specimens. Especially the study of imprints of the arms of cuttle-fishes gives important informations. Dead animals drifted in the water of the Solnhofen basin. When they sunk to the sea floor sometimes they came down first with their arms and left regular eight-rayed rosettes. Then they canted over and were embedded immediately beside these imprints. Evidently the water movement was insignificant. Perhaps this caused poverty in oxygene which may be the reason for the good preservation of the fossils.

However, in some parts of the sedimentary basins, especially in the eastern outcrops, considerable water movements have existed at least sometimes. This is proven by the findings of marks produced by rolling empty ammonite shells (A. SEILACHER 1963). Thus the genesis of the Solnhofen shales is by no means exactly known.

6.4. The shallow water facies

During the Kimmeridgian the development of sponge-algal bioherms had lead to a considerable submarine relief (p. 34). For long times the subsidence of the sea floor seems to have equalled the growth of the bioherms. As it is indicated by the autochthonous faunas the depth of the sea appears to have never been less than about 70 to 100 m even on the summits of the bioherms.

However, in the late Kimmeridgian signs of shallowing of the sea set in. It is not quite certain whether this shallowing is the result of the continuing growth of the bioherms or of some epirogenetic movements. In the Swabian Alb several submarine slumps, breccias, and resediments are known from the "Liegende Bankkalke". Similar phenomena are widespread in the lower Tithonian of the southern Franconian Alb.

When culminations of the sponge-algal bioherms grew up to a position near the sea-level (or when they were uplifted to this position) they were overgrown by a fauna of reef corals and their allies. The first coral growth took place in the surroundings of Kelheim in the southeasternmost Franconian Alb. There it is of upper Kimmeridgian age (basal *beckeri* zone, perhaps even *eudoxus* zone). Other coral faunas in the southern Franconian Alb and in the eastern parts of the Swabian Alb are younger (lower Tithonian: *Gravesia* zone).

Most famous is the locality of Nattheim (eastern Swabian Alb). The revision of the corals of the Swabian Alb by O. F. GEYER (1954) showed that at Nattheim predominantly reef detritus is present. The same is likely for most other localities. In some places, however, the fauna is more or less autochthonous and the former bioherms and biostromes are preserved rather well (e. g. Arnegg and Laisacker).

The coral fauna of the lower Tithonian in the Swabian Alb is extremely rich in species. O. F. GEYER (1954, p. 209) records about 150 species, some of which being restricted to only one or a few localities. According to O. F. GEYER (1954, p. 209), in Kelheim only 85 species are present. They are found in a restricted area with only few outcrops, however.

The reef corals are accompanied by a great variety of other shallow water fossils. In the Swabian Alb, where about 130 species are recorded (O. F. GEYER 1953a, p. 137), especially thick-shelled pelecypods and gastropods are well represented. The majority of the pelecypods belongs to the Pteriomorpha (e. g. *Trichites*, *Arctostrea*, limids, pectinids). The most important gastropods are pleurotomariids and nerineids. Ammonites are extremely rare. In addition to the molluscs a rich

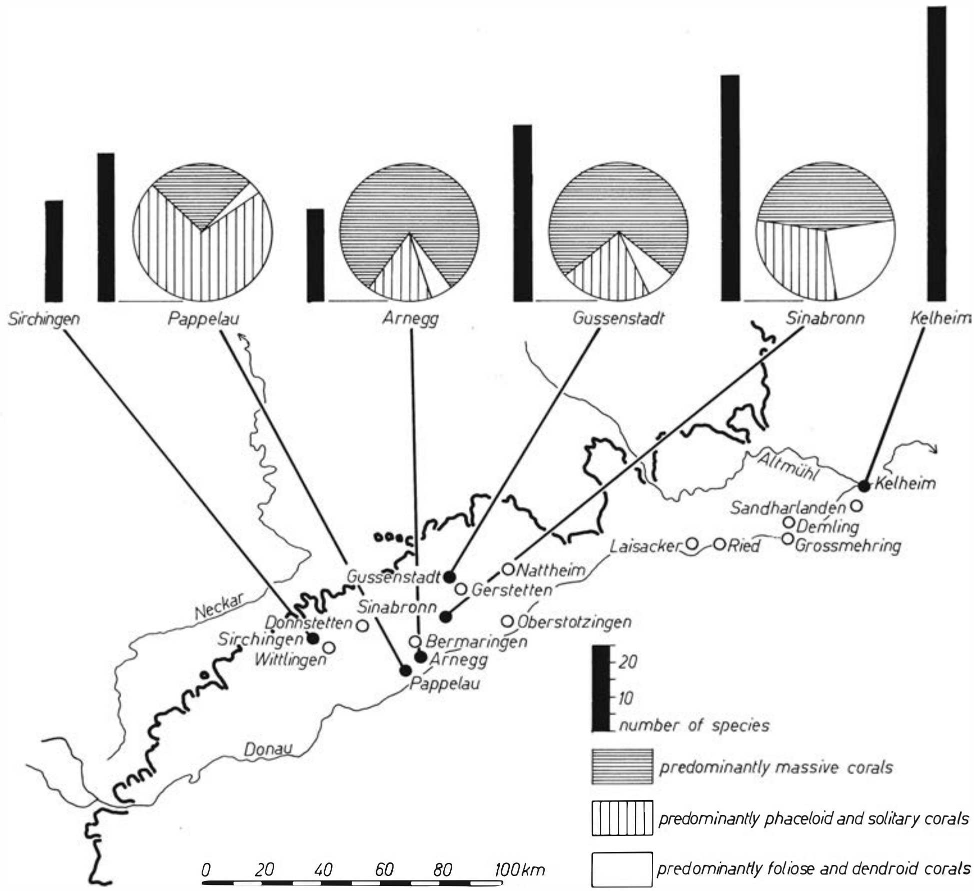


Fig. 41. The composition (according to individuals) of major ecological groups and the diversity of some coral faunas of the upper Malm of southern Germany. After O. F. GEYER (1954).

fauna of calcareous sponges, brachiopods (e. g. *Septaliphoria, Juralina, Cheirothyris)*, and echinodermata (especially *Millericrinus* and cidaroids) is present.

In the southern Franconian Alb the composition of the mollusc fauna seems to differ somewhat from that in the Swabian Alb. Whereas *Diceras* is very rare in the Swabian Alb (O. F. GEYER 1953 b) it occurs frequently in Franconia (e. g. in Kelheim and Großmehring). Therefore the recifal limestones of Kelheim are named the "*Diceras*-Kalk". Moreover heterodont pelecypods are well represented in the southern Franconian Alb but are rare in Swabia. However, perhaps this is due to differences in preservation or even in collecting.

6.5. The Neuburg formation

The recifal and related sequence of the lower Tithonian is followed by regularly bedded limestones which are preserved only in a very restricted area near Neuburg an der Donau. Consequently this formation is named the Neuburg formation. It is proven to be of middle Tithonian age, the topmost parts belonging to the upper Tithonian.

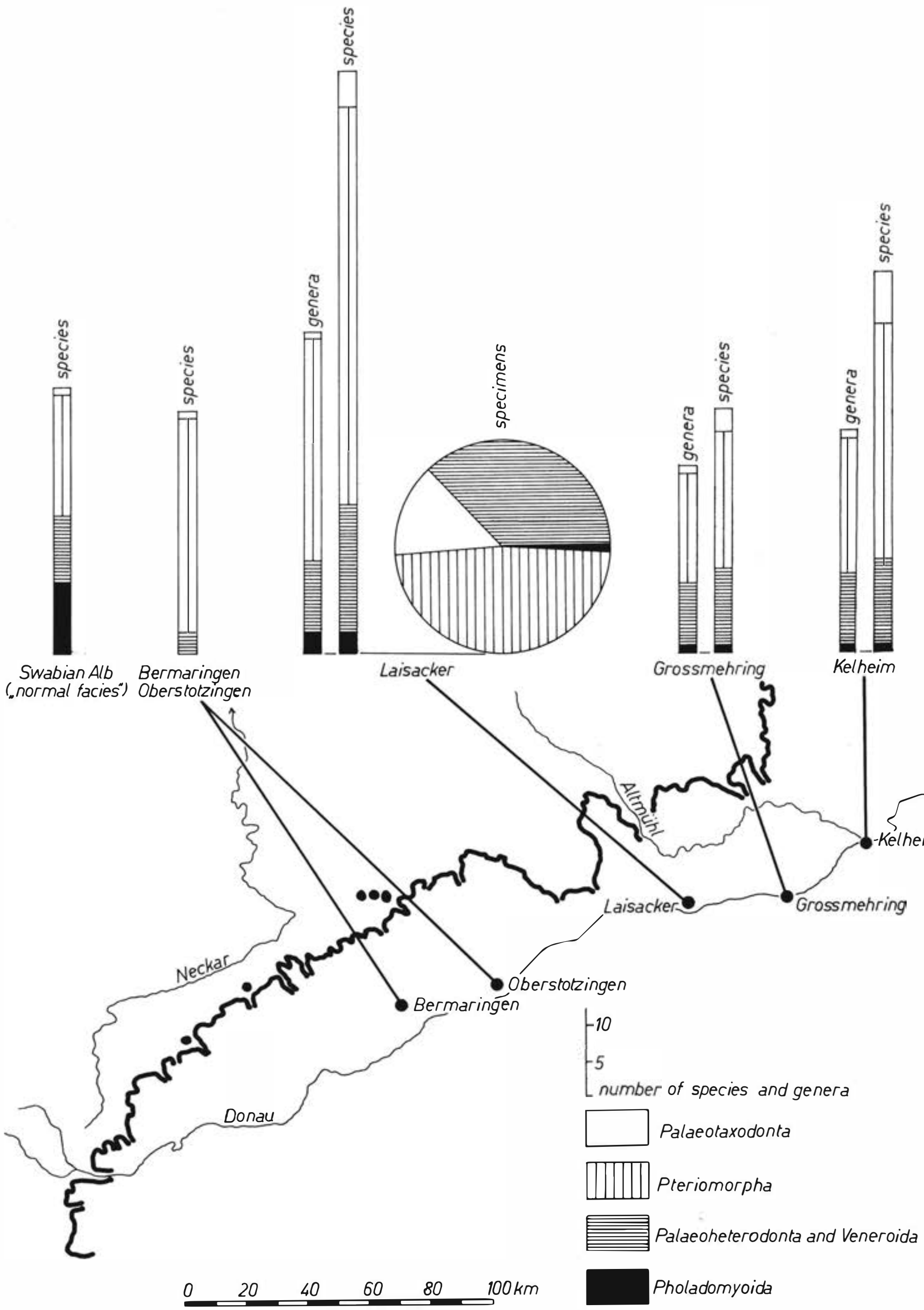


Fig. 42. The composition of major groups and the diversity of some pelecypod faunas of the upper Malm of southern Germany. Swabian Alb after TH. ENGEL (1908). Bermaringen and Oberstotzingen after O. F. GEYER (1953 a). Laisacker, Großmehring, and Kelheim after S.-A. YAMANI (1973; 1975; 1976), and S.-A. YAMANI & G. SCHAIRER (1975).

The lower and middle parts of the Neuburg formation (Unterhausen beds and lower Oberhausen beds) yeald a rich fauna of ammonites (TH. SCHNEID 1915; K. W. BARTHEL 1962; K. W. BARTHEL & J. R. GEYSSANT 1973), pelecypods (P. WELLNHOFER 1964), and gastropods (V. JANICKE 1966). Corals and especially sponges are recorded only with few specimens (D. HERM 1966; W. WAGNER 1965). Frequent microfossils are foraminifers (J. TH. GROISS 1967; J. TH. GROISS & B. WINTER 1967), ostracods being present, too, but badly preserved and of poor diversity (H. J. OERTLI 1965).

The ammonites are dominated by perisphinctids. The most frequent pelecypods are *Grammatodon, Pinna, Exogyra, Rollierella,* and *Loripes.* Gastropods are much less frequent than pelecypods, being represented especially by *Amberleya* and *Procerithella.* In the foraminifers a preponderance of the Rotaliina, especially of the Nodosariacea, over the Textularida is documented. Of special interest is the presence of *Pseudocyclammina.*

In the upper part of the Neuburg formation (upper Oberhausen beds) once more signs of shallowing of the sea are obvious. Ammonites are missing. Pelecypods and gastropods are well represented. Especially the presence of certain pelecypods *(Eocallista, Neomiodon, Eomiodon, Thracia, Unio)* indicates reduced salinity. However, in the uppermost beds genera as *Nuculoma, Inoperna, Lima,* and *Myophorella* point to normal salinity. The most significant foraminifera are large agglutinating forms (*Anchispirocyclina* and *Pseudocyclammina*) which are accompanied especially by *Ammobaculites,* miliolids, and *Trocholina.* In addition a variety of algae is present (K. W. BARTHEL 1969).

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Plate 1

Fig. 1. *Perisphinctes (Arisphinctes) elisabethae* (DE RIAZ).
Lower White Jurassic α (*transversarium* zone), Blumberg. — Natural size.

Fig. 2. *Ochetoceras hispidum* (OPPEL).
Lower White Jurassic α (*transversarium* zone), Laufen an der Eyach. — Natural size.

Fig. 3. *Gregoryceras romani* (DE GROSSOUVRE).
Lower White Jurassic α (*transversarium* zone), Blumberg. — Natural size.

Fig. 4. *Dichotomoceras bifurcatus* (QUENSTEDT).
Lower White Jurassic α, Blumberg. — Natural size.

Fig. 5. *Trimarginites arolicus* (OPPEL).
Lower White Jurassic α (*transversarium* zone), Blumberg. — Natural size.

Fig. 6. *Epipeltoceras bimammatum* (QUENSTEDT).
Upper White Jurassic α (*bimammatum* zone), Lochen. — Natural size.

Fig. 7. *Amoeboceras alternans* (VON BUCH).
Upper White Jurassic α (*bimammatum* zone), Lochen. — Natural size.

Fig. 1–7: Staatliches Museum für Naturkunde in Stuttgart.

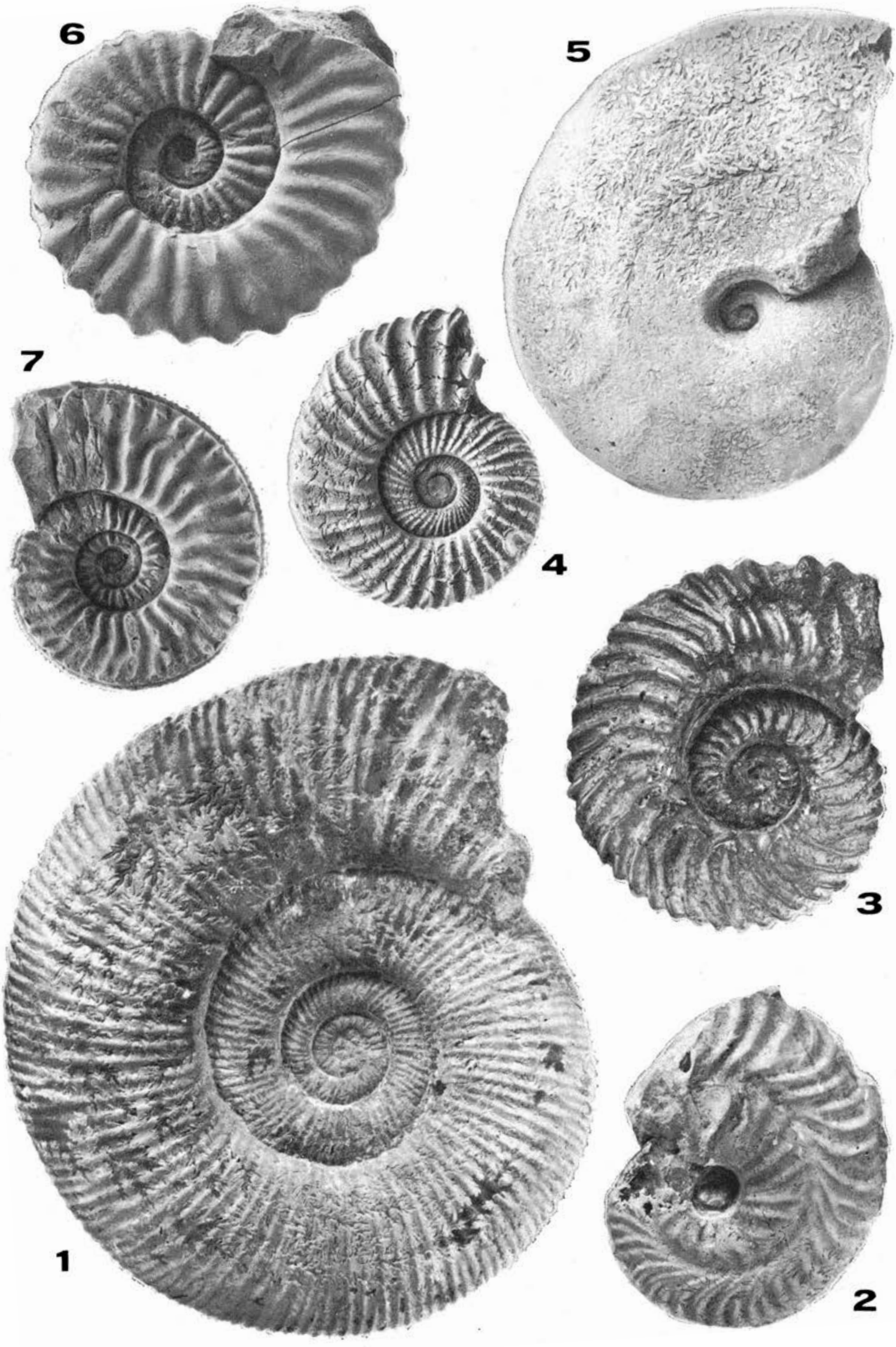
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Plate 2

Fig. 1. *Taramelliceras costatum* (QUENSTEDT).
White Jurassic β (*planula* zone), Laufen an der Eyach. — Natural size.

Fig. 2. *Idoceras (Subnebrodites) laxevolutum* (FONTANNES).
White Jurassic β (*planula* zone), Unterweckerstell near Donzdorf. — Natural size.

Fig. 3. *Sutneria galar* (OPPEL).
Upper White Jurassic β (*planula* zone, *galar* subzone), Immendingen. — Natural size.

Fig. 4. *Amoeboceras lineatum* (QUENSTEDT).
White Jurassic β (*planula* zone), Nendingen. — Natural size.

Fig. 5. *Orthosphinctes tiziani* (OPPEL).
White Jurassic β (*planula* zone), Laufen an der Eyach. — Natural size.

Fig. 6. *Glochiceras (Lingulaticeras) lingulatum* (QUENSTEDT).
White Jurassic β (*planula* zone), Braunenberg near Aalen. — Enlarged x 1,5.

Fig. 7. *Taramelliceras falculum* (QUENSTEDT).
White Jurassic β (*planula* zone), Fürsitz near Aalen. — Enlarged x 1,5.

Fig. 1—6: Staatliches Museum für Naturkunde in Stuttgart.

Fig. 7: Institut und Museum für Geologie und Paläontologie der Universität Tübingen.

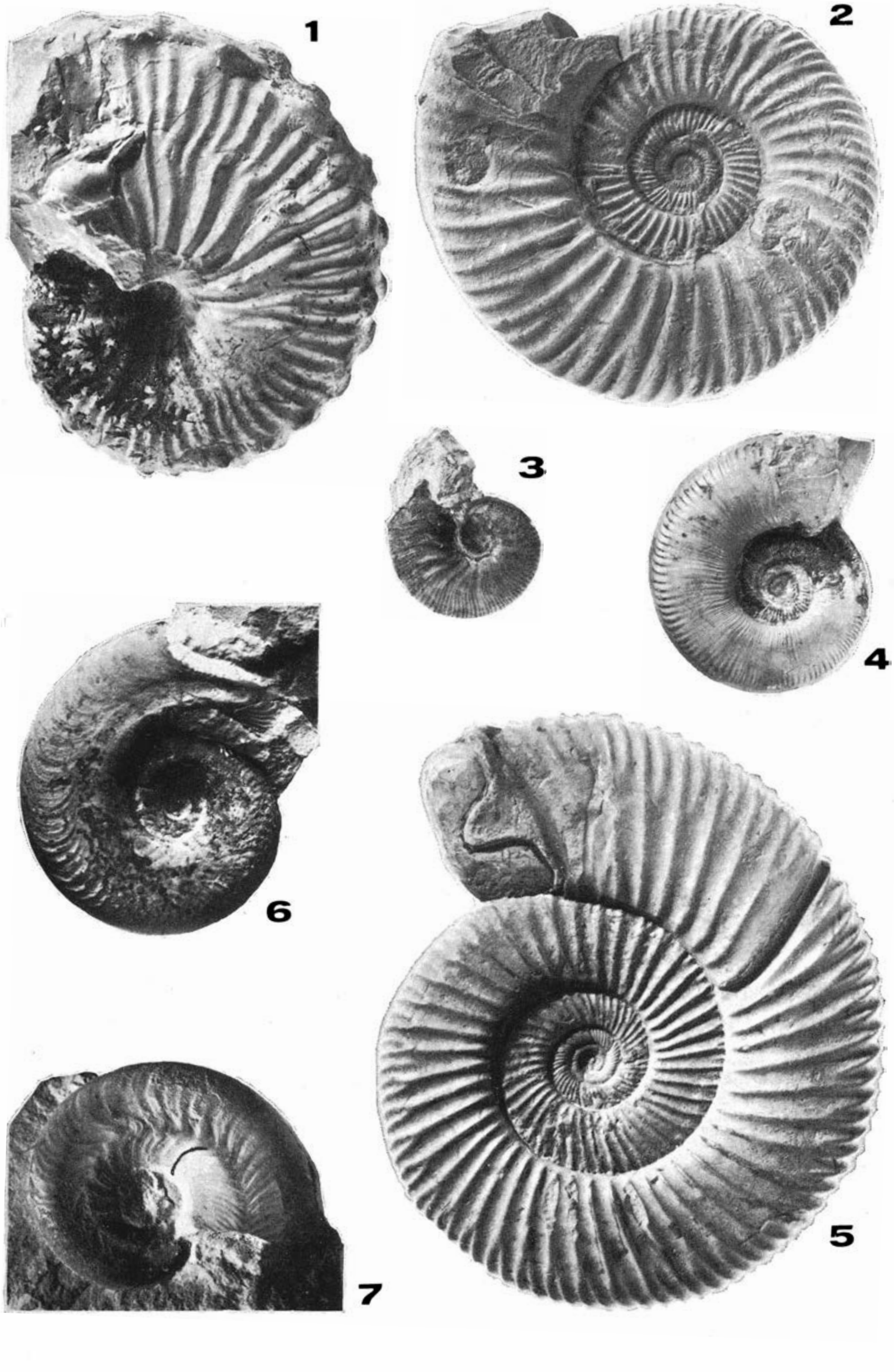
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Plate 3

Fig. 1. *Ataxioceras (Parataxioceras) planulatum* (QUENSTEDT).
White Jurassic γ (*hypselocyclum* zone), Albstadt-Truchtelfingen. — Natural size.

Fig. 2. *Ataxioceras (Ataxioceras) hypselocyclum* (FONTANNES).
White Jurassic γ (*hypselocyclum* zone), Unterkochen. — Natural size.

Fig. 3. *Sutneria platynota* (REINECKE).
Lower White Jurassic γ (*platynota* zone), Swabian Alb. — Natural size.

Fig. 4. *Creniceras dentatum* (REINECKE).
White Jurassic γ (*hypselocyclum* zone), Weckerstell near Donzdorf. — Enlarged x 1,5.

Fig. 5. *Idoceras (Idoceras) balderum* (OPPEL).
Upper White Jurassic γ (*divisum* zone), Swabian Alb. — Natural size.

Fig. 6. *Streblites tenuilobatus* (OPPEL).
White Jurassic γ (probably *hypselocyclum* zone), Laufen an der Eyach. — Natural size.

Fig. 1—3, 5, 6: Staatliches Museum für Naturkunde in Stuttgart.

Fig. 4: Institut und Museum für Geologie und Paläontologie der Universiät Tübingen.

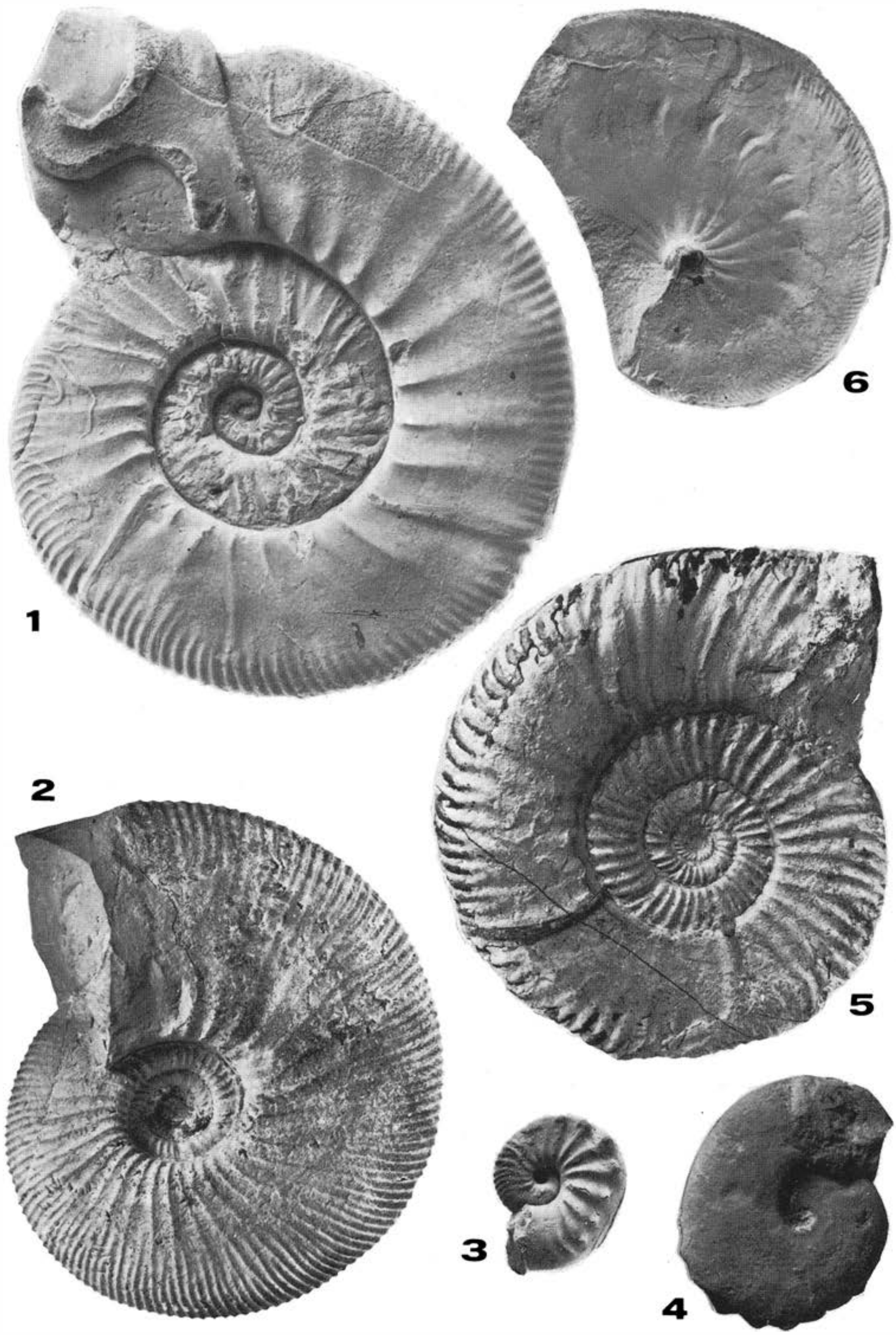

Plate 4

Fig. 1. *Aspidoceras acanthicum* (OPPEL).
Lower White Jurassic δ (*acanthicum* zone), Swabian Alb. — Reduced x $^2/_3$.

Fig. 2. *Katroliceras (Crussoliceras) divisum* (QUENSTEDT).
Upper White Jurassic γ (*divisum* zone), Bartholomä. — Reduced x $^1/_2$.

Fig. 1—2: Staatliches Museum für Naturkunde in Stuttgart.

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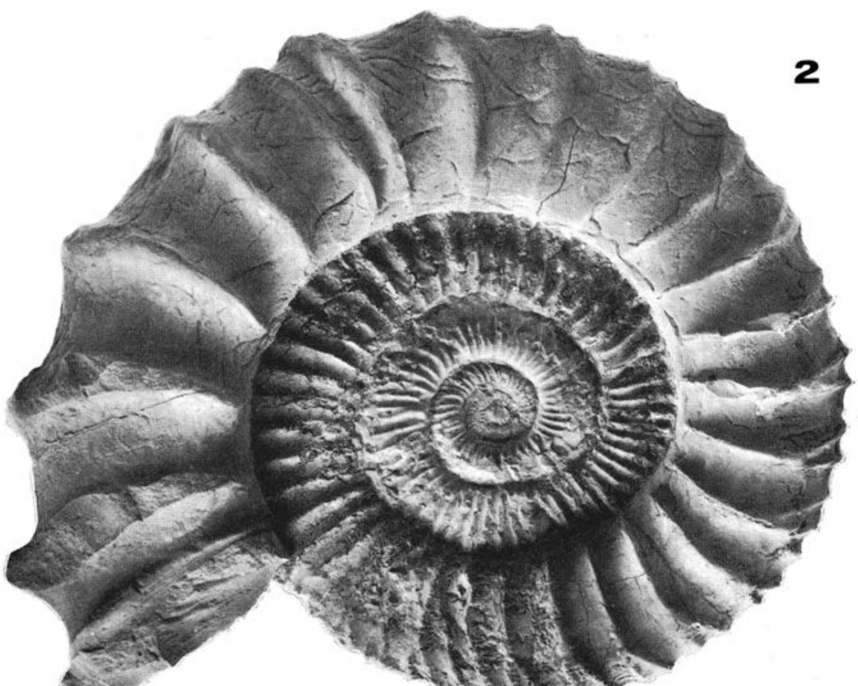

Plate 5

Fig. 1. *Aulacostephanus (Aulacostephanus) pseudomutabilis* (DE LORIOL).
Upper White Jurassic δ (*eudoxus* zone), Bräunesberg near Nendingen. — Natural size.

Fig. 2. *Aulacostephanus (Aulacostephanoceras) eudoxus* (D'ORBIGNY).
Upper White Jurassic δ (*eudoxus* zone), Blaubeuren. — Natural size.

Fig. 3. *Aulacostephanus (Aulacostephanites) eulepidus* (SCHNEID).
Lower White Jurassic δ (*acanthicum* zone), Tuttlingen. — Natural size.

Fig. 4: *Sutneria eumela* (D'ORBIGNY).
Upper White Jurassic δ (*eudoxus* zone), Stetten an der Donau. — Natural size.

Fig. 5. *Orthaspidoceras schilleri* (OPPEL).
White Jurassic δ (lower *eudoxus* zone), Hülben near Urach. — Reduced x $^2/_3$.

Fig. 1—5: Staatliches Museum für Naturkunde in Stuttgart.

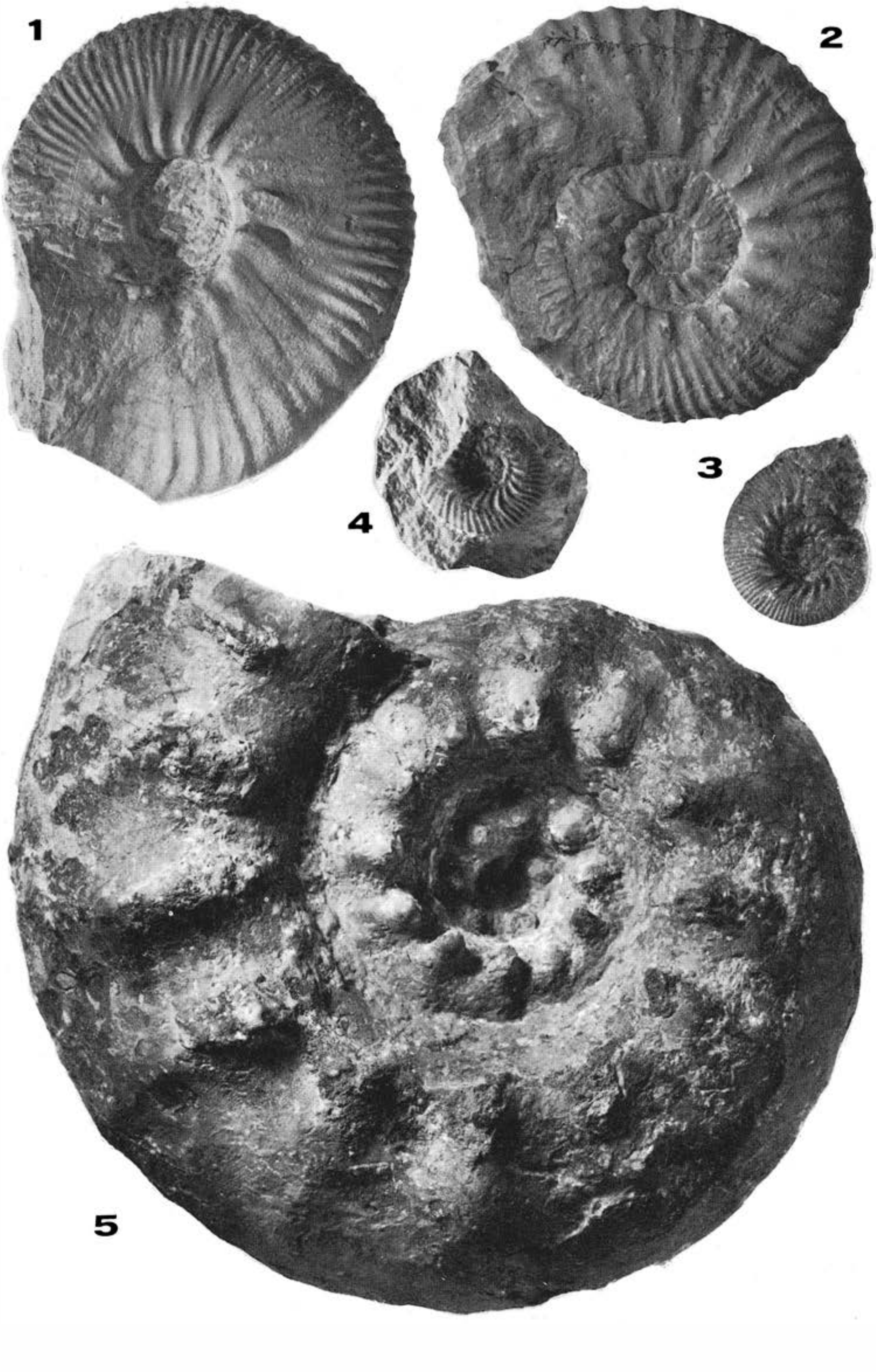
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Plate 6

Fig. 1. *Hybonoticeras beckeri* (NEUMAYR).
White Jurassic ε (probably *subeumela* subzone), Herrlingen. — Natural size.

Fig. 2. *Sutneria subeumela* (SCHNEID).
White Jurassic ε (*beckeri* zone, *subeumela* subzone), Herrlingen. — Natural size.

Fig. 3. *Oxyoppelia fischeri* (BERCKHEMER).
White Jurassic ε (*beckeri* zone, probably *subeumela* subzone), Herrlingen. — Natural size.

Fig. 4. *Virgataxioceras setatum* (SCHNEID).
Upper White Jurassic ε (*beckeri* zone, *setatum* subzone), Kolbingen. — Natural size.

Fig. 5. *Gravesia gigas* (ZIETEN).
Upper White Jurassic ζ ("Hangende Bankkalke"), Riedlingen. — Natural size.

Fig. 1—5: Staatliches Museum für Naturkunde in Stuttgart.

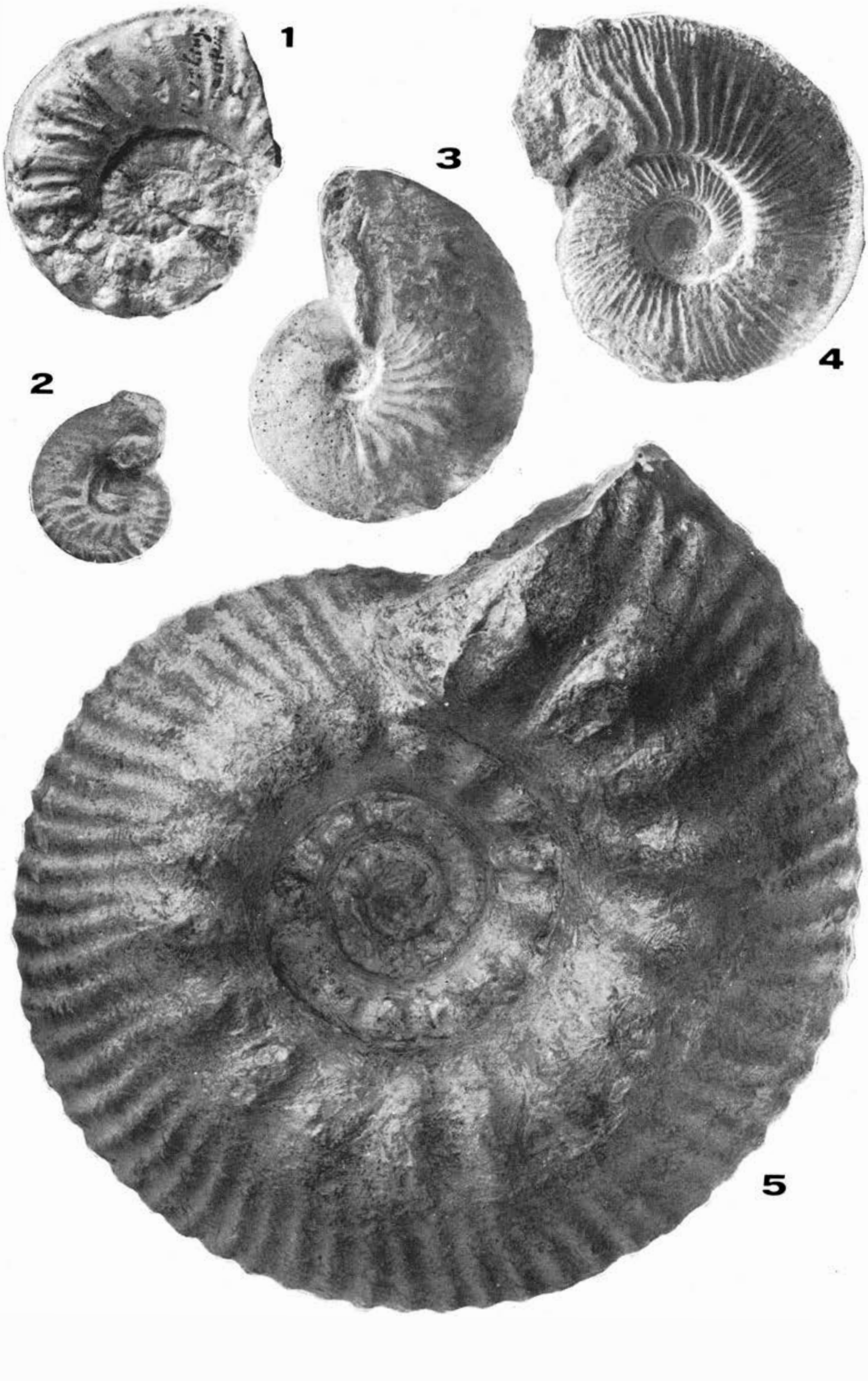
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Plate 7

Fig. 1. *Hybonoticeras hybonotum* (OPPEL).
Upper White Jurassic ζ ("Hangende Bankkalke"), Riedlingen. — Reduced x $^1/_2$

Fig. 2. *Lithacoceras ulmense* (OPPEL).
Lower White Jurassic ζ ("Liegende Bankkalke"), Ulm region. — Natural size.

Fig. 1: Staatliches Museum für Naturkunde in Stuttgart.

Fig. 2: Bayerische Staatssammlung für Paläontologie und Historische Geologie München

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Plate 12

Ammonites of the middle and upper part of the Lower Tithonian of the Franconian Alb

Fig. 1: *Usseliceras parvinodosum* ZEISS
Large specimen: holotype; small specimen: paratype.
Lower Rennertshofen formation, Bertoldsheim member.
Ammerfeld W.
Bayerische Staatssammlung für Paläontologie u. Historische Geologie München, no. 1948 I/22.
Reduced x 1/2.

Fig. 2: *Usseliceras tagmersheimense* ZEISS, holotype.
Usseltal formation, Tagmersheim member.
Tagmersheim.
Geologisches Institut der Universität Erlangen, no. S 30.
Reduced x 1/2.

Fig. 3: *Danubisphinctes palatinus* ZEISS, holotype.
Upper Rennertshofen formation, Finkenstein member.
Ellenbrunn.
Geologisches Institut der Universität Erlangen, no. S 250.
Reduced x 1/2.

Fig. 4: *Dorsoplanitoides triplicatus* ZEISS, holotype.
Lower Rennertshofen formation, Bertoldsheim member.
Bertoldsheim.
Geologisches Institut der Universität Erlangen, no. S 132.
Reduced x 1/2.

Fig. 5: *Franconites vimineus* (SCHNEID), paratype.
Middle Rennertshofen formation, Ammerfeld member.
Rohrbach S.
Geologisches Institut der Universität Erlangen, no. S 510.
Reduced x 1/2.

Fig. 6: *Neochetoceras mucronatum* BERCKHEMER & HÖLDER.
Usseltal formation, Tagmersheim member.
Hagenau.
Geologisches Institut der Universität Erlangen, no. S 728.
Reduced x 1/2.

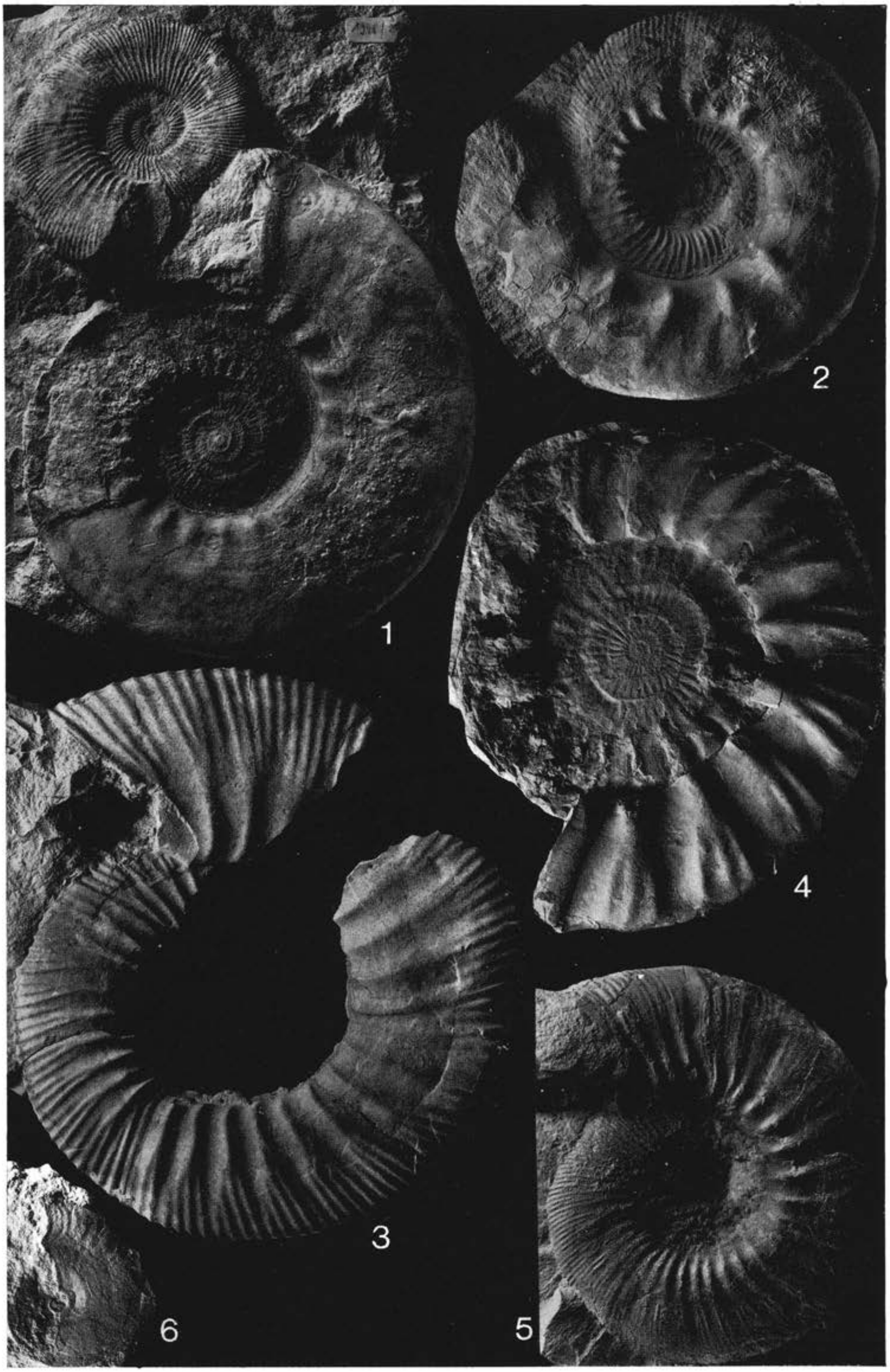
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Plate 8

Fossils of the sponge-algal facies

Fig. 1. *Stauroderma lochense* (QUENSTEDT).
Skeleton of the hexactinellid sponge worked out by acid. Upper Oxfordian (*bimammatum* zone), Streitberg (Franconia). — Reduced x $^2/_3$.

Fig. 2, 3. *Lacunosella trilobata* (ZIETEN).
Kimmeridgian, Swabian Alb. — Reduced x $^3/_4$.

Fig. 4. *Cnemidiastrum stellatum* (GOLDFUSS).
Calcified sponge "mummy". Lower Kimmeridgian, Lochen region. — Reduced x $^3/_4$.

Fig. 5. Lower surface of a hexactinellid sponge settled by serpulids and the bryozoan *Berenicea*.
Upper Oxfordian (upper White Jurassic α, *bimammatum* zone), Bärenthal. — Enlarged x 3,5.

Fig. 1—4: Staatliches Museum für Naturkunde in Stuttgart.

Fig. 5: Paläontologisches Institut und Museum der Universität Zürich.

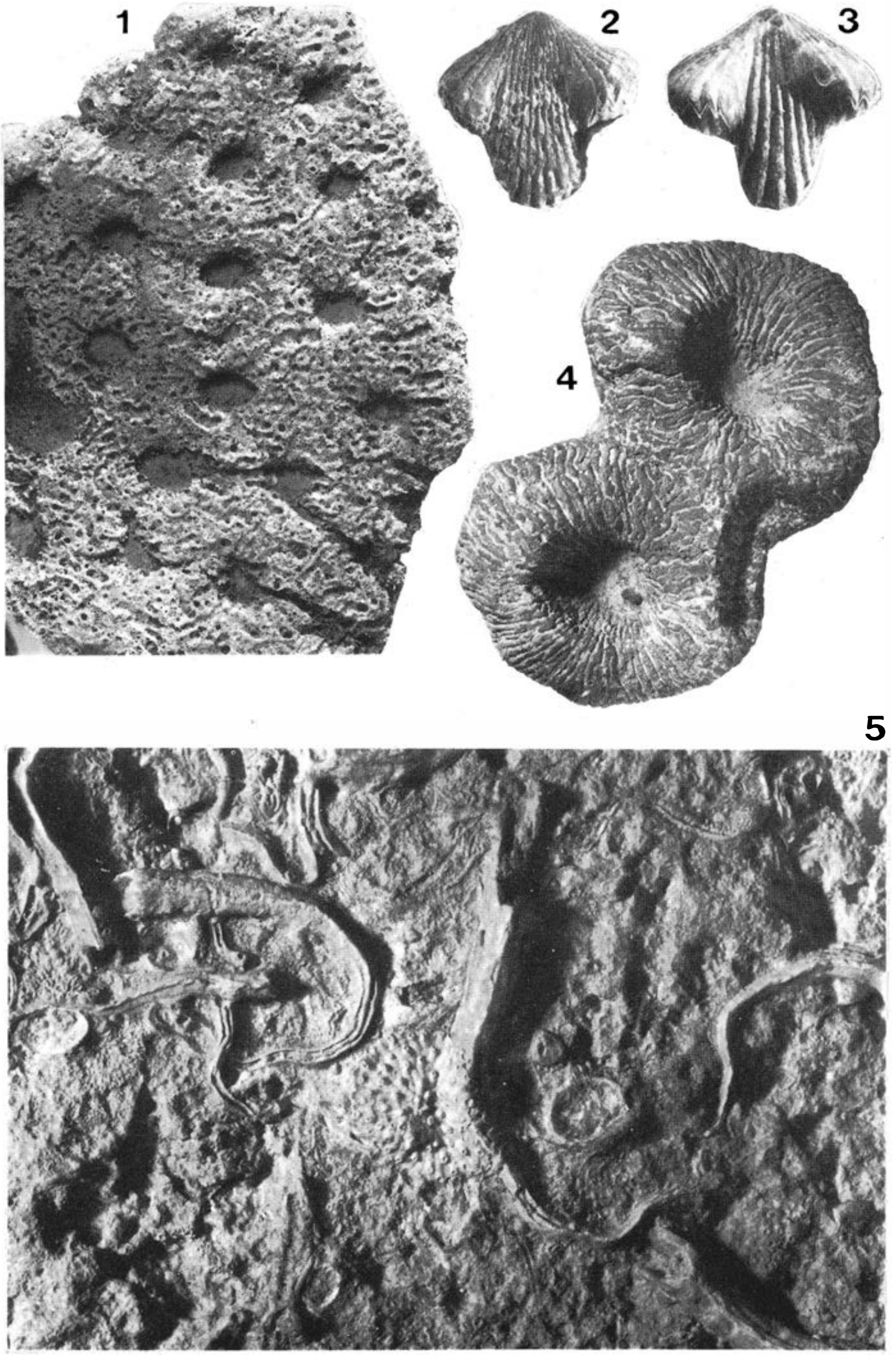
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Plate 9

Fossils of the Lochen facies

Fig. 1. *Amoeboceras alternans* (v. BUCH), phragmocone.
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 2. *Epipeltoceras semiarmatum* (QUENSTEDT).
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 3, 4. *Taramelliceras pichleri* (OPPEL).
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 5. *Taramelliceras lochense* (OPPEL).
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 6, 7. *Glochiceras canale* (QUENSTEDT).
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 8—10. *Trigonellina pectunculus* (SCHLOTHEIM).
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 11—12. *Trigonellina loricata* (SCHLOTHEIM).
Upper Oxfordian (*bimammatum* zone), Mühlheim an der Donau. — Enlarged x 2.

Fig. 13. *Nucleata nucleata* (SCHLOTHEIM).
Probably lower Kimmeridgian (*platynota* or *hypselocyclum* zones), Lochen region near Balingen. — Enlarged x 2.

Fig. 14—15. *Tylasteria jurensis* (QUENSTEDT), marginal plates of sea stars.
Upper Oxfordian (probably *bimammatum* zone), Geislingen. — Enlarged x 2.

Fig. 16. *Magnosia nodulosa* (GOLDFUSS).
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 17. *Sporadopyle obliqua* (GOLDFUSS), siliceous sponge.
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 18. *Peronidella jurassica* (ETALLON), calcareous sponge, settled by a serpulid.
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 19. *Plegiocidaris* sp.
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 20. *Eugeniacrinites caryophyllatus* (GOLDFUSS).
Upper Oxfordian (*bimammatum* zone), Lochen near Balingen. — Enlarged x 2.

Fig. 1—20: Staatliches Museum für Naturkunde in Stuttgart.

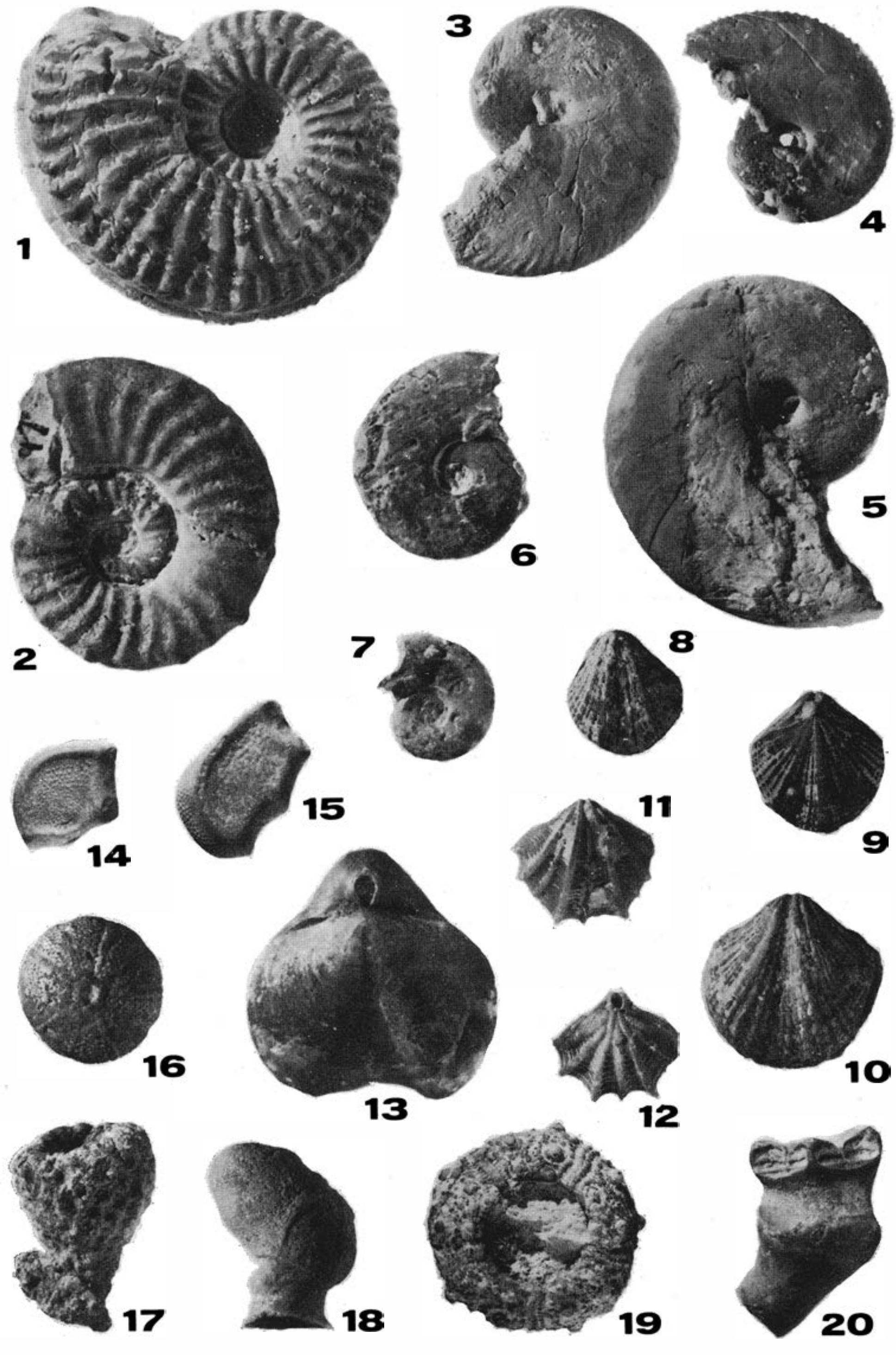
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Plate 10

Fossils of the calcareous shales of the lower Tithonian

Fig. 1. *Saccocoma pectinata* GOLDFUSS; free swimming crinoid.
Lower Tithonian (*Gravesia* zone, ?Solnhofen formation), "Solnhofen", Franconia — Reduced x 1/2.

Fig. 2. *Glochiceras (Paralingulaticeras) lithographicum* (OPPEL).
Lower Tithonian (*Gravesia* zone, ?Solnhofen formation), "Solnhofen", Franconia — Reduced x 3/4.

Fig. 3. Marks of rolling ammonites (perisphinctids).
Lower Tithonian (*Gravesia* zone, Solnhofen formation), Painten, Franconia. — Reduced x 1/2.

Fig. 4. *Leptolepis*, well preserved specimen, scales present.
Lower Tithonian (*Gravesia* zone, Solnhofen formation), "Eichstätt", Franconia. Reduced x 1/2.

Fig. 5. *Leptolepis*, partly disintegrated specimen.
Lower Tithonian (*Gravesia* zone, Solnhofen formation), Zandt, Franconia. — Reduced x 1/2.

Fig. 6. *?Propterus*, partly disintegrated specimen.
Lower Tithonian (*Gravesia* zone, Solnhofen or Mörnsheim formation), Mörnsheim, Franconia. — Reduced x 1/2.

Fig. 7. *Leptolepis*, totally disintegrated specimen.
Lower Tithonian (*Gravesia* zone, Solnhofen formation), Zandt, Franconia. — Reduced x 1/2.

Fig. 8. *Leptolepis*, partly disintegrated specimen, scales mostly missing.
Lower Tithonian (*Gravesia* zone, Solnhofen formation), Zandt, Franconia. — Reduced x 1/2.

Fig. 1: Staatliches Museum für Naturkunde in Stuttgart.

Fig. 2: Bayerische Staatssammlung für Paläontologie und Historische Geologie, München.

Fig. 3—4: Paläontologisches Institut und Museum der Universität Zürich.

Fig. 5—8: Philosophisch-Theologische Hochschule Eichstätt.

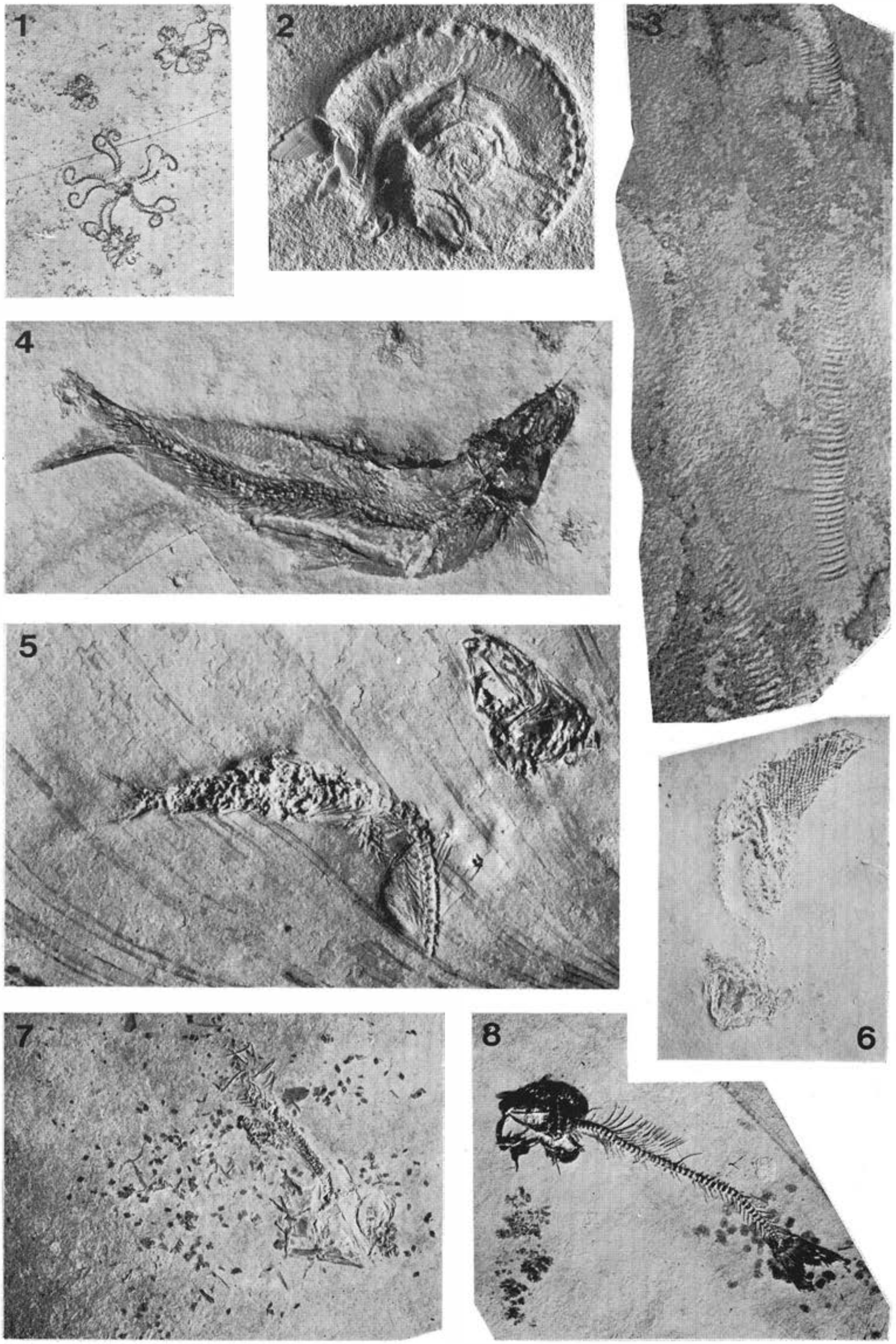


Plate 11

Fossils of the coral facies of the lower Tithonian

Fig. 1. *Arctostrea gregarea* (SOWERBY).
Lower Tithonian (*Gravesia* zone), Nattheim. — Enlarged x 3.

Fig. 2. *Juralina insignis* (ZIETEN).
Lower Tithonian (*Gravesia* zone), Nattheim. — Natural size.

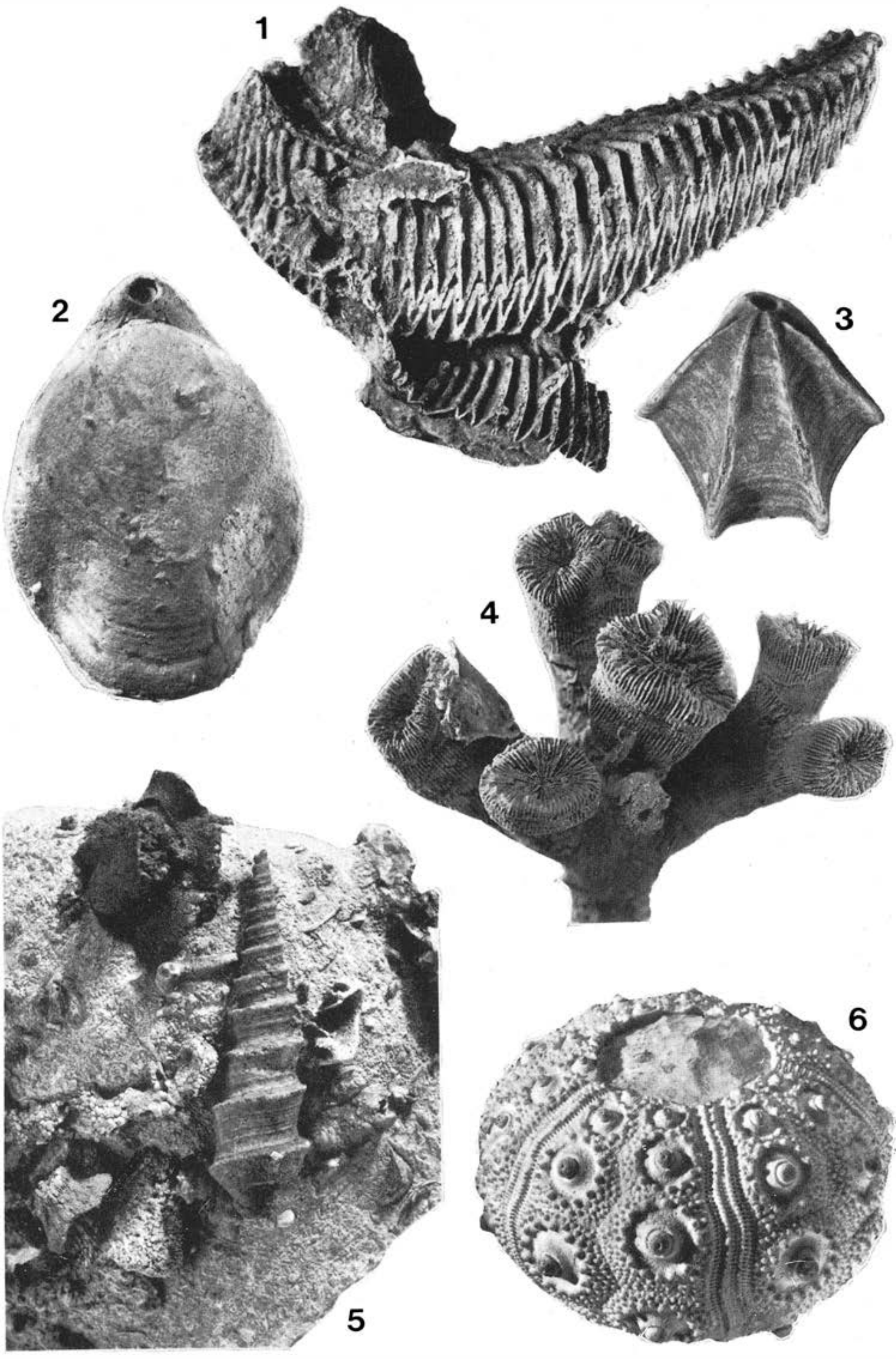
Fig. 3. *Cheirothyris trigonella* (SCHLOTHEIM).
Lower Tithonian (*Gravesia* zone), Nattheim. — Enlarged x 2,5.

Fig. 4. *Thecosmilia trichotoma* (GOLDFUSS).
Lower Tithonian (*Gravesia* zone), Nattheim. The coral is settled by serpulids, an oyster, and a calcareous sponge. — Natural size.

Fig. 5. A gastropod of the family Nerineidae embedded in a bioclastic limestone.
Lower Tithonian (*Gravesia* zone), Nattheim. — Enlarged x 1,25.

Fig. 6. *Plegiocidaris coronata* (GOLDFUSS).
Lower Tithonian (*Gravesia* zone), Nattheim. — Enlarged x 1,25.

Fig. 1—6: Staatliches Museum für Naturkunde in Stuttgart.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