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Jurassic stratigraphy of Franconia

by Arnold Zeiss, Erlangen

With 8 figures

Abstract

A review on the litho- and biostratigraphy of the Jurassic beds of Franconia is provided, based on the researches of the last two decades.

Introduction

Coming from the Schwabenalb (Swabian Alb) a visitor will discover in the Frankenalb (Franconian Alb) certain changes of lithology within the rocks of the Jurassic system. These changes are caused by the more marginal situation of Franconia within the South German basin compared with the central position of Suebia; they are of various intensity during the different stages of the Jurassic system (Zeiss 1968a). Strong differences are developed in the Hettangian, Sinemurian, Lower Pliensbachian, Upper Aalenian, Oxfordian, Kimmeridgian, and Tithonian stages.

Above the Hettangian, these differences are concerning especially the Middle and Southern Frankenalb (see fig. 1). The Northern Frankenalb has had often closer relations to Suebia, documented by marls and clays as prevailing sediments, in contrast to the predominating limestone deposits of the Middle and Southern Frankenalb. Of course the limits between these areas are not fixed strictly and may shift to some degree from time to time. Sometimes there is no differentiation in the whole Frankenalb at all.

The approximate limits of the Frankenalb are given by a line running from the town of Donauwörth along the river Donau to Regensburg, than turning to the north: Amberg–Bayreuth; from here in northwestern direction to Kulmbach and Coburg. The western limits are given by a line connecting the towns of Coburg, Bamberg, Nürnberg and the Hesselberg – Ries area in the southwest, which is near the limit to Suebia (see fig. 2).

Besides the main differentiations in facies between Suebia and Franconia there are some differences between the basins of the Frankenalb, too, especially in Upper Jurassic time. In this time the regions separating the basins are marked by reef barriers. It may be supposed that old swells in the varistic basement have been rejuvenated to a certain degree during Jurassic times, and that they caused the formation of submarine swells and reef barriers (for details see Zeiss (1968a).

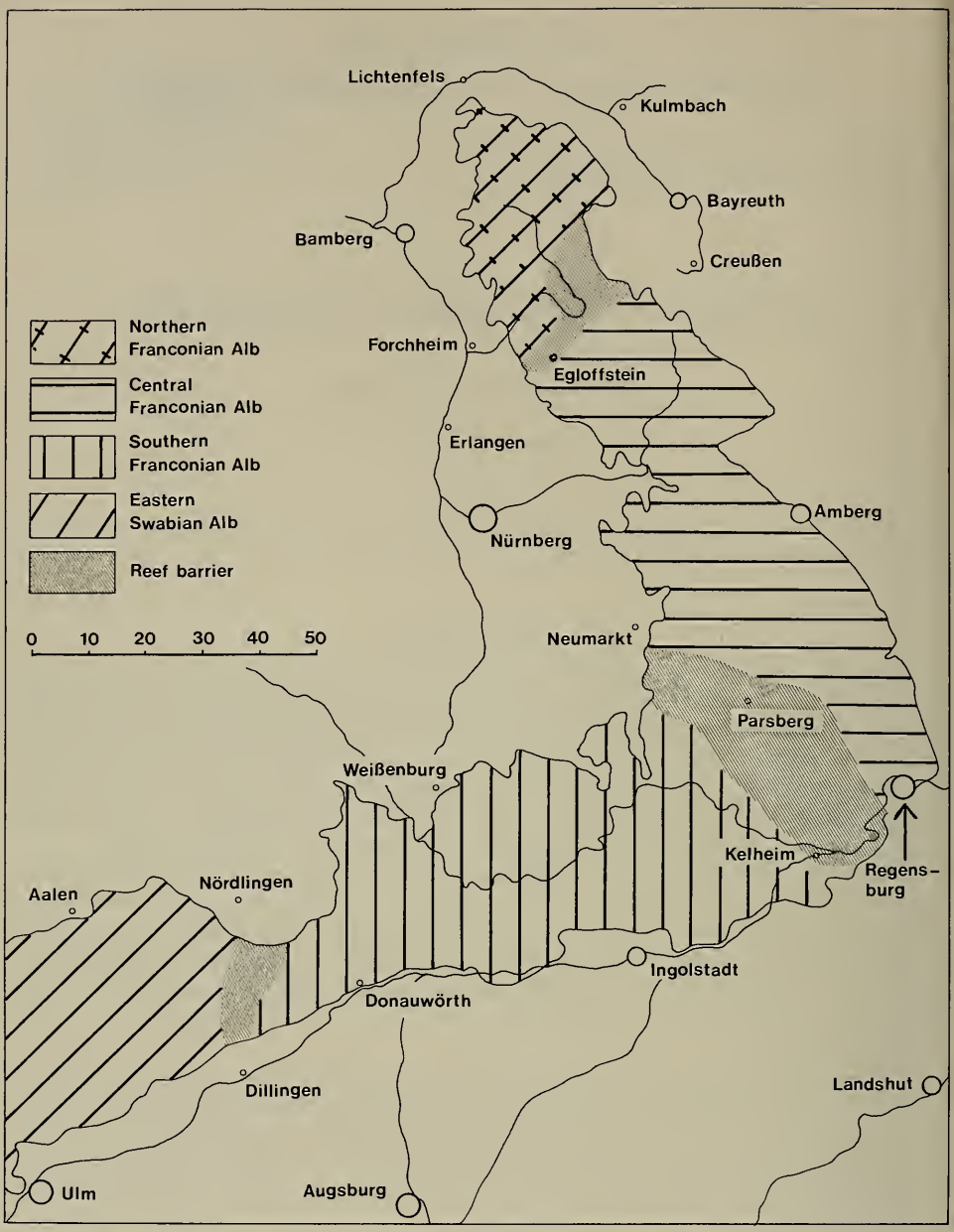

Fig. 1. The main facies areas of the Frankenalb during Upper Jurassic times.

This complex history of sedimentation in the Jurassic of the Frankenalb has not been recognized for a long time, because it has been supposed that the conditions of sedimentation in Suebia and Franconia were the same or very similar ones. Therefore the subdivision of QUENSTEDT for the Jurassic rocks of Suebia has been used also in Franconia, partly with some modifications. This has been done in the opinion that QUENSTEDT's subdivision is a chronologic, if also only a local one. It is difficult to

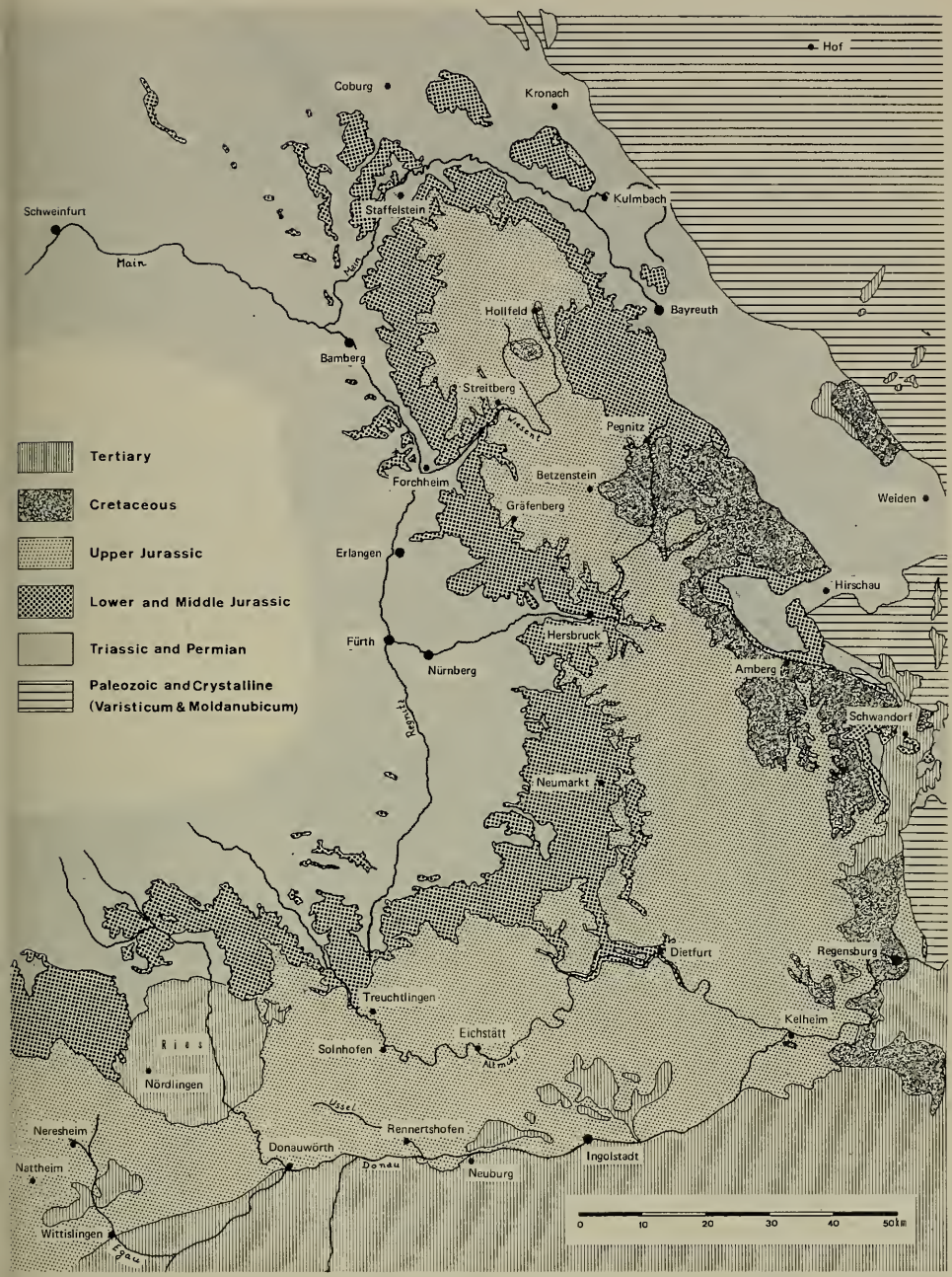

Fig. 2. Simplified geological map of the prequarternary sediments of the Frankenalb and adjacent areas (after GROISS 1975, modified).

argue if QUENSTEDT's subdivision is a lithostratigraphic or a local chronostratigraphic one (see HEDBERG 1976, p. 81) and beyond the scope of this paper. In every case it is better to limit the units of QUENSTEDT to Suebia, for which region they were established. This, on the other hand, makes it necessary to establish some new lithostratigraphic names, i. e. in Franconia the already existing lithostratigraphic units have to be completed and supplemented. Local chronostratigraphic terms have been already introduced by SCHMIDT-KALER & ZEISS (1973) for the whole Jurassic system of Franconia. Despite of the often reduced thickness of the jurassic layers in Franconia some of them have yielded a quite remarkable number of fossils. Thus some of the index ammonites of some subzones have been found here, but not in Suebia (e. g. of the Upper Sinemurian). The upper substages of the Lower Tithonian, the Middle Tithonian as well as the basal Upper Tithonian have been observed in Franconia only.

Remarks on the literature.

A bibliography of the Jurassic of Franconia doesn't exist. But the whole literature published until 1965 has been included in the bibliography of v. FREYBERG (1974a), which contains all geological and related articles on Northeast Bavaria, beginning with the year 1476. Publications after 1965 are quoted in the annual bibliography of the journal „Geologische Blätter für NO-Bayern". In 1975 the more important literature on the jurassic stratigraphy of Franconia has been mentioned by ZEISS (1975b); it has been included in a more extended compilation by MUNK (1975).

Stratigraphy of the Jurassic system in Franconia

The Jurassic system in Germany has been divided by v. BUCH (1839) in three parts: Lower, Middle, and Upper Jurassic. This subdivision is therefore valid also for our region. The present distribution of Jurassic sediments in Franconia is shown by fig. 2.

A cross-section through the Southern Frankenalb might give a first impression of the Jurassic succession of Franconia in the region, where it is rather complete (fig. 3). For each of the three parts above mentioned one or more tables have been prepared (fig. 4–8). The following explications to them are so short as possible, providing an overlook and references for those who are more interested in details. Since the Upper Jurassic is the most complicate series concerning the stratigraphy, it will be treated somewhat more comprehensively in this article.

1. Lower Jurassic

(fig. 4)

The lower Jurassic beds have been deposited on layers of different age of the Upper Triassic system. Thus, in Southern Franconia they rest on the Feuerletten (= Knollenmergel of Suebia) of supposed Norian age, but in the region north of Nürnberg on the younger Raetian „Haupt-Ton" of the Rathsberg formation (see v. FREYBERG 1974b, fig. 2, and KESSLER 1973, pl. 7). The transgression of the lower Jurassic sea began with different substages in the various parts of Franconia (see URLICHS 1966, pl. 4; VIOHL 1969, fig. 6).

No attempts have been made to introduce new lithostratigraphic names for the Lower Jurassic of Franconia. As outcrop conditions are changing rather quickly at present it is rather difficult to find appropriate type regions.

The more recent literature has been quoted by ZEISS (1975b and 1976).

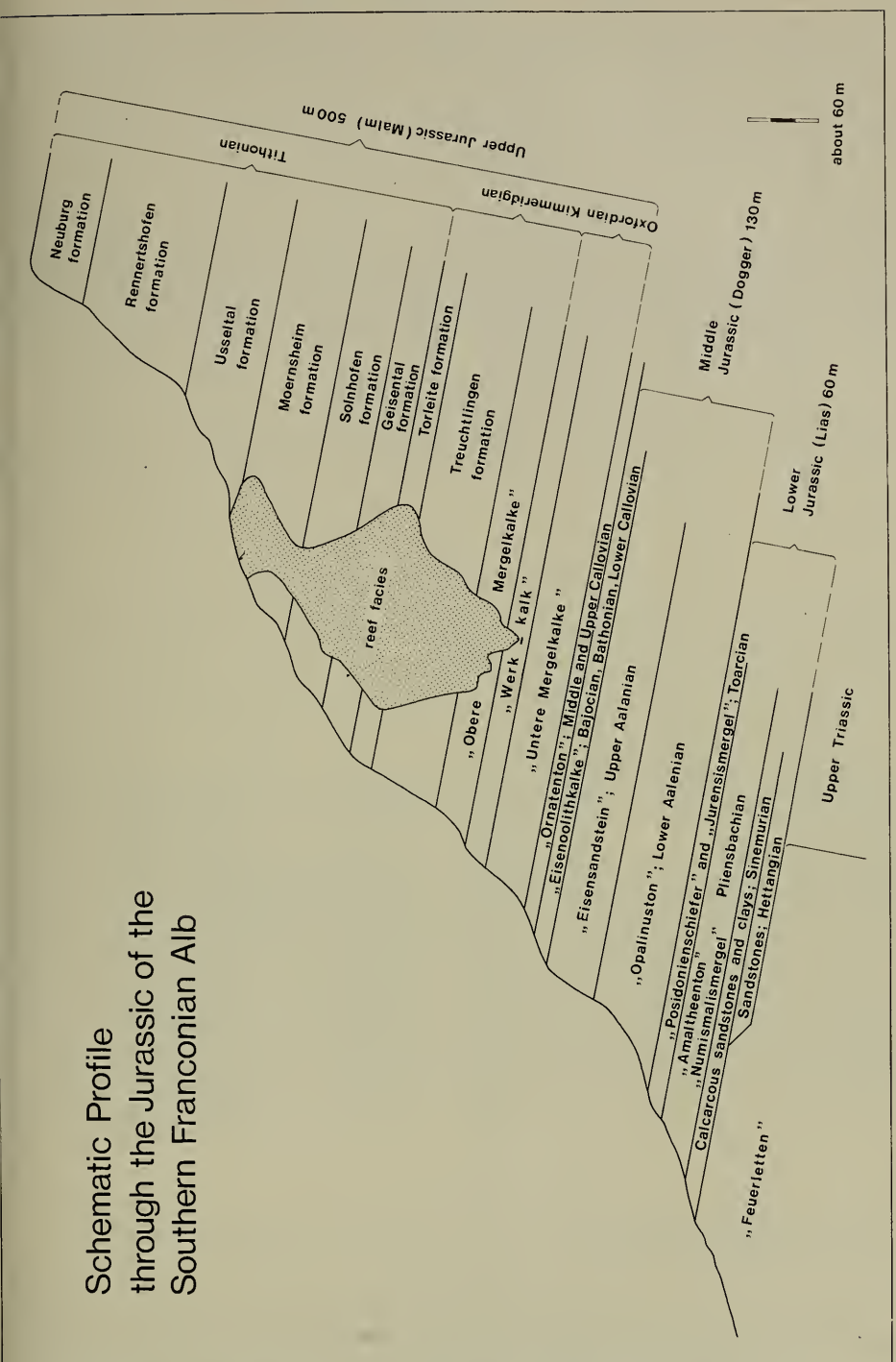

Fig. 3. Idealized geologic cross-section through the Jurassic beds of the western part of the Southern Frankenalb, approxemately from NW to SE.

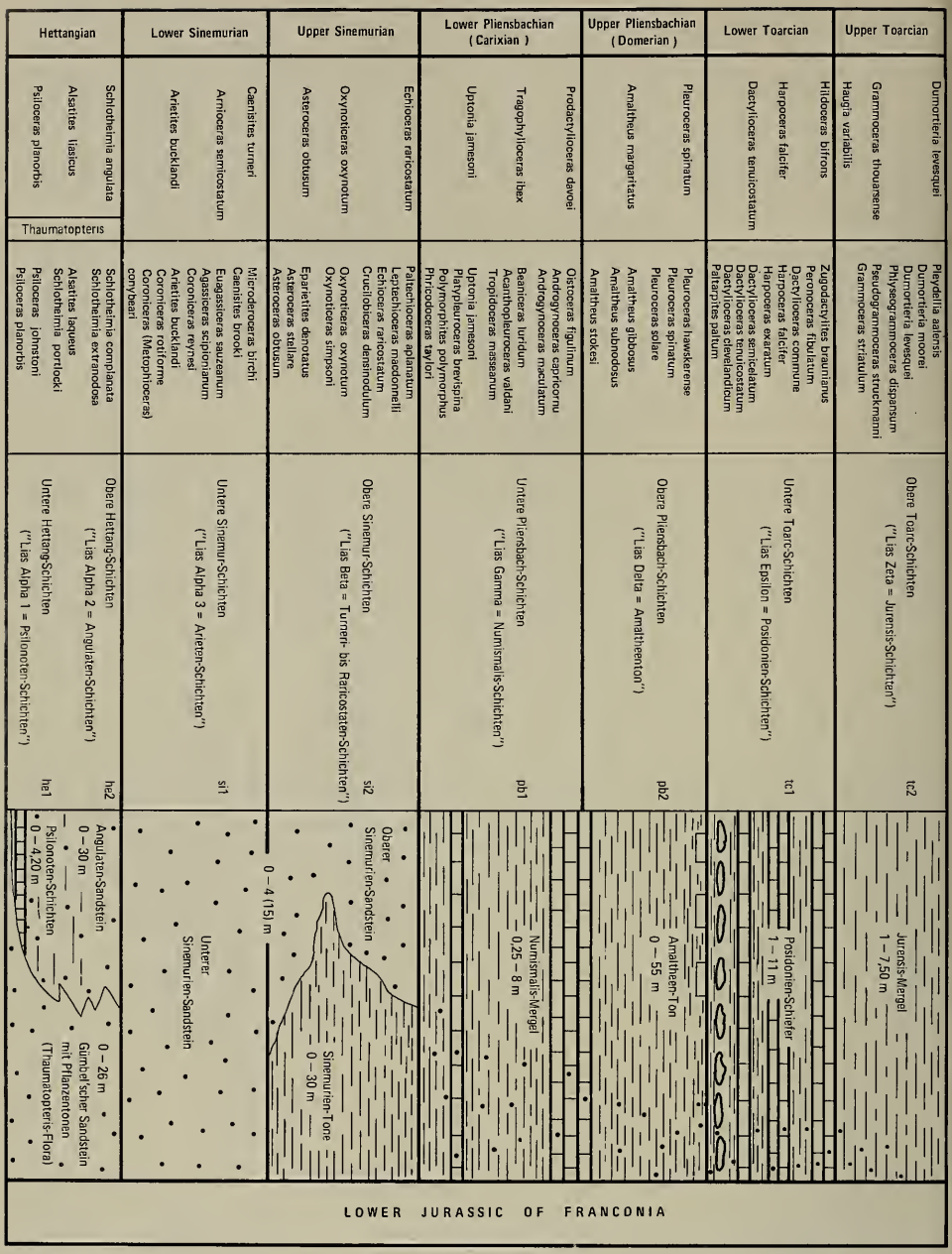

Fig. 4. The stratigraphic units of the Lower Jurassic system of Franconia and adjacent areas.

1.1. Hettangian

Lithostratigraphy. – During Hettangian time in Franconia marine as well as fluviatile-limnic sediments have been deposited. The first ones are represented by the *Psiloceras* and *Schlotheimia* beds, the second ones by the so-called „Gümbel'scher Sandstein" or „Oberer Sandstein" which contains plant-bearing clay lenses („Pflanzentone"). The age relations between these two facies types have been not clear

until the last years. Especially in the northern area, where east of Coburg the *Psiloceras*-beds are underlain by the Gümbel Sandstone, the question remained open, if there would not be also a Raetian part in this sandstone. But KESSLER (1973) could correlate this sandstone with those in the Bayreuth region, where a liassic flora has been found throughout this sandstone (WEBER 1968). Other arguments for a liassic age of the Gümbel Sandstone were brought together by v. FREYBERG (1974b and 1975) and URLICHS (1966). Thus, if the *Thaumatopteris* flora is considered to be liassic, this sandstone should belong to the Lower Liassic. Concerning the fact that the *Psiloceras* beds are overlying it in the area east of Coburg one should consider that the ammonites found there belong in most cases to the *johnstoni* subzone (upper part of the Lower Hettangian). Consequently there should be enough time for the deposition of the lower parts of the Gümbel Sandstone during the lower subzone of the Hettangian.

Biostratigraphy. – A short review of the Hettangian ammonites found in Franconia in more recent time has been given by ZEISS (1976). Until now no representatives of the zone of *Alsatites liasicus* have been found in Franconia. The *Thaumatopteris*-flora has been studied by WEBER (1968); see also JUNG (1960) and URLICHS (1966).

1.2. Sinemurian

Lithostratigraphy. – The lower part of the Sinemurian beds is built up by quartz sandstones with calcareous cement („Sinemurien-Kalksandstein") which extends into the upper Sinemurian in the western and southwestern regions (see ZEISS 1965). In the northern areas the upper part of the Sinemurian consists of grey marls, called „Sinemurien-Tone". South of the line Nürnberg–Amberg they interfinger with the Sinemurien-Sandstein. In the southwestern region often the beds with *Oxynoticeras oxynotum* are developed in this intermediate facies, whereas in the southeastern margin of the Frankenalb they are replaced by sandy sediments, if present at all.

The thickness is changing quickly, in the sandstones between 0 and 4 m, reaching its maximum in the Nürnberg–Amberg area. The clays have their maximum thickness north of the line Erlangen–Bayreuth, ranging from 4 to 30 m. The latter value has been observed in the region between Bamberg and Staffelstein.

Biostratigraphy. – The ammonites of the Sinemurian so far known have been studied by the author in 1965; also the zonal sequence has been discussed in this paper. Nearly all subzones are represented in Franconia; it is of some interest that here the two uppermost subzones of the Sinemurian have been found, but not in Suebia. Most of the ammonites have been collected in the sandy facies; they are very rare in the clay facies (see ZEISS 1976).

1.3. Pliensbachian

Lithostratigraphy. – The lower part of the Pliensbachian has been named after the development in Suebia „Numismalismergel" inspite of the appearence of different facies developments (see KRUMBECK 1936, pl. 29–31), which contain more calcareous and dolomitic layers and are characteristic for the marginal parts of the basin. The central basin facies of Suebia has been found in Northern Franconia, the marginal facies types in the eastern and southern parts of the Frankenalb.

In the marly facies of the basin in Northern Franconia the highest amounts of thickness of the Lower Pliensbachian have been observed, the lowest in the Southern Frankenalb.

The upper part is formed by the very thin-bedded marls with Amaltheids („Amaltheenton"). The thickness is fluctuating between 0 and 40 m along the Southern Frankenalb (see SCHMIDT-KALER 1969), in the other areas between 30 and 55 m in general, except the surrounding of Amberg and Regensburg with 0,05 to 2,75 m. East of Regensburg marly limestones with iron-ore deposits are known (see BAUBERGER et al. 1969)

Biostratigraphy. — The biostratigraphy of the Lower Pliensbachian has been worked out by KRUMBECK (1936, pl. 25–28). Some additions are mentioned by ZEISS (1976).

The ammonites of the Upper Pliensbachian have not been studied in detail despite of the wealth of them. The biostratigraphy is known in outlines. Some short notes may be found in the papers of SCHIRMER (1965; 1974), ZEISS & SCHIRMER (1965), URLICHS (1975), and ZEISS (1976). As the index ammonite *Pl. apyrenum* is very rare, the more frequent *Pl. solare* is prefered (cf. MOUTERDE et al. 1971, p. 6). *Pl. hawskerense* has only been found in the topmost layers of the beds with *Pl. spinatum*. – The foraminifera have been studied by WELZEL (1968).

1.4. Toarcian

Lithostratigraphy. — The lower part of the Toarcian consists of dark, grey limestones and some layers of thin-bedded sandy marls, called „Blätterschiefer". The name „Posidonienschiefer"is applied to these Lower Toarcian beds after their equivalent in Suebia. A better name should be found, and perhaps Bantz formation would be appropriate. The region of Banz is known for its richness in ammonites and reptiles, and the section Trimeusel (S of Banz) is still accessible. The thickness of the Lower Toarcian beds is largest in the northern and eastern parts of the Frankenalb, while it is reduced in the western and southwestern regions, except of the mountain Hesselberg.

The upper part of the Toarcian is developed in marly facies (Jurensismergel) almost in the whole Frankenalb. Only in the southeastern margin there are sandy intercalations. The maximum in thickness is again observed in Northern Franconia, but also near Regensburg. All other areas have reduced values of thickness.

Biostratigraphy. — In the Lower Toarcian some biostratigraphic work has been done by KRUMBECK (1932), URLICHS (1971), and ZEISS (1976). The lowermost subzones have not been identified, an argument to suppose the existance of a hiatus in the lowermost Toarcian of Franconia. Some localities are very rich in ammonites. Large collections are due to the perseverance and diligence of KRUMBECK and H. KOLB. They will be studied in the future.

The upper Toarcian ammonites and biostratigraphy have been thoroughly studied by KRUMBECK (1943/47).

2. Middle Jurassic

(fig. 5)

The stratigraphy of the Middle Jurassic of Franconia in general is well established. Nevertheless some problems are open, e. g. the representation of a lot of subzones of the international standard, the range of some index fossils as that of *L. opalinum*, and the delimitation of some zones. There are many condensed layers, especially in the middle part and in the uppermost one.

The lithostratigraphic units used hitherto are only descriptive ones, some of them taken over from Suebia like the „Opalinuston" and the „Ornatenton". Therefore

some new formation names derived from localities are proposed in informal manner in this paper. They have been selected from such regions and localities which are still offering outcrops and /or have been worked out in detail.

2.1. Aalenian

Lithostratigraphy. – The Lower Aalenian is represented by grey clays („Opalinuston" of authors). This would be a good name, but for the unity of the lithostratigraphic names of the Middle Jurassic of Franconia the name Neumarkt formation is proposed. In the region of Neumarkt/Opf., some twenty kilometers southeast of Nürnberg, larger pits are still working; there exist also natural outcrops (SCHMIDT-KALER 1974, p. 27; LAHNER & STAHL 1969, p. 21).

The thickness is generally fluctuating between 50 and 100 m throughout the Frankenalb, only in the Regensburg area it is reduced to 15–30 m. The Upper Aalenian rocks are formed by the so-called „Eisensandstein" or „Doggersandstein", a sequence of alternating, but prevailingly finegrained sandstones and clays; some deposits of iron-ores are included. The stratigraphy of the Eisensandstein has been put forward by the work of HÖRAUF (1959) and v. FREYBERG (1960). As new lithostratigraphic name for the Eisensandstein is proposed Reifenberg formation after a little village east of the town of Forchheim/Ofr. The outcrop is easily accessible and has been described by HÖRAUF (1959, fig. 3); also the lower limit may be observed there.

Biostratigraphy. – The ammonites were described by SCHMIDTILL (1926; revised by ZEISS 1960 and RIEBER 1963), and P. DORN (1935). But both authors have limited their work to the uppermost Lower Aalenian and the Upper Aalenian. Thus, for the Lower Aalenian only the paper of KRUMBECK (1925) exists and also some remarks by the author on the origin of the holotype of *L. opalinum* (FL. HELLER & ZEISS 1972).

2.2. Bajocian – Callovian

Lithostratigraphy. – For the lower and middle part only descriptive, lithologically named units exist (see fig. 5). The upper part is named „Ornatenton" after *Kosmoceras ornatum*, found only in the upper part of the „Ornatenton"; but sometimes the whole series of Bajocian to Callovian beds is called „Ornatenton", especially by applied geologists. For this reasons it is useful to look for more appropriate names.

For the lower part of the series the name Berching formation is proposed, as in the surrounding of this little town many good outcrops exist and have been described (but not all are published); in this area there are also good fossil localities. The Berching formation consists of iron-oolithic marls and limestones, sometimes the oolites are missing. The lower part has been well described in the Weiße Laber area, a little river east of Berching between Deining and Dietfurt (see HERTLE 1962, fig. 2, p. 9–13). This part, the Weiße Laber member, is built up by calcareous sandstones, blue limestones and clays; also conglomerates are characteristic of this member.

The upper part of the Bajocian-Callovian series is well exposed in a quarry at Sengenthal, some kilometers south of Neumarkt/Opf. This outcrop has been described by KOLB (1965) and is accessible. Therefore the name Sengenthal formation is proposed here for the Ornatenton. It consists of dark, grey, somewhat sandy marls with some phosphorites; the uppermost layer besides is characterized by glauconite and muscovite. As this development extends into the Upper Jurassic a seperate name is given to this special facies of the Sengenthal formation: Sachsendorf member (see p. 15—16).

Stages	Zones	Subzones	Lithostratigraphic units		
Upper Callovian	Quenstedtoceras lamberti	Quenstedtoceras lamberti Quenstedtoceras henrici	0 - 20 cm Glaukonitsandmergel	Lower Sachsendorf member	Zeitlarn formation
	Peltoceras athleta	Hecticoceras treezense Collotia collotiformis			
Middle Callovian	Kosmoceras castor	Kosmoceras grossouvrei Kosmoceras obductum	0 - 15,10 m Ornatenton	Sengenthal formation	
	Kosmoceras jason	Kosmoceras jason Kosmoceras medea			
Lower Callovian	Sigaloceras calloviense (Macrocephalites gracilis)	Kosmoceras enodatum Chanasia michalskii Sigaloceras calloviense Proplanulites koenighi			
	Macrocephalites macrocephalus	Macrocephalites kamptus Bullatimorph. bullatus			
Bathonian	Clydoniceras discus	Clydoniceras discus Clydoniceras hollandi	0 - 12 m Brauneisen-oolithische Kalke und Mergel		?
	Prohecticoceras retrocostatum (Oxycerites aspidoides)	Prohectic.blanazense Prohectic.retrocostatum Epistrenoc.histricoides Hemigarantia julii			
	Tulites subcontractus	Morrisiceras morrisi Tulites subcontractus			
	Zigzagiceras zigzag	Asphinct.tenuiplicatus Oxycerites yeovilensis Morphoceras macrescens Parkinsonia convergens		Berching formation	
Upper Bajocian	Parkinsonia parkinsoni	Parkinsonia bomfordi Parkinsonia densicosta Parkinsonia subarietis			
	Garantiana garantiana	Garantiana tetragona Garantiana subgaranti Garantiana dichotoma			
	Strenoceras subfurcatum	Garantiana baculata Caumonitsph.aplous Caumonitsph.polygyralis			
Middle Bajocian	Teloceras blagdeni				
	Stephanoceras humphriesianum				
Lower Bajocian	Otoites sauzei		0 - 6,50 m Blaukalke, Tone und Kalksandsteine	Weiße Laber member	
	"Sonninia sowerbyi"	Witchellia laeviuscula Sonninia ovalis Hyperlioceras discites			
Upper Aalenian	Graphoceras concavum	Graphoceras cornu Graphoceras concavum	30 - 75 m Eisensandstein	Reifenberg formation	
	Ludwigia murchisonae	Ludwigia bradfordensis Ludwigia murchisonae Staufenia sehndensis Ancolioc.opalinoides			
Lower Aalenian	Leioceras comptum	Leioceras crassicostatum Leioceras bifidatum	10 - 100 m Opalinuston	Neumarkt formation	
	Leioceras opalinum	Leioceras lineatum Leioceras opaliniforme Leioceras subglabrum			

Middle Jurassic stratigraphy of Franconia.

Fig. 5. The stratigraphic units of the Middle Jurassic system of the Frankenalb and adjacent areas.

The thickness of these beds is greatest in the northwest of the Frankenalb again, very low in the middle part, and changes somewhat to the southwest; it is zero in certain localities of the east (see GUDDEN & TREIBS 1961, suppl. 3). But going from here to the south one will find rather high thickness of these beds in the surrounding of Regensburg.

Some jurassic outcrops of this age can be observed in the area between Regensburg and Passau; they have been described by v. AMMON (1875) as „Zeitlarner Schichten" (Zeitlarn formation); new data have been given by TROLL (1960). The Zeitlarn formation is built up by limestones containing crinoids and oolites.

Biostratigraphy. – Important contributions to clarify the ammonite succession and biostratigraphy are those of: P. DORN (1927), SCHMIDTILL & KRUMBECK (1931 and 1938), MODEL & KUHN (1935), R. & E. MODEL (1938), KUHN (1939), ARKELL (1952), and JEANNET (1955). Foraminifera have been studied by J. ZIEGLER (1959). Many cores of iron-ore drills have been worked on by SCHMIDTILL (1953) and ZEISS (1957 a, b, and 1961), see also MUNK (1976), who gave many new informations on the stratigraphy of the Middle Jurassic of Franconia. It must be mentioned in this context that much material of the DORN collection has never been published und has to be monographed with a revision of the earlier works in the light of the new studies of W. HAHN (1968–1971). Also the ammonites of the Callovian of the so-called Goldschnecken-Facies of Northern Franconia need urgently a revision.

3. Upper Jurassic

(fig. 6)

As already mentioned above, the Upper Jurassic deposits of Franconia are differentiated to some extent by reef barriers („Riffschranken") which are dividing the whole basin into three smaller basins (see fig. 1); resulting are the three facies complexes of the Northern, Middle, and Southern Frankenalb. Sometimes the differences between them are very strong, but at other times not so conspicuous. The differences are influenced by the more distal or proximal situation of the sedimentary basin to the ancient shore-line and the central basin, respectively. The differences concern the ratio of marls to limestones and their thickness.

3.1. Oxfordian

(fig. 7)

Much research work has been undertaken to decipher the stratigraphic correlation problems within the Oxfordian facies complexes. In contrast to the Schwabenalb, there is not a constant, ± isochronous boundary between the „Impressamergel" of the Weißer Jura α (= „Untere Graue Mergelkalke" in Franconia) and the „Wohlgeschichtete Bankkalke"of the Weißer Jura β (= „Werkkalke" in Franconia), but this boundary lies in different heights above the Upper Jurassic base, is diachronic and often not sharply developed, i. e. there is a transition zone between both units, consisting of an alternation of marls and limestones. Both members cannot be separated by geological field work, thus a lithostratigraphic unit is needed which units both in Franconia. As the development in the three basins of Franconia is rather different three formations have been proposed (for details see below). To clarify the stratigraphic correlation proplems it had been necessary to undertake a very careful study of the bedded limestone complexes; the reef complexes are not considered in this article. Each limestone bed has been numbered and measured; afterwards the whole sequence of one outcrop has been delineated in the scale 1: 50. By this method

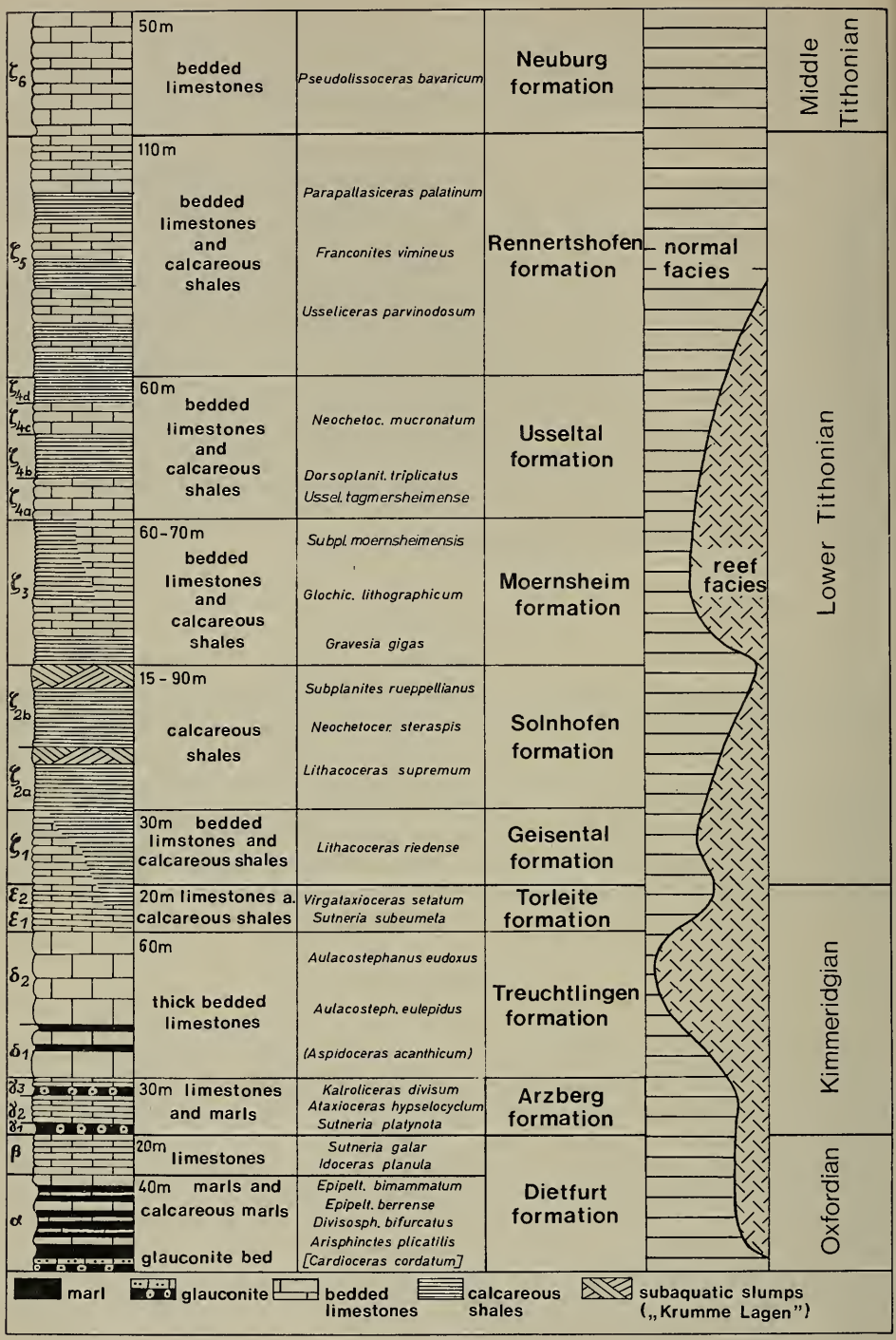

Fig. 6. Scheme of the Upper Jurassic system in Franconia (Southern Frankenalb) to show general lithologic development, important ammonite zones and the former applied subdivision (first column) in relation to the international standard stages.

(for details see v. FREYBERG 1966) of stromatometric correlation of quarries within the same facies complex it was possible to solve the stratigraphic problems. Of course the method has been controlled and supplemented by investigations on the biostratigraphy of ammonites (see below) and of foraminifera (GROISS 1970).

Southern Frankenalb

Lithostratigraphy. – The stromatometric method was applied practically in the region of Dietfurt/Opf. for the first time; STREIM (1960; 1961 a) had success to find outcrops down to the base of the Upper Jurassic and upwards to the limit to the Lower Kimmeridgian (see 1961 a, fig. 1). Because in this region the whole section is available, it is proposed as type area of the Dietfurt formation; the type section must be composed of different sections (see STREIM 1961 a, fig. 1). STREIM was followed by BECHER (1960) in the more northwestward situated region of Thalmässing, and SCHMIDT-KALER (1962b; 1970; 1971) in the western part of the Frankenalb (Treuchtlingen region). SCHMIDT-KALER (1962b)was able to correlate by this method nearly 160 beds over a distance of 60 km; these limestone beds are not very thick and belong to the middle and upper part of the Oxfordian. There had been no possibility to correlate the beds no. 1–75 of the lower part, due to the missing outcrops (see SCHMIDT-KALER 1969, fig. 10) and the predominating marls in the western area. More to the north, between Thalmässing and Dietfurt/Opf., there are intercalated more calcareous layers in the lower part of the outcrops; more quarries are therefore exploited there, and correlation is possible also between bed 40 and 75.

The Dietfurt formation and the Arzberg formation (see p. 16) are major subdivisions of the Heidenheim group, which has been established by NITZOPOULOS in 1975 as „Heidenheim-Folge". Each of them comprises three of the minor units errected by this author (see fig. 7).

Biostratigraphy. – The correlations were controlled by a systematic search for ammonites bed by bed. By this the very useful horizon of the „Berrense-Bänke" has been discovered. In this sequence of mostly micritic limestones „*Epipeltoceras berrense*" is the most important guide fossil. The true *Epipeltoceras bimammatum* is rather scarce and occurs in general in higher beds. *Epipeltoceras uhligi* has been found in the lowermost part of the Berrense-Bänke. – Other useful guide fossils are in the upper part *Idoceras planula* and *Sutneria galar* and to some extent *Taramelliceras litocerum* and *Taramelliceras costatum.*

Correlation with the Schwabenalb has been possible only for the upper part of the Oxfordian beds (SCHMIDT-KALER 1962a, fig. 1), i. e. between the „Weißer Jura β" of Württemberg and the Planula beds of Franconia.

Middle Frankenalb

As the researches in the Southern Frankenalb were successful, one tried to apply the stromatometric method also in the other parts of the Frankenalb and to correlate the layers within the other two basins respectively, and between the three basins. Such tentative correlations between the Southern and Middle Frankenalb were given by SCHMIDT-KALER (1962a, pl. 2), HERTLE (1962, fig. 5), SCHULER (1965, fig. 1, pl. 1), v. FREYBERG (1966, pl. 8), and GAUCKLER & HÄRING (1973, suppl. 1). Correlations within the basin of the Middle Frankenalb are provided by v. FREYBERG (1966), HERTLE (1962), SCHMIDT-KALER (1962a), GOETZE et al. (1975), NEUPERT (1959), GAUCKLER & HÄRING (1973), and DOBEN & FR. HELLER (1968).

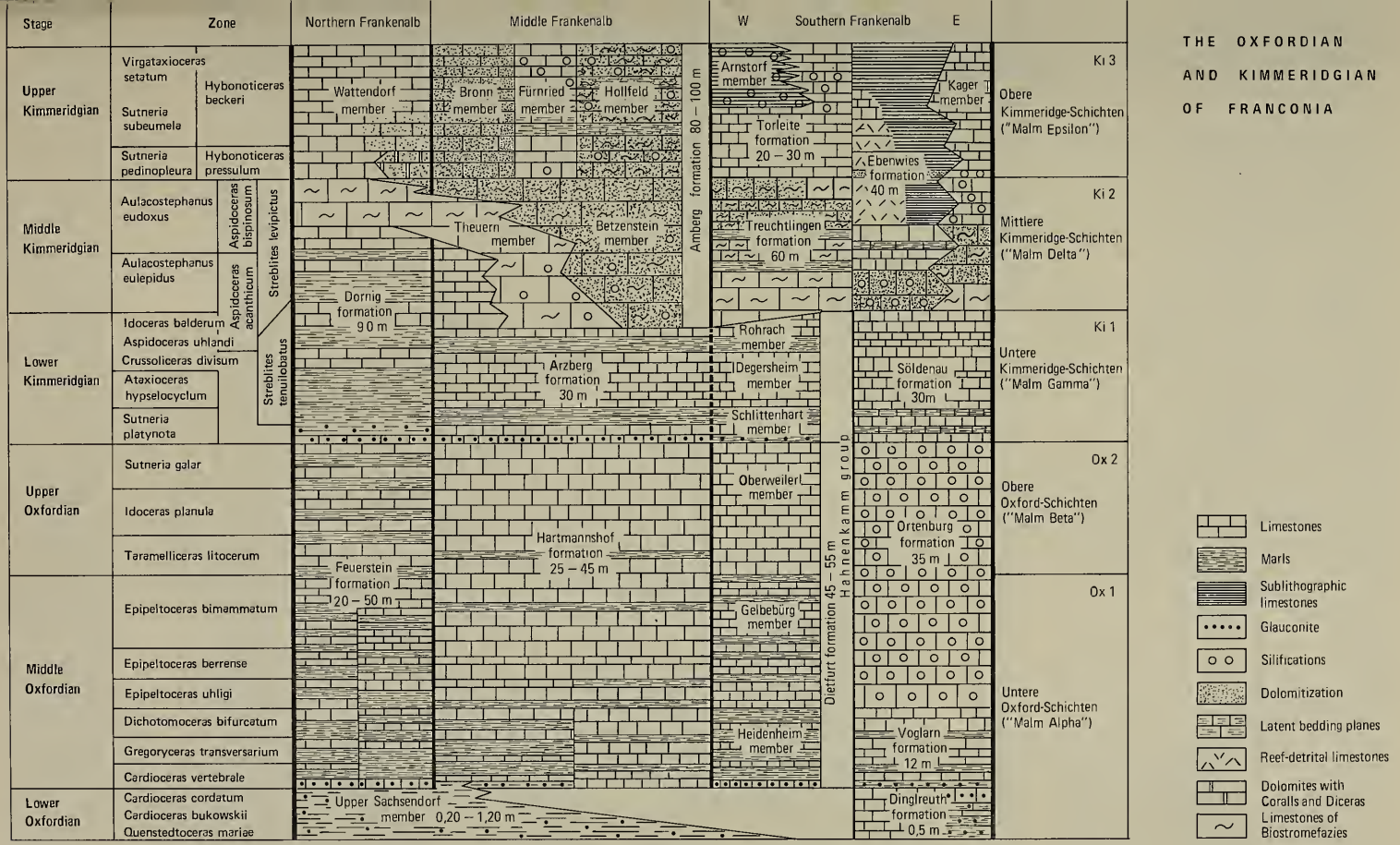

Fig. 7. The stratigraphic units of the Oxfordian and Kimmeridgian stages of the Frankenalb and adjacent areas. The twofold colums in the lower part of the Oxfordian of the Northern and Middle Frankenalb show the different developments in the northern and southern regions of the first and the western and eastern regions of the second one.

Lithostratigraphy. – In the basin of the Middle Frankenalb the facies in Oxfordian time is more of limestone character; marls are limited to basal layers and predominate in the western parts. The differences in thickness are considerable, the single limestone bed is thicker as in the Southern Frankenalb. Thus the standard section of Hartmannshof contains only 104 beds for the whole Oxfordian. As this quarry offers a complete section through the Oxfordian beds, it is the reference section for the enumeration of the „Hartmannshofer Bankfolge" (see v. FREYBERG 1966) and seems also to be very appropriate as type section of the Hartmannshof formation of the same scope and containing nearly all Oxfordian beds of the Middle Frankenalb. It has been figured by v. FREYBERG (1966, pl. 7). Only the lowermost deposits of the Oxfordian belong still to the Sachsendorf member of the Sengenthal formation (see below and fig. 7).

The differences in thickness, mentioned already above, concern mainly the lower part of the sequence, i. e. the beds below the zone of *Epipeltoceras berrense.* The Hartmannshof formation has its minimum thickness in the northwestern and northeastern parts, e. g. at Gräfenberg, east of Erlangen, where the famous fauna of DORN has been collected (see v. FREYBERG 1966, p. 38–39).

The studies mentioned above show that the facies of the Middle Frankenalb is rather different from that of the Southern Frankenalb. It had been more influenced by reefs, which are not rarely found in this facies also within the bedded limestones. This region seems to have been situated closer to the shore, especially in the eastern part, and to have been not so deep as the Southern Frankenalb basin, as indicated by the reduced sedimentation of marls and the numerous reefs. Only to the southeast, in the Regensburg area, there are again intercalations of marls (BAUBERGER & CRAMER 1961; BAUBERGER et. al. 1969), perhaps indicating a little deeper channel of the Regensburg strait. Farther to the southeast, in direction to Passau, v. AMMON (1875) has described some formations of Oxfordian age of other lithologic character. Outcrops are very bad today in this region. Some observations have been added by TROLL (1960).

Biostratigraphy. – The best compilation of the recent ammonite collections has been given by SCHULER (1965). In this formation the ammonites described by DORN (1930) have been collected. It is supposed that the fauna from Gräfenberg mainly comes from a condensed bed (see DORN 1958, v. FREYBERG 1966). In general the lower part of the formation is characterized by *Gregoryceras* (see ZEISS 1966, p. 111), but needs further investigations. Unpublished material shows that the *vertebrale* subzone may also be present. Further the *bifurcatus* zone has been proven. The „Berrense-Bänke" are the same important guide horizon as in the Southern Frankenalb; above *E. bimmamatum* and *E. treptense, Idoceras planula* and *Sutneria galar* are important. The index of the Lower Oxfordian, *Qu. mariae,* has been found in the Sachsendorf member of Sengenthal, the higher *Cardioceras cordatum* is reported from Gräfenberg (see ZEISS 1966) also from this member of the Sengenthal formation.

Northern Frankenalb

Between the Middle and the Northern Frankenalb a reef barrier is covering the area between Forchheim in the west and Bayreuth in the east, following the little river Wiesent and called therefore Wiesenttal reef complex. North of the Wiesenttal reef barrier the sedimentary character of the Oxfordian basin is influenced by more intercalations of marly layers (v. FREYBERG 1966, fig. 3 and 16, pl. 6), also in the upper part of the sequence.

Lithostratigraphy. – Due to the rather strong fluctuations in thickness and perhaps due to the intercalation of a further reef barrier (Würgau-Gorau reef) there are too many differences to correlate the lower and middle parts over the whole area of the

basin; but it is possible to correlate the upper part (*Idoceras planula* beds). Correlation is possible in the lower part if the distances of the sections are not too great and the thickness of the beds is not too different. Such conditions are given in the northern region of the Frankenalb (see MEYER et al. 1972, suppl. 1), and in the southern part of the Ebermannstadt-Streitberg region (K. W. MÜLLER 1958, pl. 1, and GOTTWALD 1958, fig. 1), but not in the middle part (ANTONIADIS et al. 1972, suppl. 2). In the southern region the most complete section is available at the Feuerstein mountain near Ebermannstadt; it has been selected as type of the „Feuerstein-Bankfolge" by v. FREYBERG (1966, pl. 6). The section is accessible easily except of the lowermost beds, which must be excavated. It is used as the type section of the Feuerstein formation. In figure 7 the somewhat different developments in the northern and southern parts have been tried to plot. The northern part of much less thickness has got its own numeration by HEGENBERGER & SCHIRMER (1967, fig. 2) which is useful for local correlations, but in general has been replaced by the Feuerstein numeration (v. FREYBERG 1966). — The lowermost part of the Oxfordian is built up by dark, grey, sandy marls with glauconite and muscovite and named after the thickest development in the borehole Sachsendorf/Ofr. (see p. 9 and for details ZEISS 1962b).

Biostratigraphy. – The zonal sequence has been elucidated for the timespan *berrense* to *galar* zones; below no new material could be collected, with the exception of the lowermost part, the Sachsendorf member of the Neumarkt formation (see ZEISS 1962b, 1966; ANTONIADIS et al. 1972), which yielded ammonites of the *mariae* and *cordatum* zones.

For the northern Frankenalb of interest is the appearence of *Prorasenia* at the base of the *planula* zone, and of *Ringsteadia*, beginning with the base of the *berrense* zone in the northernmost sections of the Frankenalb.

3.2. Kimmeridgian

(fig. 7)

The two reef barriers which caused the lithologic differentiations of the three major Oxfordian basins are continuing during Kimmeridgian times. The differences between the Middle and Southern Frankenalb are becoming less distinct (see R. MEYER 1974b, fig. 2–5, 6, 12). Thus, in the Lower Kimmeridgian the sedimentary conditions differed apparently only in minor degree between these two areas (see fig. 7); therefore only one formation has been proposed, which covers the two regions (Arzberg formation). But there are some differences in the rocks of Middle and Upper Kimmeridgian time, reflected by four formations (Amberg, Treuchtlingen, Torleite, and Ebenwies formations). In contrast to the predominating limestone facies of the Middle and Southern Frankenalb, in the Northern Frankenalb a marly facies incorporated in the Dornig formation prevails during the Lower and Middle Kimmeridgian.

3.2.1. Lower Kimmeridgian

Southern and Middle Frankenalb

Lithostratigraphy. – Lower Kimmeridgian rocks consist of three parts; the lower and upper part is built up by limestones and marls, the middle one by limestones. The far-distance correlation has been established within the Southern Frankenalb by SCHMIDT-KALER (1962b, fig. 10; 1969, fig. 11). There are some differences in thickness (4 m less in the east), and of course some problems are connected with that, but in

general the correlation can be considered well established. – Some problems more exist concerning the correlation between the Southern and Middle Frankenalb, especially of the lower marly layers (cf. GAUCKLER & HÄRING 1973, suppl. 1), M.MÜLLER (1961, fig. 4), HERTLE (1962, fig. 7), DOBEN & HELLER (1968, suppl. 2). As the numeration of the Oxfordian limestone beds is continued into the Lower Kimmeridgian the type section has been selected also in the region of Dietfurt; the Arzberg section (STREIM 1961 b, fig. 2) seems the best one: the formation begins with bed 234 or the marl below (seen better in the Töging section of the same author), and is terminated with bed 371.

In the region between Regensburg and Passau v. AMMON (1875) described a limestone series (Söldenauer Schichten) which seems to be an own development and therefore considered to be a seperate formation. Outcrop conditions are rather poor in this region today.

Biostratigraphy. – The outlines of Lower Kimmeridgian biostratigraphy are evident: The lower part belongs to the zone of *Sutneria platynota,* the middle part to the zone of *Ataxioceras hypselocyclum,* and the upper to the zones of *Crussoliceras divisum, Aspidoceras uhlandi,* and *Idoceras balderum.* Some papers by SCHAIRER are dealing with Lower Kimmeridgian ammonites, see also WEGELE (1929), BARTHEL (1963), SCHMIDT-KALER (1962b), STREIM (1961a), GEYER (1961), and SCHNITTMANN (1955 and 1958). It should be mentioned in this context that the first representatives of *Aspidoceras acanthicum* have been found just above the Crussoliensis marls (FR. HELLER 1964). *Idoceras balderum* has been found from 2 to 9 m above these marls (for detail see ZEISS 1964b).

Northern Frankenalb

Lithostratigraphy. – As shown by the descriptions of K. W. MÜLLER (1958, fig. 1), v. FREYBERG (1962), SCHÜTZ (1962), ANTONIADIS et al. (1972, fig. 4), HEGENBERGER & SCHIRMER (1967, fig. 6, 7, 9), and MEYER et al. (1972, fig. 3) the Lower Kimmeridgian of northern Franconia is developed in a marly facies, especially in the middle and northern part of the Northern Frankenalb. To the south there are intercalations of limestones; even in the upper part of the Lower Kimmeridian of the inner Wiesenttal region there are some thicker bedded limestones as in the Middle and Southern Frankenalb (K. W. MÜLLER 1968, fig. 2). – This marly facies is similar to the equivalent deposits of Suebia (HEGENBERGER & SCHIRMER 1967, tab. 2), especially in the northern regions of the Northern Frankenalb. In Franconia this facies development is best considered to form an own formation (together with the Middle Kimmeridgian beds), the Dornig formation. The name is derived from the mountain Dornig, where a section has been studied in detail by v. FREYBERG (1962) and ZEISS (1962a) and should be therefore the reference section;but, as this section doesn't quite reach the base of the formation, it must be completed by another nearby situated section, like Kaspauer or Kasendorf of the Weismain region (R. MEYER et al. 1972, fig. 3), which are extending downward to the top of the Feuerstein formation.

Biostratigraphy. – There are no great differences to the Middle and Southern Frankenalb. For the local biostratigraphy see HEGENBERGER & SCHIRMER (1967), MEYER 1972b, MEYER et al. (1972), ANTONIADIS et al. (1972), K. W. MÜLLER 1958, ZEISS (1962a; 1964b), and SCHÜTZ (1962). Descriptions of ammonites of this area have been published by SCHNEID (1939; 1940; 1944).

3.2.2. Middle Kimmeridgian
(fig. 7)

Southern Frankenalb

A general review on the facies of the Southern Frankenalb has been provided by MEYER (1975a). For special details one should use the contributions of M. MÜLLER (1961), BAUSCH (1963), MEYER (1975b), and K. & H. J. BEHR (1976).

Lithostratigraphy. – The Treuchtlingen formation („Treuchtlinger Marmor" or „Treuchtlinger Schichten" of authors) consists of 60 m of thick and well-bedded „sponge-biostromes" (MEYER 1975a, p. 176) in its typical development. Often dolomitization occurs in the higher parts, or increasing growth of sponges is observable, what means transition to true recifal development in most cases. The formation has been well described by STREIM (1961a), SCHMIDT-KALER (1962b; 1969), ZEISS (1964a, b), v. FREYBERG (1964b), and others. A reference section can easily be selected from one of the sections of SCHMIDT-KALER (1962b, fig. 5), e. g. Wettelsheim near Treuchtlingen.

In the southeastern part (some kilometers west of Regensburg) a rather remarkable change occurs: within the Ebenwies formation, above thick-bedded dolomites follow rather thin-bedded, marly limestones, which seem to represent the first sublithographic development in Franconia. Above that follows a large lense of reef detritus until an intercalated dolomitic layer; the type section has been described and figured by STREIM (1961b, fig. 2); the Ebenwies formation is extending into the Upper Kimmeridgian.

The biostrome-limestones of the Treuchtlingen formation are much influenced by the surrounding reefs; the transitions may be studied in the Altmühl Valley or in the quarry Bonhof, NE of Treuchtlingen (see E. FLÜGEL et al. 1975, p. 207–209, fig. C 19–19a).

Middle Frankenalb

Lithostratigraphy. – The facies development of the Middle Kimmeridgian in the Middle and Northern Frankenalb has been graphed by MEYER (1974b, fig. 5–6), and offers a good overlook. – The sections of the so-called „Dickbankfazies" (MEYER 1974b, p. 17) are built up by thick-bedded limestones, which in contrast to the limestones of the Treuchtlingen formation consist of less sponges, tuberoids, and sessil foraminifera, are splitting up more easily and are very rich in silifications. Best examples of this facies can be observed in the Vils Valley, south of the town of Amberg (DOBEN & F. HELLER, 1968, suppl. 2). It is proposed to use the name Theuern member for these limestones; the name is derived from a quarry near the village Theuern in the Vils Valley having the largest section concerning the vertical range, and has been figured (quotation above). The Theuern member is a part of the Amberg formation, a name already used by GÜMBEL for rocks of such kind. Further in the Amberg formation is included the so-called „Tafelbankiger Dolomit", which has been studied by MEYER (1972a; 1974b) and GOETZE et al. (1975). This unit can be subdivided in a lower and an upper part. After the localities with good development of the facies types here the names Betzenstein member for the lower part, and Hollfeld member for the upper part are proposed. The Hollfeld member can be distinguished from the Betzenstein member by its thinner and more regular bedding planes and the stronger silification (MEYER 1974b, p. 20). Both members are distributed over a large area of the Middle Frankenalb (cf. MEYER 1974b, fig. 5–6, 12). – Besides this dolomitic

development easy-splitting, thin-bedded limestones occur locally, e. g. near Betzenstein (GOETZE et al. 1975). No special name has been given to this facies due to its very limited occurence.

Northern Frankenalb

Lithostratigraphy. – As mentioned above in the Northern Frankenalb the Dornig formation continues in Middle Kimmeridgian time, too, up to the lower part of the *eudoxus* zone, thus covering the areas with non-recifal sedimentation. But only in the highest part of the Middle Kimmeridgian the whole area is covered by biostrome limestones and dolomites, sponge bioherms, partly dolomitized (MEYER 1974b, HEGENBERGER & SCHIRMER 1967). These upper sediments are of the facies types of the Amberg formation.

Biostratigraphy of the whole Frankenalb: The Treuchtlingen formation as well as the Amberg formation begin partly in the uppermost part of the Lower Kimmeridgian. But the main parts belong to the Middle Kimmeridgian, which in Franconia is containig the zones of *Aulacostephanus eulepidus* and *Au. eudoxus*. Also *Aspidoceras acanthicum* is a useful index in the lower part, but appears already in the upper Lower Kimmeridgian beds. Other guide fossils are *Aspidoceras bispinosum, Streblites levipictus, Sutneria eumela,* and others. A description of the fauna has been undertaken by BANTZ (1970); the foraminifera were described by WINTER (1970); other contributions see B. ZIEGLER (1958; 1962), SCHMIDT-KALER (1962b), SCHÜTZ (1962), HEGENBERGER & SCHIRMER (1967), ZEISS (1962a; 1964b), and SCHNEID (1914/15).

3.2.3. Upper Kimmeridgian

(fig. 7)

Above the Middle Kimmeridgian beds the differentiation of the sedimentary basin into three parts is missing. Therefore the units can be treated for the whole area of the Frankenalb. It should be pointed out that beginning with the sediments of the Upper Kimmeridgian these units are so-called „Wannen-Füllungen" between reef complexes; i. e. above reefs or recifal sediments and surrounded by them begins a new kind of sedimentation with thin-bedded micritic limestones in the lower part changing to sublithographic limestones in the upper part (for detail see FESEFELDT 1962 and v. EDLINGER 1964).

Lithostratigraphy. – In the Southern Frankenalb the main unit is the Torleite formation (cf. ZEISS 1964b), named after the mountain Torleite between Eichstätt and Solnhofen, south of the river Altmühl (ZEISS 1964b, fig. 1). The Torleite formation at the type locality is built up by 20 m of rather thin-bedded, yellow, micritic limestones, splitting well, with intercalations of siliceous concretions. The top is marked by a red marl layer of 20 cm. To the west the colour of the limestones is becoming grey, the beds are somewhat thicker, and the red marl is not developed: the transition to the lower part of the Rögling formation is indicated. To the east beginning in the surrounding of Kipfenberg/Altmühl, i. e. in the middle part of the Southern Frankenalb (SCHNITZER 1965), the upper part of the limestones is replaced by sublithographic limestones, partly silicified. These are exposed with their upper part and boundary in the lower section of the quarry Rygol near Painten (STREIM 1961a, p. 22, fig. 9). The best outcrops of the lower part and boundary are situated some kilometers south of Dietfurt/Opf. near the little village Arnstorf (see STREIM 1961a, p. 20–22, pl. 1). From this locality the name has been derived. Seperated by large reef complexes the Arnstorf member is apparently also developed in the basin of Parsberg/Opf. and Oberpfraundorf (M. MÜLLER 1961).

To the north, in the area of the Middle and Northern Frankenalb, within the large reef complexes and the dolomites of the Hollfeld member of the Amberg formation only minor basins of normal-bedded micritic limestones and dolomites exist. Thus in the surrounding of the Autobahn Nürnberg–Amberg, 40 km east of Nürnberg, the „Poppberg-Wanne" is crossed; it is filled with yellow, rather thin-bedded limestones with some marly intercalations, the Fürnried member (for detail see WINTER 1964; MEYER 1974b). Farther to the northwest one can observe between Betzenstein and Bronn about 50 km east of Erlangen thin-bedded, fine-grained dolomites, very poor in fossils, named after the village Bronn, where these dolomites have been exploited in some quarries for industrial purposes; they were described by EXLER (1955, p. 10–19, fig. 9), GOETZE et al. (1975, p. 49), and MEYER (1972a, 1974b). Some parts of this member are not dolomitized, and may also reach into the Lower Tithonian.

Interrupted again by reefs and recifal sediments in the most northern part of the Frankenalb, 30–40 km east of the town of Bamberg the „Wanne" of Wiesentfels and Wattendorf is filled with rather thin-bedded limestones and also some dolomites with latent bedding planes (regional distribution see MEYER 1974b, fig. 12; description by HEGENBERGER & SCHIRMER 1967, p. 64, and MEYER et al. 1972). The name „Wattendorf Schichten" has been used provisionally by HEGENBERGER & SCHIRMER (1967) and is here adopted as the Wattendorf member of the Torleite formation. In the southeastern margin of the Südliche Frankenalb the Ebenwies formation, consisting of detrital limestones and sublithographic limestones, is extending into the Upper Kimmeridgian, too (STREIM 1961a); to the east there is evidence for a transition of the sublithographic limestones into yellow, marly limestones of the surrounding of Kager, a village in the westernmost periphery of the town of Regensburg. For these limestones the name Kager member seems to be appropriate; they were described by BAUBERGER et al. (1969). Outcrops are situated north of the river Danube.

Biostratigraphy. – There are three zones in the Upper Kimmeridgian, that of *Sutneria pedinopleura* or *Hybonoticeras pressulum*, of *Sutneria subeumela* and of *Virgataxioceras setatum*. The last two ones are sometimes also united as the zone of *Hybonoticeras beckeri*.

The latter zone has been discovered by SCHNEID (1914/15); later BERCKHEMER & HÖLDER (1959) as well as SEEGER (1961) described the fauna, mainly of Württemberg. For Franconia the author gave a review (1968a, p. 18–20);supplements have been provided by FAY (1976) and MEYER (1972a; 1974b).

3.3. Tithonian

(fig. 6 and 8)

Since there are already some reviews on the Tithonian stage of the Frankenalb, here only a short outline with some additions is given. The following papers are dealing with all the Tithonian beds of Franconia, as well: v. FREYBERG (1968), ZEISS (1968; 1974; 1975), KEUPP (1975), and MEYER (1975). In this paper some further lithostratigraphic names have been introduced to provide a better survey over the different limestone and lithostratigraphic limestone complexes.

3.3.1. Lower Tithonian

Lower Subdivision

Two large units have been proposed in the past, the „Altmühltal-Schichten" (v. FREYBERG 1964) and the Lehnberg formation (FAY 1976), which represent the whole

lower subdivision of the Lower Tithonian. The limit between both is somewhat arbitrary, but may be drawn in the middle of the Altmühl Valley; both are considered to be of group rank. Thus the western unit is the Altmühltal group, including the main development of true lithographic limestones, but also similar facies types and one limestone formation of other type as well. The following units belong to the Altmühltal group: Rögling formation, Geisental formation, Solnhofen, Eichstätt, and Pfalzpaint formations, Groppenhof formation, and Mörnsheim formation with Mühlheim, Daiting, Großanger, and Neufeld members. The Lehnberg group in the east comprises the main development of limestone and marly formations, and to some degree sublithographic and also lithographic limestones. To this group are ranked the following units: Hopfental formation, Reisberg formation with Weltenburg, Teufelskopf, Ried, Katzengraben, Reisberg, Haselberg, Lindlberg, Biesenhard, and Buxheim members, Painten formation with Hennhüll, Öchselberg, and Zandt members, Hepberg and Denkendorf formation with Kelsbach member. All these units are figured in fig. 8.

Lithostratigraphy

a. Western region (Altmühltal group).

In the westernmost region the lower part of the group is built up by a limestone series, the Rögling formation; going to the east the limestones are gradually replaced by sublithographic limestones of the Geisental formation. The top of it is a silicified layer, which is a good limit to the overlying beds. The Geisental formation has been established by v. FREYBERG (1964), the Rögling formation by FESEFELDT (1962). The Geisental formation can be followed until the region of Kipfenberg approxemately.

The middle part of the Altmühltal group is in the west composed by the famous Solnhofen formation (KRUMBECK 1928), containing in its upper part the very true lithographic limestones (FESEFELDT 1962); the lower part is built up by some layers of sublithographic limestones and submarine slumps („Krumme Lage"); also the upper part may contain submarine slumping beds at its top. For details see FESEFELDT (1962). Somewhat different is the development in the Eichstätt formation (v. EDLINGER 1964): the lithographic limestones are thin-bedded, extending up higher in the stratigraphic column. The lower part is developed as marls at the base, then follow sublithographic and lithographic limestones. The upper part is built up by thin lithographic limestones, and subaquatic slumps (v. EDLINGER 1964; 1966). The „Wanne" of Solnhofen is separated from that of Eichstätt by reefs including the Ried-Wanne with a quite different facies of siliceous and marly sublithographic limestones and reef detritus; this peculiar development is seperated here as the Groppenhof formation (description see ZEISS 1964 d, p. 19–20, pl. 1). There are some transitional developments in the eastern part of the Solnhofen Wanne, i. e. the area of Haunsfeld, to this facies type.

East of Eichstätt there is again a thicker and partly not so fine-grained development of lithographic limestones in the „Wanne" of Pfalzpaint (v. EDLINGER 1964), for which the name „Pfalzpaint formation" is introduced (sections see v. EDLINGER 1964, fig. 27–28), but has been already used by v. EDLINGER (1964) as the „Pfalzpaintener Schiefer-Fazies", like the term „Eichstätter Schiefer-Fazies" for the Eichstätt formation (see above). The Pfalzpaint formation is well-known for their fossil medusae.

Concerning the origin of the lithographic limestones KEUPP (1975) has given a review of most of the existing theories. – As it has been pointed out by the author (ZEISS 1968 b, p. 154) the main elements of the fauna are nectonic. The appearance of animals (ammonites) of all ontogenetic stages seems to be characteristic of good

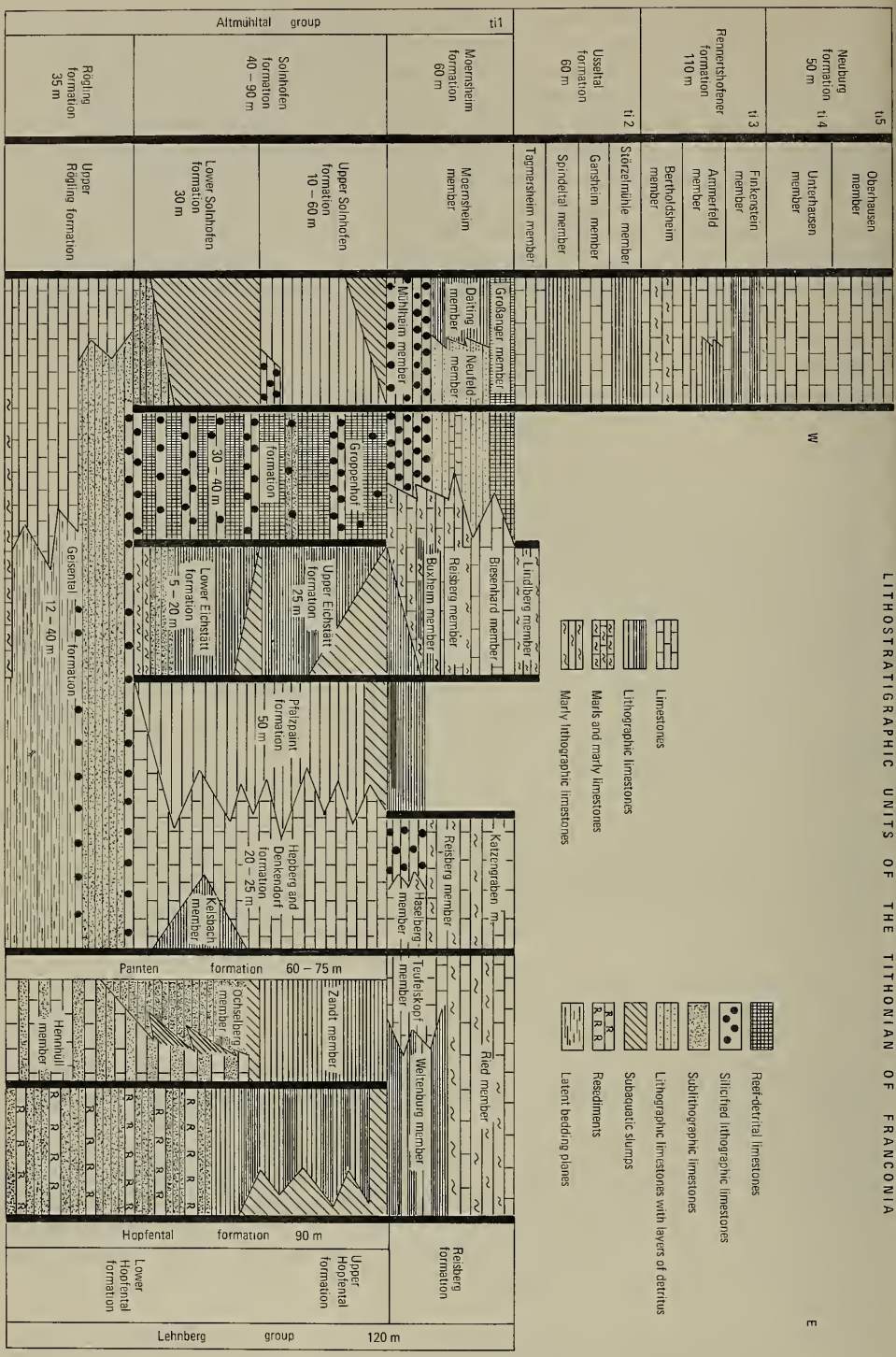

Fig. 8. The lithostratigraphic units of the Tithonian of Franconia (Southern Frankenalb).

conditions for life at least at distinct times. Those times probably were present during reduced or interrupted deposition of lime mud, since, in general, fossils can be found not within the limestones, but on the bedding planes or within the marly sediments. As for most of the fossils quick embedding must be supposed, this may be a hint that, beginning with a new lime-mud sedimentation, the conditions of environment in the sea became so unfavourable (by change of temperature, salinity, ph-value or other factors) that the majority of the then living animals came to death and was deposited and preserved on the bedding planes between the last and the new arising limestone layer.

With this theory in rather good accordance are the results of KEUPP[1]), who is developing a new model based on researches with the Stereoscan Microscope (1976). These studies helped him to elucidate the delicate problem of the origin of the limestones themselves. He could demonstrate that the lithographic limestones of the Upper Solnhofen and Eichstätt formations have been built up by coccoid bluegreen algae, while in the marly sediments between them or on the bedding-planes Coccolithophoridae and Calcisphaerulidae have been found. The first ones are supposed to be deposited under hypersaline conditions, the second ones after an overturn, which was happening from time to time, in a normal marine milieu; at those times a normal marine fauna could invade into the basin, for a certain time. With growing evaporation the sea became more and more hypersaline and the invaded fauna died and was conserved at the sea floor by a film of new produced coccoid blue-green algae. – Of course many questions, e. g. the migration routes, remain to be solved, also the origin of the sublithographic limestones of the eastern regions, but it is hoped that the discussion on the origin of the Solnhofen limestones will be brought forward by these studies. One should also keep in mind that the environmental factors influencing the deposition of the lithographic and sublithographic limestones of the Franconian Alb may have been modified from Wanne to Wanne. A model which could explain all problems of the genesis of these limestones convincingly does not yet exist (see also HEMLEBEN 1977).

The upper part of the Altmühltal group is formed by the Mörnsheim formation (KRUMBECK 1928), which is composed by four members, already known to FESEFELDT (1962) as „Fazies-Typen", but only named after localities in one case. In the area from the Ries to the Wellheim Valley the lower part is mostly represented by partly silicified lithographic limestones, the Mühlheim member (Fazies 1 of FESEFELDT 1962), named after the area with the best outcrops (see FESEFELDT 1962, p. 38–41). The middle part is built up either by lithographic limestones, the Daiting member (Fazies 3 of FESEFELDT 1962, p. 41), or alternations of this facies with intercalations of thin-bedded limestones and marls with fine detritus, the Neufeld member (Fazies 2, Neufeldfazies of FESEFELDT 1962, p. 40). In general the upper part is formed by detrital limestones and marls of the Grossanger member (facies 4 and 5 of FESEFELDT 1962, p. 42). All the names were derived from localities where typical outcrops have been described by FESEFELDT (1962).

The typical development of all these members is limited to the western part of the Southern Frankenalb; only the Mühlheim member has been observed farther to the east, too („Kieselplatten", see v. FREYBERG 1964; SCHNITZER 1965), and east of the Wellheim Valley the transition beds to the Reisberg formation has been recognized (ZEISS 1964d).

b. Eastern region (Lehnberg group)

In the area of Kelheim the lower and middle part of the group has been studied by RUTTE (1961), SCHMIDT-KALER (1968), and FAY (1976). The name Hopfental-

[1]) Apparently also the model of BUISONJÉ (1972) fits this theory.

Schichten has been given to these rocks by FAY, who also gave instructive figures and selected reference localities for the lower and upper part of this formation (1976, p. 55–56, fig. 3a–3b). The lower part is built up by sublithographic limestones and resedimentary breccias, the upper part by thin-bedded lithographic limestones and submarine slumps. A tentative correlation with other parts of the Frankenalb has been also provided.

Leaving the Kelheim area and directing northward we come to the Wanne of Painten, and northwestward to the Wanne of Schamhaupten. This area has been studied by STREIM (1961a, b) and BAUSCH (1963). It has not been possible to separate the lower and the middle part as clear as in the Solnhofen–Eichstätt area; therefore the sediments of these parts have been united as the Painten formation. The Hennhüll member of this formation consists of sublithographic limestones with intercalations of algal limestones and thicker-bedded limestones and slumps. Good sections are described from the region of Hennhüll-Painten (STREIM 1961b, p. 22–30, fig. 7–12, 15–16), some kilometers south of Hemau/Opf. – A thinner bedded development of the sublithographic limestones has been described by BAUSCH (1963, p. 20–21) as the „Öchselbergschieferfazies" of the Wanne of Schamhaupten situated above and transitional to the facies of the Hennhüll member; it is considered here as Öchselberg member. The name is derived from the mountain Öchselberg, about 10 km southwest of Riedenburg/Altmühltal. A more recent description of the Hennhüll member has been given by FLÜGEL et al. (1975, p. 195). – The top of the Hennhüll and Öchselberg members is formed by a subaquatic slump mass.

Above, lithographic limestones of various properties and thickness appear, called „Zandter Schiefer" by BAUSCH (1963, p. 22), here named Zandt member; the name refers to the village Zandt, about 4 km east of Denkendorf at the Autobahn Ingolstadt–Altmühltal. East of this village there are quarries in the lithographic limestones yielding well-preserved fossils (see BANTZ 1970). While the development at the type locality is characterized by thicker bedding, there occur thinner bedded lithographic limestones in the Painten area, called „Schieferfazies", but presumably belonging to this member, too.

Proceeding to the west the lithographic development is becoming subordinate and replaced by normal limestones. They have been named by SCHNITZER (1965) „Untere Bankkalke" or „Hepberg-Denkendorfer Kalk", transfered here to the Hepberg-Denkendorf member; for detailed description and figures see SCHNITZER (1965, p. 16–19). South of this area there is an intercalation of sublithographic limestones again, the Kelsbach member (PATZELT 1963, SCHNITZER 1965, tab. 1), appearently interfingering with the Hepberg-Denkendorf member.

The upper part of the Lehnberg group is named „Reisberg formation". The typical development of it is around the Reisberg mountain, situated about 12 km northwest of Ingolstadt/Donau; but as the sediments of the eastern regions are similar, they are also included in this formation. In the type area the lower part of the formation is formed by marls and limestones of the Haselberg member („Haselberg-Schichten", SCHNITZER 1965, p. 18 and 22, fig. 5), overlain by the Reisberg member („Mergelkalkserie", SCHNITZER 1965, p. 18, 24–25, fig. 8–9), consisting of marls and marly limestones in a characteristic development, and the Katzengraben member at the top, built up by thick limestones with some marly intercalations („Obere Bankkalke", SCHNITZER 1965, p. 18 and 26–27, fig. 10–12). From the Reisberg area to the west there are some changes: the Haselberg and the Katzengraben members are not present, the Reisberg member is replaced partly by the Buxheim member („Buxheimer Schiefer", v. FREYBERG 1974, p. 43, fig. 10), a rather marly development of sublithographic limestones, and the Biesenhard member („Dickbankkalke", v. FREYBERG 1964, p. 44, fig. 10), named after the village Biesenhard, east of which some

quarries have been exploited. Farther to the west (eastern margin of the Wellheim Valley) the whole lower and middle part of the formation is built up only by the Reisberg member. At the top marls in cores of bore-holes have been observed, which might belong to younger beds than the Moernsheim formation (see v. FREYBERG 1964, p. 44, fig. 10). They have been named „Lindlberg Mergel" by v. FREYBERG (1968, pl. 1) and are here treated as the Lindlberg member. In the eastern part of the range of the Reisberg formation the lower subdivision of this formation consists of either thick-bedded limestones of the Teufelskopf member („Teufelskopfkalke", BAUSCH 1963, p. 22, tab. 4 and 6, the name of which is derived from the Teufelskopf hill, west of the Öchselberg; s. above), or the very thin-bedded, marly, lithographic limestones and marls of the Weltenburg member (FAY 1976, p. 56) which represents the former „Papierschiefer" (BAUSCH 1963, p. 27). The upper subdivision is formed by the Ried member (FAY 1976, p. 57), i. e. the so-called „Runzelkalke" of BAUSCH (1963, p. 26). Correlation of all these formations and members is possible only tentatively. But the discovery of some ammonites, which are rather rare in these formations, helped to solve the major problems (see ZEISS 1964c, 1968b; v. FREYBERG 1964, p. 46; BAUSCH 1963, p. 22; SCHNITZER 1965, p. 24–25; SCHMIDT-KALER 1968, p. 30).

Biostratigraphy

First studies on the ammonites have been made by OPPEL (1863); he was succeeded by SCHNEID (1915b) and BERCKHEMER & HÖLDER (1959). All ammonites as far as known have been listed by ZEISS (1968b, p. 21–26); also the zonal sequence has been established in this publication (1. c. p. 133–135). The ammonite fauna needs revision, which is planned for the future; by this a better fundament will be gained what concerns the correlation with Württemberg. For the moment as guide fossils are considered (from below) *Lithacoceras riedense, Subplanites rueppelianus,* and *Subplanites moernsheimensis* forming the (super) zone of *Hybonoticeras hybonotum;* there are other important guide fossils like *Neochetoceras praecursor* in the lower part, *Neochetoceras steraspis, Glochiceras lithographicum,* and *Gravesia gigas* in the middle and upper part. *Lithacoceras ulmense* (OPPEL) has been found in the whole Altmühltal group, but is rather scarce. Other fossils which occur especially in the Solnhofen and other lithographic limestones have been listed and figured by O. KUHN (1961; 1966), a new edition of the latter is in press.Also MAYR (1967) published an extensive study on the Fauna of Solnhofen-Eichstätt district. „Solnhofen" fossils have been figured well by LEICH (1968). For the Kelheim region compare RUTTE (1961).

3.3.2. Middle and Upper Subdivision of the Lower Tithonian, Middle and Upper Tithonian

(fig. 6 and 8)

In contrast to Württemberg in Franconia the jurassic succession persists into younger zones than that of *Hybonoticeras hybonotum.* In this region the ammonite succession of the middle and upper part of the Lower Tithonian as well as of the Middle Tithonian could be observed for the first time (SCHNEID 1915a; BARTHEL 1962, 1975; ZEISS 1968b). Therefore the Southern Franconian Alb has been proposed as type area for this part of the Jurassic (ZEISS 1975a; BARTHEL 1975).

Since for this sequence comprehensive reviews in English language already exist (BARTHEL 1975; ZEISS 1975a and b) and detailed papers in German language are available (BARTHEL 1962; 1969; ZEISS 1964d; 1968b; SCHAIRER & YAMAMI 1973) only the following short report is provided.

The middle and upper subdivision of the Lower Tithonian, the Usseltal and Rennertshofen formations, comprise an alternation of thick, yellow limestones and lithographic limestones. This alternation occurs twice in the Usseltal formation. In the Rennertshofen formation the deposition of lithographic limestones is reduced, limestones and marly limestones predominate. Full descriptions of these formations have been published by FESEFELDT (1962, p. 46–59, fig. 23–27), STREIT (1963, p. 10–17, fig. 4), and ZEISS (1964d, p. 33–35); the biostratigraphy and the description of ammonites have been treated by ZEISS (1968b), the foraminifera by GROISS (1963). These formations are characterized by a typic ammonite fauna which contains in the Usseltal and lower Rennertshofen formation (middle part of the Lower Tithonian) species of *Usseliceras, Neochetoceras* (*mucronatum* group), *Dorsoplanitoides* (*triplicatus* group), and *Subplanitoides,* while in the middle and upper Rennertshofen beds (upper part of the Lower Tithonian) *Franconites, Parakeratinites, Dorsoplanitoides* (*bavaricus* group) as well as the first *Danubisphinctes, Sublithacoceras, Parapallasiceras,* and *Lemencia* are representative. The following zones could be distinguisted (from below): 1. (middle part of the Lower Tithonian) *Usseliceras tagmersheimense,* 2. *Dorsoplanitoides triplicatus,* 3. *Usseliceras parvinodosum,* 4. (upper part of the Lower Tithonian) *Franconites vimineus* and *Dorsoplanitoides palatinus.*

The Middle and Upper Tithonian (Neuburg formation) is built up by white to grey limestones and some marly layers. The details on lithostratigraphy, correlation, and fossils can be found in the papers of BARTHEL (1962, 1969 and 1974), GROISS (1963 and 1967), and STREIT (1963). The succession of ammonite zones has still to be worked out in detail. An overlook on the vertical distribution of ammonites has been given by BARTHEL (1974). The Middle Tithonian is characterized mainly by *Pseudolissoceras bavaricum.* A farther subdivision is possible by the following assemblages (from below): 1. *Virgatosimoceras – Sublithacoceras* (*penicillatum* group), 2. *Lemencia* – (?) *Sublithacoceras* (*glaber* group), 3. *Isterites.* The Upper Tithonian is represented only in the uppermost bed by the calpionellid *Crassicollaria* (BARTHEL 1969).

An open problem is the boundary between the Middle and Upper Tithonian (see BARTHEL 1974). Above the zone with *Pseudolissoceras bavaricum,* which is true Middle Tithonian, the beds in the Neuburg area yield only *Isterites;* it is supposed that these beds correspond with the zone of *Pseudovirgatites puschi,* which is an equivalent of the uppermost part of the *Ilowaiskya pseudoscythica* zone, belonging to the subboreal province (KUTEK & ZEISS 1964). The *puschi* zone has been considered to be of lowermost Upper Tithonian age, mainly on the first appearance of true *Pseudovirgatites.* New correlations by the author make it more probable that the *puschi* zone belongs to the uppermost Middle Tithonian (ZEISS 1977).

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Adress of the author: Prof. Dr. Arnold Zeiss, Institut für Paläontologie der Universität Erlangen-Nürnberg, Loewenichstr. 28, D-8520 Erlangen.