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The Lower Jurassic in Southwestern Germany

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with 6 plates, 11 figures and 2 tables

1. Introduction

Some years ago summaries of the papers dealing with the Jurassic of SW-Germany were published by Geyer & Gwinner (1962; 1964) and Hölder (1964). Since then a lot of papers about litho- and biostratigraphy, sedimentology, and micropaleontology have appeared, and therefore this further summary will be published.

The Lower Jurassic forms the subedge plain northwards and northwestwards of the Swabian Alb. Furthermore, small areas of Lower Jurassic sediments are known from the surroundings of Langenbrücken (south of Heidelberg) and south of Freiburg (Upper Rhine Graben).

The Lower Jurassic sediments are made up mainly of dark clays and marls. There are intercalated in its lower part sandstones, in its upper part bituminous shales, and in the total sequence some thin limestone beds. The maximum thickness of the Lower Jurassic reaches 150 m in the foreland of the Swabian Alb, mainly in the surroundings of Plochingen (southeast of Stuttgart). It diminishes to 50 m in the E near Aalen and also in the SW at the Wutach river. In the outlier of Langenbrücken the total thickness of the Lower Jurassic reaches 200 m.

The nearest landmass to the Swabian Lower Jurassic during the time of deposition was not, as assumed in former times, the Black Forest (Schwarzwald), which was covered by sea in reality. The nearest shore, as has been verified by boreholes, laid in southeastern direction, east of the river Lech (Lemcke 1970). The landmass in the east was already identified by Gümbel (1861) as a southwestern prolongiation of the Bohemian Massif, and he named it (1891, p. 3) „Vindelizisches Gebirge". It existed during the Lower and Middle Lias and submerged during the Toarcian. A southern landmass has been investigated in the northern part of Switzerland by Trümpy (1949, p. 173) and it has been named „Alemannisches Land" by him. It also submerged during the Lias.

The Swabian Alb (Schwäbische Alb) is the birth place of zonal stratigraphy. L. v. BUCH (1839, p. 65) was the first, who divided the Jurassic of Germany into: „Unterer Jura" (= Lias), „Mittlerer Jura", and „Oberer Jura". He characterized (v. BUCH 1839, p. 63) these groups by their black, brown, or white colour. Subsequently, QUENSTEDT (1843, p. 122), in his famous book „Das Flözgebirge Würtembergs . . .", named them „Schwarzer Jura", „Brauner Jura", and „Weisser Jura". He (QUENSTEDT 1843) subdivided the Lias or „Schwarzer Jura" into a lower, middle, and upper part and these again into two lithological units, respectively, and used Greek letters, α (alpha) to ζ (zeta), for them. The Greek letters were originally the numbers of the chapters of this book. But these abbreviations of QUENSTEDT's units soon came into general use. Already in the preface of the 2nd edition of the „Flözgebirge . . ." (1851) QUENSTEDT himself used the Greek letters and later on also. In all papers QUENSTEDT wrote „Schwarzer Jura", „Brauner Jura", and „Weißer Jura". The abbreviations „Schwarzjura", „Braunjura", and „Weißjura", which were introduced by ENGEL (1883; 1908), are still in use today. QUENSTEDT's (1843) subdivision is first of all a lithological one. But it is also characterized by typical fossils, for example: „Schwarzer Jura δ: dunkle Thone mit *Amaltheus margaritatus*" [= grey clays with . . .]. The Greek alphabet is still in use, because of its handiness and by convenience. However, it was interpreted in two different ways. At first (QUENSTEDT 1843) it was used as a lithological subdivision, later (QUENSTEDT 1858; 1885) also in a biostratigraphic sense. Most of the subsequent authors use QUENSTEDT's subdivision as a biostratigraphic one, and in this case the boundaries were mostly shifted to the boundaries of zones and stages. In this paper QUENSTEDT's subdivision will be used in the original sense. This subdivision is consequently only valid in Württemberg (first of all in the Middle Swabian Alb), to which QUENSTEDT referred. However, it has been applied also in the Wutach area and the Upper Rhine Graben up to this day.

QUENSTEDT's pupil OPPEL (1856—1858) shook himself free from the Greek alphabet; he founded the zonal system and opened the possibility of correlation over far distances. For this he used index fossils (= „Leitmuschel", OPPEL 1856, p. 123) and he (1856, p. 135) characterized his proposed zones in the following way: „Jeder der einzelnen Zonen sind immer diejenigen Arten beigeschrieben, welche sie besonders charakterisieren und noch in keiner anderen Schichte gefunden wurden" [= Those species are designated for each single zone which characterize especially them and which were not yet found in another bed].

2. Subdivision of Quenstedt

2.1. Schwarzer Jura α

The Lower Jurassic is underlain by beds of the middle and upper Keuper, mostly of the „Knollenmergel" (red marlstone with limestone nodules) and, in western and central Württemberg, by finegrained sandstones and clays of the Rhaetian (Upper Triassic). At the top of „Rhätsandstein" a bonebed has often developed. The sequence just above the Rhaetian up to the top of the marls and limestones with Arietitidae has been named „α) Sand- und Thonkalke" by QUENSTEDT (1843, p. 123). Later QUENSTEDT (1858, p. 39 ff.) divided this formation into three members: „1) Psilonotenkalk", „2) Malmstein" or „Angulatensandstein" and „3) Arietenkalk". The numbers of these chapters were used by W. LANGE (1923, p. 461) for the further biostratigraphic subdivision „α_1, α_2, α_3". He added Latin letters a-f to the numbers characterizing his very detailed zonal subdivision (indices of LANGE). WALLISER (1956) and RIEK (1966), however, like QUENSTEDT (1843), used the subdivision „α_{1-3}" as a lithological one

Fig. 1. Map of Southwestern Germany with the cited localities (stippled: lower Jurassic).

2.1.1. Schwarzer Jura α_{1-2}

According to BLOOS (1976), the lower and middle member of the „Schwarzer Jura α" is built up by three types of sediment units. „They are often arranged in a characteristic sequence, beginning with a clay unit at the base, followed by a unit containing a sandstone body in the middle, and terminated by reworking at the top. As a rule, the boundaries between these units are sharp" (BLOOS 1976). „Within the clay units the fossil content as well as the carbonate content decreases from the W towards the E. The units with sandstone body exhibit the following lateral sequence of facies from W to E: bioturbated silty clay — interbedded clay and siltstone slabs — sandstone body — interbedded clay and siltstone slabs with scour channels. The sandstone bodies consist of laminated sandstone beds with intercalated clay and silt layers, the portion of which become more or less reduced towards the center of the bodies. The bodies form lenses from 40 to more than 200 kilometers long, from 15 to 70 kilometers wide, and from 1 to 4 meters thick. Their long axes follow the general trend of the basin, N—S or NNE—SSW." (BLOOS 1976). „The units with features of repeated reworking are beds of limestone or calcareous sandstone, rich in fossil debris and reworked concretions more or less. There is a rather wide variety of lithology. Frequently these units contain iron oolithes, which are always associated with yellow, limonitic shell particles. Frequent tendencies of lateral changing of facies within these units are the increase of sand content from W to E, the increase of portion and grain size of shell debris, strong bioturbation in the W, primary sedimentary structures in the E." (BLOOS 1976). These various beds have been numbered and partly named by BLOOS (1976) (see fig. 2).

No other bed of the Swabian Jurassic has been investigated so often as the base of the Lower Lias, the „Psilonotenbank" („Schwarzer Jura α1I" of BLOOS 1976). It is a horizon with a maximum thickness of 1,50 m which is made up of one, two, or sometimes more limestone beds with intercalations of thin marlstone or claystone beds (ALTMANN 1965, SEILER & VILLINGER 1966). This horizon is absent only at some localities in the eastern part of Württemberg, but it is recorded again in southern Franconia (JAHNEL 1970). In SW- and Middle Württemberg a characteristic sequence of beds is recorded. Single beds may be absent for short distances, or are found in lenses (WETZEL 1929; ALTMANN 1965; BLOOS 1976). Besides the „Psilonotenbank", the „Oolithenbank" (base of „Schwarzer Jura $\alpha_2 = \alpha$2I" of BLOOS 1976, see fig. 2) is the most distinct bed in the „Schwarzer Jura α" of SW-Germany. Conspicuous in this bed are the biodetritus of a yellowish-brown colour and brown limonite or dark chamosite ooids. A detailed study of this bed has been published by SCHLOZ (1972).

Formerly, VOLLRATH and FRANK assumed that the „Oolithenbank" grades into the „Psilonotenbank" towards SW and E, and, similarly, that the „Kupferfelsbank" (base of the „Schwarzer Jura α_3") of Balingen grades into the „Oolithenbank" (base of the „Schwarzer Jura α_2") of the Wutach area. From this they concluded, that *Psiloceras, Schlotheimia,* and *Arietites,* which occur elsewhere in vertical succession, occur in SW-Germany in a lateral succession within the same horizon. This opinion caused vehement discussions and opposition. A summary of these discussions has been published by WALLISER (1956). Moreover, he revised the sections which were investigated by VOLLRATH and FRANK, and he was able to disprove this theory point by point. According to BLOOS (1976), the „Psilonotenbank" (base of the „Schwarzer Jura α_1") has been identified all over SW-Germany, even in Southern Franconia (JAHNEL 1970). But in the upper part of the „Schwarzer Jura α_{1-2}" the beds wedge out successively towards the E (see fig. 2), as has recently been observed by BLOOS (1976).

The „Schwarzer Jura α_{1-2}" reaches the greatest thickness of 34 m near Plochingen (southeast of Stuttgart). Eastwards it decreases down to a minimum of 2 m E of Ellwangen (see fig. 2), southwestwards to 4,5 m in the Wutach area.

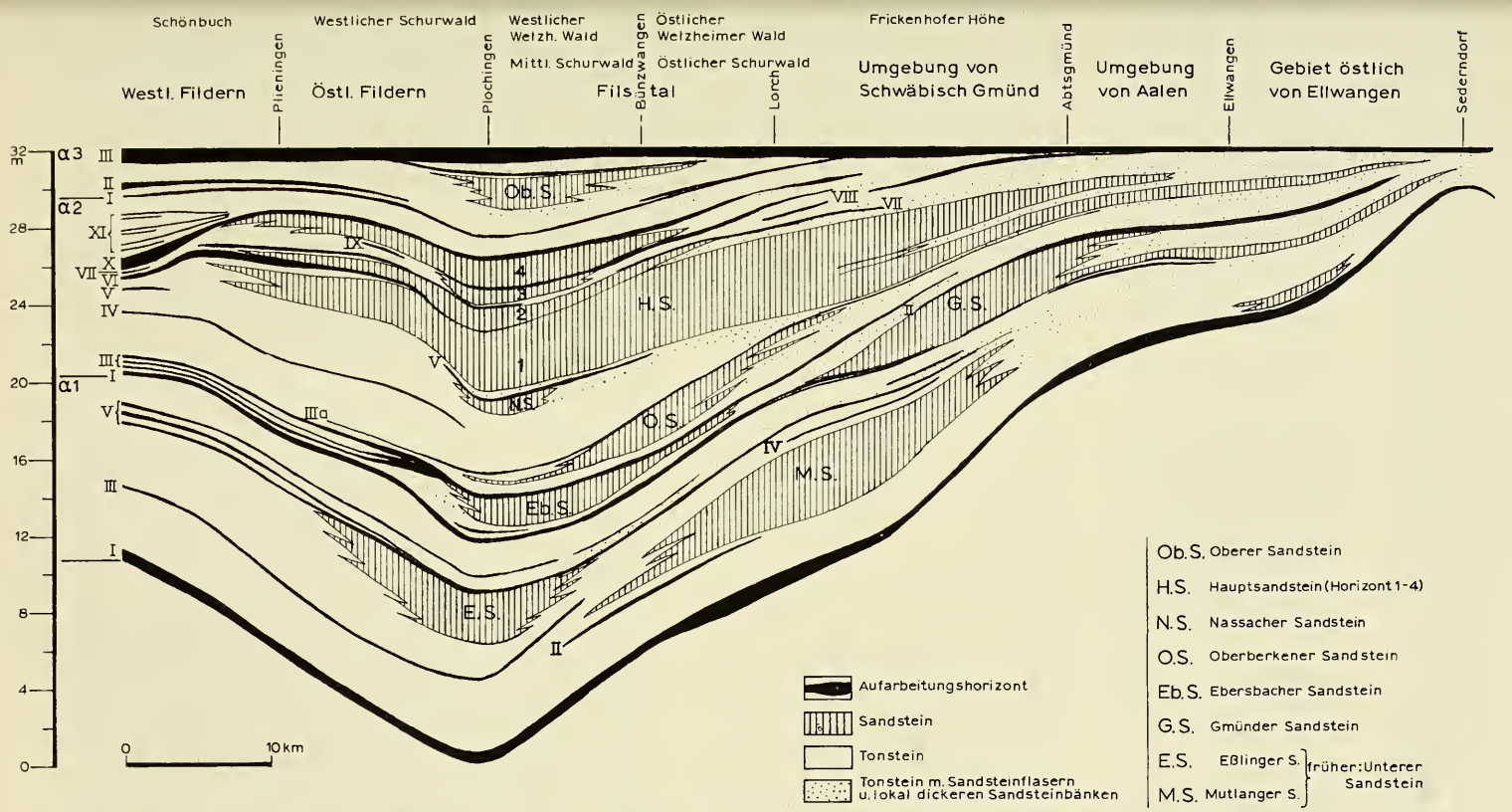

Fig. 2. Schematic crossection of the Schwarzer Jura $\alpha_{1\ 2}$ and the basal beds of α_1 (Hettangian and lowermost Sinemurian) in the area between Stuttgart-Vaihingen and Ellwangen (copy of BLOOS 1976, fig. 6). black: horizons with features of repeated reworking, hatched: sandstones, white: claystones, stippeled: claystones with increased content of fine sand and sandstone.

2.1.2. Schwarzer Jura α_3

The member „Schwarzer Jura α_3" („Arietenkalk", „Gryphaeenkalk") is built up by limestone beds with a maximum thickness of half a meter and with intercalations of marlstones or claystones. In the Stuttgart area these intercalations are as thick as the limestones or even thicker. Towards the SW and E they recede to thin layers. In the area between Stuttgart and Balingen the marl- and claystones are partly replaced by dark bituminous shales (= „Ölschiefer"). In the Stuttgart area these shales occur in the middle and upper part of the „Schwarzer Jura α_3" and in the Balingen region only in the upper part. A sandstone with a maximum thickness of 2,5 m is intercalated in the lower part in the area between Plochingen and Göppingen („Plochinger Sandstein", Bloos 1976). The base of the „Schwarzer Jura α_3" is an oolithic limestone bed („Kupferfelsbank" in the Balingen region = „Schwarzer Jura α3I" of Bloos 1976). The other beds are fine-grained, marly limestones in the W of Württemberg, towards the E they grade into coarse-grained shell hashes. East of Aalen they contain coarsely grained quartz sand. Walliser (1956) divided the „Schwarzer Jura α_3" in the area between Balingen and the Wutach river into 7 lithologic horizons. In the surroundings of Stuttgart Riek (1966) subdivided this formation into lower, middle, and upper „Schwarzer Jura α_3" and numbered typical limestone beds. Bloos (1976) published a further subdivision. He differentiated 11 lithologic units, from which each encloses one or more limestone beds (fig. 3).

The „Schwarzer Jura α_3" reaches the maximum thickness of 16 m SW of Stuttgart and diminishes to 1,5 m towards the E (NW of Aalen), to 4,0 m towards the SE (at Urach), and to 4,0 m towards the SW (in the Wutach area).

2.2. Schwarzer Jura β

Quenstedt (1843, p. 153) named the dark clays above the „Arietenkalk" and below the „Numismalismergel": „β) Thone mit verkiesten aber sparsam verteilten Muscheln" [= β) clays with pyritized but rare shells] or „Turnerithone". These clays have been called „Turneritone" up to the present day, although *Caenisites turneri* has never been traced in them (see. p. 20). The name is based on „*Ammonites turneri*" of Zieten, which, according to Hoffmann (1964, p. 142), is an *Asteroceras obtusum*. Later Quenstedt found a characteristic limestone bed approximately in the upper quarter of the clay, and he named it „Betakalkbank". This bed has been found in the region between Göppingen and Erzingen near Balingen. It is a layer with a maximum thickness of 0,25 m and with a variable lithology. It is developed as a massive limestone bed rich in fossils and phosphorite nodules or as a nodular limestone horizon. According to Söll (1956, p. 373), a thin marlstone bed above this bed also belongs to the „Betakalkbank". Quenstedt (1884, p. 138) named the clays below the „Betakalkbank" „untere Betatone" and those above „obere Betatone". In addition, Hoffmann (1936) divided the „Schwarzer Jura β" into lower Lias β or β_1 („Planicostaschichten" and „Betakalkbank"), middle Lias β or β_2 („Oxynotenschichten"), and upper Lias β or β_3 („Subplanicosta-" and „Raricostatenschichten"). These beds are, according to Hoffmann (1936, p. 300), identical with one zone or more. Along the Middle Swabian Alb Söll (1956) made an improved division of the upper „Schwarzer Jura β", in which each horizon is identical with a biostratigraphic unit. Each of them begins with a thin marlstone-bed (Mergellage I-IV of Söll 1956, see also fig. 4). According to Etzold, Hahn & Koerner (1975, p. 126), in the Middle Swabian Alb these marlstones may have developed locally also as limestones. These marlstone beds are absent in the Wutach area and 0,10 m below the top of the „Schwarzer Jura β" a 0,5 m thick limestone bed, the „Obliquabank", is developed. It is irregularly bedded and consists of more or less marly limestones rich in phophorite nodules and fossils (fig. 5).

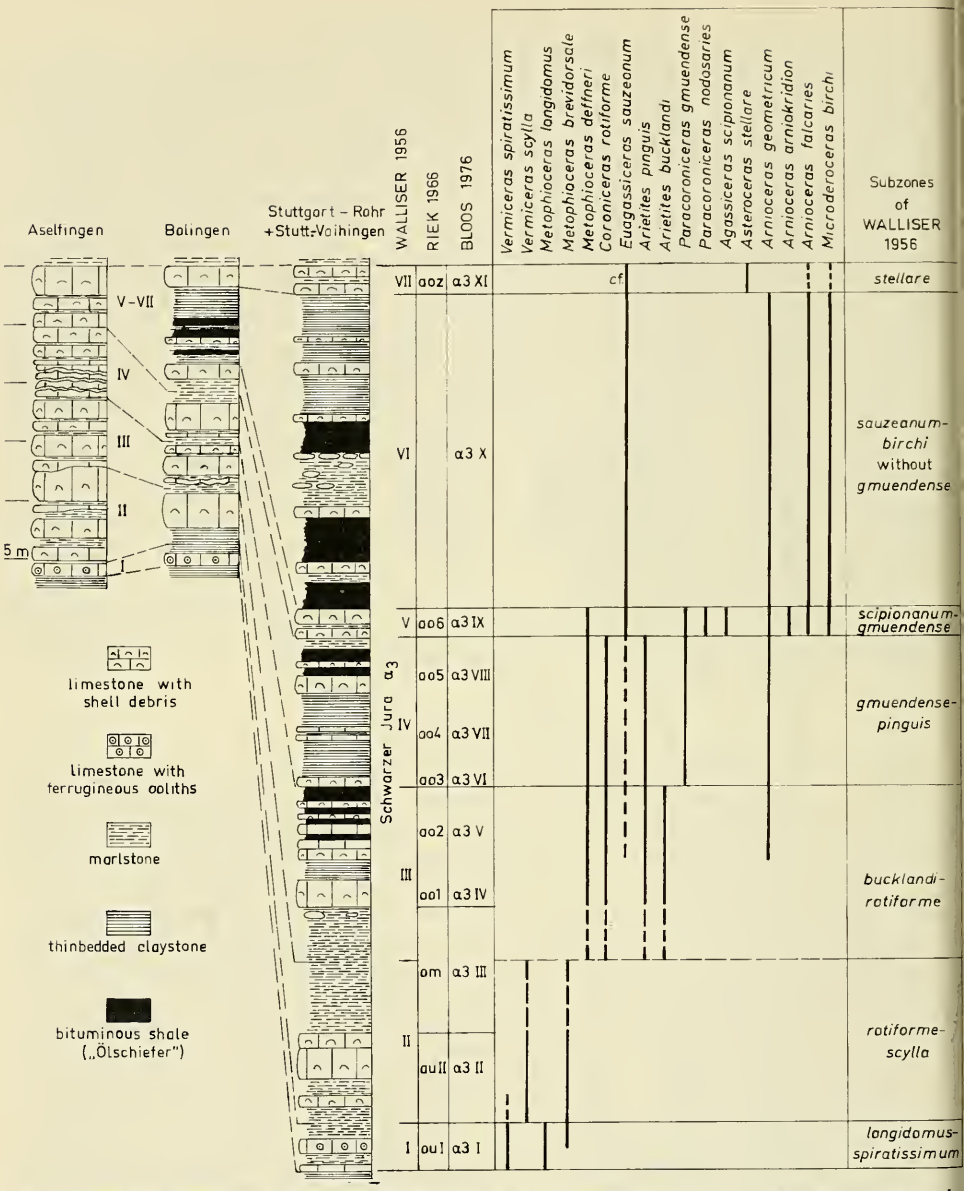

Fig. 3. Lithology, ammonites and zonal subdivision of the „Schwarzer Jura α_3" (Lower Sinemurian and base of the Upper Sinemurian); (according to WALLISER 1956 and RIEK 1966).

According to K. HOFFMANN (1964, p. 140), the „Schwarzer Jura β" of the Wutach area shows great similarity to Lorraine, and the „Obliquabank" corresponds partly to the „Calcaire Ocreux" of Lorraine.

In the foreland of the Swabian Alb the greatest thickness of 43 m was found in the borehole Mössingen (south of Tübingen) by ETZOLD, HAHN & KOERNER (1975, p. 123). It diminishes towards the E down to 5 m near Aalen and wedges out E of Ellwangen. Towards the SW it diminishes down to 5—15 m in the Wutach area (see SÖLL 1956, fig. 6). In the outlier of Langenbrücken the thickness reaches 65 m and more (HOFFMANN 1948).

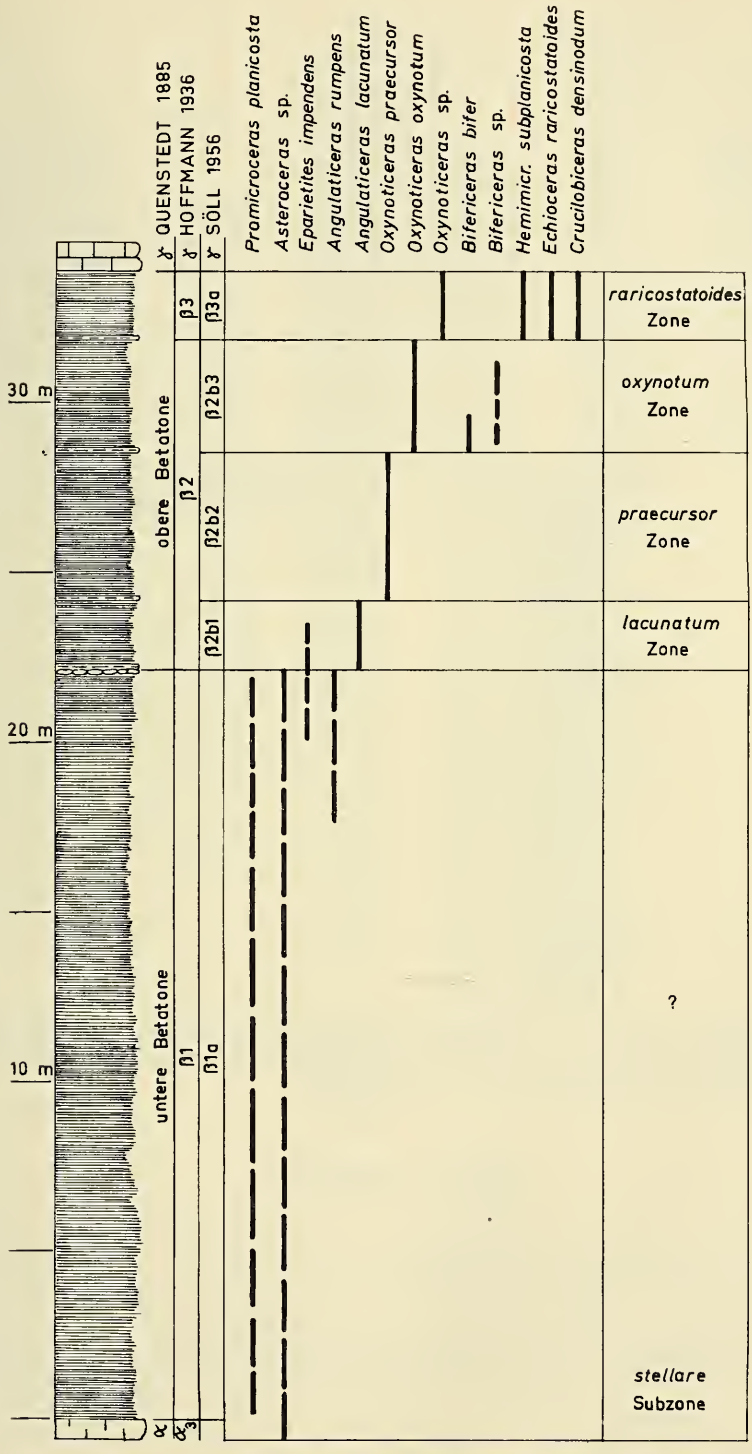

Fig. 4. Lithology, ammonites and zonal subdivision of the „Schwarzer Jura β" in the area of Kirchheim (according to SÖLL 1956). Signatures see fig. 7.

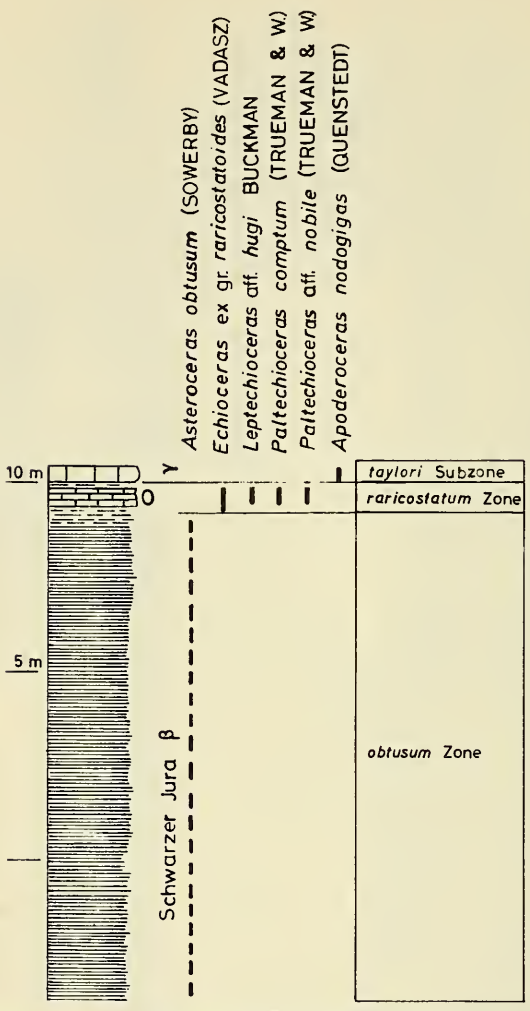

Fig. 5. Lithology, ammonites and zonal subdivision of the Upper Sinemurian near Aselfingen/Wutach (according to K. HOFFMANN 1964; signatures see fig. 7). The *obtusum* Zone of HOFFMANN is a synonym of the *stellare* Subzone (O = „Obliquabank").

2.3. Schwarzer Jura γ

QUENSTEDT (1843, p. 164) named the marlstones above and below the thick claystone formations of the „Schwarzer Jura β" and „δ": „ γ) grauschäckiger Steinmergel mit *Terebratula numismalis*" or „Numismalismergel" for short. Along the Middle Swabian Alb this formation is made up of grey marlstones with a variable number of limestone or marly limestone beds. Along the Southwestern and Eastern Swabian Alb the limestones predominate and the marlstones recede (fig. 6). For boundaries and further subdivision see SCHLATTER (1977). A synoptic table showing the sections hitherto known has been published by SCHWEITZER (1968, pl. 21).

In the foreland of the Swabian Alb the greatest thickness of approximately 15 m has been found at Nürtingen. It diminishes towards the E to less than 1 m and towards the

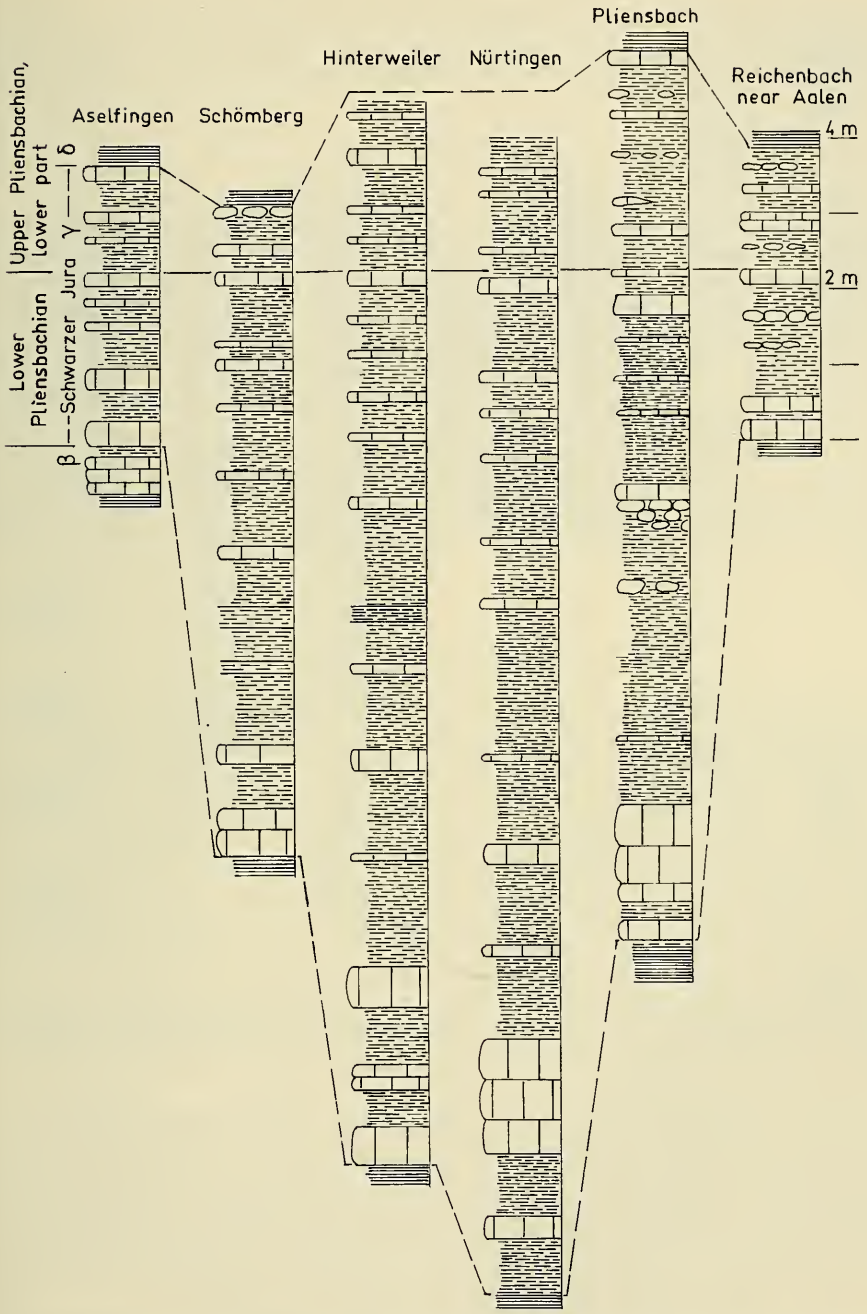

Fig. 6. Lithology of the „Schwarzer Jura" γ" (Lower Pliensbachian and base of the Upper Pliensbachian) along the Swabian Alb (according to SCHWEITZER 1968 and SCHLATTER 1977). Signatures see fig. 7.

SW down to about 2 m. An isopachous map of the „Schwarzer Jura γ" along the Swabian Alb has been drawn up by SCHWEITZER (1968, pl. 20). In the outlier of Langenbrücken the thickness reaches approximately 12 m (HETTICH 1974, p. 95).

2.4. Schwarzer Jura δ

QUENSTEDT (1843, p. 203) named the marlstones and limestones above the „Numismalismergel" and below the „Posidonienschiefer": „δ) dunkle Thone mit *Amaltheus margaritatus*" or „Amaltheenton" for short. It is subdivided into two members: a lower, consisting of claystones and marly claystones („Amaltheenton"), and an upper, calcareous one („Costatenkalk"). In the Middle Swabian Alb the „Amaltheenton" is much thicker than the „Costatenkalk". In the Wutach area, however, both members show about the same thickness (fig. 7). For further subdivision and boundaries see URLICHS (1977).

In the foreland of the Swabian Alb the greatest thickness of 25 m has been found at Reutlingen. It diminishes towards the E to 13 m at Reichenbach near Aalen and towards the SW to 9,5 m in the Wutach area (see fig. 7). In the outlier of Langenbrücken the thickness reaches 26—50 m (K. HOFFMANN 1948, p. 154; HETTICH 1974, p. 97).

2.5. Schwarzer Jura ε

QUENSTEDT (1843, p. 213) named the bituminous shales above the „Costatenkalk": „ε) Posidonienschiefer mit Stinksteinen" or „Posidonienschiefer" for short. Later QUENSTEDT (1858, p. 207—209) divided this formation into lower „Schwarzer Jura ε" or „Seegrasschiefer", middle „Schwarzer Jura ε" or „eigentlicher Posidonienschiefer", and upper „Schwarzer Jura ε" or „Leberboden" = „Wilder Schiefer", and numbered the respective chapters. Subsequently, HAUFF (1921) used these numbers as additional symbols: „Schwarzer Jura ε_I, ε_{II}, ε_{III}". Furthermore, HAUFF made a detailed subdivision of the „Schwarzer Jura ε" in the Holzmaden area and numbered typical beds (see also fig. 7). But QUENSTEDT (1858, p. 206—208; 1885, p. 345) had already enumerated most of them adopting the names used by the quarriers. HAUFF's subdivision of the „Schwarzer Jura ε" is still in use (HAUFF 1953, ALDINGER 1965, PANNKOKE 1965, GRÜN, PRINS & ZWEILI 1974, BRENNER 1976). The fossils from the workshop HAUFF, which are dispersed all over the world, are also labelled with the numbers of these beds.

In the foreland of the Middle and Western Swabian Alb the lower „Schwarzer Jura ε" is made up of dark, bituminous, laminated shales, bituminous shales with fucoids („Seegrasschiefer") and grey marlstones. Towards the E, in the surroundings of Aalen, the marlstones recede and the shales predominate (see JOACHIM 1970, pl. 1). HAUFF (1921) includes the uppermost part of the „Costatenkalk" („Blaugraue Mergel") in the „Schwarzer Jura ε", but the base has been exactly defined by QUENSTEDT (1858, p. 165; 1885, p. 303) above this bed at the base of the „Tafelfleins".

In the middle „Schwarzer Jura ε" dark, bituminous, laminated shales predominate. They have a bitumen content of 8—20 %, from which only 3—6% oil can be distilled. The light coloured laminae in the shales are made up mainly of Coccolithophoridae (MÜLLER & BLASCHKE 1969; GRÜN, PRINS & ZWEILI 1974). Within these shales three characteristic bituminous limestone beds are intercalated. They can be traced over a distance of 200 km (EINSELE & MOSEBACH 1955, fig. 5; EINSELE & SEIBOLD 1961, fig. 35; JOACHIM 1970, pl. 1). In weathered sections, each of

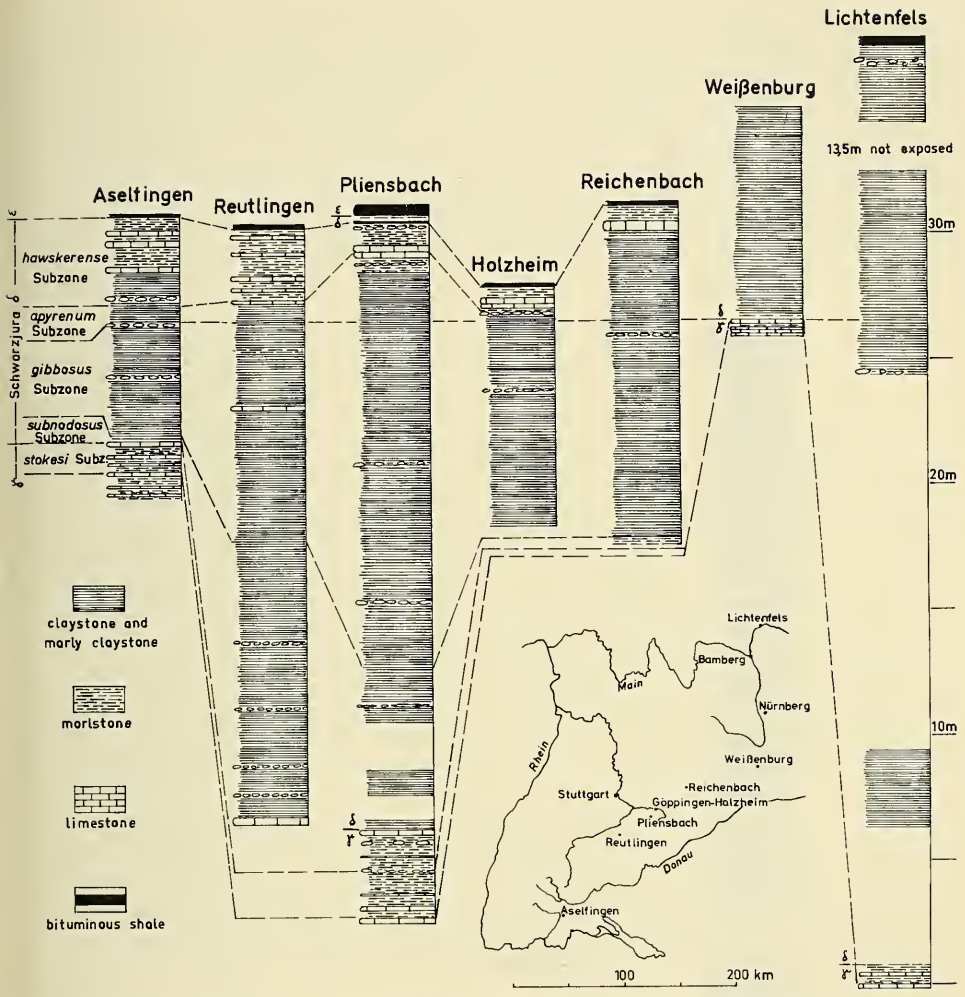

Fig. 7. Lithology and zonal subdivision of the Upper Pliensbachian in South Germany. The boundary „Schwarzer Jura γ/δ" lies in different subzones (according to FRENTZEN 1934, revised by HOWARTH 1958 and Jordan 1960, completed by URLICHS 1977 and HOFFMANN 1967).

these beds can be recognized by characteristic features: The lowermost one is thinly laminated and it often rhythmically changes its thickness („Unterer Stein" = „Schwarzer Jura $\varepsilon_{II\,5}$"); the next one is poorly laminated and weathers with a yellow tint („Gelbe Platte" = „Schwarzer Jura $\varepsilon_{II\,7}$"); the third one is very uniform in thickness and finely laminated („Oberer Stein" = „Schwarzer Jura $\varepsilon_{II\,8}$"). Other limestone beds have developed locally. For example, one to three thin shell beds rich in fish debris, belemnite rostra and hooks are present at the top of the middle „Schwarzer Jura ε" in the Holzmaden area („Schlacken" = „Schwarzer Jura $\varepsilon_{II\,12}$"). Other shell beds, consisting of *Meleagrinella substriata*, have been found in the surroundings of Göppingen („Monotisplatte", QUENSTEDT 1858, p. 203; BIRZER 1936).

The upper „Schwarzer Jura ε" („Leberboden" or „Wilder Schiefer") consists of irregularly laminated dark shales with a lower bitumen content than in the middle part. These beds are not found at all localities; there they were either not sedimentated or eroded by bottom-currents. On the top of the „Schwarzer Jura ε" a 0,10—0,20 m

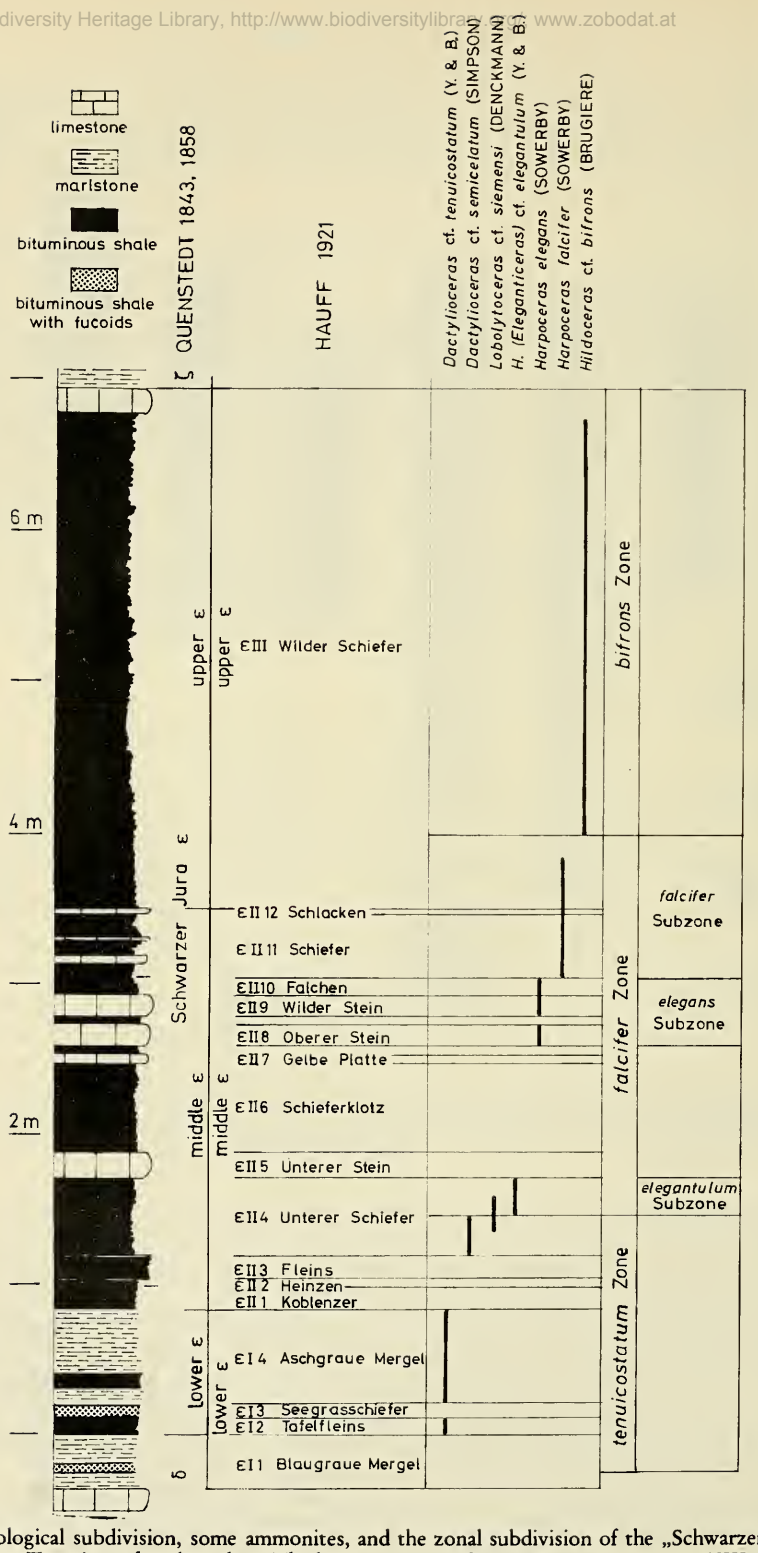

Fig. 8. Lithological subdivision, some ammonites, and the zonal subdivision of the „Schwarzer Jura ε" (Lower Toarcian) of Holzmaden. (The lower part according to HAUFF 1921, Nr. XXIII, measurements of the middle and upper „Schwarzer Jura" have been taken in the quarry Gotthilf Fischer = Nr. XX of HAUFF 1921, pl. 1. Range of the ammonites according to PANNKOKE 1965, systematics partly revised by WEITSCHAT 1973).

thick bituminous limestone bed bearing fucoids is developed in nearly all outcrops in SW-Germany (W. FISCHER 1964, p. 96). At some localities it is replaced by a dark marlstone bed rich in pyritized specimens of *Catacoeloceras crassum* and *Hildoceras bifrons* (pl. 5, fig. 4) („Crassusbett" of QUENSTEDT 1858, p. 252).

Since the thickness of the upper „Schwarzer Jura ε" varies extremely the total thickness is also variable. The latter amounts to 4—12 m in the surroundings of Aalen, to 5—14 m in the area between Göppingen and Hechingen, to 7—10 m in the Wutach area, and to 11—41 m in the outlier of Langenbrücken. In the Swabian Alb the greatest thickness of 26 m has been found in the borehole Ehingen 1 by SCHNEIDER (1962, p. 165).

2.6. Schwarzer Jura ζ

QUENSTEDT (1843, p. 267) named the grey marlstones above the „Posidonienschiefer": „ζ) lichtgraue Kalkmergel mit *Ammonites jurensis*" or „Jurensismergel" for short. It is a typical lithological unit of a variable thickness. The base is very sharp, whereas the transition to the clays of the „Opalinuston" („Brauner Jura α") takes place gradually. The „Schwarzer Jura ζ" normally consists of yellow to grey marlstones alternating with bluegrey to yellowgrey, continuous or nodular limestone beds (fig. 9). These beds extend only over short distances and they cannot be correlated from outcrop to outcrop. In the lower part thin beds of bituminous shale may also occur, which have a bitumen content less than in the „Posidonienschiefer". In the middle part limestone or nodular limestone beds predominate („Kalkknauer-Horizont" of W. FISCHER 1964), yellow to grey marlstones in the upper part. The condensed sequence consists of limestones and marly limestones, in which a thin layer of stromatolites is embedded at Bad Boll and Hammerstadt near Aalen (BRUDER 1968, p. 47—53).

The thickness of the „Schwarzer Jura ζ" changes frequently and over short distances. Great thickness of the „Schwarzer Jura ζ" corresponds to a minimum or even a hiatus of the upper „Schwarzer Jura ε" and reversely a minimum thickness of the „Schwarzer Jura ζ" corresponds to a great thickness of the upper „Schwarzer Jura ε" (fig. 10). This has been observed by BRUDER (1968, p. 149, pl. 21). There is no consense, if these great differences in thickness were caused by tectonic movements or by erosion.

An isopachous map has been published by W. FISCHER (1964, fig. 2). In the foreland of the Swabian Alb the greatest thickness of 12 m has been found at Weilheim and the minimum of 0,6 m 6 km eastwards at Bad Boll. In the Swabian Alb the maximum of 13 m has been found in the borehole Buttenhausen 1 (W. FISCHER 1964, p. 94). In the upper Rhine Graben the thickness reaches 28—30 m (HETTICH 1974, p. 99, and OHMERT 1976, p. 94).

3. Biostratigraphy

In 1856—1858 OPPEL founded his zonal system, based on the Swabian Jurassic. Therefore the classification in this area is very important.

The zonal system of DEAN, DONOVAN & HOWARTH (1961) is not generally used in SW-Germany, and zones or subzones restricted to SW-Germany have been proposed. In the following they are referred to the standard zones of NW-Europe (see tab. 1).

A clearly arranged survey of the ammonites from S-Germany has recently been given by SCHLEGELMILCH (1976). This book is important because many holotypes or

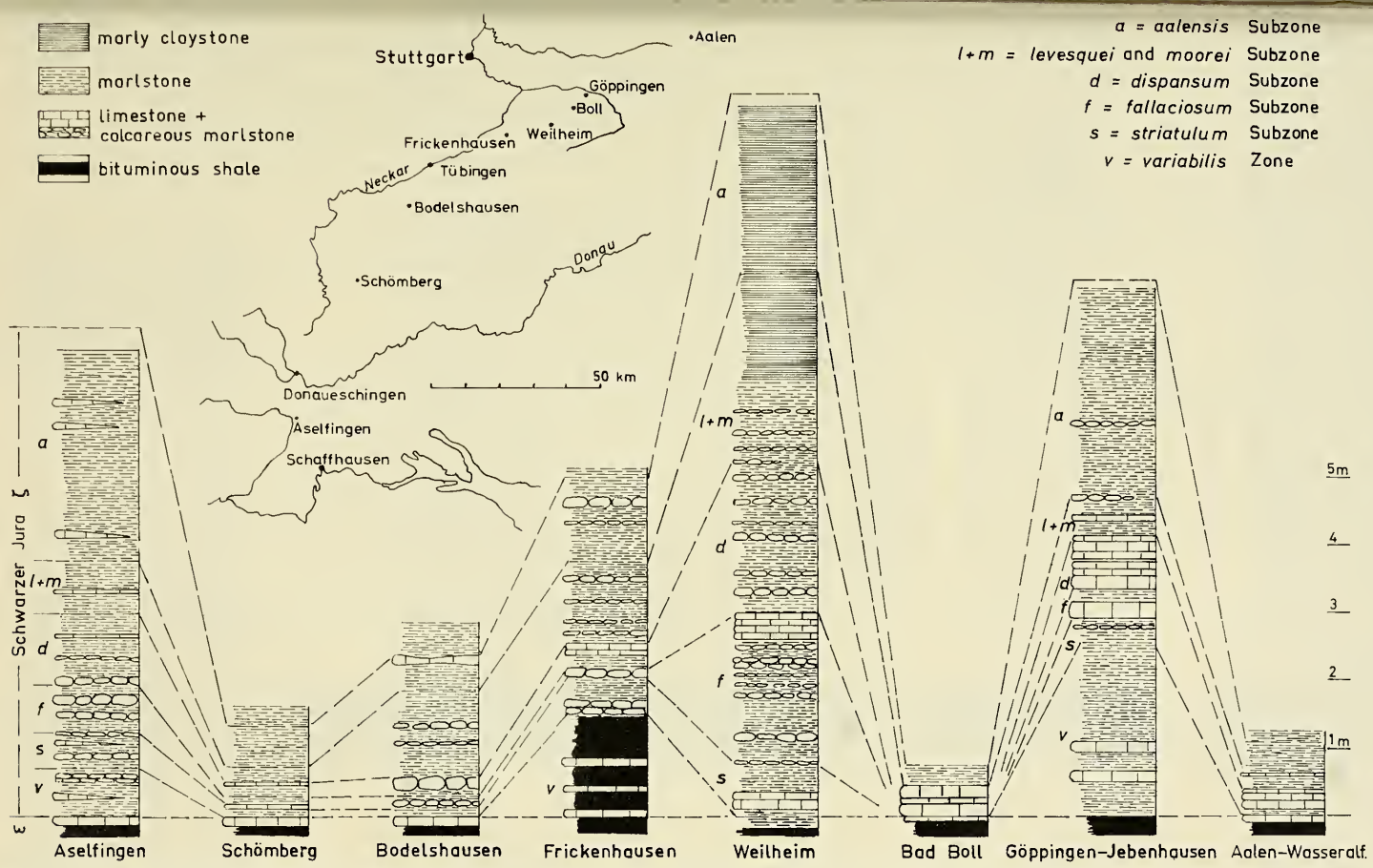

Fig. 9. Lithology and zonal subdivision of the „Schwarzer Jura ζ" along the Swabian Alb (except section Göppingen-Jebenhausen according to BROCKERT 1959; zonal subdivision according to FISCHER 1964, revised).

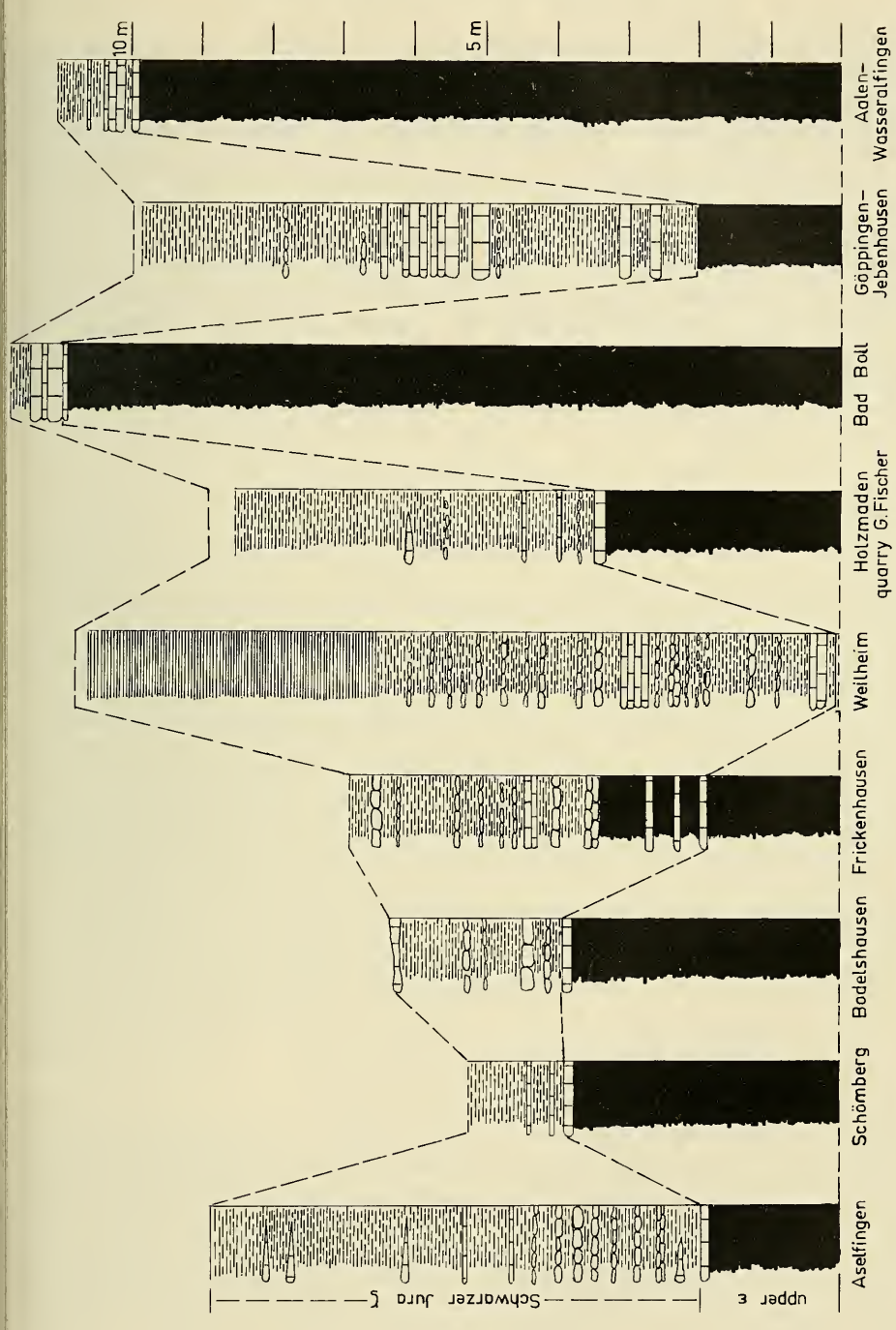

Fig. 10. Variations of thickness of the Upper „Schwarzer Jura ε" and „Schwarzer Jura ζ" in the foreland of the Swabian Alb (signatures: see fig. 9).

newly designated lecto- and neotypes are figured. In addition to the ammonites other groups, especially foraminifers and ostracods, have been used for stratigraphic purposes. The papers before 1959 dealing with microfossils have been summarized by STAESCHE (1960). Since then some papers dealing with ostracods from SW-Germany have been published: KLINGLER & TRIEBEL (1959): Upper Pliensbachian to Aalenian; K. HOFFMANN & MARTIN (1960): Lower Toarcian; W. FISCHER (1961 b, c; 1962; 1963): Upper Toarcian; KLINGLER (1962): total Lias; LORD & MOORLEY (1974 a-c): Upper Pliensbachian, and MALZ (1966; 1971; 1975): Upper Pliensbachian. Only two papers dealing with foraminifers from SW-Germany have been published since the summary of STAESCHE (1960): BACH, HAGENMEYER & NEUWEILER (1959): Sinemurian to Lower Pliensbachian and K. HOFFMANN & MARTIN (1960): Lower Toarcian. Revisions of the other groups like brachiopods, lamellibranchs, and gastropods dealing with the material from SW-Germany have not yet been made. Only the belemnoids have been revised by SCHWEGLER (1961—1971) and STURZ-KÖWING (1960).

3.1. Hettangian

The „Schwarzer Jura α_{1-2}" contains ammonites of the Hettangian from the base up to the top. The biostratigraphic subdivision of this member is very inadequately known. Only the fauna of the „Psilonotenbank" (base of the „Schwarzer Jura α_1" = „α1I" of BLOOS 1976) has been studied repeatedly and in detail (literature see ALTMANN 1965). Three horizons have been distinguished by WETZEL (1929) and ALTMANN (1965). The lowermost includes *Psiloceras psilonotum* (pl. 1, fig. 1) and *Psiloceras plicatulum.* Most of the authors regard *Ps. psilonotum* as a synonym of *Ps. planorbis.* According to LANGE (1941, p. 74), the crushed holotype of *Ps. planorbis* is more involute than *Ps. psilonotum.* In the horizon above *Caloceras johnstoni* has been found. The identification of this species has been questioned by LANGE (1941, p. 93), because a comparison of well preserved specimens with the crushed holotype is impossible. *C. johnstoni* has been recorded by BLIND (1963, p. 51) and ALTMANN (1965, p. 100) from SW-Germany. Typical species from this horizon are *Curviceras harpoptychum* (pl. 1, fig. 3) and *C. subangulare.* According to ALTMANN (1965), the third horizon contains *Psiloceras (Discamphiceras)* cf. *megastoma,* which is stated to be closely related to *Psiloceras (Discamphiceras) nuertingense* (pl. 1, fig. 2) and *Ps. longipontinum.* However, *Ps. longipontinum* is quite different as regards its involution, ribbing, and whorl section. Often one or two of these horizons are not developed. The inverse succession has been found by WETZEL (1929) in one exposure, which is due to reworking, according to ALTMANN (1965).

From the beds above the „Psilonotenbank" index fossils of the zones of NW-Germany, which were introduced by LANGE (1923), are also known. But the identification of some is dubious, and of others the stratigraphic level is unknown. According to ALTMANN (1965, p. 101), a typical horizon is the „hagenowi-Bank" („Schwarzer Jura α1IVa" of BLOOS 1976) with *Psilophyllites hagenowi* (pl. 1, fig. 5). Above occurs a level with *Alsatites laqueus* (pl. 1, fig. 4), which, according to SCHLOZ (1972, p. 112—113), extends in the surroundings of Stuttgart from 1,2 m below the „Oolithenbank" up to this bed. *Saxoceras schroederi,* the index fossil of LANGE's *schroederi* Zone, has been illustrated by ALTMANN (1965, pl. 1, fig. 8), but its exact horizon is unknown.

In the „Oolithenbank" (base of the „Schwarzer Jura α_2") *Schlotheimia angulata* occurs for the first time beside reworked specimens of *Alsatites.* A specimen of *Schlotheimia* sp. is recorded from the claystones below the „Oolithenbank" by ETZOLD, HAHN & KOERNER (1975, p. 125). I have reidentified this specimen as a

species of *Saxoceras*. The *Schlotheimia* beds are still undivided and *Schlotheimia angulata* is recorded from many sections without description and illustration. All these determinations are approximate. No revision of the Schlotheimiidae from SW-Germany has been published since QUENSTEDT (1882—1885) and POMPECKJ (1893). It is now in preparation by G. BLOOS.

Zonal subdivision of the Hettangian

The Hettangian was first subdivided by OPPEL (1856) into the *planorbis* and *angulata* Zones. Later OPPEL (1862, p. 131) proposed the *longipontinum* Zone, which lies above the *planorbis* and below the *angulata* Zone. According to DEFFNER & FRAAS (1859, p. 16), *Psiloceras longipontinum* was found together with *Alsatites laqueus*. The determination of *A. laqueus* was later confirmed, since one of these specimens has been illustrated and described by QUENSTEDT (1882, p. 14). OPPEL's *longipontinum* Zone is therefore a senior synonym of the *laqueus* Subzone, respectively Zone. It is not an equivalent of the *portlocki* Subzone of the NW European Province, as supposed by DEAN, DONOVAN & HOWARTH (1961, p. 445). *Psiloceras longipontinum* has not been found by the subsequent collectors, and this synonym of the *laqueus* Zone was not used in later times.

The zonal system of the lower Hettangian was subdivided in detail by LANGE (1923; 1925; 1941), who studied more than 2000 specimens collected bed by bed in NW-Germany. LANGE (1925; 1941) also commented on the situation in SW-Germany. Subsequently K. HOFFMANN (*in:* FRENTZEN & HOFFMANN 1937, p. 116), JÜNGST (1938), and HÖLDER (1964, p. 17) accepted the *hagenowi* and *laqueus* Zones of NW-Germany also for SW-Germany. They regard the subzones of the NW-European Province as zones. The *planorbis* Zone in the lowermost part of the „Psilonotenbank" is characterized by *Psiloceras psilonotum*. The *johnstoni* Zone is represented in the middle part of the „Psilonotenbank". These zones correspond to the *planorbis* and *johnstoni* Subzones, respectively, of DEAN, DONOVAN & HOWARTH (1961). Furthermore, a zone with *Psiloceras (Discamphiceras)* cf. *megastoma*, which was found in the uppermost part of the „Psilonotenbank", was proposed by ALTMANN (1965, p. 101). Since „*Waehneroceras*" *portlocki* is not recorded from SW-Germany, the correlation of the *portlocki* Subzone with the *hagenowi* Zone is uncertain.

The *angulata* Zone is well developed in SW-Germany but has not been subdivided so far.

3.2. Sinemurian

The Sinemurian begins at the base of the „Arietenkalk". In the area between Balingen and the Wutach river WALLISER (1956) divided the „Arietenkalk" („Schwarzer Jura α_3") into 7 horizons, each of which bears a characteristic fauna (fig. 3). He proposed 7 subzones and drew the boundaries in the marls intercalating the limestone beds. At the base of the „Schwarzer Jura α_3" *Metophioceras longidomus* and *Vermiceras spiratissimum* appear. They are followed in the horizon II by *Vermiceras scylla* and *Coroniceras rotiforme*. It is remarkable that in SW-Germany the index fossil *Coroniceras rotiforme* extends from horizon II into the next higher horizon with *Arietites bucklandi*. Furthermore, *Paracoroniceras gmuendense* (= *P. charlesi* DONOVAN) extends from horizon IV to V; in the latter *Agassiceras scipionianum* occurs for the first time. For these facts two explanations are possible: in SW-Germany either these species extend into the next higher subzone, or the boundaries between these subzones are situated inside the limestone beds, and the fossils are

somewhat condensed therein. *Euagassiceras sauzeanum* occurs together with *Paracoroniceras gmuendense* in the horizon IV and extends up to the top of the „Arietenkalk". According to WALLISER (1956a, p. 202), the species *Euagassiceras spinaries* (QUENSTEDT), which is present in France and England in the *scipionianum* Subzone, is synonymous with *E. sauzeanum.* Taking this into account, the range of *E. sauzeanum* may be somewhat shorter. *Agassiceras scipionianum* is recorded by WALLISER (1956a) from the horizon V. This species is very rare in SW-Germany and difficult to determine. Typical for this horizon is *Agassiceras nodulatum* (pl. 3, fig. 2). *Microderoceras birchi* (pl. 3, fig. 5) and *Promicroceras capricornoides* (pl. 3, fig. 3) extend from the horizon V to VI. From horizon VII *Asteroceras stellare* is recorded. *Asteroceras obtusum* also occurs in the „Arietenkalk" of SW-Germany (pl. 3, fig. 6), but its exact horizon is not mentioned by WALLISER (1956a). *Asteroceras stellare* and *A. obtusum* extend into the „Turneriton" (= Lower „Schwarzer Jura β"). HOFFMANN (1964, p. 143) records *Promicroceras planicosta* together with them. HOFFMANN regards this species as an index fossil; in NW-Germany he found *P. planicosta* above *P. capricornoides* and distinguished a *planicosta* and a *capricornoides* Subzone. SCHLATTER (1976, p. 12), however, describes in the Wutach area the inverse succession: *Promicroceras capricornoides* above *Promicroceras planicosta.* According to DEAN, DONOVAN & HOWARTH (1961, p. 454) and SCHLATTER (1976, p. 12), the species of *Promicroceras* seem to be of less stratigraphic value than the Asteroceratinae. Therefore the subdivision of the upper part of the „Arietenkalk" proposed by WALLISER (1956a) has been accepted here.

The „Schwarzer Jura β" comprises the higher part of the Sinemurian. The lower beds of the „Schwarzer Jura β", from the base to the „Betakalkbank" inclusively, have not been investigated in detail, and no revision of the ammonite fauna has been made. The claystones up to the „Betakalkbank" are very poor in fossils, and only the „Betakalkbank" has provided rich ammonite faunas. From this bed *Asteroceras obtusum, A. stellare* and *„Asteroceras"* cf. *brooki* have been recorded by K. HOFFMANN (1964, p. 142). In the collection of the Stuttgart Museum I reidentified the following species from the „Betakalkbank", which come from Balingen, Erzingen, and Endingen near Balingen:

Asteroceras suevicum (QUENSTEDT)
Asteroceras cf. *confusum* SPATH
Caenisites cf. *subturneri* (SPATH)
Aegasteroceras sagittarium (BLAKE)
Aegasteroceras simile SPATH
Eparietites undaries (QUENSTEDT)

The lectotype of *Angulaticeras densilobatum* (POMPECKJ 1893, pl. 7, fig. 1; designated by SCHLEGELMILCH 1976, p. 79), which is originally recorded from the *raricostatum* Zone, probably also comes from the „Betakalkbank" judging by its preservation. Furthermore, *Oxynoticeras oxynotum* from the „Betakalkbank" has been described by M. SCHMIDT (1925, p. 301). This species was later determined as *O.* cf. *simpsoni* by HOFFMANN (1944, p. 320). The only remaining specimen described by M. SCHMIDT (1925, p. 301) is that with the inner whorls visible. It has now been identified as *Oxynoticeras praecursor* (pl. 3, fig. 1). According to DEAN, DONOVAN & HOWARTH (1961, p. 457), *O. praecursor* „appears not very different from *O. simpsoni*". Whorl section and ribbing, however, are different (see SÖLL 1956). Very closely related to *O. praecursor* is the specimen of *O. limatum* (SIMPSON), which has been described by K. HOFFMANN (1944, p. 328) from the *gagateum* Subzone of NW-Germany. *Oxynoticeras* aff. *doris,* which is closely related to *Gleviceras paniceum* (QUENSTEDT), is also found in the „Betakalkbank" and has been described by M. SCHMIDT (1925, p.

SW-Germany				NW-European Province	
Quenstedt 1843, 1858	Hettangian Holder 1964; Lower Sinemurian Wallisер 1956; Upper Sinemurian Spath 1956; R. Richardson 1964, Zeiss 1968; Lower Pliensbachian, Schlatter 1977; Upper Pliensbachian, Frentzen 1934, revised by Howarth 1958, Johnson 1960; Lower Toarcian: Pannoke 1965, revised by Weitschat 1973, Upper Toarcian Brockert 1959, revised by Fischer 1964			Dean, Donovan & Howarth 1961, completed by Howarth 1973 (Lower Toarcian) and Getty 1973 (Upper Sinemurian).	
Lithostratigraphic units	Zone	Subzone	Substage	Zone	Subzone
Schwarzer Jura ζ	*Pleydellia aalensis*		Upper Toarcian	*Dumortieria levesquei*	*Pleydellia aalensis*
	Dumortieria ssp.				*Dumortieria moorei*
					Dumortieria levesquei
	Phlyseogrammoceras dispansum				*Phlyseogrammoceras dispansum*
	Pseudogrammoceras fallaciosum			*Grammoceras thouarsense*	*Pseudogrammoceras struckmanni*
	Grammoceras thouarsense				*Grammoceras striatulum*
	Haugia variabilis			*Haugia variabilis*	
Schwarzer Jura ε	hiatus	*Hildoceras bifrons*	Lower Toarcian	*Hildoceras bifrons*	*Zugodactylites braunianus*
					Peronoceras fibulatum
					Dactylioceras commune
	Harpoceras falciferum			*Harpoceras falciferum*	*Harpoceras falciferum*
					Harpoceras exaratum
	Dactylioceras tenuicostatum or *Dactylioceras semicelatum*			*Dactylioceras tenuicostatum*	*Dactylioceras semicelatum*
					Dactylioceras tenuicostatum
					Dactylioceras clevelandicum
Schwarzer Jura δ					*Protogrammoceras paltum*
Schwarzer Jura γ	*Pleuroceras spinatum*	*Pleuroceras hawskerense*	Upper Pliensbachian Domerian	*Pleuroceras spinatum*	*Pleuroceras hawskerense*
		Pleuroceras apyrenum			*Pleuroceras apyrenum*
	Amaltheus margaritatus	*Amaltheus gibbosus*			*Amaltheus gibbosus*
		Amaltheus subnodosus		*Amaltheus margaritatus*	*Amaltheus subnodosus*
		Amaltheus stokesi			*Amaltheus stokesi*
	Prodactylioceras davoei	*Oistoceras figulinum*	Carixian	*Prodactylioceras davoei*	*Oistoceras figulinum*
		Androgynoceras maculatum +			*Androgynoceras capricornus*
		Androgynoceras capricornus			*Androgynoceras maculatum*
	Tragophylloceras ibex	*Beaniceras luridum*	Lower Pliensbachian	*Tragophylloceras ibex*	*Beaniceras luridum*
		Acanthopleuroceras valdani			*Acanthopleuroceras valdani*
	Uptonia jamesoni	*Tropidoceras masicanum*			*Tropidoceras masicanum*
		Uptonia jamesoni		*Uptonia jamesoni*	*Uptonia jamesoni*
		Platypleuroceras brevispina			*Platypleuroceras brevispina*
		Polymorphites polymorphus			*Polymorphites polymorphus*
		Phricodoceras taylori			*Phricodoceras taylori*
Schwarzer Jura ε	hiatus	hiatus *Palteloceras aplanatum*	Upper Sinemurian Lotharingian	*Echioceras raricostatum*	*Palteloceras aplanatum*
		Lepiechioceras macdonelli			*Lepiechioceras macdonelli*
	Echioceras raricostatum + *Crucicloboceras denisoni* +				*Echioceras raricostatoides*
					Crucicloboceras denisonodulum
	Oxynoticeras oxynotum			*Oxynoticeras oxynotum*	*Oxynoticeras oxynotum*
	Oxynoticeras praecursor				*Oxynoticeras simpsoni*
	Angulaticeras latunatum			*Asteroceras obtusum*	*Eparietites denotatus*
		Asteroceras stellare			*Asteroceras stellare*
Schwarzer Jura α$_2$	— — — — —	not mentioned			*Asteroceras obtusum*
		Microderoceras birchi – *Euagassiceras sauzeanum*	Lower Sinemurian	*Caenisites turneri*	*Microderoceras birchi*
					Caenisites brooki
				Arnioceras semicostatum	*Euagassiceras sauzeanum*
		Agassiceras scipionianum *Paracoroniceras gmuendense* = *Paracoroniceras charlesi*			*Agassiceras scipionianum*
		Paracoroniceras gmuendense + *Arietites proparis*			*Coroniceras reynesi* (= *Coroniceras lyra*)
		Arietites bucklandi + *Coroniceras rotiforme*		*Arietites bucklandi*	*Arietites bucklandi*
		Coroniceras rotiforme + *Vermiceras scylla*			*Coroniceras rotiforme*
		Coroniceras (*Metophioceras*) *longidomus* + *Vermiceras spiratissimum*			*Coroniceras* (*Metophioceras*) *conybeari*
Schwarzer Jura α$_{1b}$	*Schlotheimia angulata*		Upper Hett.	*Schlotheimia angulata*	*Schlotheimia complanata*
					Schlotheimia extranodosa
Schwarzer Jura α$_{1a}$	*Alsatites laqueus*		Lower Hettangian	*Alsatites laqueus*	*Alsatites laqueus*
	Psilophyllites hagenowi				*Schlotheimia* / *Waehneroceras portlocki*
	Psiloceras (*Caloceras*) *johnstoni*			*Psiloceras planorbis*	*Psiloceras* (*Caloceras*) *johnstoni*
	Psiloceras planorbis				*Psiloceras planorbis*

Tab. 1 Zonal subdivision of Southwestern Germany and of the NW-European Province

307). These two species of *Oxynoticeras* probably came from a higher horizon, because, according to ETZOLD, HAHN & KOERNER (1975, p. 126), above the „Betakalkbank" one or two limestone beds are present locally along the Middle Swabian Alb.

According to SÖLL (1956, p. 383), the „Betakalkbank" is a horizon with features of condensation. It is, however, uncertain, wether or not all described material originates from this bed.

According to SÖLL (1956, p. 375—377), along the Middle Swabian Alb *Angulaticeras rumpens* and *Eparietites impendens* occur above the „Betakalkbank". In the marlstone bed II of SÖLL (1956) these species are replaced by *Oxynoticeras praecursor*, which extends up to the base of marlstone bed III. In this bed *Bifericeras, Leptonotoceras, Cheltonia accipitris* and *Oxynoticeras oxynotum* appear. They extend up to the base of marlstone bed IV, where *Echioceras raricostatum, Hemimicroceras subplanicosta* and *Crucilobiceras densinodus* appear. These species extend along the Middle Swabian Alb to the top of the „Schwarzer Jura β". At the base of the „Schwarzer Jura γ" *Apoderoceras nodogigas* (= *A. armatus* of OPPEL) appears by which Oppel has fixed the base of the Pliensbachian. From the „Obliqua-Bank" of the upper „Schwarzer Jura β" in the Wutach area HOFFMANN (1964, p. 139) records *Echioceras* ex gr. *raricostatoides* together with *Euechioceras* aff. *nobile* (= *Paltechioceras* aff. *aplanatum* BUCKMAN), *Plesechioceras comptum* (= *Paltechioceras*), and *Leptechioceras* aff. *hugi*. According to GETTY (1973), *Paltechioceras* and *Leptechioceras* are restricted to the next higher subzones, the *macdonelli* and *aplanatum* Subzones. The index fossils of these subzones, *Leptechioceras macdonelli* and *Paltechioceras aplantum* from Southern Franconia have also been described by ZEISS (1965, p. 37).

Zonal subdivision of the Sinemurian

Different zonal schemes of the Sinemurian have been proposed for three regions: NW-Europe by DEAN, DONOVAN & HOWARTH (1961), Lotharingian of Germany by K. HOFFMANN (1964), and SW-Germany: Lower Sinemurian by WALLISER (1956) and Upper Sinemurian by SÖLL (1956).

Lower Sinemurian

OPPEL (1856, p. 134) introduced the *bucklandi* Zone, and for its upper part he proposed the *geometricum* Zone, which was still used by GEYER & GWINNER (1962). It was already proposed by JUDD (1875) that this should be the *semicostatum* Zone, because *A. geometricum* OPPEL is a homonym of *A. geometricum* PHILLIPS, and the *bucklandi* Zone was restricted to the lower part (teste DEAN, DONOVAN & HOWARTH 1961, p. 448, 451). *Arnioceras geometricum* OPPEL has been renamed *Arnioceras oppeli* by GUERIN-FRANIATTE (1966, p. 267).Furthermore, the index fossil *Arietites bucklandi* has been replaced by *Epammonites latisulcatus* (QUENSTEDT) by PALMER (1972, p. 52). This species has been described for the first time by QUENSTEDT (1882, p. 86) from Stuttgart-Vaihingen. Its stratigraphic occurence is not mentioned by WALLISER (1956). Only *Epammonites* cf. *latisulcatus* has been recently listed from the *bucklandi-rotiforme* Subzone (horizon III of WALLISER 1956) by GEBHARD & SCHLATTER (1977, fig. 1).

WALLISER (1956a) recognized no zones in SW-Germany and introduced 7 subzones, which can be approximately correlated with the subzones of the NW-European Province of DEAN, DONOVAN & HOWARTH (1961). The lowermost subzone of the

Sinemurian, which is identical with the horizon I of WALLISER (1956a), was named *longidomus-spiratissimum* Subzone by him. It corresponds to the *conybeari* Subzone. Horizon II of WALLISER, his *rotiforme-scylla* Subzone, corresponds to the *rotiforme* Subzone, and horizon III, the *bucklandi-rotiforme* Subzone, approximately to the *bucklandi* Subzone. Horizon IV, the *gmuendense-pinguis* Subzone, corresponds to the *reynesi* Subzone. *Paracoroniceras gmuendense* (= *P. charlesi)* cannot be exactly defined, because no type material is known and therefore this species cannot be used as an index fossil. DEAN, DONOVAN & HOWARTH (1961, p. 451) replaced it by *Coroniceras reynesi,* which, according to GUERIN-FRANIATTE (1966, p. 134), is a synonym of *C. lyra* HYATT. *C. lyra* was described from Württemberg by HYATT (1889, p. 179) for the first time; its occurence and its horizon are not mentioned by WALLISER (1956). The *scipionianum-gmuendense* Subzone of WALLISER (1956) which is present in horizon V, corresponds to the *scipionianum* Subzone of the NW-European Province. The *birchi-sauzeanum* Subzone of WALLISER, identified in horizon VI, corresponds approximately to the *sauzeanum* and *birchi* Subzones. The *brooki* Subzone of the NW-European Province, which lies between them, is not recorded from SW-Germany, because, according to K. HOFFMANN (1964, p. 137) and SCHLATTER (1976, p. 12), *Caenisites brooki* has not been identified here. According to OPPEL (1856, p. 171, 202), K. HOFFMANN (1938, p. 21; 1964, p. 137), and SCHLATTER (1976, p. 12), *Caenisites turneri* has not been found in SW-Germany, too.

Upper Sinemurian

The boundary between the Lower and Upper Sinemurian is not exactly fixed in SW-Germany, because the *turneri* Subzone has not been identified. According to HOFFMANN (1964), *Asteroceras obtusum* has the same range as *Asteroceras stellare* in SW-Germany. The *stellare* Subzone has been recorded from the uppermost Arietenkalk (horizon VII, according to WALLISER 1956a) and from „Turneriton" and „Betakalkbank" (Lower „Schwarzer Jura β", according to HOFFMANN 1964). The *lacunatum* Zone of SÖLL (1956) corresponds to the *denotatus* Subzone of DEAN, DONOVAN & HOWARTH (1961). The specimens of *Angulaticeras densilobatum* and *Eparietites undaries,* found in the „Betakalkbank", also belong to the *lacunatum* Zone. The *praecursor* Zone of SÖLL (1956) corresponds to the *gagateum* Subzone of NW-Germany, because *Oxynoticeras praecursor* is closely related to *O. limatum,* which has been described from the *gagateum* Subzone by HOFFMANN (1944). On the other hand, the *gagateum* Subzone is a synonym of the *simpsoni* Subzone of DEAN, DONOVAN & HOWARTH (1961). The *oxynotum* Zone of SÖLL (1956) is a synonym of the *oxynotum* Subzone of the NW-European Province. The *raricostatum* and *densinodus* Zones cannot be separated from each other in SW-Germany, because *Echioceras raricostatum* and *Crucilobiceras densinodus* occur there together in the same bed. The *macdonelli* and *aplanatum* Subzones are not represented along the Middle Swabian Alb. They have been identified only in the „Obliqua-Bank" of the Wutach area by the findings of HOFFMANN (1964, p. 139) and in Southern Franconia in a condensed bed by ZEISS (1965, p. 47).

3.3. Pliensbachian

The zonal designations of the Pliensbachian used all over Europe are those originally proposed for SW-Germany by OPPEL (1856). His study was so excellent that no changes have been necessary.

The more detailed subdivision of the Lower Pliensbachian into subzones proposed by DEAN, DONOVAN & HOWARTH (1961) has now also been applied to the type area by SCHLATTER (1977). Only one change has recently been made by SCHLATTER (1977, p. 8): The *masseanum* Subzone has been included into the *jamesoni* Zone, because *Uptonia* persists into the beds with *Tropidoceras masseanum* (see tab. 1). Along the Eastern and Southwestern Swabian Alb the „Schwarzer Jura γ" shows small thickness and is poor in ammonites in its lower part. From these areas no modern investigations are at hand.

All subzones of the Upper Pliensbachian have been identified in SW-Germany by FRENTZEN (1934), JORDAN (1960; 1974), and now also at the type locality of the Pliensbachian by URLICHS (1977). Along the Southwestern and Middle Swabian Alb the clays of the „Amaltheenton" (Lower „Schwarzer Jura δ") include the *margaritatus* Zone, along the Eastern Swabian Alb the *margaritatus* and the lower *spinatum* Zone, in Southern Franconia only the *spinatum* Zone, and in Northern Franconia both zones (fig. 7).

3.4. Toarcian

The Toarcian has been subdivided into two zones by OPPEL (1856): the zone with *Posidonia bronni* and the zone with *„Ammonites" jurensis.* Later proposals and subdivisions have already been reviewed by DEAN, DONOVAN & HOWARTH (1961). A more detailed zonal subdivision has been proposed by MOUTERDE et al. (1971) and GABILLY et al. (1974).

Lower Toarcian

In SW-Germany the biostratigraphy of the Lower Toarcian is very inadequately known. The notoriously poor preservation of the ammonites is the reason for this. Details of the boundary Pliensbachian/Toarcian have been reviewed by URLICHS (1977).

Only in the Holzmaden area the Lower Toarcian has been subdivided in detail by PANNKOKE (1965). But in the shales all ammonites are flattened and the shells have been completely dissolved without replacement, leaving a brownish periostracal film. Therefore, the identifications are dubious and I add to the determinations of PANNKOKE (1965) „cf." Only the determinations of *Harpoceras elegans* and *H. falcifer* (pl. 5, fig. 1+2) are certain, because the main characteristics, ribs and involution, are also visible in flattened state.

In the „Aschraue Mergel" of the Lower „Schwarzer Jura ε" *Dactylioceras* cf. *tenuicostatum* has been found by PANNKOKE (1965, p. 17). *Dactylioceras* cf. *annulatum,* which has been included in *D. tenuicostatum* by HOWARTH (1973, p. 258), is recorded from the „Tafelfleins" („Schwarzer Jura ε_{I2}") up to the lower part of the „Unterer Schiefer" („Schwarzer Jura ε_{II4}"). From this bed *Dactylioceras* cf. *semicelatum* is also recorded by PANNKOKE (1965, p. 18). In the upper part of the „Unterer Schiefer" *Harpoceras* cf. *pseudoelegans,* which, according to WEITSCHAT (1973, p. 58), is a synonym of *H. (Eleganticeras) elegantulum,* has been found by PANNKOKE (1965, p. 33). *Harpoceras capellinum,* which, according to WEITSCHAT (1973, p. 35), is a synonym of *H. elegans,* has been identified by PANNKOKE (1965, p. 35) from the beds „Schwarzer Jura $\varepsilon_{II8,9,10}$" („Oberer Stein, Wilder Stein, Falchen"). *Harpoceras mulgravium,* which, according to WEITSCHAT (1973, p. 60), is a synonym of *H. falcifer,* has been found by PANNKOKE (1965, p. 27) in the „Schwarzer Jura $\varepsilon_{II11-12}$", and it persists into

the lower „Wilder Schiefer" („Schwarzer Jura ε_{III}"). Above this *Hildoceras* cf. *bifrons* occurs up to the top of the „Schwarzer Jura ε". *Peronoceras* cf. *fibulatum* is absent in the Holzmaden area and it has been described by PANNKOKE (1965, p. 26) from the uppermost „Wilder Schiefer" of Bad Boll. At the top of these beds, a marlstone bed with well-preserved pyritized specimens of *Hildoceras bifrons* (pl. 5, fig. 4) and *Catacoleoceras crassum* has developed at some localities, e.g. Heselwangen near Balingen, Reutlingen, and Metzingen.

Zonal subdivision of the Lower Toarcian

These observations justify the following zonal subdivision. The *tenuicostatum* Zone *(semicelatum* Zone of PANNKOKE 1965) has been identified in the Lower „Schwarzer Jura " up to the lower part of the „Unterer Schiefer". But a further subdivision is impossible because of the poor preservation of the ammonites. The *falcifer* Zone is represented in the Middle and the base of the Upper „Schwarzer Jura ". The limits of the zones lie within the „Unterer Schiefer" and the „Wilder Schiefer". Therefore, as PANNKOKE (1965, p. 59) has already stated in contrary to HAUFF (1953, p. 14), the boundaries of the zones are not congruent with the limits of the lithological subdivision. The famous vertebrate skeletons come mainly from the lower and middle „Schwarzer Jura " (= *tenuicostatum* and *falcifer* Zones), and occur most frequently in the „Fleins" and in the „Unterer Schiefer" (= uppermost *tenuicostatum* and base of the *falcifer* Zone).

A more detailed subdivision of the *falcifer* Zone in NW-Germany has been proposed by WEITSCHAT (1973). The lowermost subzone is characterized by *Harpoceras (Eleganticeras) elegantulum*, which is probably to be found in the „Unterer Schiefer" at Holzmaden. The following subzone has not been identified, because no *Harpoceras exaratum* has been described from Holzmaden. The *elegans* Subzone is recorded from the beds „Schwarzer Jura $\varepsilon_{II\,8,9,10}$" by the findings of *Harpoceras elegans* and the *falcifer* Subzone in the uppermost part of the „Schwarzer Jura ε_{II} " and at the base of „ ε_{III}".

The *bifrons* Zone from Holzmaden has been described without subdivision. The *fibulatum* Subzone only has been found at Bad Boll by PANNKOKE (1965). At this locality, a condensation bed, the „Boller Breccie", follows above this zone. It includes the *thouarsense* and *levesquei* Zones of the Upper Toarcian. Therefore a hiatus comprising the *crassum* Subzone and the *variabilis* Zone has been identified at Bad Boll. In other outcrops at Holzmaden the *bifrons* Zone is totally absent, because, according to HAUFF (1921, p. 12), the upper „Schwarzer Jura ε" is not developed locally. The *crassum* Subzone is found only at Reutlingen, Metzingen, and Heselwangen near Balingen at the top of the „Schwarzer Jura ε".

Upper Toarcian

QUENSTEDT (1858, p. 278, 1885, p. 376) has divided OPPEL's *jurense* Zone into *radians*, *jurensis*, and *aalensis* Beds. They correspond to the *striatulum*, *fallaciosum*, *dispansum-moorei*, and *aalensis* Subzones of DEAN, DONOVAN & HOWARTH (1961). Later ENGEL (1894; 1908, p. 272) found the *variabilis* Zone for the first time. Along the Swabian Alb the biostratigraphy of the Upper Toarcian is now founded on the thesis of BROCKERT (1959), which has unfortunately not been published. From the Upper Rhine Graben some sections and their ammonite fauna have been described by

KLÖCKER (1966; 1967) and OHMERT (1976). In addition detailed investigations have been made by KRUMBECK (1943; 1947) in the northeastern vicinity of SW-Germany, in Franconia (Northern Bavaria).

Zonal subdivision of the Upper Toarcian

Along the Swabian Alb more or less complete zonal successions are found only in the Wutach area, in the surroundings of Göppingen, and between Nürtingen and Metzingen. But also in these areas horizons with condensation are found. Elsewere the *variabilis* Zone is absent, and in general the sequence is more condensed. Originally, BROCKERT (1959) divided the Upper Toarcian into *variabilis, toarcense, fallaciosum, dispansum* Zones, *Dumortieria* Superzone and *aalensis* Zone. FISCHER (1964) correlated this subdivision with the zonal subdivision of the NW-European Province of DEAN, DONOVAN & HOWARTH (1961), and he applied the latter to SW-Germany. The range of the species investigated by BROCKERT (1959) is listed on table 2, and the following comments are made on it: *Pseudopolyplectus bicarinatus,* which is found in France in the *variabilis* Zone and in the *bingmanni* Subzone recently proposed by MOUTERDE et al. (1971), has been found by BROCKERT (1959) in SW-Germany in the *variabilis* Zone and *striatulum* Subzone. Perhaps the upper beds with *P. bicarinatus* have been included in the *striatulum* Subzone (= *toarcense* Zone of BROCKERT 1959). This suggestion has been confirmed by observations in the section Göppingen-Jebenhausen. Above beds with *Haugiella vitiosa,* I found (fig. 11) a horizon with *Pseudopolyplectus bicarinatus, Pseudogrammoceras bingmanni,* and *P. muelleri.* This is a typical fauna of the *bingmanni* Subzone. *Pseudogrammoceras saemanni,* which occurs in France and NW-Germany in the *bingmanni* Subzone, occurs in the *fallaciosum* Zone, according to BROCKERT (1959). This is probably a misidentification of *P. subquadratum,* which I found in the *fallaciosum* Subzone at Göppingen. The *fallaciosum* Subzone has been named *struckmanni* Subzone by BUCKMAN & WILSON (1896) (teste DEAN, DONOVAN & HOWARTH 1961, p. 487). As ERNST (1924, p. 1—9) has already stated, *Pseudogrammoceras struckmanni* has been described for the first time by DENCKMANN (1887) from the *variabilis* Zone (= *illustris* Zone of DENCKMANN), and this occurrence has been confirmed by ERNST (1924). The confusion about the *struckmanni* Subzone has been caused by BUCKMAN (1890, p. 206), who made *P. struckmanni* synonymous with *P. fallaciosum.* These species have now been revised by GABILLY (1976). In France *P. struckmanni* also occurs below the *striatulum* in the *bingmanni* Subzone, which has been introduced by GABILLY (in: MOUTERDE et al. 1971). The *levesquei* and *moorei* Subzones have not been separated by BROCKERT, and he has named them *Dumortieria* Superzone. Recently they have also been found separated from each other at Göppingen (fig. 11). The lower one contains coarsely ribbed species of *Dumortieria* and the upper one includes the fine-ribbed species *D. radiosa* (pl. 6, fig. 2) and *D. pseudoradiosa.* The *aalensis* Subzone is well-developed all over the Swabian Alb and nowhere it is condensed with the other Subzones. At Göppingen the lower part is characterized by *Dumortieria costula, Pleydellia mactra, P. subcompta,* and the upper part by *Pleydellia aalensis* in abundance (fig. 11).

In the Rhine Graben at Ballrechten near Freiburg a section with thick Upper Toarcian has recently been described by OHMERT (1976). From a 22 m thick section, the *variabilis* Zone up to the *levesquei* Subzone has been found. The faunas listed from there are important, because the relations to France are so close that OHMERT took over the zonal subdivision proposed by GABILLY (in: MOUTERDE et al. 1971, and Gabilly et al. 1974). Near Freiburg the *aalensis* Subzone, which is at least 6,5 m thick, has been subdivided by KLÖCKER (1966; 1967) into a lower subzone with *Pleydellia aalensis* and *Dumortieria costula* and an upper without *D. costula.*

Pachylytoceras jurense (ZIETEN)				●	●	
sublineatum (OPPEL)						●
Alocolytoceras germaini (D'ORBIGNY)			●			
Pleurolytoceras hircinum (SCHLOTHEIM)		●				
Pseudolioceras compactile (SIMPSON)		●				
Osperlioceras pompeckji (ERNST)			●			
Polyplectus discoides (ZIETEN)					●	●
Pseudopolyplectus bicarinatus (ZIETEN)						●
Grammoceras doerntense (DENCKMANN)						●
thouarsense (D'ORBIGNY)					●	
striatulum (SOWERBY)					●	
Pseudogrammoceras fallaciosum (BAYLE)				●		
quadratum (HAUG)					●	
saemanni (OPPEL)				●		
Phlyseogrammoceras dispansum (LYCETT)			●			
Pleydellia aalensis (ZIETEN)	●					
costula (REINECKE)	●					
distans (BUCKMAN)	●	●				
mactra (DUMORTIER)	●					
subcompta (BRANCO)	●					
Huddlestonia serrodens (QUENSTEDT)						
Dumortieria levesquei (D'ORBIGNY)		●				
munieri (HAUG)		●				
nicklesi (BENECKE)		●				
pseudoradiosa (BRANCO)		●				
radiosa (SEEBACH)		●				
striatulocostata (QUENSTEDT)		●				
Phymatoceras erbaense (HAUER)						●
Esericeras eseri (OPPEL)					●	
Haugia illustris (DENCKMANN)						●
navis (DUMORTIER)						●
variabilis (D'ORBIGNY)						●
Hammatoceras insigne (ZIETEN)			●			
semilunatum (QUENSTEDT)			●			
speciosum (JANENSCH)			●			
Zone		*levesquei*		*thouarsense*		*variabilis*
Subzone	*aalensis*	*levesquei* and *moorei*	*dispansum*	*fallaciosum*	*striatulum*	

Tab. 2. Range of the ammonite fauna from the Upper Toarcian, described by BROCKERT 1959.

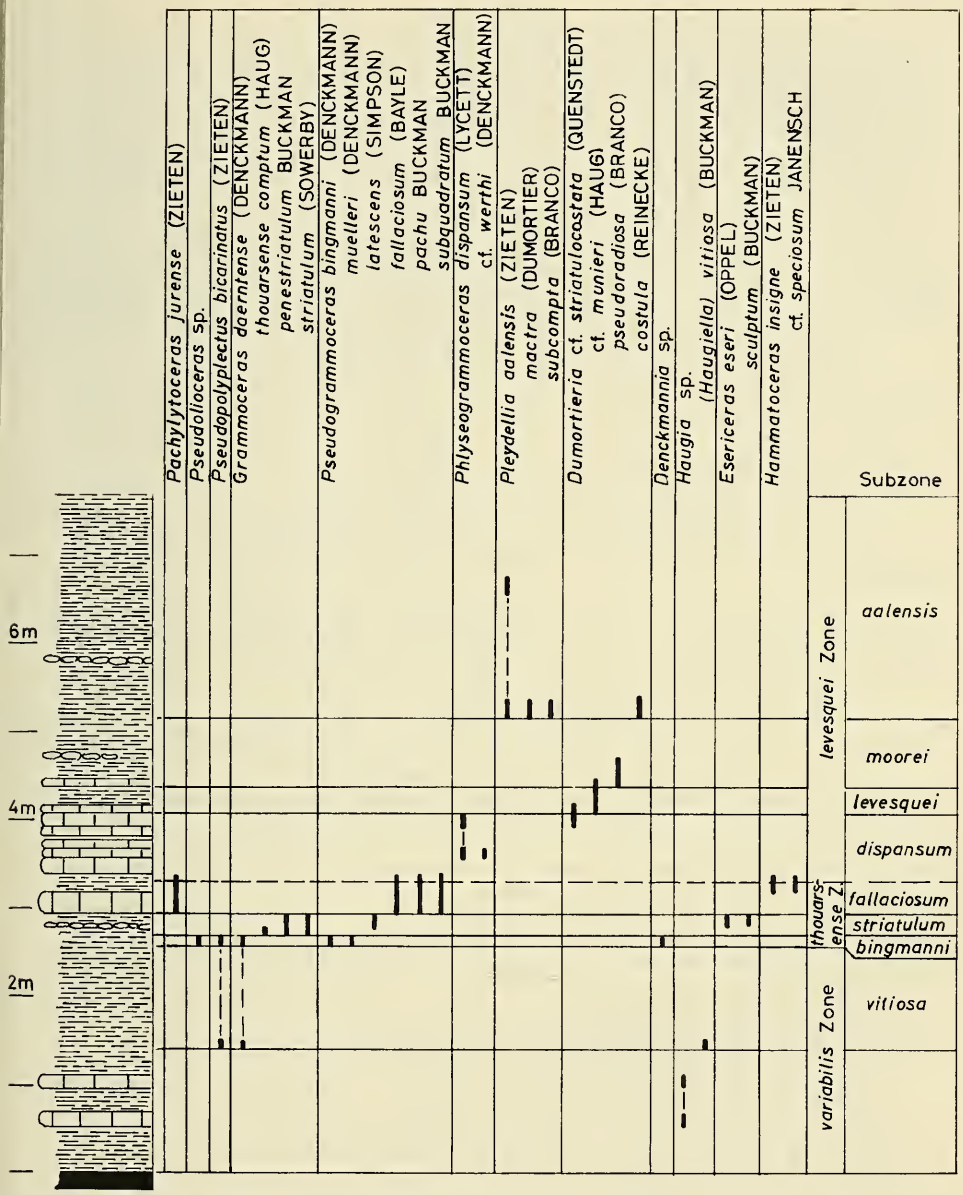

Fig. 11. Lithology, ammonites, and zonal subdivision of the Upper Toarcian at Göppingen-Jebenhausen (excavation of the new district hospital). Signatures: see fig. 9.

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Plate 1

Fig. 1. *Psiloceras psilonotum* (Quenstedt); Schwarzer Jura α_1; Nellingen near Stuttgart; inv.-no. 10007. — x 1.

Fig. 2. *Psiloceras (Discamphiceras) nuertingense* (Holland); holotype Holland 1900, pl. 9, fig. 1; Schwarzer Jura α_1; Nürtingen; inv.-no. 23202. — x 0,5.

Fig. 3. *Curviceras harpoptychum* (Holland); lectotype Holland 1900, pl. 8, fig. 1, designated by Schlegelmilch 1976, p. 35; 3a: lateral view, 3b: ventral view; Schwarzer Jura α_1; Nürtingen; inv.-no. 23201. — x 1.

Fig. 4. *Alsatites laqueus* (Quenstedt); 4a: ventral view, 4b: lateral view; Schwarzer Jura α_1; Stuttgart-Degerloch; inv.-no. 23204. — x 1.

Fig. 5. *Psilophyllites hagenowi* (Dunker); Schwarzer Jura α_1; Stuttgart-Vaihingen; inv.-no. 23203. — x 1.

Fig. 6. *Schlotheimia angulata* (Schlotheim); 6a: lateral view, 6b: ventral view; Schwarzer Jura α_2; Manolzweiler near Waiblingen; inv.-no. 23205. — x 1.

All specimens: Staatliches Museum für Naturkunde Stuttgart.
Foto: H. Lumpe.


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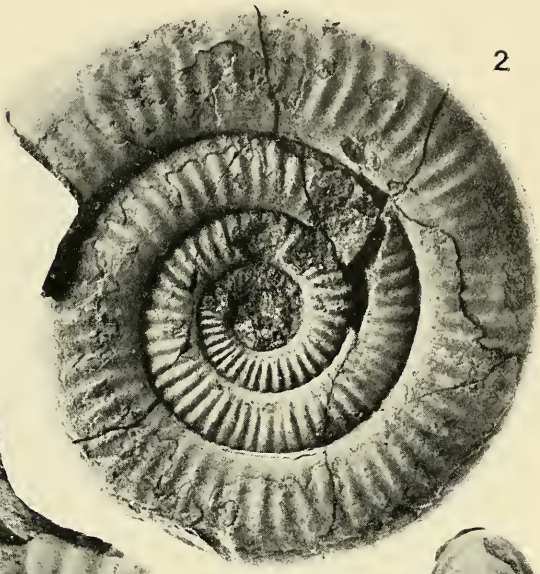
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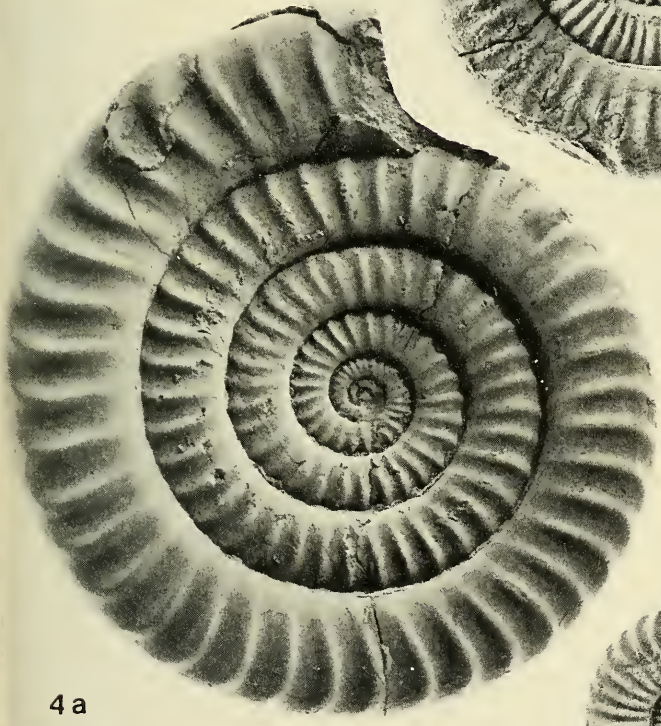
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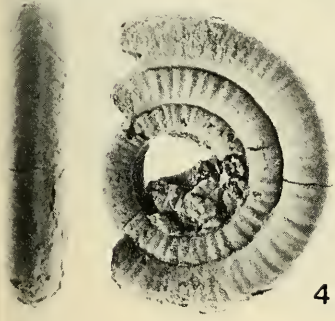
3b

4a


6a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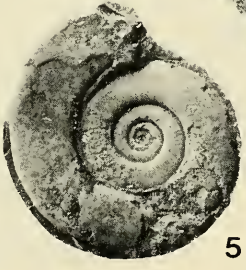
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6b

Plate 2

Fig. 1. *Vermiceras spiratissimum* (QUENSTEDT); 1a: lateral view, 1b: frontal view; Schwarzer Jura α_3; Nellingen near Stuttgart; inv.-no. 23016. — x 1.

Fig. 2. *Paracoroniceras charlesi* DONOVAN (= *Paracoroniceras gmuendense* OPPEL); 2a: lateral view, 2b: ventral view; Schwarzer Jura α_3; Trossingen; inv.-no. 23206. — x 0,5.

Fig. 3. *Arietites bucklandi* (SOWERBY); Schwarzer Jura α_3; Württemberg, locality unknown; inv.-no. 23009. — x 0,5.

All specimens: Staatliches Museum für Naturkunde Stuttgart.
Foto: H. Lumpe.

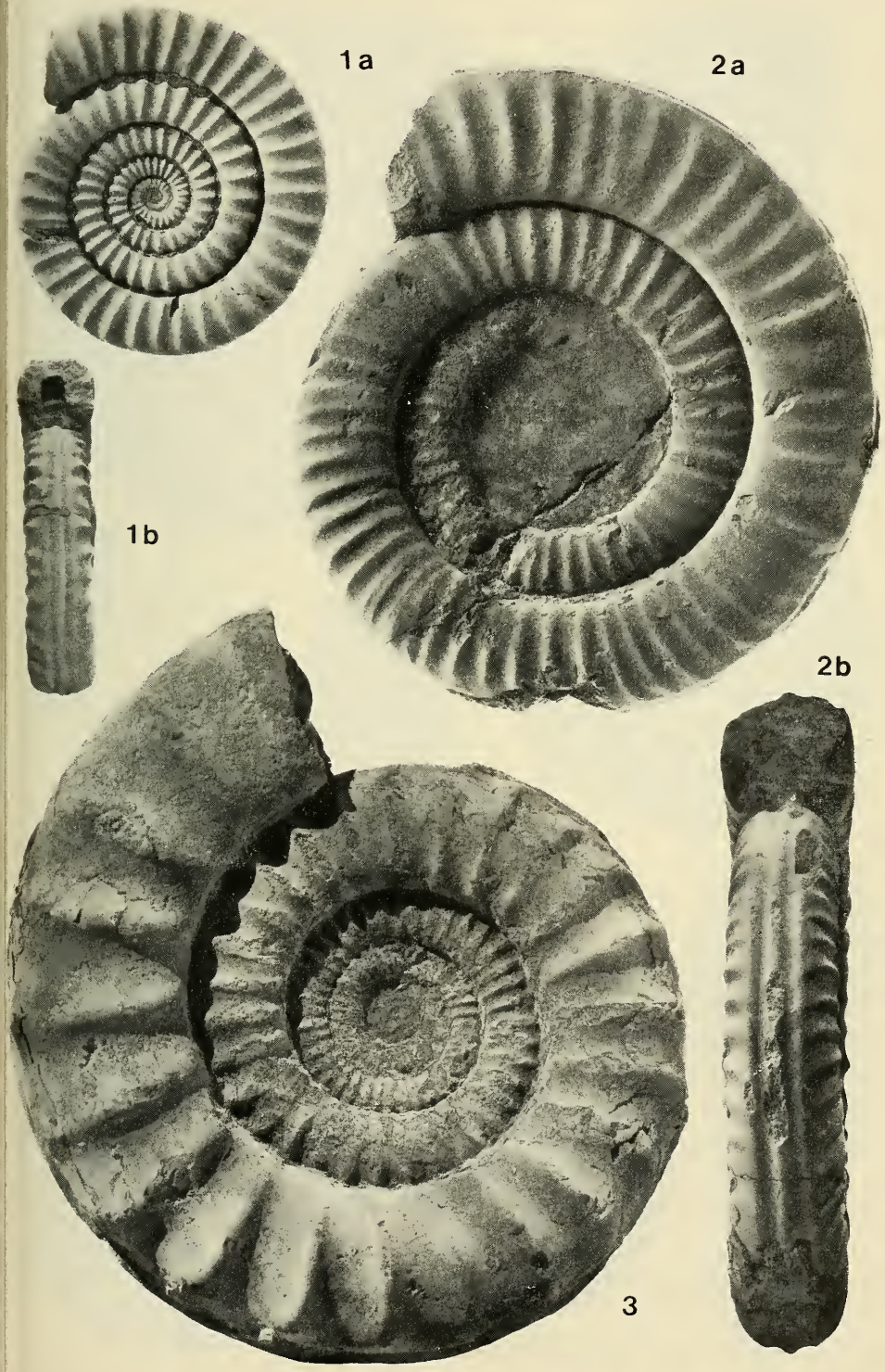


Plate 3

Fig. 1. *Coroniceras rotiforme* (Sowerby); Schwarzer Jura α_3; Stuttgart-Vaihingen; inv.-no. 20813. — x 0,5.

Fig. 2. *Agassiceras nodulatum* Buckman; Schwarzer Jura α_3; Göppingen; inv.-no. 23021. — x 0,5.

Fig. 3. *Promicroceras planicosta* (Sowerby); 3a: lateral view, 3b: frontal view; Schwarzer Jura β; Kirchheim; inv.-no. 16757. — x 1,0.

Fig. 4. *Euagassiceras sauzeanum* (D'Orbigny); 4a: lateral view, 4b: frontal view; Schwarzer Jura α_3; Wetzgau near Schwäbisch Gmünd; inv.-no. 20813. — x 1.

Fig. 5. *Microderoceras birchi* (Sowerby); Schwarzer Jura α_3; Weiler near Ebersbach/Fils; inv.-no. 23022. — x 0,5.

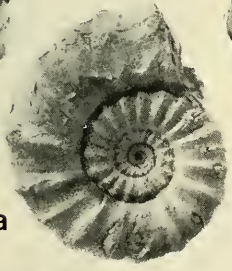
Fig. 6. *Asteroceras obtusum* (Sowerby); 6a: lateral view, 6b: frontal view; Schwarzer Jura α_3; Straßdorf near Schwäbisch Gmünd; inv.-no. 23207. — x 0,5.

All specimens: Staatliches Museum für Naturkunde Stuttgart.
Foto: H. Lumpe.


1


2


3b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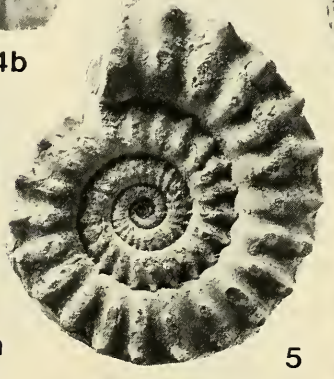
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6b

Plate 4

Fig. 1. *Oxynoticeras praecursor* SÖLL; Schwarzer Jura β, Betakalkbank; orig. M. SCHMIDT 1925, p. 301; Tuningen 5 km SE Schwenningen; inv.-no. 23209. — x 1.

Fig. 2. *Asteroceras stellare* (SOWERBY); Schwarzer Jura α_3; 2a: lateral view, 2b: ventral view; Mögglingen near Schwäbisch Gmünd; inv.-no. 23208.— x 0,5.

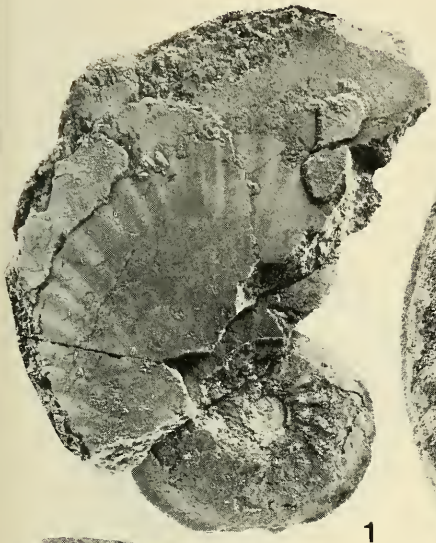
Fig. 3. *Oxynoticeras oxynotum* (QUENSTEDT); orig. E. FRAAS 1910. pl. 47, fig. 14; Schwarzer Jura β; Frommern near Balingen; inv.-no. 11494. — x 1.

Fig. 4. *Bifericeras curvicosta* (QUENSTEDT); 4a: lateral view, 4b: ventral view; Schwarzer Jura β; Frommern near Balingen; inv.-no. 23024. — x 1.

Fig. 5. *Crucilobiceras densinodus* (QUENSTEDT); Schwarzer Jura β; Nürtingen; inv.-no. 11366. — x 1.

Fig. 6. *Echioceras raricostatum* (ZIETEN); Schwarzer Jura β; Maitis near Schwäbisch Gmünd; inv.-no. 20977. — x 1.

All specimens: Staatliches Museum für Naturkunde Stuttgart.
Foto: H. Lumpe.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4a


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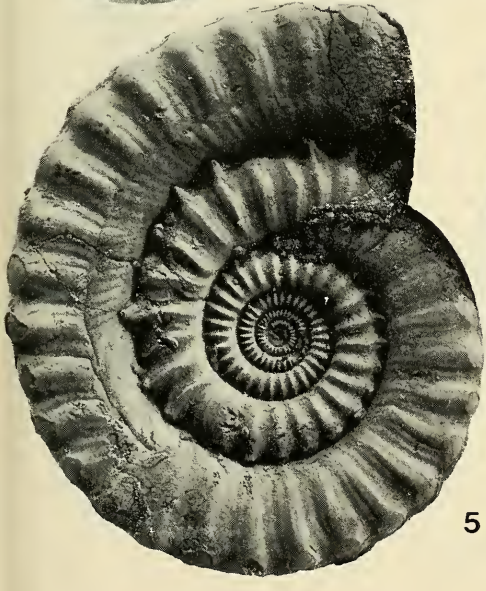
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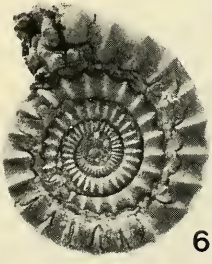
6a


6b

Plate 5

Fig. 1. *Harpoceras elegans* (SOWERBY); Schwarzer Jura $\varepsilon_{II\,8}$ (= „Ob. Stein"); quarry Gotthilf Fischer, Holzmaden; inv.-no. 23210. — x 1.

Fig. 2. *Harpoceras falcifer* (SOWERBY); Schwarzer Jura $\varepsilon_{II\,11}$ (= shale below „Schlacken"); quarry Gotthilf Fischer, Holzmaden; inv.-no. 23211. — x 1.

Fig. 3. *Grammoceras penestriatulum* BUCKMAN [= *G. thouarsense* (D'ORBIGNY) of BROCKERT 1959]; Schwarzer Jura ζ; Göppingen-Jebenhausen; inv.-no. 23212. — x 1.

Fig. 4. *Hildoceras bifrons* (BRUGIERE); top of the Schwarzer Jura ε; Heselwangen near Balingen; inv.-no. 21843. — x 1.

Fig. 5. *Grammoceras striatulum* (SOWERBY); Schwarzer Jura ζ; Göppingen-Jebenhausen; inv.-no. 23213. — x 1.

Fig. 6. *Haugia variabilis* (D'ORBIGNY); Schwarzer Jura ζ; Heiningen; inv.-no. 21012. — x 1.

All specimens: Staatliches Museum für Naturkunde Stuttgart
Foto: H. Lumpe.


1


2


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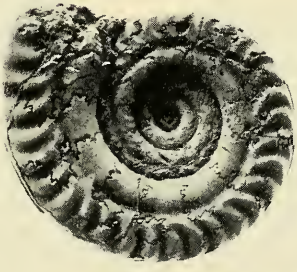
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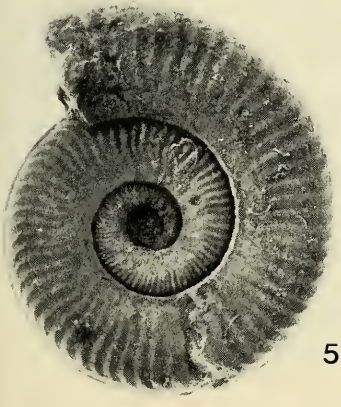
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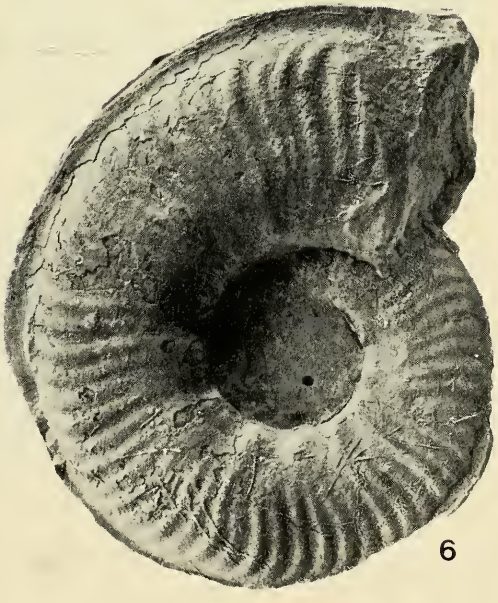
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Plate 6

Fig. 1. *Grammoceras fallaciosum* (BAYLE); Schwarzer Jura ζ; Göppingen-Jebenhausen; inv.-no. 23214. — x 1.

Fig. 2. *Dumortieria radiosa* (SEEBACH); Schwarzer Jura ζ; Reichenbach near Aalen; inv.-no. 23215. — x 1.

Fig. 3. *Phlyseogrammoceras dispansum* (LYCETT); Schwarzer Jura ζ; quarry Gotthilf Fischer, Holzmaden; inv.-no. 23216. — x 1.

Fig. 4. *Dumortieria levesquei* (D'ORBIGNY); Schwarzer Jura ζ; Aalen-Wasseralfingen; inv.-no. 21809. — x 1.

Fig. 5. *Pleydellia aalensis* (ZIETEN); Schwarzer Jura ζ; Schömberg near Balingen; inv.-no. 13197. — x 1.

All specimens: Staatliches Museum für Naturkunde Stuttgart.
Foto: H. Lumpe.

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