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The Buntsandstein

The Buntsandstein (Lower Triassic) of the Thuringian Basin is characterized by its marginal position in the southeastern part of the Germanic Basin. The facies of the Lower and Middle Buntsandstein fluctuate between fluvial sandstones and lacustrine deposits, pointing to an extended basin with very low morphological gradients. Compared with the deposits in the central Germanic Basin (Poland, Northern Germany), enhanced sand content, occurrence of pebbles, and predominance of fluvial deposits indicate a more marginal position of the Thuringian Buntsandstein in the southeastern part of the Thuringian Basin, although no alluvial fans can be recognized. Only a few investigations deal with the provenance of the sandstones of the Buntsandstein. The distribution of facies belts points to an extended source area in the south comprising the Moldanubian (Bohemian) Massif. Near the western border of the Bohemian Massif, stacked conglomerates of alluvial fans provide the nearest proximal depositonal area recognized recently (SCHROEDER 1982). GÖTZE (1998) identified characteristic quartz and feldspar of a Hercynian granite in Middle Buntsandstein deposits near Jena, which is situated 50
and feldspar of a Hercynian granite in Middle Buntsandstein deposits near Jena, which is situated 50
km to the SE (Kirchberger Granit, Erzgebirge).

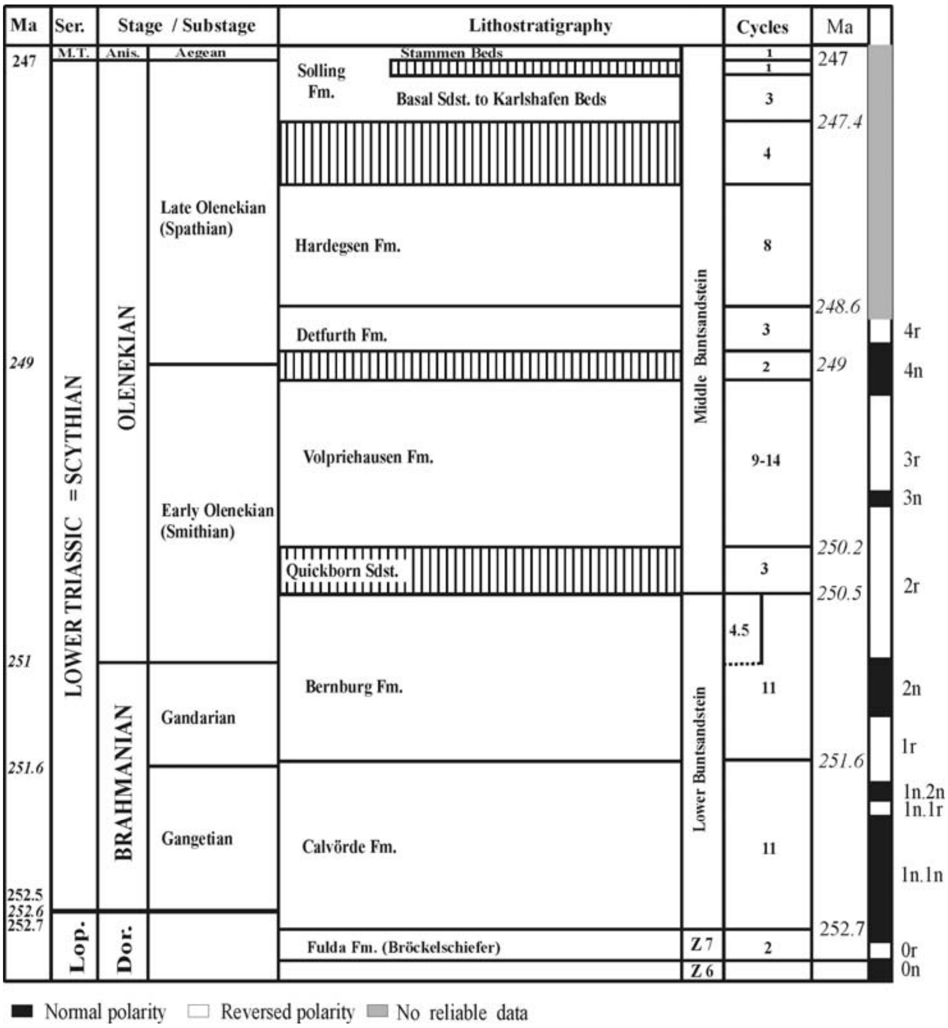


Fig. 1: Correlation of the Germanic uppermost Zechstein, Lower and Middle Buntsandstein (BACHMANN & KOZUR, 2004).

The northern margin of the Thuringian Basin marks the transition to the basinal sections of the central Germanic Basin. Lithostratigraphic subdivision of the thick clastic and nearly unfossiliferous deposits of the Buntsandstein uses an asymmetric cyclic grain-size pattern, which seems to be traceable across the whole basin (BOIGK 1956, 1959). The Buntsandstein of Thuringia was subdivided into several mappable units (Fig. 1) which were compared to the proposed basinwide lithostratigraphic scheme (HOPPE 1959, HOPPE 1974, RADZINSKI 1995, PUFF 1995). The thickness distribution of the Buntsandstein proves differentiated subsidence, which was reduced along the Eichsfeld Swell (NW Thuringia) and increased to the east along the Thuringian Basin. The eastern flank of the Thuringian Basin indicates the transition to an assumed east Thuringian Swell, which is not preserved due to later erosion of the Triassic cover. The trend of these paleotectonic elements is NNE-SSW and does not coincide with the tectonic axis of the Thuringian Basin.

The Lower Buntsandstein of the Thuringian Basin (200 – 350 m) starts above red massive mudstones of the Upper Permian (Zechstein) with sandstones which prograde from the southeast into the Basin. The facies at the southern and southeastern margins comprise channel sandstones, various flood-plan deposits and eolian intercalation. Two large-scale fining-upward cycles can be recognized (Calvörde Formation, Bernburg Formation). In the centre of the Thuringian Basin, the succession of the Buntsandstein contains oolitic limestone horizons, pointing to a southward elongated embayment of the large shallow lake of the central Germanic Basin (USDOWSKI 1961, HOPPE 1966, PUFF 1995).

The sedimentary environment of the Middle Buntsandstein is fluvial to lacustrine, with more proximal facies in the south, general transport from S to N or NNE, and with transition to more lacustrine facies to the north. Distinct fining-upward cycles allow on the distinguish four formations of regional distribution, starting with fluvial channel sandstones and passing to floodplain or even lacustrine deposits. The typical stacking pattern of the Middle Buntsandstein is interpreted to be either the result of reorganisation of the basin (pronounced uplift of the source area; SEIDEL 1965, WURSTER 1965, HOPPE 1974) or the reflection of global sea-level changes (e.g. AIGNER & BACHMANN 1992, Fig. 3).

The Volpriehausen and the Detfurth Formations of the Middle Buntsandstein are easy to define due to their well-developed fining-upward cycles. The whole succession is dominated by sandy deposits of braided rivers. Towards the top of both formations the floodplain/channel ratio increases. The tops of the fining-upward cycles are dominated by lacustrine deposits, indicated by bivalves and abundant chonchostracans. In contrast to the Lower Buntsandstein, no stromatolites or oolitic limestones were formed. The maximum extension of the central lake is indicated in the upper Volpriehausen Formation by the occurrence of bivalves (*Avicula muchisoni*). While the stratigraphy of the older four formations of the Buntsandstein is, in general, simple, the Hardegsen Formation comprises some minor cycles and is possibly locally incised into older deposits.

The Solling Formation starts with coarse fluvial deposits, resting on a widely distributed erosional unconformity, and includes a tripartite succession traceable in the whole Thuringian Basin (PUFF 1976). Of particular interest is the reduced thickness of pre-Solling formations on top of the intrabasinal Eichsfeld Swell, which is explained as erosion of several hundred meters of older deposits (TRUSHEIM 1961, WYCISK 1984). Climatic change to more precipitation is indicated by plat fossils (*Pleuromeia, Voltzia, Schizoneura*), calcretes and large-scale channels of probably perennial streams. Vertebrate trace fossils (especially the famous footprints of *Chiotherium barthi*i) provide evidence for locally better living conditions in the Mideuropean Triassic desert (HAUBOLD & PUFF 1976).

The Upper Buntsandstein (Röt Formation) is sharply separated from the underlying Solling Formation, and is characterized by the first clearly marine ingression into the Germanic basin. The Röt Formation is dominated by various mudstone facies ranging from shallow-marine dolomitic claystones to sabkha-mudplain environments. The first marine ingression led to basinal sulphate and salt deposits, while playa and sabkha environments prevailed in the marginal areas. Short periods of dessication were followed by short ingressions of sea water, during which even cephalopods (*Beneckeia tenuis*) migrated into the Thuringian Basin. The maximum southern extension of the shoreline is marked by the marginal-marine to fluvial “Plattensandstein” of southern Germany. During sea-level lowstands, thin sand layers with a complex depositional history reached the central Thuringian Basin. Monotonous red mudstones with layers of nodular gypsum characterize the Middle Röt, which is often interpreted as a mud plain with ephemeral lakes. Towards the north, these sabkha sulfates correspond to thick marine gypsum beds (JUBITZ 1959). The Upper Röt (*Myophoria Beds*) starts with an alternation of fossiliferous limestones and marls, overlain by mudstones of the topmost Röt. Above, the sedimentation turns to the limestones of the Muschelkalk facies. It is important to note that the base of the Myophoria Beds corresponds with the base of the Muschelkalk in Upper Silesia (Poland).

The Muschelkalk

The Muschelkalk is marked by a prevailing marine environment and is subdivided into three units, which reach (on average) a total thickness of about 250 m (Fig. 2.).

The Lower Muschelkalk (Jena Formation) of the Thuringian Basin is not sharply separated from the marine marls of the Upper Röt, although laminated cryptalgal dolostones of a coastal sabkha and a widespread conglomeratic bed at the base of the micritic limestone succession point to renewed transgression on a flat landsurface. The Lower Muschelkalk (Jena Formation) of the Thuringian Basin consists mainly of micritic limestones with different types of diagenetic bedding (wavy-, flaser- and nodular structures). The typical “Wellenkalk” (wavy limestone) facies is interpreted to have been deposited in a shallow subtidal environment. Bioclastic arenites (tempestites) occur very often and indicate water depths above storm wave base (hummocky cross-bedding). The fauna of the Thuringian Lower Muschelkalk is characterized by a marine fauna comprising bivalves, crinoids, gastropods and rare ammonites. Three horizons (between 3 and 15 m thick), which contain massive limestones of varying composition (Oolitebank Member, Terebratelbank Member, Schaumkalk Member), are of nearly basinwide distribution in the Lower Muschelkalk (SCHWARZ 1972).

The arenitic, partly amalgamated, beds reflect high energy environments (bioclastic rudites, hardgrounds, calarenites with hummocky cross-bedding), which likely indicate stages of lowered sea level (SEIDEL 1974). Of particular interest are synsedimentary deformed beds in the Lower Muschelkalk (slumps, slides and debrites) which are recently explaines as seismically induced resedimentaion (SZULC 1993, VOIGT & LINNEMANN 1995, KNAUST 1996, RÜFFER 1996) and will be discussed at the outcrops. Although the Lower Muschelkalk shows only minorfacies variations, continuance of the Thuringian Basin is indicated by the increasing average clay content and thinner storm beds in comparison, to the eastern and western flanks of the basin.

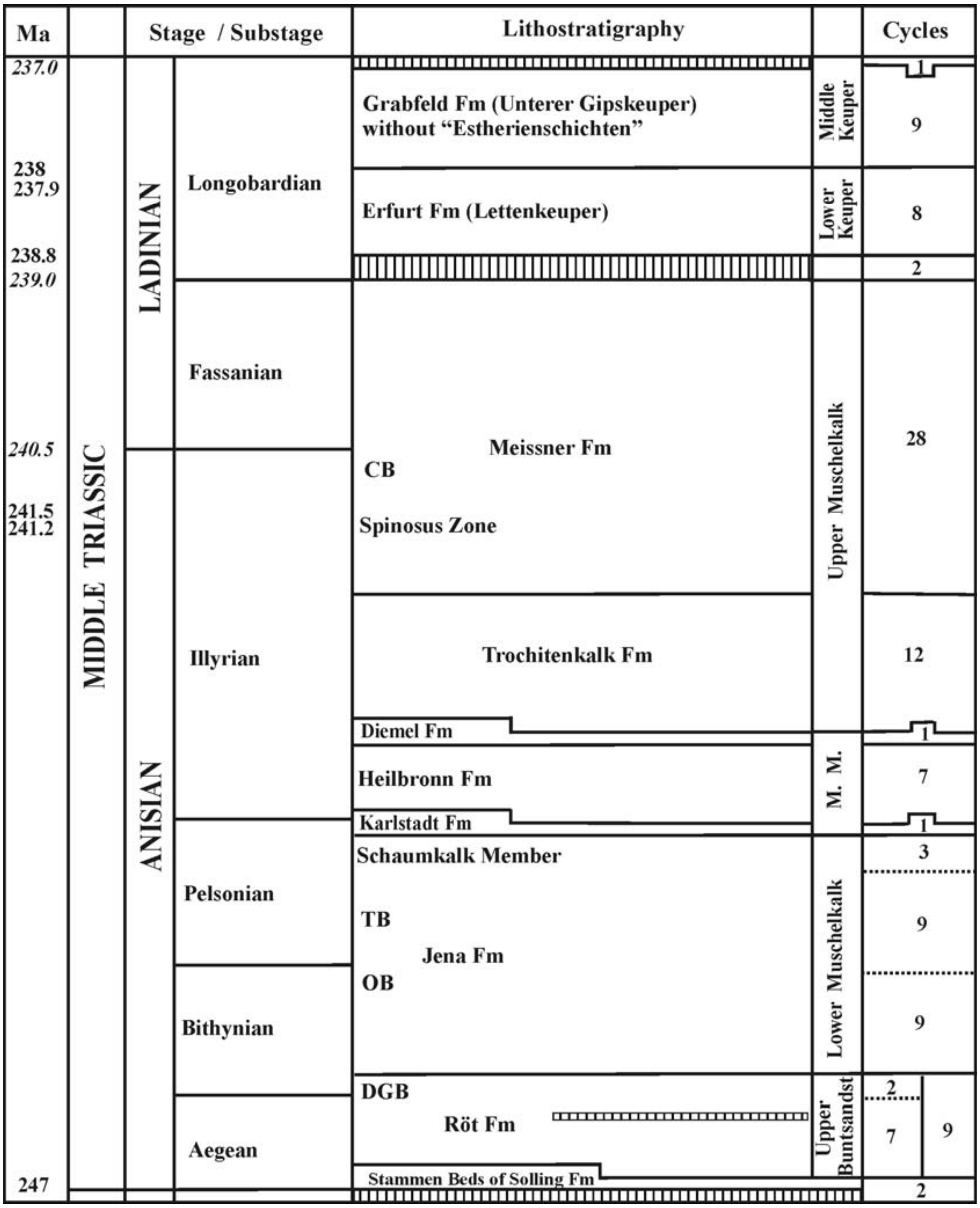


Fig. 2: Correlation of the Germanic Middle Triassic with the international chronostratigraphic scale, short eccentricity cycles and radiometric numerical ages. Further details see Fig. 1 (BACHMANN & KOZUR, 2004).

Evaporites, such as dolomitic marls, gypsum and even rock salt, dominate the Middle Muschelkalk and were deposited during temporary hypersaline conditions of the Muschelkalk sea. The transition to the Middle Muschelkalk is characterized by yellow, platy to laminated dolomites and stromatolites, which turn to marly unfossiliferous dolomites (Karlstadt Formation). The middle part (Heilbronn Formation) comprises anhydrite and rock salt, which was dissolved unter the influence of groundwater in the subsurface of the basin margins. Nevertheless, thickness maps of complete sections reflect a superimposed trend to separated depocentres of halitic deposits in southern Thuringia/Franconia and central Thuringia (SEIDEL 1995). Dolomitic limestones, with continuously increasing faunal diversity, represent the top of the Middle Muschelkalk (Diemel Formation).

The Upper Muschelkalk limestones and marls of Thuringia were deposited in an open marine environment, reflecting enhanced water exchange with the Tethys due to the opening of a sea strait in the area of southern Germany. In the excursion area, thick-bedded bioclastic limestones (predominantely crinoids and bivalves) represent the basal Trochitenkalk Formation (5 – 10 m), which can contain thick oolite bodies locally. The upper part (Meißner Formation, 40 – 50 m) consists of alternating thick-bedded to platy limestones and grey marls and mudstones (SEIDEL 1995), which were deposited in a subtidal storm-dominated environment (AIGNER 1985). The Upper Muschelkalk especially is very rich in fossils and contains the endemic evolution row of the Germanic Ceratites, but is not the subject of our excursion.

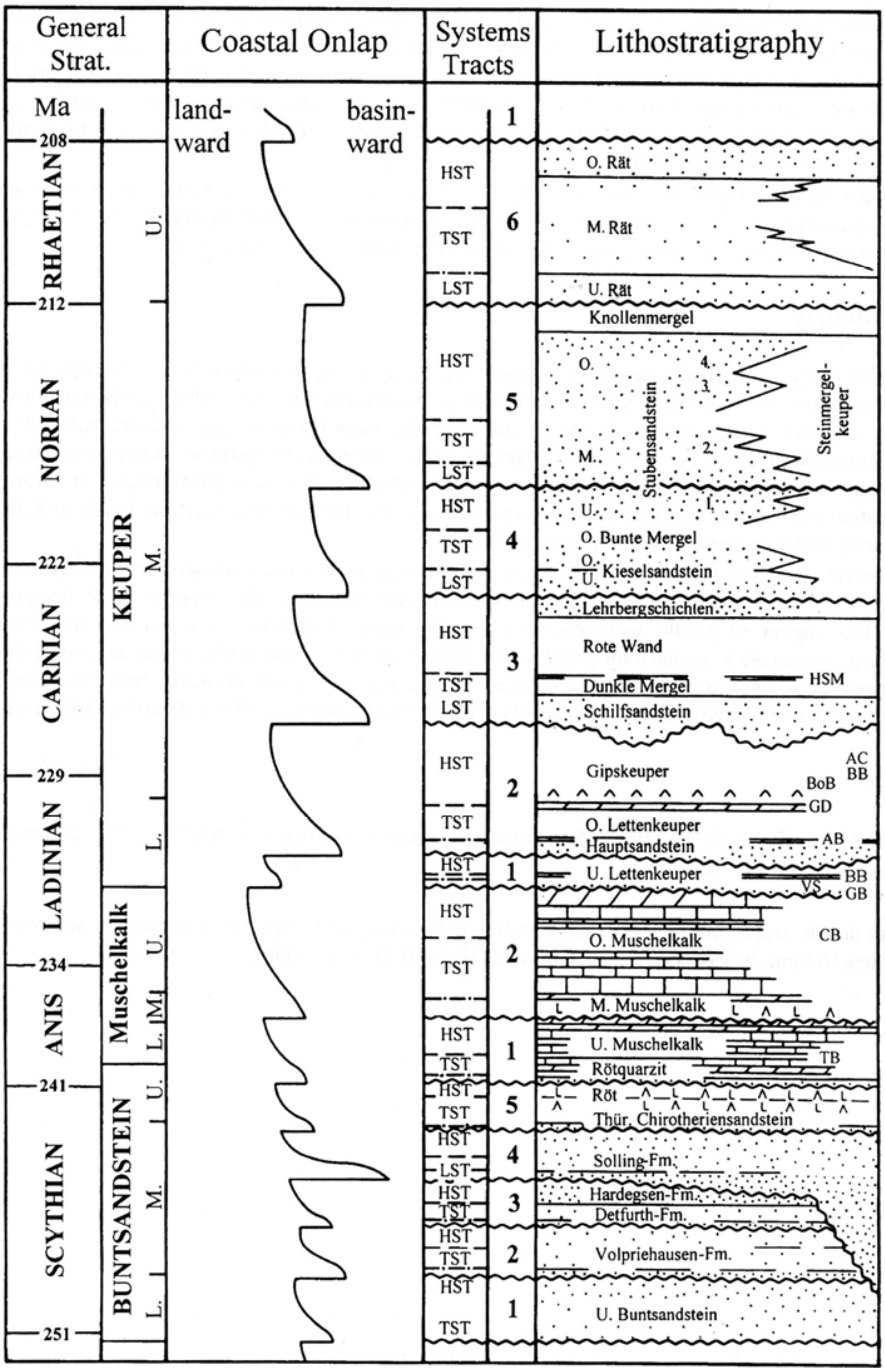


Fig. 3: Sequence stratigraphic framework of the Germanic Triassic as originally published bay Aigner & Bachmann (1992), modified. Not to scale.

The Keuper

The term “Keuper“ is derived from a Franconian dialect name for brittle shale. According to EMMERT (1994), the teacher HORNSCHUCH was the first (1791) to use the term in a stratigraphical sense. In a description of the regional geology of the “Weser Osnabrück Bergland“ (mountainous region), HOFFMANN (1825) already called the strata between the Muschelkalk and “Gryphea Beds“ (Liassic) the “Keuper Formation“. Since the monograph of FRIEDRICH VON ALBERTI (1834), Keuper is defined as the uppermost unit of the Triassic, including the Rhaetian.

1 Introduction

Thuringia is a classical region for investigations of the Keuper in Germany. Research of the Keuper started in the first decade of the 19th Century. The Keuper sediments are located in two areas: in the “Thüringer Becken” (Thuringian Basin) and South Thuringia. The Thuringian basin is a geomorphological unit, which is bounded by the Harz Mountains in the north and the “Thüringer Wald” (Thuringian Forest) and the “Thüringer Schiefergebirge” (Thuringian Slate Mountains) in the south (Fig. 4a, 4b). In the Thuringian Basin the occurrences of the Keuper are limited to the central parts of this depression. The best outcrops are situated in regional fault zones, such as the Eichenberg-Gotha-Saalfeld Fault zone. The excursion will concentrate on this Keuper area. In South Thuringia, the Keuper occurs in the Grabfeld depression, where the transition to the Keuper of Franconia takes place.

In the Thuringian Basin the Keuper is characterised by a more or less complete succession with a dominance of pelitic series, and a high portion of evaporitic sediments. The sandstone horizons in the Lower and Middle Keuper have a Fennoscandic origin, sandstones from the Vindelician Massif are very rare or missing. Therefore, the Thuringian Keuper belongs to the basinal deposits of northern Germany in contrast to the more marginal Keuper of southern Germany. The thicknesses of the complete section vary from 400 to 650 m (Fig. 4c). The axis of the depocenter is to the northeast of the depression (Fig 4c).

The stratigraphical subdivision of the Thuringian Keuper has a long history, therefore a very detailed stratigraphy exists (DOCKTER et a. 1970). According to the new proposal of the German Keuper Working Group, the basinal subdivision (Tab. 1a, 1b) can be used for Thuringia. In accordance with this subdivision the Keuper in the Thuringian Basin can be subdivided into six formations.

For the Erfurt Formation and the Arnstadt Formation the type sections are defined in Thuringia. Both sections will be visited. Further, we will view a most important reference section of the Exter Formation (Rätkeuper), including the transition to the overlying Liassic. Such sections are not often found in Germany. Additional topics of the excursion are discussions on the cyclicity of the the sedimentary succession and on the depositional environments. With these outcrops, the excursion participants will visit all relevant parts of the Thuringian Keuper in the order from top to base. Most of the important formation boundaries will be visited.

Table 1a

Ma		Stage	Substage	Lithostratigraphy				
199.6	UPPER TRIASSIC	RHAETIAN		Triletes Beds			Exter Fm.	Upper Keuper
				Contorta Beds				
				Trossingen Fm. (Knollenmergel)	Postera Sandstone			
				uppermost Löwenstein Fm. (4. Stubensandstein)	uppermost Arnstadt Fm.	lower & middle Postera Beds		
205								
206		NORIAN	Sevatian					
211			Alaunian	Löwenstein Fm., pars (1. - 3. Stubensandstein + 1. - 3. Hangendletten, uppermost Obere Bunte Mergel)	Arnstadt Fm.			Middle Keuper
216			Lower Norian ("Lacian")					
225								
226		CARNIAN	Tuvalian	Mainhardt Fm. (Heldburggips / Obere Bunte Mergel, pars)	Weser Fm. (Oberer Gipskeuper)			
				Hassberge Fm. (Coburg-Sandstein and Blasensandstein)				
				Steigerwald Fm.: Lehrberg Beds				
				Steigerwald Fm.: Rote Wand				
231			Julian	Stuttgart Fm: Dunkle Mergel				
				Stuttgart Fm: Schilfsandstein				
			Cordevolian	upper Grabfeld Fm. ("Estherienschichten")				
237								

Correlation of the Germanic Upper Triassic with the international scale and numerical ages. Rhaetian base not yet decided upon (probably at 206 to 205 Ma) (BACHMANN & KOZUR 2004).

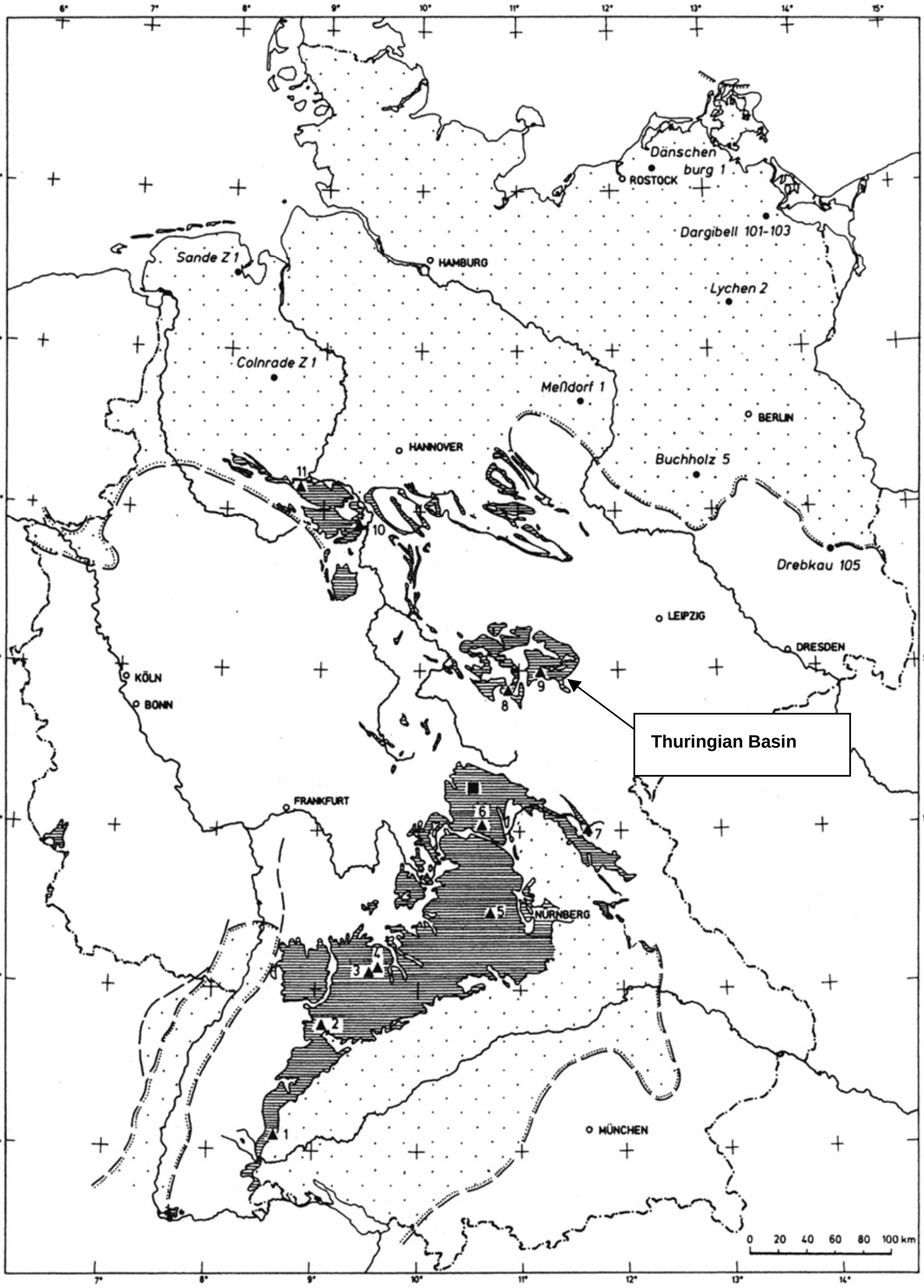


Fig. 4a: Keuper Distribution.

Outcrop areas (horizontally shaded regions), subsurface areas (stippled regions).

Important boreholes (e. g. Colnrade Z1)

Type sections 1-11: 1 - Trossingen, 2 - Stuttgart, 3 - Löwenstein, 4 - Mainhardt, 5 - Steigerwald, 6 - Hassberge, 7 - Benk, 8 - Arnstadt, 9 - Erfurt, 10 - Weser, 11 - Exter; black square: Grabfeld.

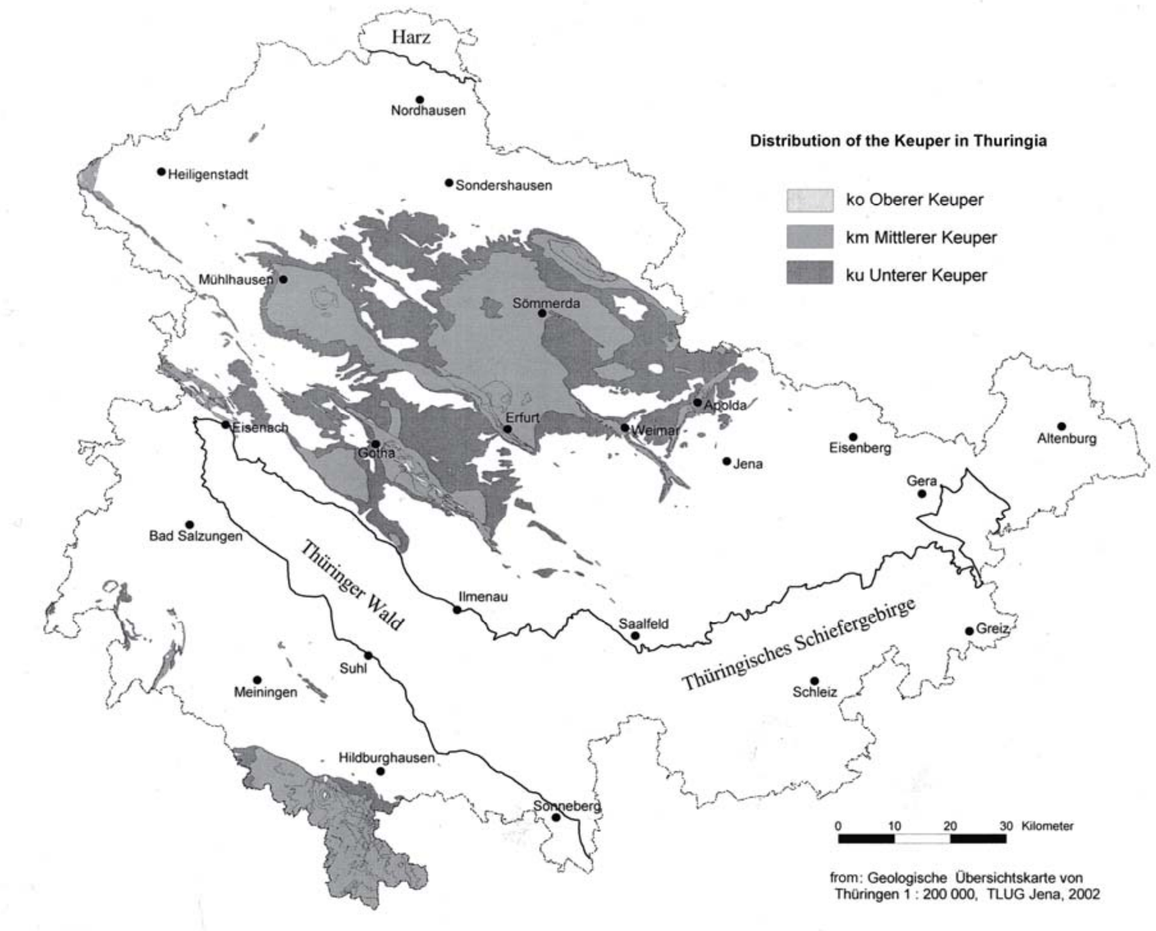


Fig.4b: Distribution of the Keuper in Thuringia (Stratigraphie von Deutschland – BEUTLER et al. (2005).

2 Palaeogeography

During Early and Middle Keuper times the palaeogeographical situation and the internal subdivision of the Germanic Basin was nearly the same as in Muschelkalk times. The basin was surrounded to the north and east by the surrounding Fennoscandian and Ukrainian Massifs. In the south, the basin was bounded by the Vindelician-Bohemian Massif. The connection to the Tethyan Ocean, via the East-Carpathian and the Moravo-Silesian Gates, was interrupted after Middle Muschelkalk time.

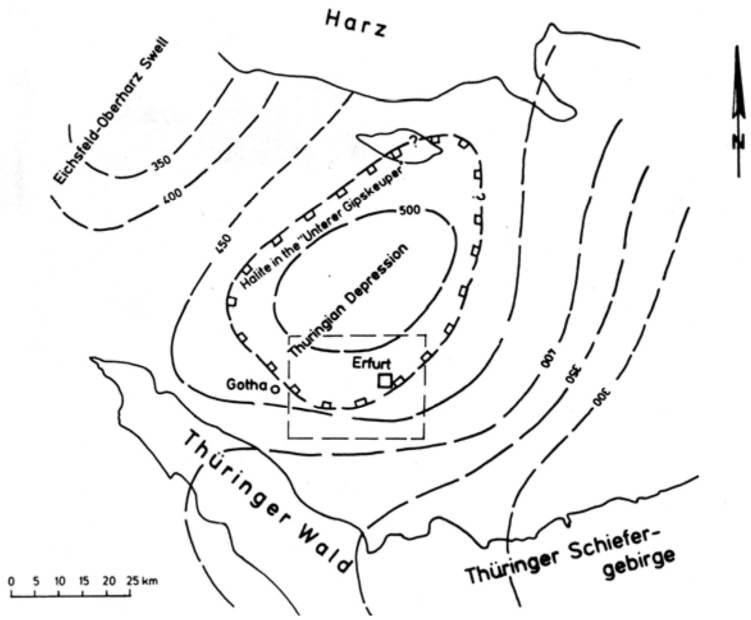


Fig.4c: Generalized thickness of the Keuper in Thuringian Basin.

In the Late Muschelkalk times the so-called Burgundy Gate developed, which was situated between the Armorican Massif and the Vindelician Massif. This connection to the Tethyan Ocean had a considerable influence on the depositional environment of the Lower and Middle Keuper, as minor marine ingressions periodically reached the Germanic Basin in this way. During this period, the southern boundary of the basin shifted southwards; at the same time the Paris Basin came into existence.

In the North Sea area the basin was bounded by the Mid-North Sea High and, to the west, in Great Britain, by the London-Brabant Massif and by the Peninne High (ZIEGLER 1990).

In Late Keuper (Rhaetian) times a new palaeogeographical pattern originated. As a result of the early Atlantic rifting several new gates opened to the west. The high diversity of the fossiliferous Rhaetian deposits of Great Britain indicates that the marine ingressions came from the west, from the Protoatlantic Ocean, but the Burgundian Gate still existed.

A marine connection to the boreal Triassic realm did not exist during the entire Keuper time. The Keuper Basin was generally a rather flat basin, with a rapidly changing lake/sea level. The fluctuations of water level were controlled by climatic and tectonic processes. From the neighbouring highlands, clastic material was transported in different proportions. One can distinguish between clastic influx derived from Fennoscandia ("Nordic Keuper"), and influx derived from Bohemian-Vindelician Massif ("Vindelician Keuper").

3 Biostratigraphy

The biostratigraphical subdivisions of the Keuper are very restricted because the fossil content is not continuous, and most of the fossils are not marker fossils.

The most important fossil group are the palynomorphs, which allow a subdivision of the entire Keuper group. Other fossil groups, e. g. ostracods and megaspores, can be used only for certain parts of the Keuper. A good example is the subdivision of the Upper Keuper with ostracods (WICHER 1951, 1957, WILL 1953, 1969).

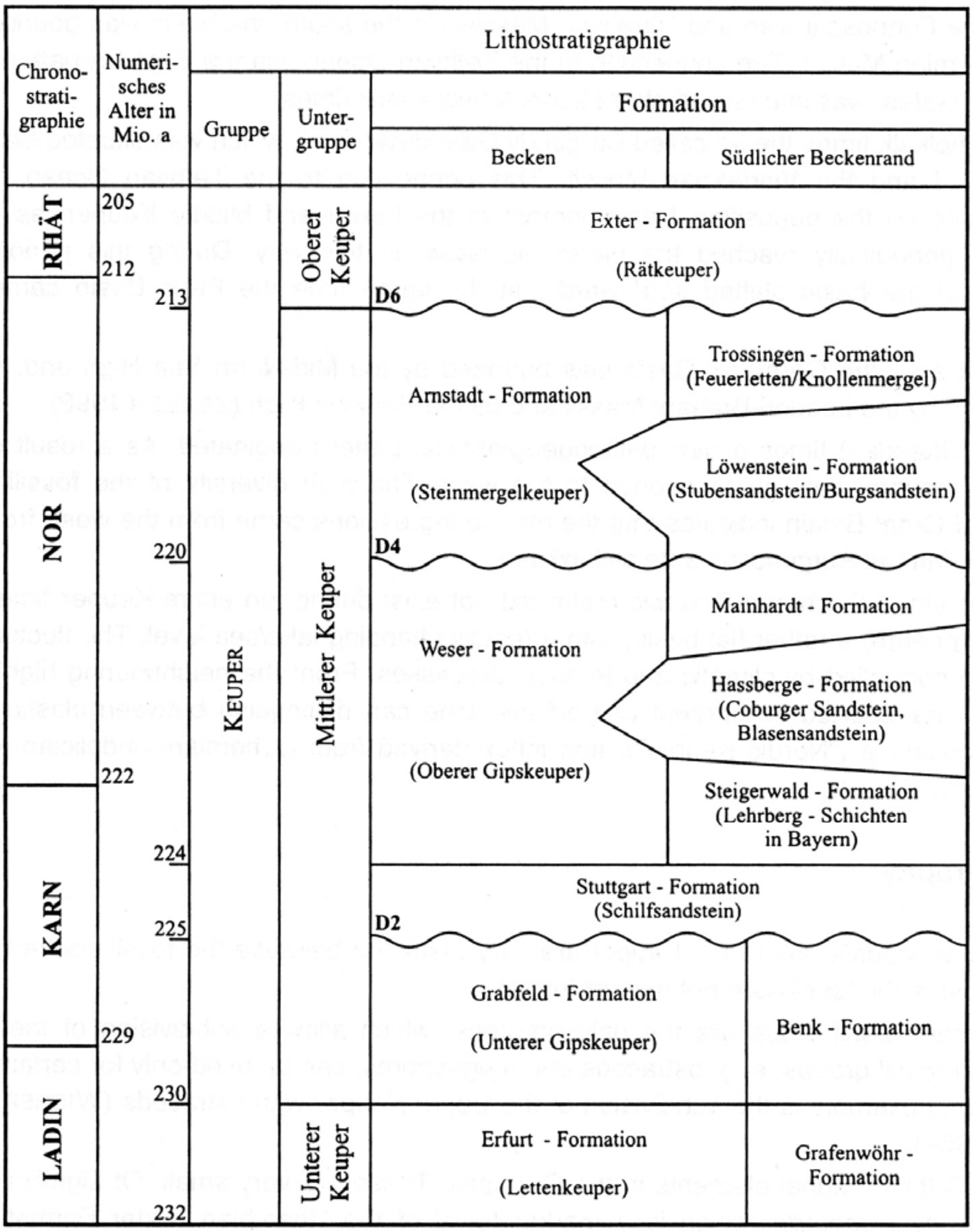
The number of Tethyan faunal elements in the Germanic Triassic is very small. Of significance is the bivalve *Rhaetavicula contorta,* which is a marker fossil of the Rhaethian (Exter Formation) in western parts of Germany.

Other important lamellibranchs and ostracods are *Myophoria kefersteini* in the Bleiglanzbank (Grabfeld Formation), *Simeonella brotzenorum alpina* and *Lutkevichinella oblonga* in the basal beds of the Schilfsandstein (Stuttgart Formation), and *Lutkevichinella keuperea* in the Postera beds of the Rhaetian (Exter Formation). For correlation with the Tethyan Triassic some megaspores can also be used (DOCKTER et al. 1980).

On the chronostratigraphical scale the Keuper comprises the interval of Late Ladinian to Rhaetian; at 24 Ma this is the longest period of the Triassic.

However, the correlation with the chronostratigraphic stages is not exact (Tab. 1).The Ladinian/ Carnian boundary is situated in the lowermost part of the Grabfeld Formation, below or at the Bleiglanzbank. The upper boundary of the Carnian is above the Stuttgart Formation, but below the Lehrberg Beds.

In the Lehrberg Beds the first Norian fossils occur, therefore the Carnian/Norian boundary is situated in the Rote Wand horizon, which is barren of fossils. According to the ostracods, the uppermost boundary of the Norian is well-defined. The ostracod fauna of the Postera beds is typical for the Sevatian. A sharp faunal and microfloral break characterizes the boundary of Upper Norian/ Rhaetian. Also, the upper boundary of Keuper is based on excellent biostratigraphical data, with the first appearance of the Liassic fauna.



Tab. 1b: Lithostratigraphic Time Chart of the Keuper (New Nomenclature).

4 Lithostratigraphy

Lithostratigraphy is the most important stratigraphical method used for subdivision and correlation of the Keuper Group. On account of its long history of research, a highly complex system has developed, and the nomenclature contains numerous synonymous and homologous terms. In 1997, the German Keuper Working Group proposed a new lithostratigraphical nomenclature (Tab. 1).

The Keuper Group is subdivided into three subgroups, i.e. Lower, Middle and Upper Keuper. Each consists, in turn, of formations and subformations (members). Because of significant differences in facies, it is necessary to distinguish between the Keuper deposits of the basin and of the margins. The basinal Keuper comprises six formations and the marginal Keuper nine formations. These formations are integrated in the Keuper subgroups as follows:

The **Lower Keuper** consists of one formation. This formation is defined by the classical outcrop in Erfurt-Melchendorf in Thuringia, the name **Erfurt Formation** is derived from this type locality. The

Lower Keuper in Thuringia is characterized by six fining-upward cycles, consisting of fluviatile sandstone at the base, overlain by grey or multicoloured shale, partly coal-bearing, and a carbonate (dolomite) bed at the top. The distribution of the sandstones at the base is not uniform in the basin. Fig. 5 shows the extent of the individual sandstones in southern Germany. They are characterized by a high content of feldspar, mica and rock debris, hence they are a kind of greywacke.

The clastic influx is derived mainly from the Fennoscandian High, and transported in fluviatile channels which produced a characteristic facies pattern (inset in Fig. 5).

Large areas of the overbank deposits are situated between the shoestring-like channels. Whereas a more brackish environment with dark claystones and fossiliferous carbonates dominates in southern Germany, red beds with gypsum/anhydrite nodules prevail in northern Germany. The boundary of these facies is indicated by the northern limit of the character fossil *Costatoria goldfussi* in the “Grenzdolomit“. Fully marine fossils (bivalves, cephalopodes) are restricted to southern and central Germany; this distribution emphasizes the marine ingressions from SW via the Burgundy Gate.

At the southeastern margin of the basin, in Franconia, a coarse clastic facies prevails, which represents the upper part of the **Grafenwöhr Formation**, spanning the Upper Muschelkalk/Keuper boundary.

The basinal facies of the **Middle Keuper** is subdivided into four formations; and the marginal facies of southern Germany into seven formations (Tab.1). Generally, the Middle Keuper is characterized by frequent evaporitic deposits.

The first evaporitic unit is the **Grabfeld Formation** (syn.: Unterer Gipskeuper, Gipskeuper, Salzkeuper, Pseudomorphosenkeuper).It was first defined by GWINNER (1980) after the “Grabfeld“, a region in northern Bavaria and southern Thuringia. The formation consists of cyclic deposits of grey or multicoloured shales, containing numerous beds of massive or nodular gypsum/anhydrite, and thin dolomite banks. Halite occurs in local depocenters, especially in northern Germany, but also in Thuringia and, presumably, in Baden-Württemberg.

A further subdivision of the Grabfeld Formation can be made on the basis of its cyclicity, and by the use of the thin dolomite banks as marker horizons. Some of these dolomites contain bivalves, gastropods and vertebrate remains, indicating occasional marine ingressions.

The facies distribution of the Grabfeld Formation is shown in Fig. 6. The depocenters of the basin are indicated by the occurrence of halite. Halite is concentrated to northern Germany, where it attains thicknesses up to 1000 m, e. g. in the Glückstadt Graben. A great part of the basin is occupied by sulfate facies. One can distinguish between a “nodular anhydrite facies“ and a “platy anhydrite facies“ (BEUTLER & SCHÜLER 1979). The nodular anhydrite facies is distributed in large areas of the basin center, whereas the platy anhydrite facies is developed at the flanks of the palaeohighs (e.g. Rügen Swell, Eichsfeld Altmark Swell, Hunte Swell), and commonly surrounds the areas of halite deposits.

The marginal coarse clastic facies occurs in a broad area in Franconia. The formation is called **Benk Formation** (syn.: Benker Sandstein, including the sandstone facies of the so-called “Estherienschichten“) after a small village. It is characterized by typical coarsening-upward cycles of grey or multicoloured shales (“Basisletten“) and fine- to coarse-grained, arcosic sandstone (“Dacharkose“). A similar facies was described in wells of the Darss-Zingst region in Mecklenburg-Vorpommern (BEUTLER & SCHÜLER 1979) and at the southern border of the Brabant Massif (DITTRICH 1989).

The Grabfeld Formation is unconformably overlain by the **Stuttgart Formation** (Schilfsandstein Member, including “Dunkle Mergel“ and “Ansbach Sandstein“ Member). In NW Germany erosional gaps of more than 100 m have been observed.

GWINNER (1980) was the first to introduce the term “Stuttgart Folge“. Its type locality is situated in the city of Stuttgart (abandoned quarries at the “Killesberg“ and in the “Feuerbacher Heide“).

The Stuttgart Formation is characterized by a high diversity of facies (WURSTER 1964).One can distinguish between fluviatile channel facies and overbank deposit facies. The channel fill consists commonly of thick greywacke-like sandstones, intercalated by grey and red shales. Sedimentary structures, e.g. ripple lamination, cross-bedding, and intraformational conglomerates indicate a high energy system. Pelitic rocks are dominant in the overbank deposits. Intercalated sandstones are thin and characterized by parallel bedding. A distinct pedogenic overprint with root horizons (partly oxidised), vertisols and haematite nodules is commonly found.

Plant remains (*Equisetites arenaceus*, *Calamites sp.*), megaspores (e.g. *Narkisporites harrisi*), and (partly) ostracods are rather frequent. Bivalves and gastropods occur only in a few places.

The mapping of the facies distribution started with THÜRACH (1888/89) in the outcrop area of Franconia. WURSTER (1964) was the first who gave a comprehensive description ("Geologie des Schilfsandsteins").

Fig. 7 shows a facies map of the Stuttgart Formation using WURSTER`s data from south Germany and the well data of northern Germany. The channel systems are shown in two different scales. WURSTER`s surface mapping resulted in a facies pattern which is characterized by channel widths from 500 to 1000 m. In contrast, the widths of the channel systems, resulting from the well interpretations, vary from 5 to 15 km. Despite this, both scales have a good fit to each other. The clastic material of the Schilfsandstein is derived from the Fennoscandian High and, in this channel system, was transported from the area of the Baltic Sea both to the SW, via the Burgundy Gate, and to the SE, via the East-Carpathian and the Moravo-Silesian Gates, into the Tethyan Basin. Origin of the channels and the sedimentation in the channels both support a connection with global sea level changes.

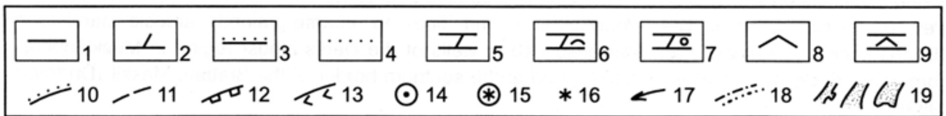
Without a sedimentary break, the second evaporitic unit of the Middle Keuper follows, the Weser Formation. This formation was defined by DUCHROW (1984), however its lithostratigraphical range had to be changed. The type locality is situated north of the village Polle, in the valley of the Weser river. The lithological composition of this formation is similar to the Grabfeld Formation. Pelitic rocks with gypsum/anhydrite nodules and layers, massive gypsum/anhydrite beds, and local halite horizons are the main components of the succession.

The dominant rock colours are red-brown and violet; green rock colours are associated with sulfate intercalations. Dolomite beds are not common, but are of special importance for regional correlation. In the lower part of the section is the so-called Lehrberg Horizon, consisting of three dolomite banks with lacustrine fauna, intercalated with green, violet and red-brown shales. This marker horizon can be correlated from Baden-Württemberg to Lower Saxony.

Another most important horizon for regional correlation is the so-called "Heldburg Gips" (NAUMANN 1911). This gypsum bed is up to 10 -15 m thick and is considered to be the uppermost horizon of the Weser Formation. Based on the large regional distribution from northern Germany to Thuringia, the Heldburg Gips is very useful for the definition of the boundary between the Weser Formation and the overlying Arnstadt Formation.

The marginal facies equivalent of the Weser Formation is characterized by the intercalation of two thick sandstones in the middle part. Due to these intercalations, the succession can, from top to bottom, be subdivided into three formations:

Mainhardt Formation **Hassberge Formation** **Steigerwald Formation**.



1-shale; 2-dolomitic shale; 3-sandstone / shale alternations; 4-sandstone; 5-dolomite; 6-dolomite with shells; 7-oolitic dolomite; 8-nodular anhydrite; 9-platy anhydrite; 10-margin; 11-facies bonduarry; 12-extension of halite; 13-extension of Lehrberg Beds; 14-finds of *Costatoria goldfussi*; 15-finds of cephalopods; 16-redbeds; 17-currents of clastic influx; 18-extension of sandstones; 19-channel systems

Legend for the Figs. 2 - 7.

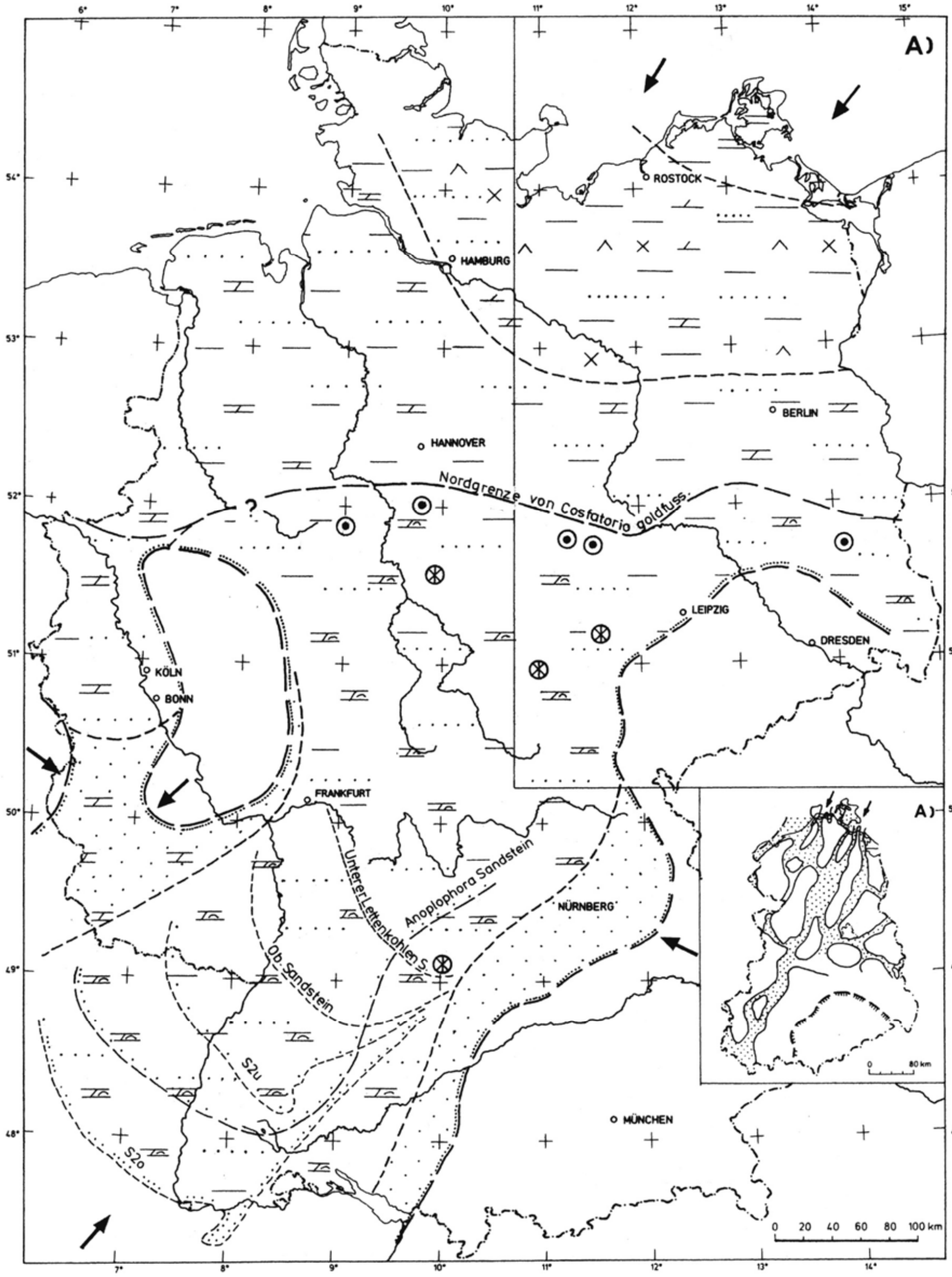


Fig. 5: Generalized facies map of the Lower Keuper (Erfurt Formation).

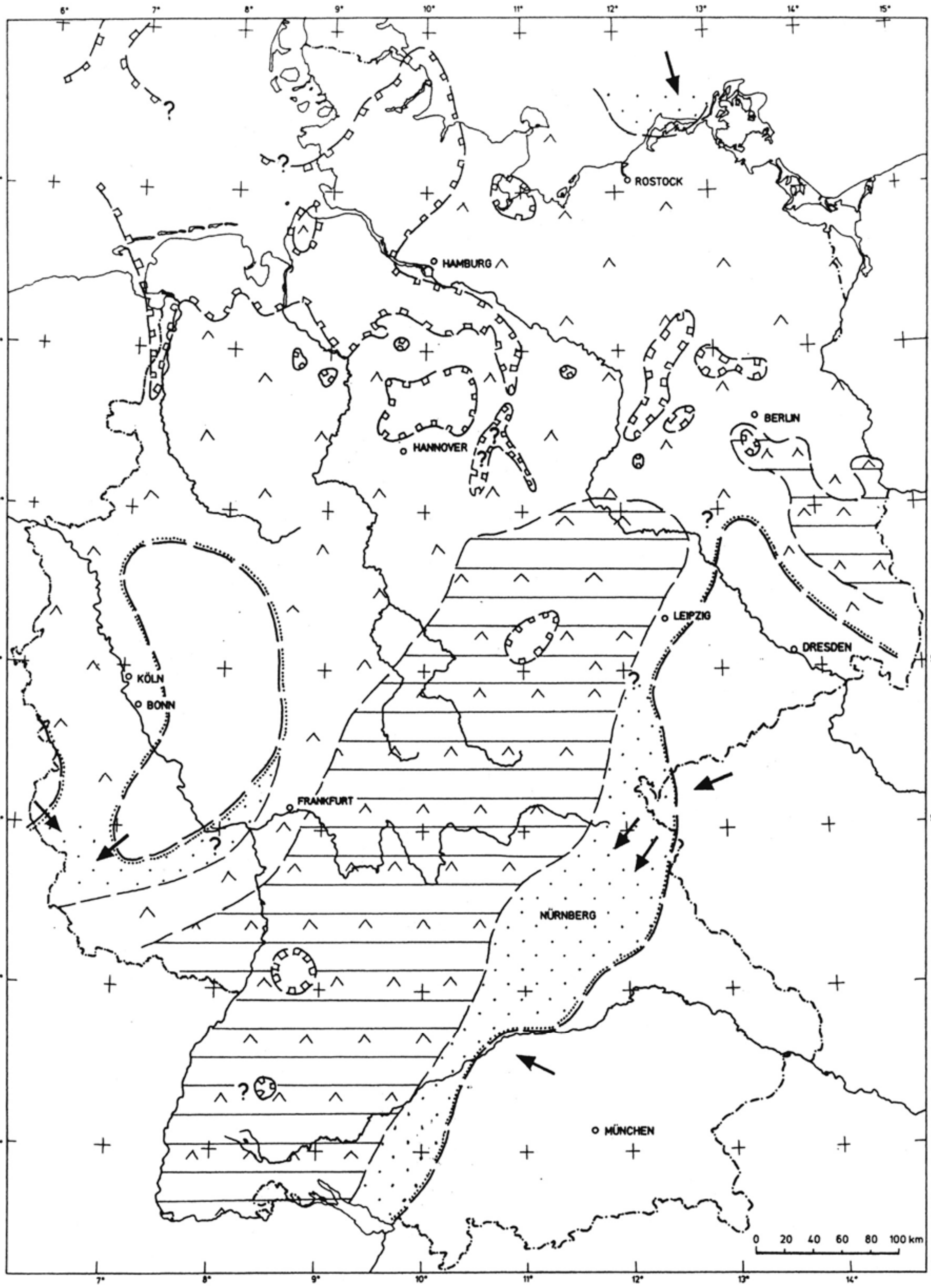


Fig. 6: Generalized facies map of the Grabfeld Formation (Unterer Gipskeuper).

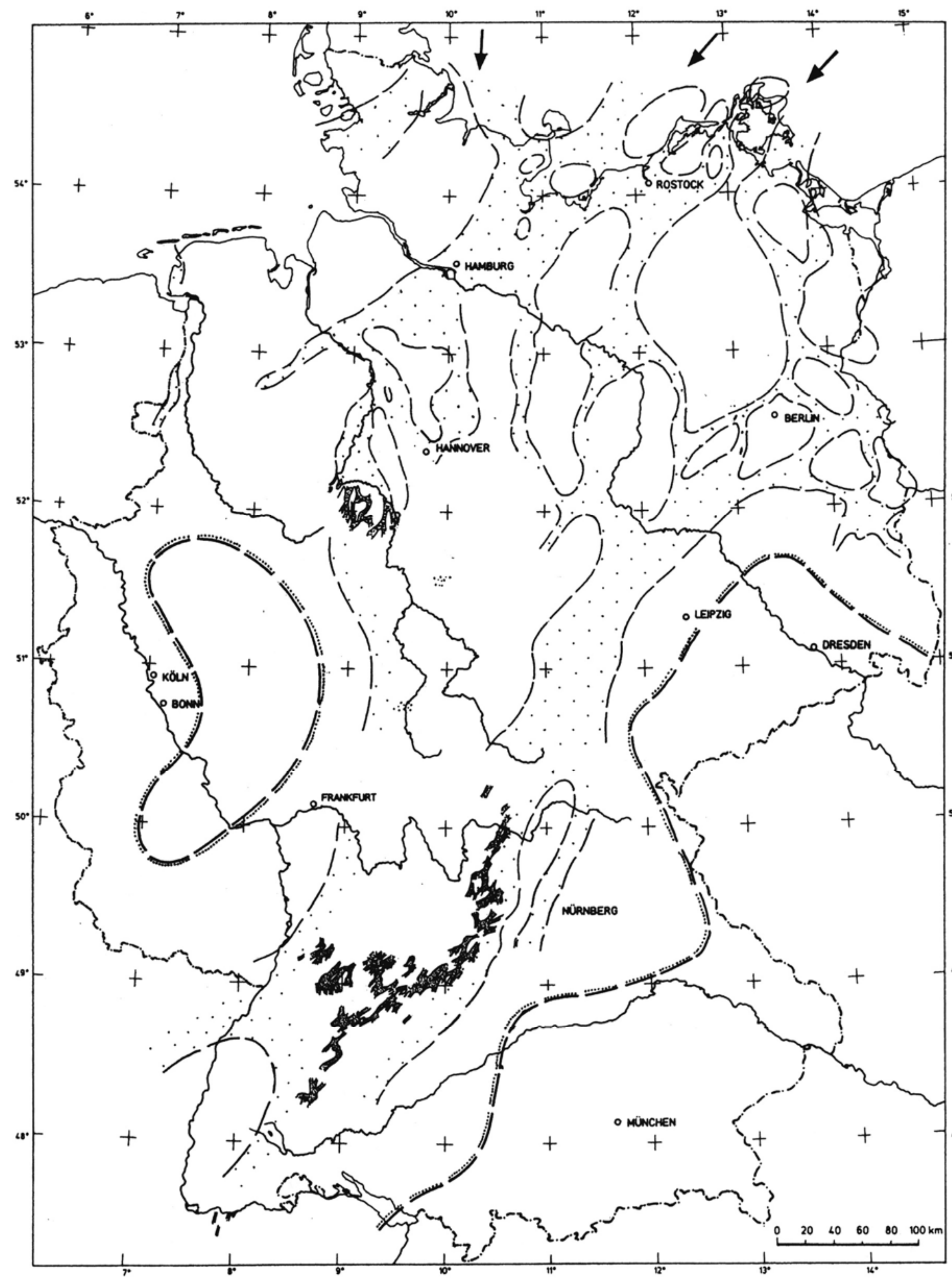


Fig. 7: Generalized facies map of the Stuttgart Formation (Schilfsandstein).

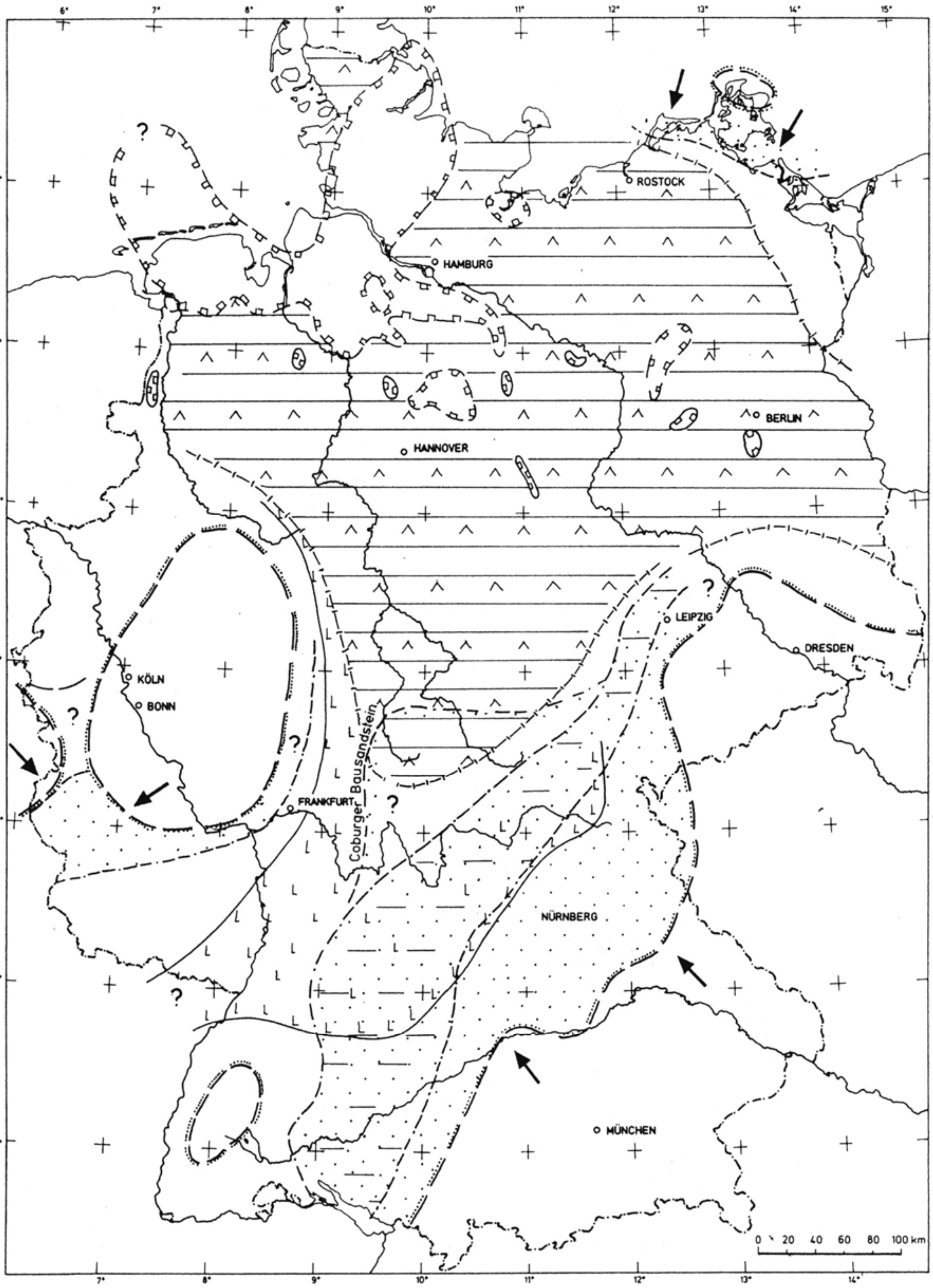


Fig. 8: Generalized facies map of the Weser Formation (Oberer Gipskeuper).

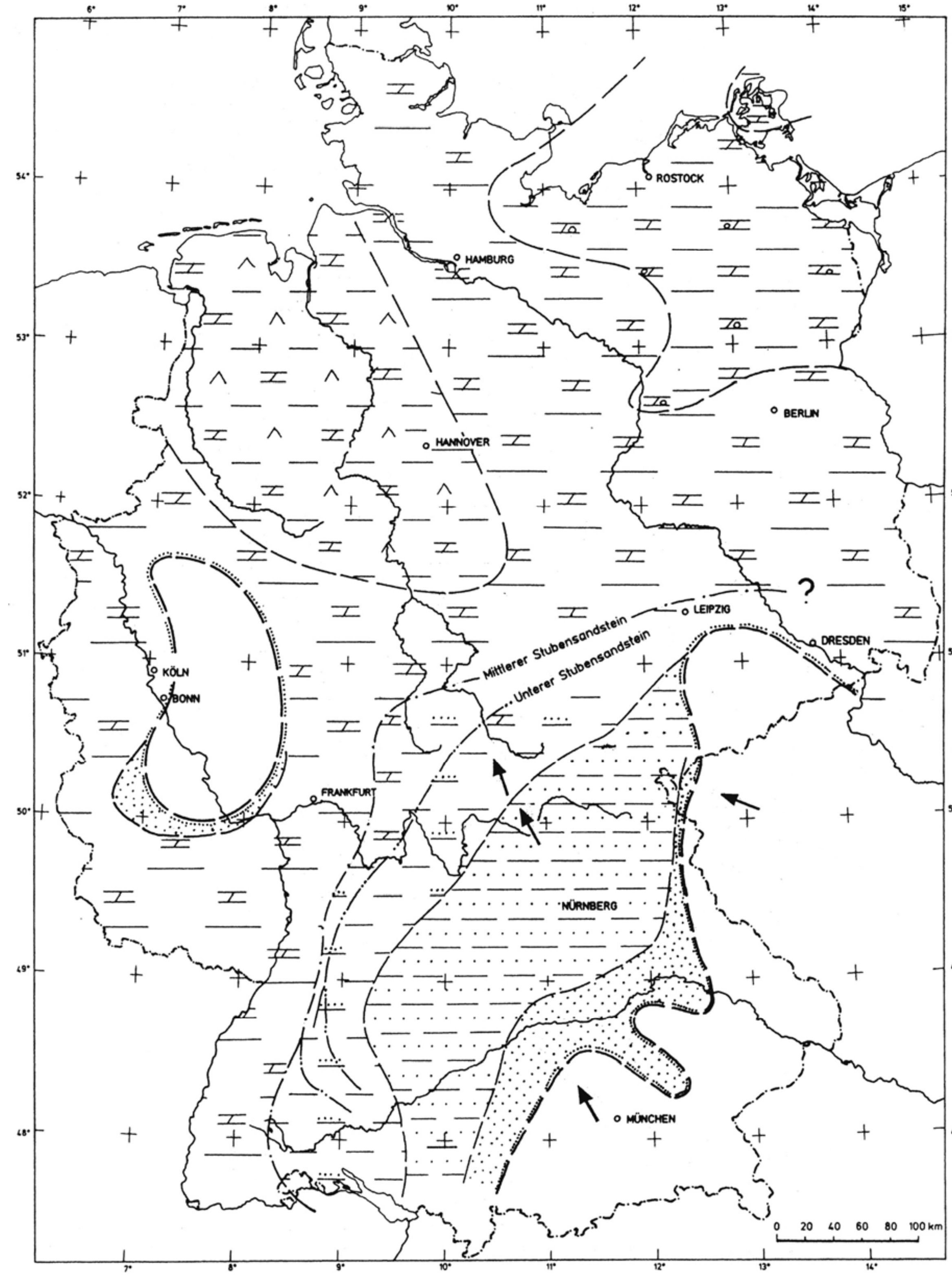


Fig. 9: Generalized facies map of the Arnstadt Formation (Steinmergelkeuper).

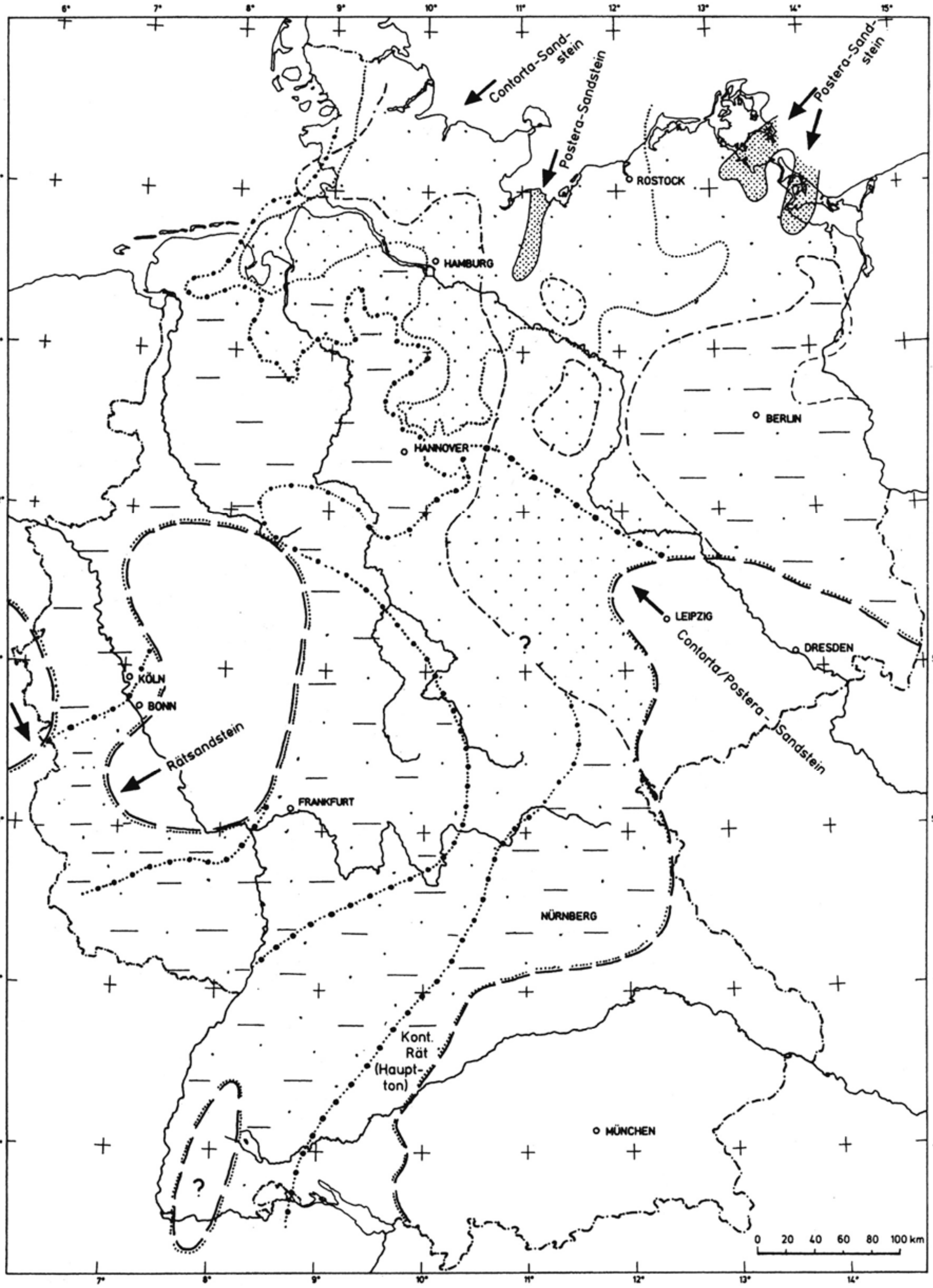


Fig. 10: Generalized facies map of the Exter Formation (Rätkeuper).

The Steigerwald Formation comprises two members, the so-called Rote Wand (Baden-Württemberg) and the Lehrberg-Schichten. Confusingly, in Bavaria the whole interval is also called Lehrberg-Schichten. The Rote Wand beds consist of red-brown, occasionally green, shales with gypsum/

anhydrite nodules, which are overlain by the multicoloured shales with up to three characteristic beds of the Lehrberg-Schichten.

The name of the Steigerwald Formation is a new proposal, and named after the type region Frankenhöhe/ Steigerwald. The proposed type section, Langenzenn, is situated here.

The following Hassberge Formation is characterized by two sandstone intervals, which in Franconia are called: Blasensandstein and Coburg Sandstein. In Baden-Württemberg they are known as Kieselsandstein. These fluvial sandstones are derived from the Bohemian-Vindelician High. They are fine- to coarse-grained, partly conglomeratic, contain feldspar, kaolin and mica, and are hence arcosic sandstones. They were deposited in a high-energy, fluviatile channel system, as indicated by the dimensional cross-bedding laminations, layers of mud pebbles and, commonly, a sharp erosional base. Overbank deposits, shales and thin dolomites, are intercalated. Plants and vertebrate remains are the most common fossils.

The formation name is a new term and derived from the Hassberge region in Franconia; the proposed type or reference section is the quarry Schönbachsmühle near Ebelsbach.

Higher up is the Mainhardt Formation. It consists of multicoloured shales with layers of nodules and massive gypsum/anhydrite and some dolomite horizons.

The new formation name is derived from the type region Mainhardter Wald in south Germany. The proposed type locality is near Kümmelsbach, in the area of Mainhardt- Mönchberg.

Fig. 8 shows the facies distribution of the **Weser Formation**, including the limits of the marginal sandy facies, especially of the Hassberge Formation.

Remarkably, the facies distribution is similar to the Grabfeld Formation. The depocenters are indicated by the halite deposits. The main facies in the basin is characterized by gypsum/anhydrite. One can distinguish, analogous to the Grabfeld Formation, a nodular and a platy anhydrite facies. The nodular facies has the greatest extension in the basin, whereas the platy facies is restricted to the more marginal positions. In Fig. 8, the massive Heldburg Gips is indicated by a special symbol.

The marginal areas with clastic sediments are larger than in the Grabfeld Formation, both in southern Germany, as well as in the Darss-Zingst region, and at the southern border of the Brabant Massif .This is due to the uplift during the early Cimmerian tectonic movements.

As a result, parts of the sedimentary cover have been eroded (BEUTLER 1979). In many parts of the basin, therefore, the base to the overlying Arnstadt Formation is characterized by a very distinct unconformity, the “Early Cimmerian Main Unconformity“ (BEUTLER & SCHÜLER 1979).

The **Arnstadt Formation** consists of multicoloured and grey shales alternating with grey dolomite beds. The traditional German term for these dolomites is “Steinmergel“. For that reason the original name is “Steinmergelkeuper “. The new term is derived from the town of Arnstadt, where the proposed type locality of the “Drei Gleichen“ hills is situated. This facies is widespread in northern and central Germany. The facies diversity is not significant and consists of minor changes in rock colour (grey dominant in basinal parts, red dominant in marginal parts), and a slight increase in the gypsum/anhydrite to NW, to the central parts of the basin.

In southern Germany the stratigraphical equivalent of the Arnstadt Formation consists of two formations:

Trossingen Formation **Löwenstein Formation**.

This corresponds to the traditional subdivision of Stubensandstein (Baden-Württemberg) and Burgsandstein (Bavaria), and of Knollenmergel (Baden-Württemberg) and Feuerletten (Bavaria), respectively.

The Löwenstein Formation consists of an alternation of fine- to coarse-grained, partly conglomeratic and arcosic sandstones with multicoloured shales. Intercalations of pedogenic dolomites (dolcretes) are common. The ratio of sandstone/shale increases from west to east.

The proposed type locality is the “Tobelschlucht“ near Spiegelberg in the “Löwensteiner Berge“. Similar to the sandstones of the Hassberge Formation, the clastic material of the Löwenstein Formation is derived from the Bohemian-Vindelician Massif. It was transported by high energy fluviatile systems, as indicated by cross-bedding, conglomeratic horizons, and the architecture of the channel fills.

The overlying Trossingen Formation consists of red-brown and violet-brown pelitic rocks with nodules and banks of dolomite, hence the traditional names “Knollenmergel“ (i. e. “Nodular Marls“, in Baden-Württemberg) and “Feuerletten“ (“Fire Shales“ in Bavaria). This formation is renowed because of its fossil deposits in Trossingen and Halberstadt, which contain a rich vertebrate fauna (e. g. with *Plateosaurus longiceps*). Coarse clastics are restricted to the eastern marginal facies.

The surroundings of the town Trossingen were selected as the type area. The facies map of the Arnstadt Formation (Fig. 9) shows the interfingering of the basinal pelitic facies, with increasing gypsum content to the NW, and the marginal clastic facies of southern Germany, which is identical with the Löwenstein Formation. The so-called Mittlere Stubensandstein has the greatest westward extension (BRENNER 1973).

In contrast to its indistinct lower boundary of the Arnstadt Formation, the upper boundary is commonly very sharp. The base of the overlying **Exter Formation** is an unconformity, whereby parts of the Arnstadt Formation are commonly eroded. The name of the formation was originally coined by DUCHROW (1984), but in a higher stratigraphical rank (“Exter Group“). The type region is the valley of the Exter river in Nordrhein-Westfalen. Traditional terms for the Exter Formation are Rätkeuper, Rät or Rhät. According to SCHOTT (1944), the formation can be subdivided in three units (i. e. Members), which are currently known as the Lower, Middle and Upper Rhaetian. This subdivision is based both on facies changes and on the fossil content. The fossils were the reason for the terminology by WILL (1953, 1969). He proposed the following terms (from top to bottom):

Triletes Beds (Upper Rhaetian) **Contorta Beds** (Middle Rhaetian) **Postera Beds** (Lower Rhaetian).

The Postera Beds are characterized by a cyclic alternation of grey and multicoloured shales, fine-grained greenish or light-grey sandstones and of dolomite beds, which commonly have a pedogenic overprint (e. g. dolcretes and silcretes). The cyclicity is yet not well investigated. The name Postera Beds is derived from the lamellibranch *Unionites posterus*, the former “*Anodontophora postera“*. This bivalve occurs mostly in the sandstones and is very common in certain layers. The pelitic horizons partly contain a rich ostracode fauna, which is useful for biostratigraphic subdivision (WILL 1953, 1969). The fossils indicate a brackish environment, but the pedogenic structures suggest a transition to terrigenous conditions. Most of the sandstones (“Postera Sandstones“) have a Fennoscandic provenance, but the clastic material is partly derived from the Bohemian-Vindelician Massif.

A sharp lithological change marks the boundary to the Contorta Beds. The multicoloured sediments of the Postera Beds are overlain by dark, commonly black shales, which contain foraminifers and bivalves (e. g. *Rhaetavicula contorta* and others). These shales interfinger with the deltaic sediments of the Contorta Sandstone, a fine-grained quartz sandstone of high maturity, and of Fennoscandic origin. Only small parts of the clastics were derived from the south. The base of the Contorta Beds is an significant unconformity.

The overlying Triletes Beds contain fauna (ostracods) in a few places. Plant remains dominate, especially megaspores of the genus *Triletes*. This unit is characterized by greenish-grey and locally brown shales in the lower part, and a mica-rich fine-grained sandstone in the upper part.

The boundary to the Liassic is marked by the first appearance of the marine fossil of the Liassic transgression (*Psiloceras psilonotum*).

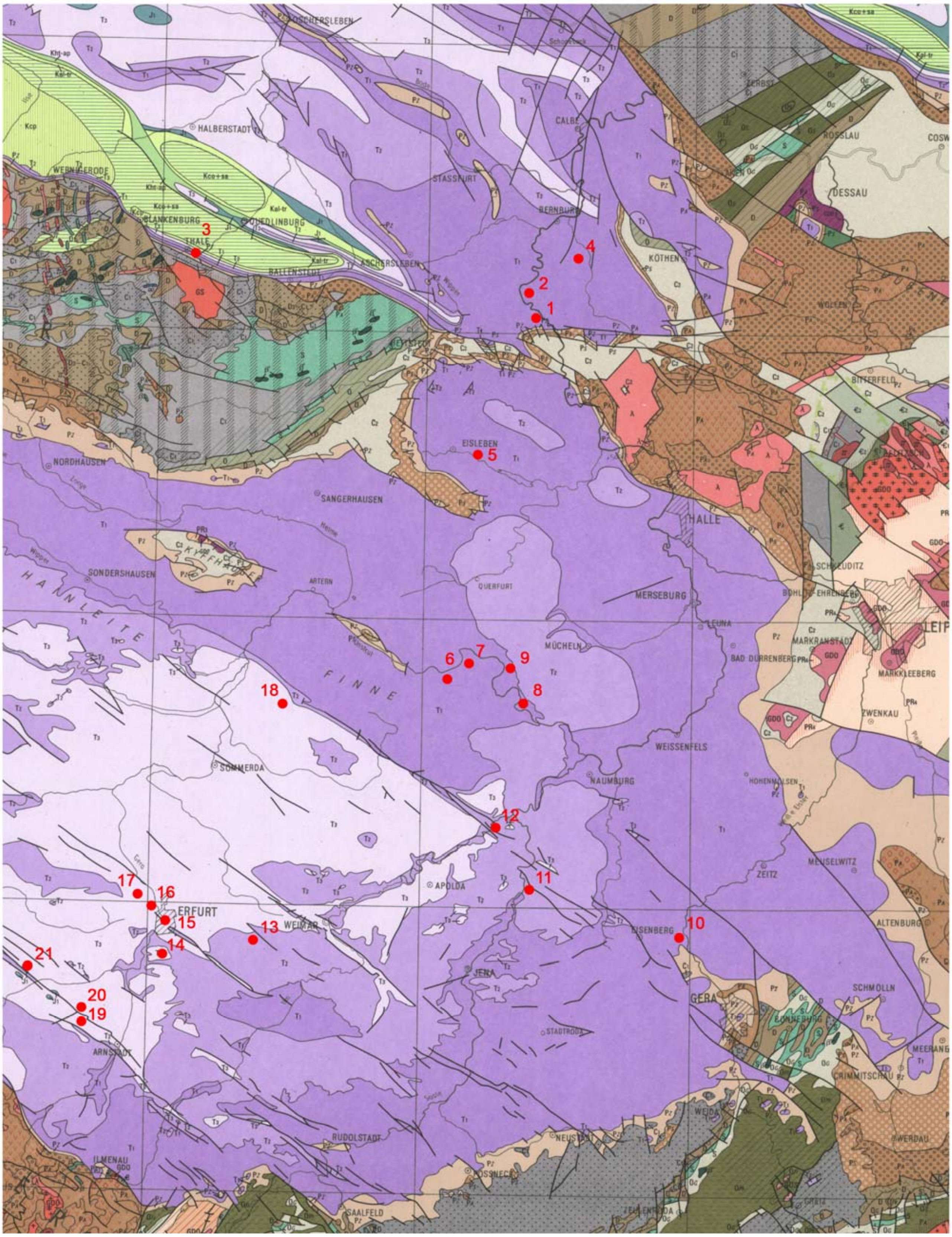
Fig. 10 shows the facies distribution of the Exter Formation. Deltaic sandstone bodies mark the northern part of the basin. Pelites dominate both in NW Germany and in SE Brandenburg.

Characteristic for NW Germany is the high diversity of the fossil-bearing sediments, which is marked by the eastern limit of *Rhaetavicula contorta*. In southern Germany, the regional interpretation of the Exter Formation is difficult because of its extreme thin and erratic development.

Excursion

Stop 1	Nelben (Fulda Fm - Calvörde Fm, PTB)	
Stop 2	Beesenlaublingen (Bernburg Fm)	
Stop 3	Thale (Calvörde Fm)	
Stop 4	Baalberge (Volpriehausen Fm)	
Stop 5	Unterrißdorf (Bernburg Fm)	Friday, 15.07.2005
Stop 6	Großwangen (Bernburg - Volpriehausen Fm)	
Stop 7	Nebra (Hardegsen - Solling Fm)	
Stop 8	Glockenseck (Röt Fm)	
Stop 9	Karsdorf (Röt - Jena Fm)	Saturday,16.07.2005
Stop 10	Caaschwitz (Leine - Fulda Fm, Calvörde Fm, PTB)	
Stop 11	Steudnitz (Jena - Karlstadt Fm)	
Stop 12	Krähenhütte near Bad Sulza (Diemel - Trochitenkalk Fm)	
Stop 13	Troistedt (Meissner Fm)	Sunday, 17.07.2005
Stop 14	Egstedter Trift (Erfurt Fm)	
Stop 15	Petersberg Erfurt (Weser Fm)	
Stop 16	Erfurt-Gispersleben (Stuttgart – Weser Fm)	
Stop 17	Schwellenburg (Weser Fm)	
Stop 18	Groß Monra (Stuttgart Fm)	Monday, 18.05.2005
Stop 19	SW-Hang Wachsenburg (Weser – Arnstadt Fm)	
Stop 20	Burg Gleichen (Arnstadt Fm)	
Stop 21	Kammerbruch (Exter Fm)	Tuesday, 19.07.2005

Geological map without Cenozoic



10 km 5 0 10 20 30 km

- T_3 Keuper, not subdivided
- T_2 Muschelkalk, not subdivided
- T_1 Buntsandstein, not subdivided

Day 1 (15. July 2005):

Buntsandstein in the Subhercynian Depression (Saxony-Anhalt)

Introduction:

In Central Germany, the ~1 km thick mainly clastic Buntsandstein, which represents the lower group of the tripartite classic Germanic Trias, was deposited in the large intracratonic Central European Basin (CEB) in predominantly fluvio-lacustrine environments with marine influences being restricted to parts of the Middle and Upper Buntsandstein (**Fig. 1**). The current lithostratigraphic framework of the mainly clastic Buntsandstein is based on 7 formations. Furthermore, the Buntsandstein reveals a distinct cyclicity of varying magnitude, pragmatically subdivided into 10 to 30 m thick small-scale fining-upward cycles, which are considered to reflect water depth variations in the large lacustrine system of the CEB due to solar-induced short eccentricity cycles. The fining-upward cycles are used for correlations in cores, outcrops and wireline logs (e.g. gamma-ray logs). With the latter they can be mapped over large parts of the CEB, in which the correlations are additionally supported by numerous well-known litho and gamma-ray markers, providing a robust high-resolution log- and lithostratigraphic framework. The correlation of the Buntsandstein with the marine scale is mainly based on conchostracans. Along with magnetostratigraphy, the Buntsandstein can be correlated in detail with the conodont-calibrated Tethyan Lower Triassic.

Stops 1 to 4 are located north of Halle within the Subhercynian Depression (**Fig. 2**), which describes the region dominated by Mesozoic formations north of the Paleozoic Harz horst and south of the outcropping Paleozoic of the Flechtingen block. All these present-day structural elements are the result of the Upper Cretaceous (Coniacian-Campanian) inversion tectonics.

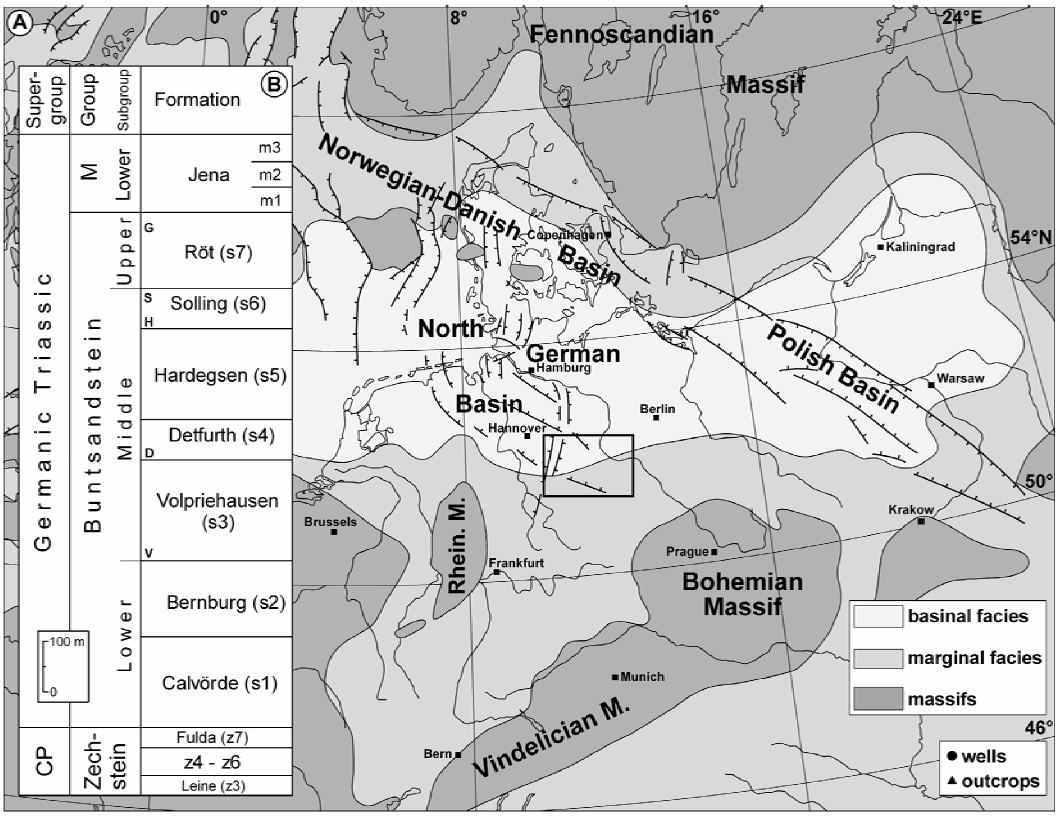


Fig. 1: (a) Buntsandstein paleogeographical map from the Central European Basin (changed after RÖHLING et al 2002) with location of subcrop map shown in Fig. 2. (b) Lithostratigraphy of the upper Zechstein to Lower Muschelkalk in Central Germany. V-G = Buntsandstein unconformities; M = Muschelkalk.

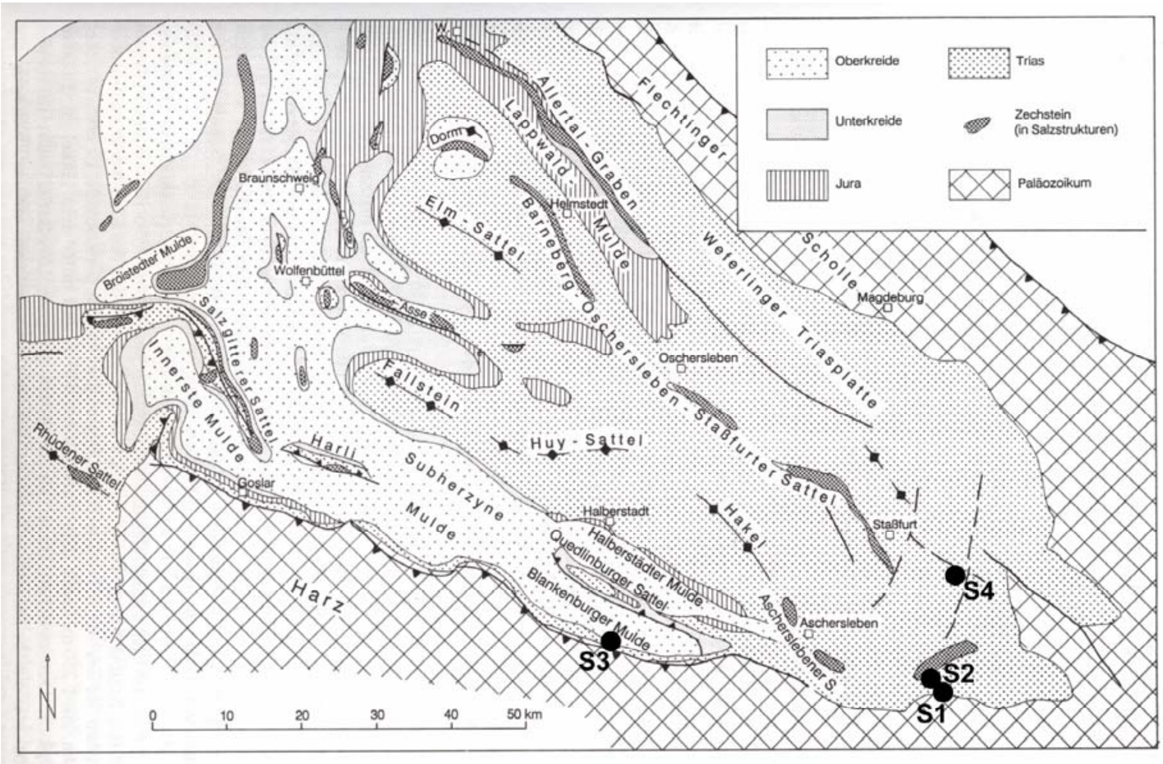


Fig. 2: Pre-Tertiary subcrop map of the Subhercynian Depression (WALTER 1995) with location of outcrops (stops 1 to 4 as S1 to S4).

Stop 1: Uppermost Zechstein to lowermost Buntsandstein near Nelben (Figs. 3-5)

Locality:

Abandoned clay pit "Tongrube an der Saalebrücke", 1 km west of Könnern.

Stratigraphy and sediments:

The section spans about 25 m of Fulda Formation (Zechstein) to lowermost Calvörde Formation (Lower Buntsandstein), which are Late Changhsingian (Permian) to earliest Indusian (Triassic) in age. In terms of magnetostratigraphy, the section encompasses the lower part of the distinctive thick normal polarity interval sn1, which straddles the base of the Buntsandstein and the *Hindeodus parvus*-calibrated Permian-Triassic boundary, respectively. In the Central European Basin, this boundary is indicated by the FAD of the conchostracan *F. verchojanica*.

The mainly clastic succession is composed of predominantly red-brown claystones and sandstones, which are interpreted to represent playa and braided river deposits, respectively. The characteristic features are gray oolitic limestones (so-called "Rogensteine", roestones), which formed in playa lakes.

Points of discussion:

Lithostratigraphic Zechstein-Buntsandstein boundary vs. biostratigraphic Permian-Triassic boundary using, e.g. biostratigraphy, magnetostratigraphy

Lithofacies and sedimentary cycles

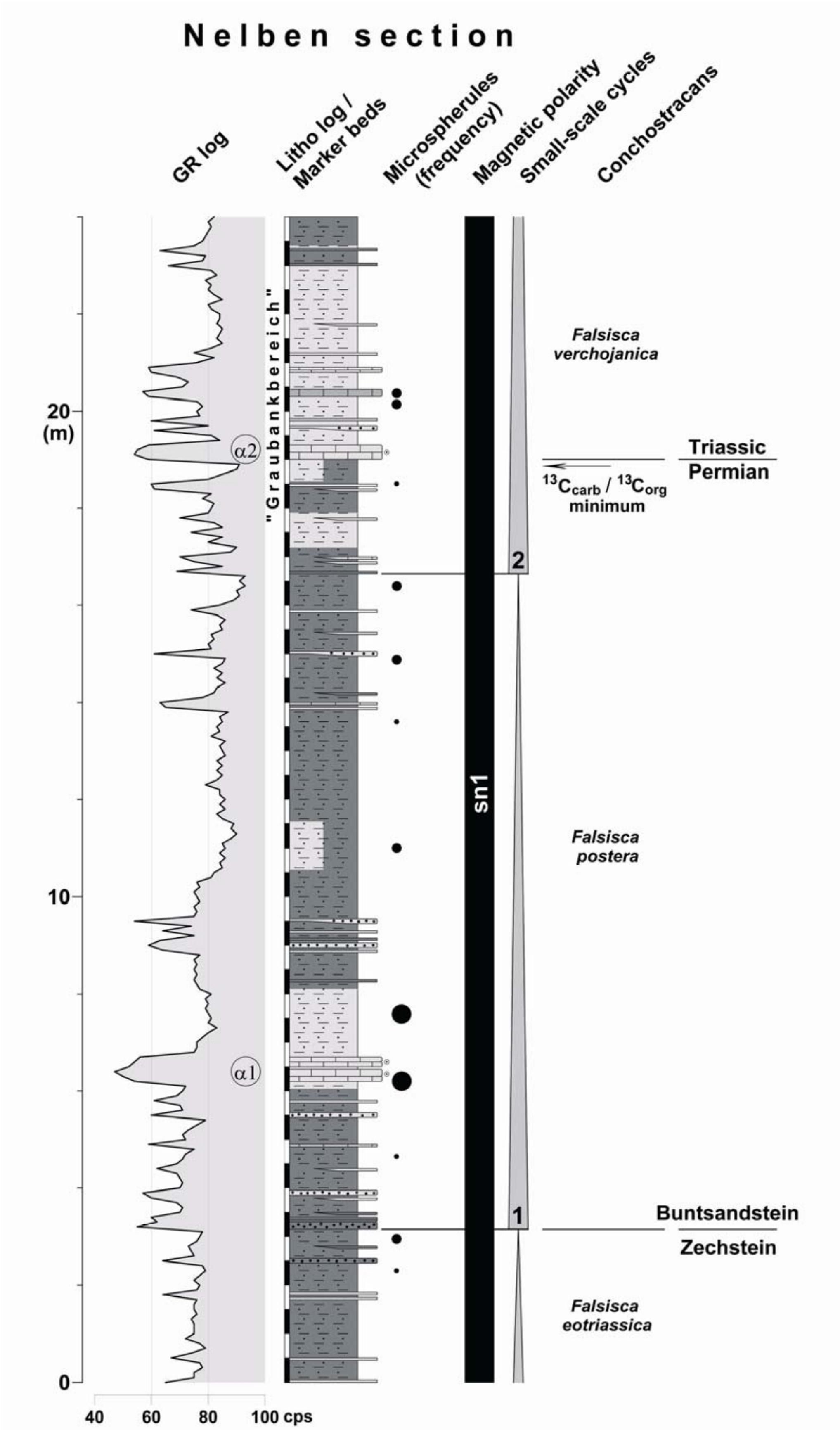


Fig. 3a: Litho-log and gamma-ray log of Nelben section, which spans the uppermost (changed after SZURLIES 1997, using data from KOZUR 1999, KOZUR & BACHMANN 2004).

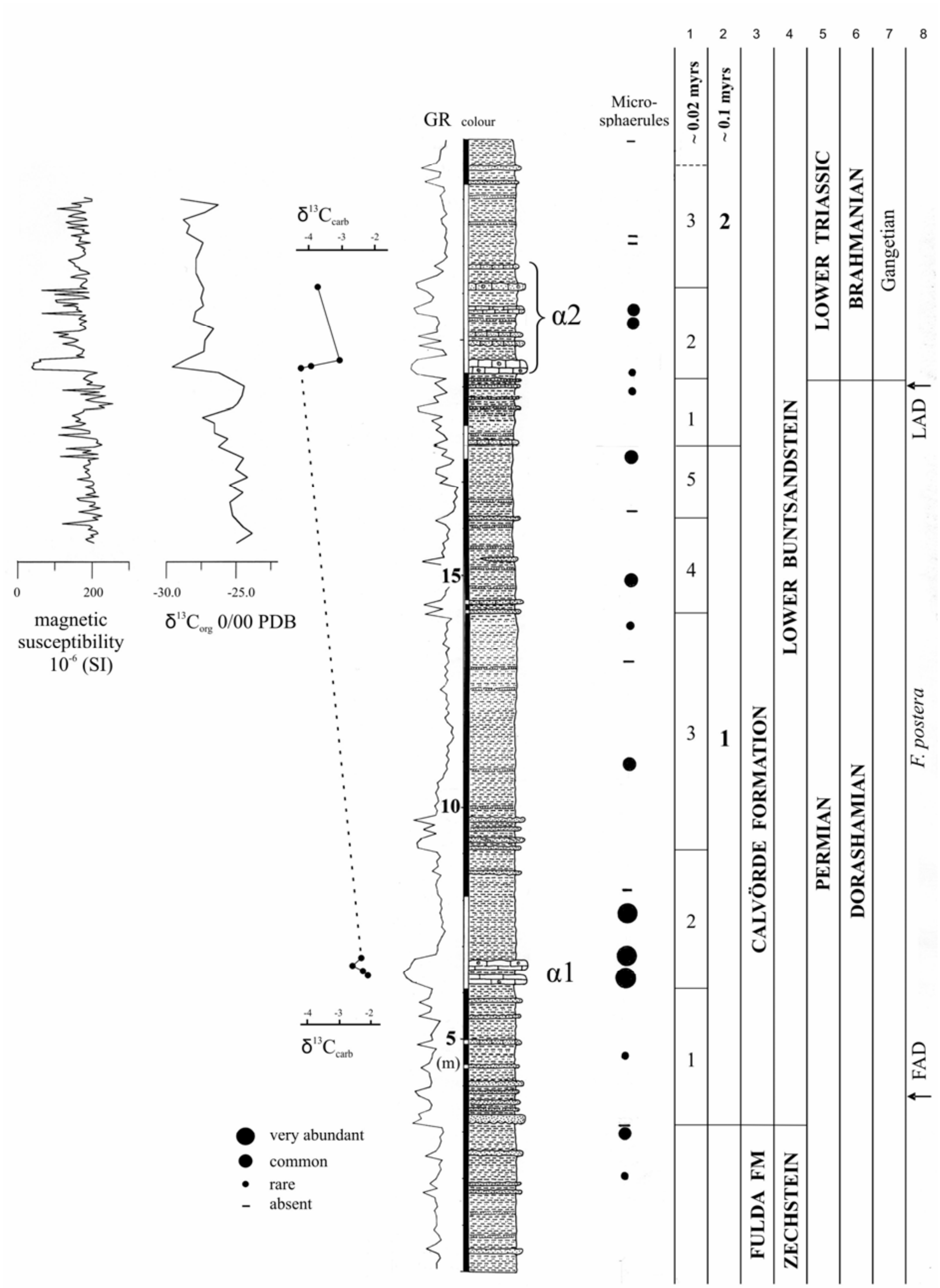


Fig. 3b: Uppermost Zechstein (Fulda Formation) and lowermost Buntsandstein (lower Calvörde Formation) at Nelben section near Könnern, 25 km NW of Halle (BACHMANN & KOZUR, 2004).

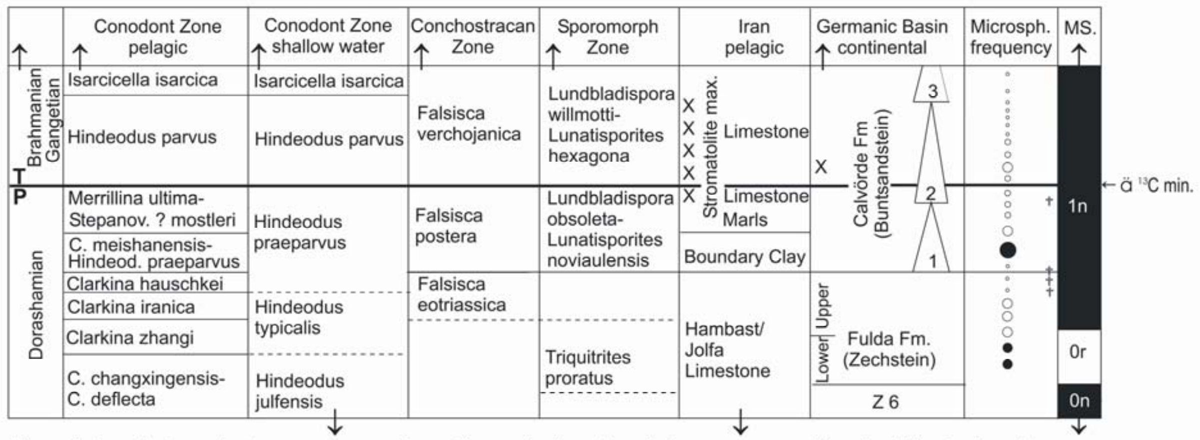


Figure 4: Conodont, conchostracan, sporomorph zonations and microsphaerule frequency around Permian -Triassic Boundary Not to scale. MS = Magnetostratigraphy. P/T = Permian-Triassic boundary. X = Stromatolites. Arrows 1, 2, 3 = ~100 kyr eccentricity cycles. Frequency of microsphaerules: ● = very common, • = common, ○ = moderately common, ◦ = rare, · = very rare (sporadic occurrence). † = level of mass extinction. max. = maximum, min. = minimum

Fig. 4: Conodont, conchostracan, sporomorph zonation and microspherules frequency around the Permian-Triassic boundary in Iran and Germany; not to scale (from KOZUR & BACHMANN 2004).

<u>Key literature:</u>

HAUSCHKE & SZURLIES (1998), SZURLIES (1999), KOZUR (1999), SZURLIES et al. (2003), KOZUR & BACHMANN (2004)

Stop 2: Lower Buntsandstein near Alsleben
(Figs. 5-7)

<u>Locality:</u>

Quarry “Tontagebau Beesenlaublingen” at Bundesstraße 6, 5 km north of Könnern.

<u>Stratigraphy and sediments:</u>

The section spans the lower 55 m of the Bernburg Formation (Lower Buntsandstein). The mainly pelitic succession is indicated by intercalations of oolitic limestones. In terms of magnetostratigraphy, the section encompasses most of polarity intervals sr2 and sn3. Along with biostratigraphy, the section can be dated as Late Indusian (Triassic) in age.

<u>Points of discussion:</u>

Biofacies (conchostracans, trace fossils)

High-resolution log- and lithostratigraphy of the Buntsandstein

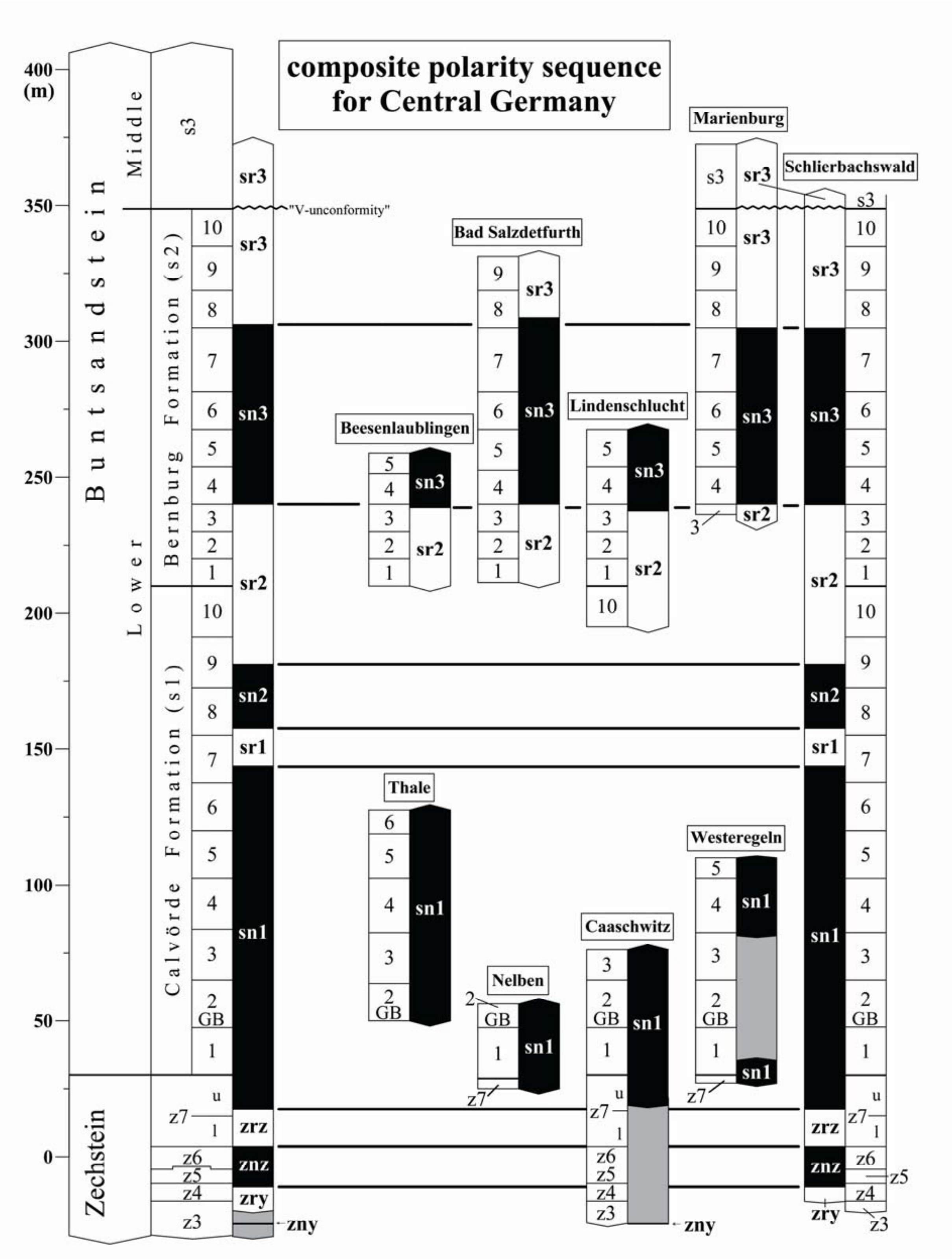


Fig. 5: Upper Zechstein to Lower Buntsandstein composite magnetostratigraphy (SZURLIES 2001, SZURLIES et al. 2003).

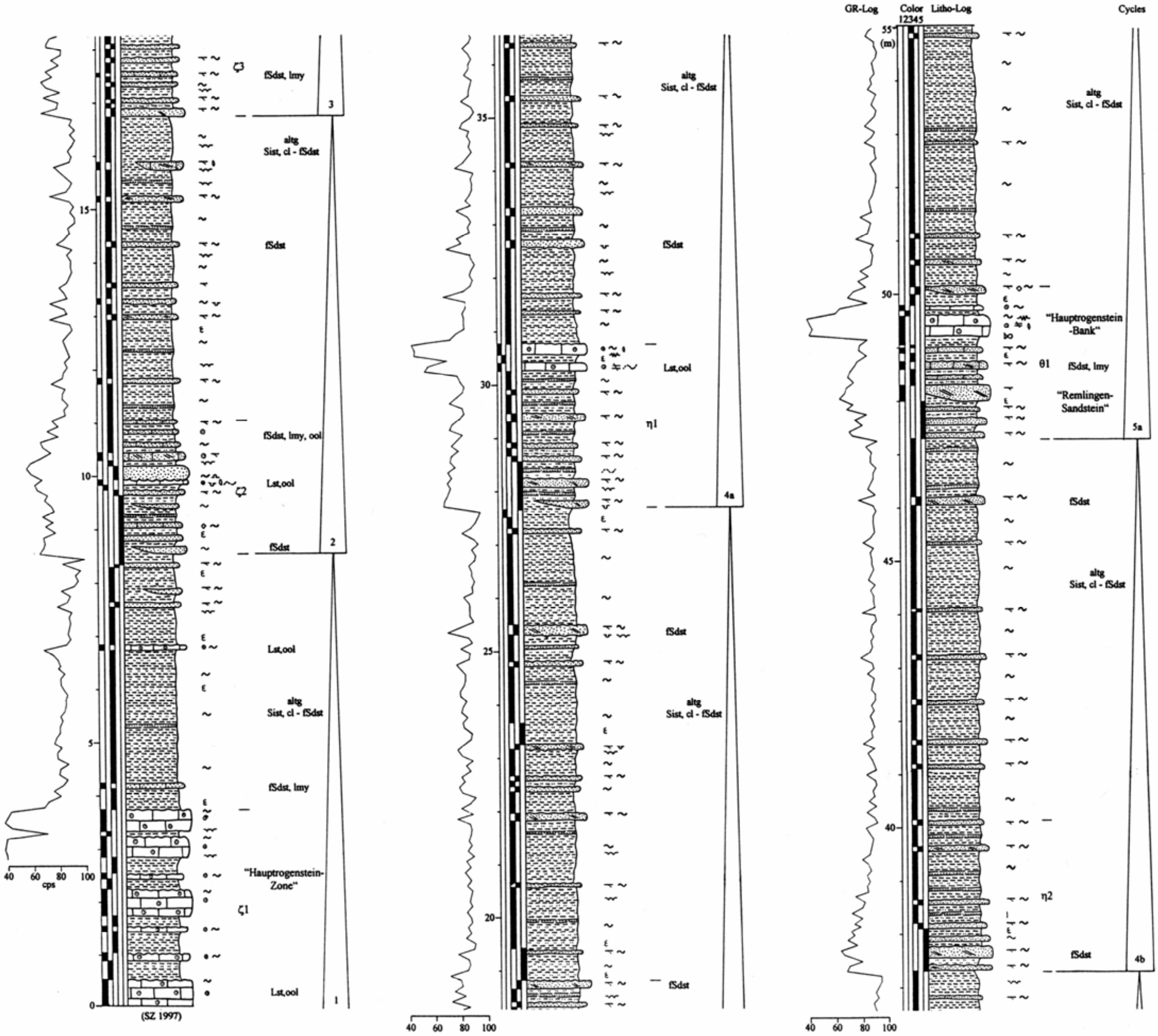


Fig. 6: Litho-log and gamma-ray log of Beesenlaublingen section (SZURLIES 1997).

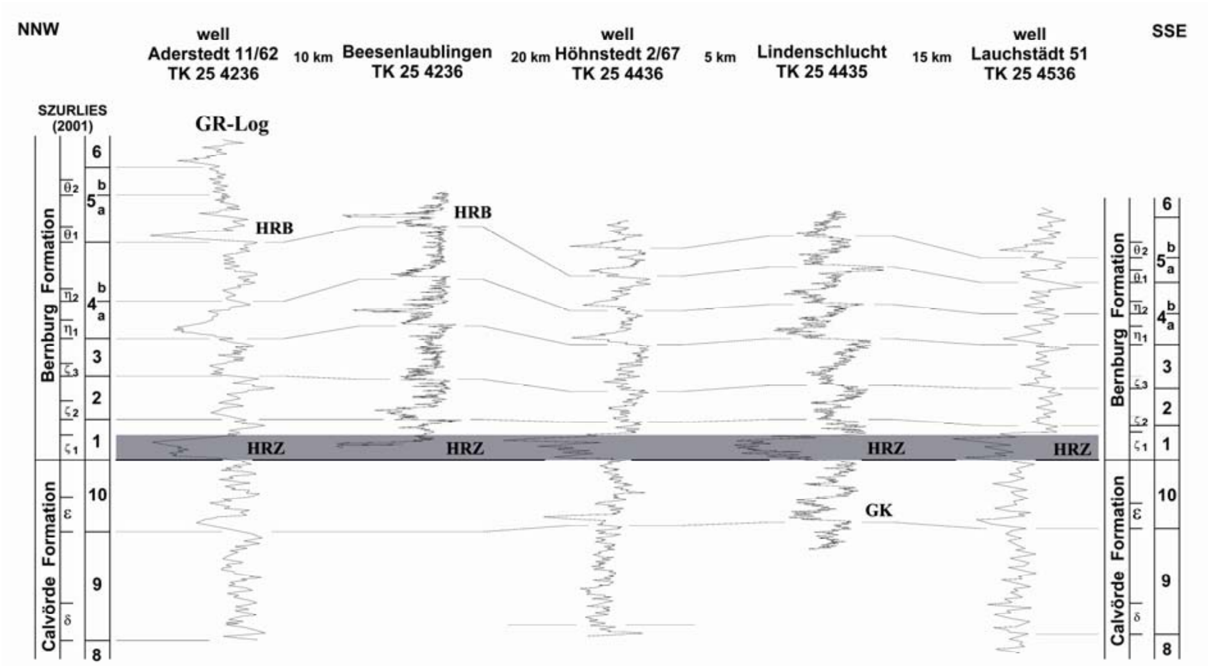


Fig. 7: Gamma-ray log correlation of the uppermost Calvörde Formation to lower Bernburg Formation (Sachsen-Anhalt) (Szurlies 2001). HRZ = Hauptrogensteinzone (= main oolitic interval 1, HRB = Hauptrogensteinbank (= main oolitic interval 2).

<u>Key literature:</u>

HAUSCHKE & SZURLIES (1998), SZURLIES (1999), KOZUR (1999), SZURLIES et al. (2003), KNAUST & HAUSCHKE (2004)

Stop 3: Lower Buntsandstein near Thale
(Figs. 5, 8-9)

<u>Locality:</u>

Railway cut in Thale

<u>Stratigraphy and sediments:</u>

The section spans about 70 m of Calvörde Formation (Lower Buntsandstein), which is Early Indusian (Triassic) in age. The succession is characterized by an alternation of claystones, sandstones and oolitic limestones. In terms of magnetostratigraphy, the section encompasses most of the distinctive thick polarity interval sn1.

<u>Points of discussion:</u>

Marker beds and sedimentary cycles

High-resolution log- and lithostratigraphy of the Buntsandstein

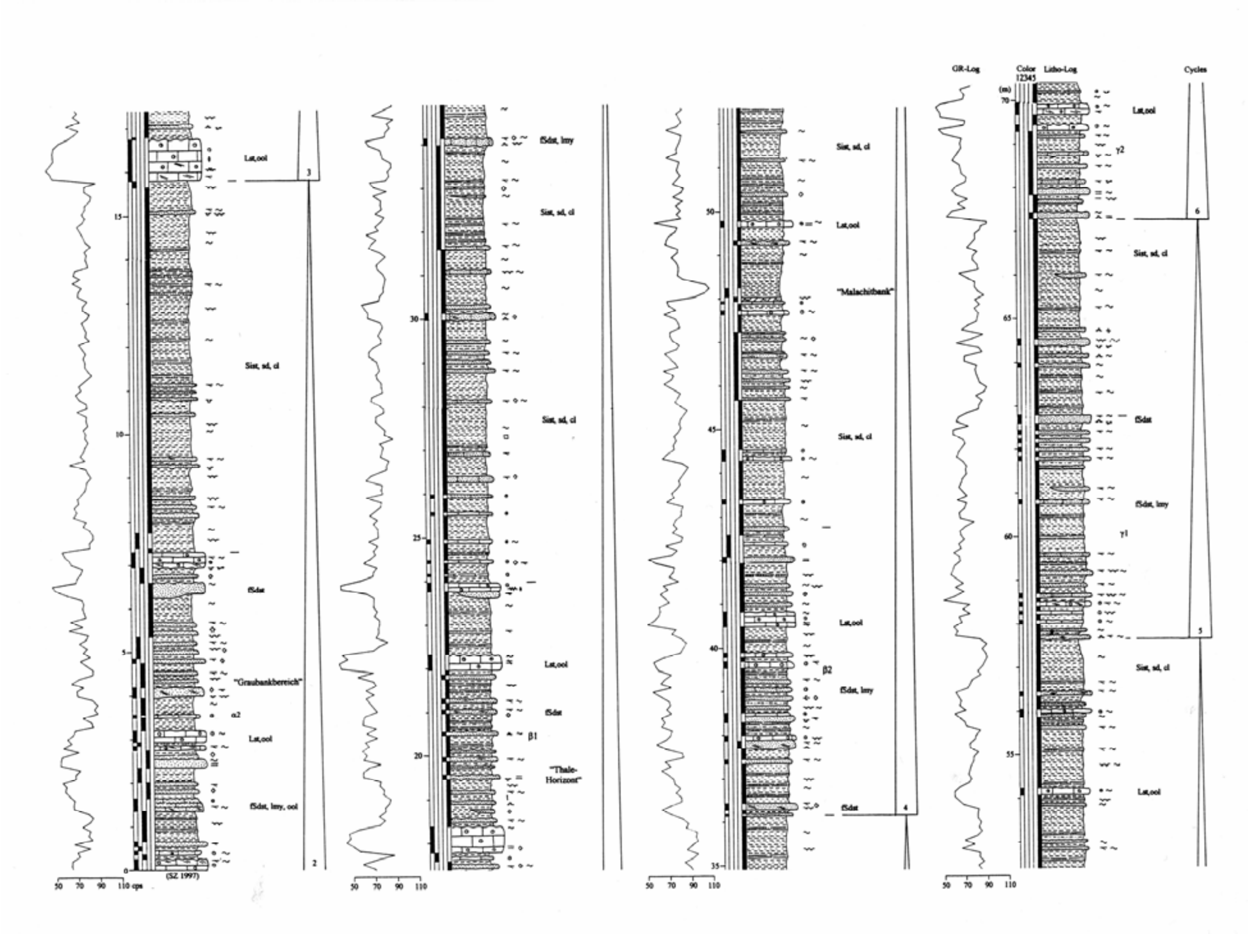


Fig. 8: Litho-log and gamma-ray log of Thale section (SZURLIES 1997).

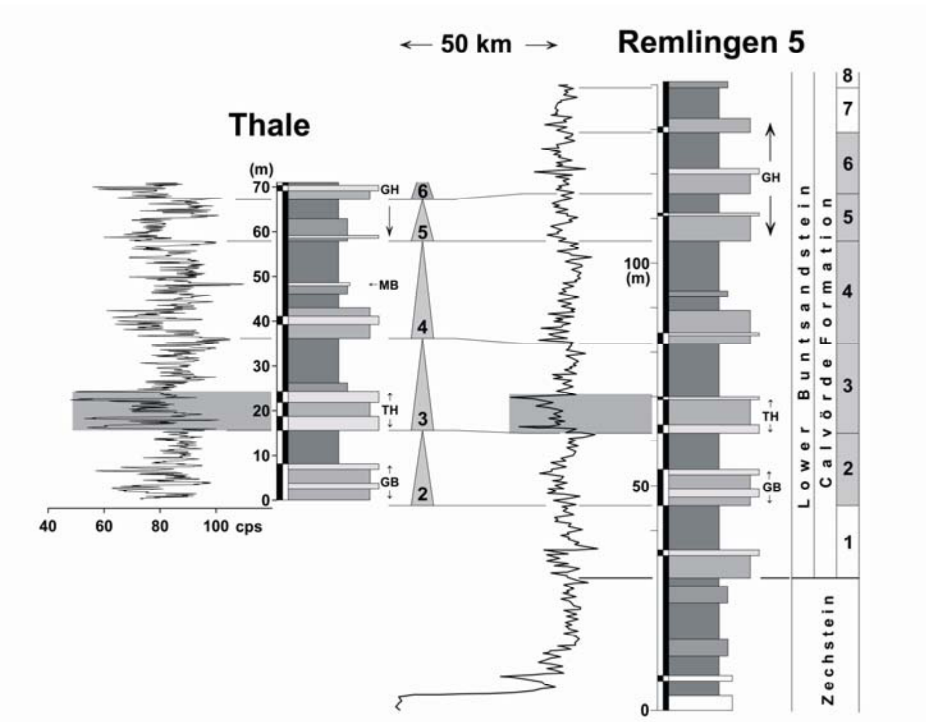


Fig. 9: Gamma-ray log correlation between Thale section and Remlingen 5 well (changed after SZURLIES 1999).

Key literature:
HAUSCHKE & SZURLIES (1998), SZURLIES (1999), SZURLIES et al. (2003)

Stop 4: Middle Buntsandstein near Baalberge
(Figs. 5, 10)

Locality:
Clay pit “Ziegelwerke Baalberge”, 2 km SE of Bernburg

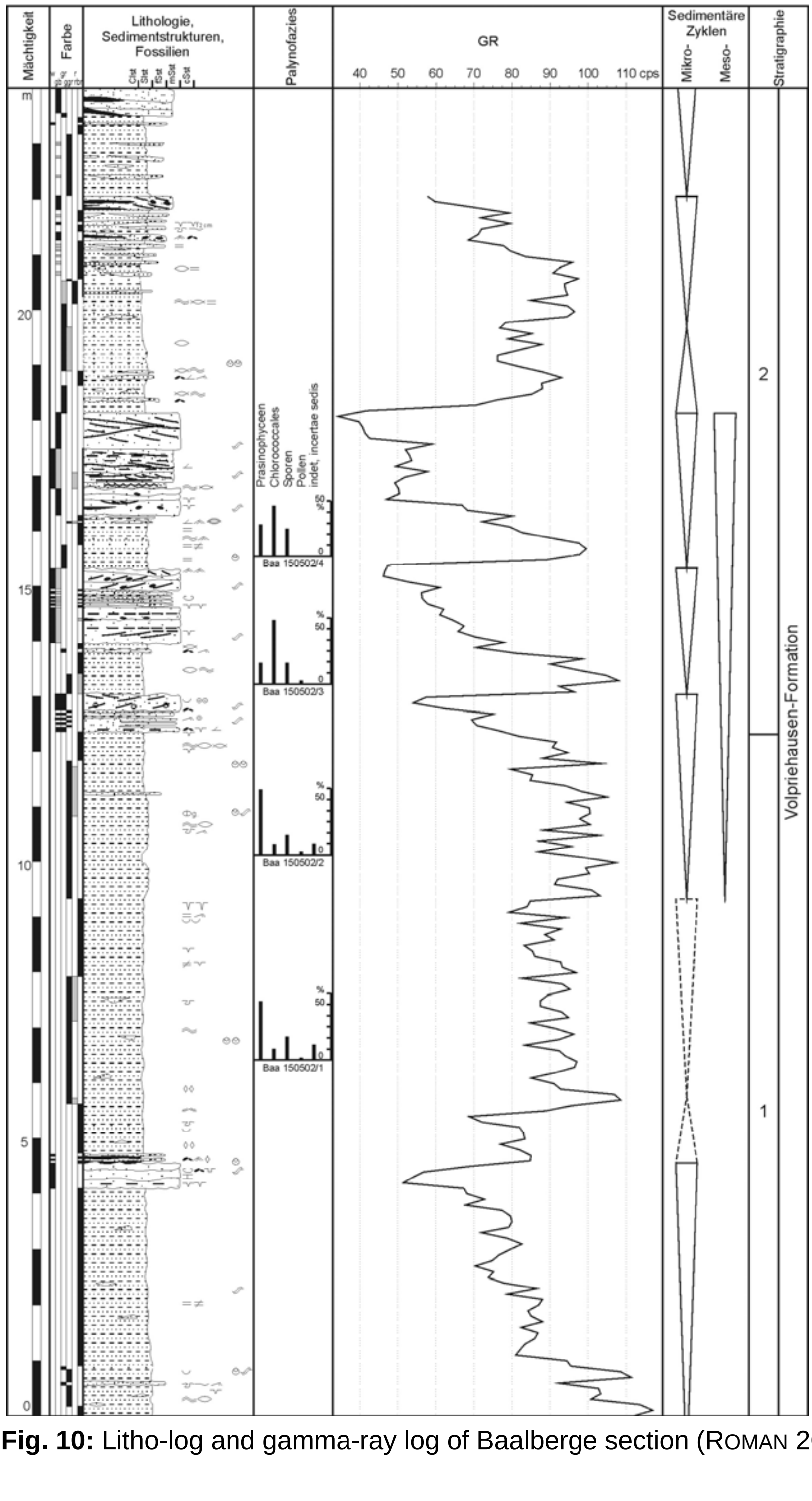


Fig. 10: Litho-log and gamma-ray log of Baalberge section (ROMAN 2004).

Stratigraphy and sediments:

The section spans about 25 m of the lower Volpriehausen Formation (Middle Buntsandstein). The mainly pelitic succession is indicated by intercalations of sandstones. Based on biostratigraphy, the succession is Early Olenekian (Triassic) in age.

Point of discussion:

Buntsandstein unconformities

Cyclicity

Key literature:

ROMAN (2004)

Stop 5: Unterrißdorf (near Eisleben)

Locality:

road-cut between Lüttchendorf and Wormsleben

Stratigraphy:

Bernburg Fm

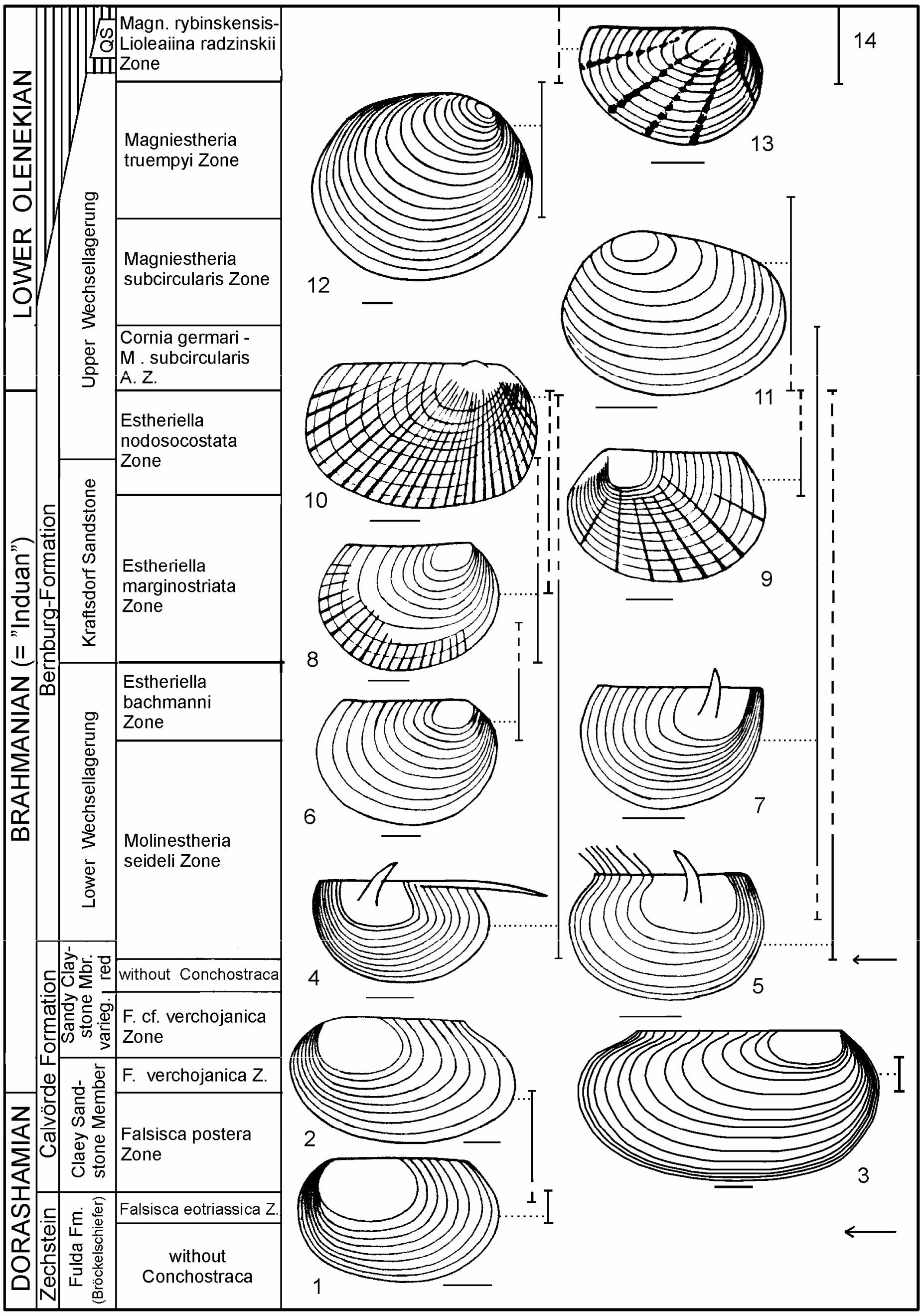
Point of discussion:

Biostratigraphy with the Conchostracans

Key literature:

BACHMANN & KOZUR (2004)

Table 2

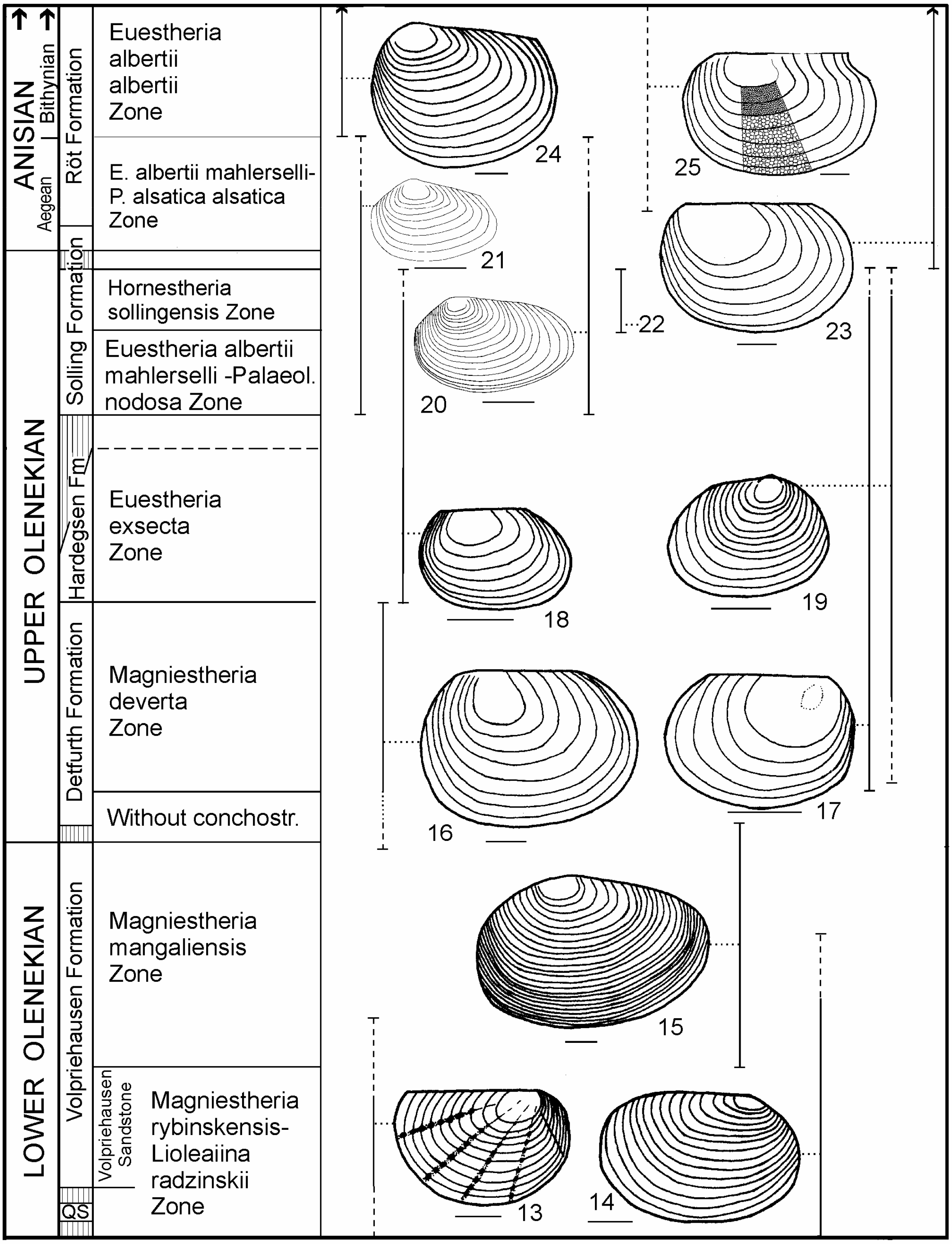


Conchostracan zonation in the uppermost Zechstein (upper Fulda Formation/upper Bröckelschiefer) and Lower Buntsandstein (Calvörde Formation and Bernburg Formation). Not to scale.

Ranges of the index species and some selected other species are also shown. Scale for conchostracans = 1 mm. The lithostratigraphic Members of the Calvörde and Bernburg Formations in the Thuringian Basin are shown in the 3rd column. Arrows indicate the time of conchostracan migration into the Germanic Basin after facies-controlled conchostracan free intervals. QS = Quickborn Sandstone.

1 = *Falsisca eotriassica* KOZUR & SEIDEL; 2 = *Falsisca postera* KOZUR & SEIDEL; 3 = *Falsisca verchojanica* (NOVOZHILOV); 4: *Molinestheria seideli* KOZUR; 5 = *Vertexia tauricornis* LJUTKEVICH; 6 = *Estheriella bachmanni* KOZUR & HAUSCHKE; 7 = *Cornia germari* (BEYRICH); 8 = *Estheriella marginostriata* KOZUR; 9 = *Estheriella nodosocostata* (GIEBEL); 10 = *Estheriella costata* WEISS; 11 = *Magniestheria ? subcircularis* (CHERNYSHEV); 12 = *Magniestheria truempyi* KOZUR & SEIDEL; 13 = *Lioleaiina radzinskii* KOZUR & SEIDEL; 14 = *Magniestheria rybinskensis* (NOVOZHILOV), range below the Volpriehausen Formation is shown (BACHMANN & KOZUR 2004).

Table 3



Conchostracan zonation in the Middle and Upper Buntsandstein. Not to scale.

The ranges and illustratations (except *Hornestheria sollingensis* KOZUR & LEPPER n. gen. n. sp.) of the index species and of some selected species are shown. Scale for conchostracans = 1 mm. QS = Quickborn Sandstone.

13 = *Lioleaiina radzinskii* KOZUR & SEIDEL; 14 = *Magniestheria rybinskensis* (NOVOZHILOV); 15 = *Magniestheria mangaliensis* (JONES); 16 = *Mangiestheria deverta* (NOVOZHILOV); 17 = *Palaeolimnadia alsatica detfurthensis* KOZUR & SEIDEL; 18 = *Palaeolimnadia nodosa* (NOVOZHILOV); 19 = *Euestheria exsecta* (NOVOZHILOV); 20 = *Euestheria albertii mahlerselli* KOZUR & LEPPER n. subsp., slender morphotyp; 21 = *Euestheria albertii mahlerselli* KOZUR & LEPPER n. subsp., stout morphotyp; 22 = *Hornestheria sollingensis* KOZUR & LEPPER n. sp., due to space only the range is shown; 23 = *Palaeolimnadia alsatica alsatica* REIBLE; 24 = *Euestheria albertii albertii* (VOLTZ); 25 = *Dictyonatella dictyonata* (REIBLE) (BACHMANN & KOZUR 2004).

Day 2 (16. July 2005)

Stop 6: Transition Lower/Middle Buntsandstein in Großwangen

Gaupp, Voigt & Roman

Locality:

Abandoned Quarry west of the small village of Großwangen

Stratigraphy:

Upper part of the Bernburg Formation, ? Quickborn sandstone and Lower part of the Volpriehausen sandstone

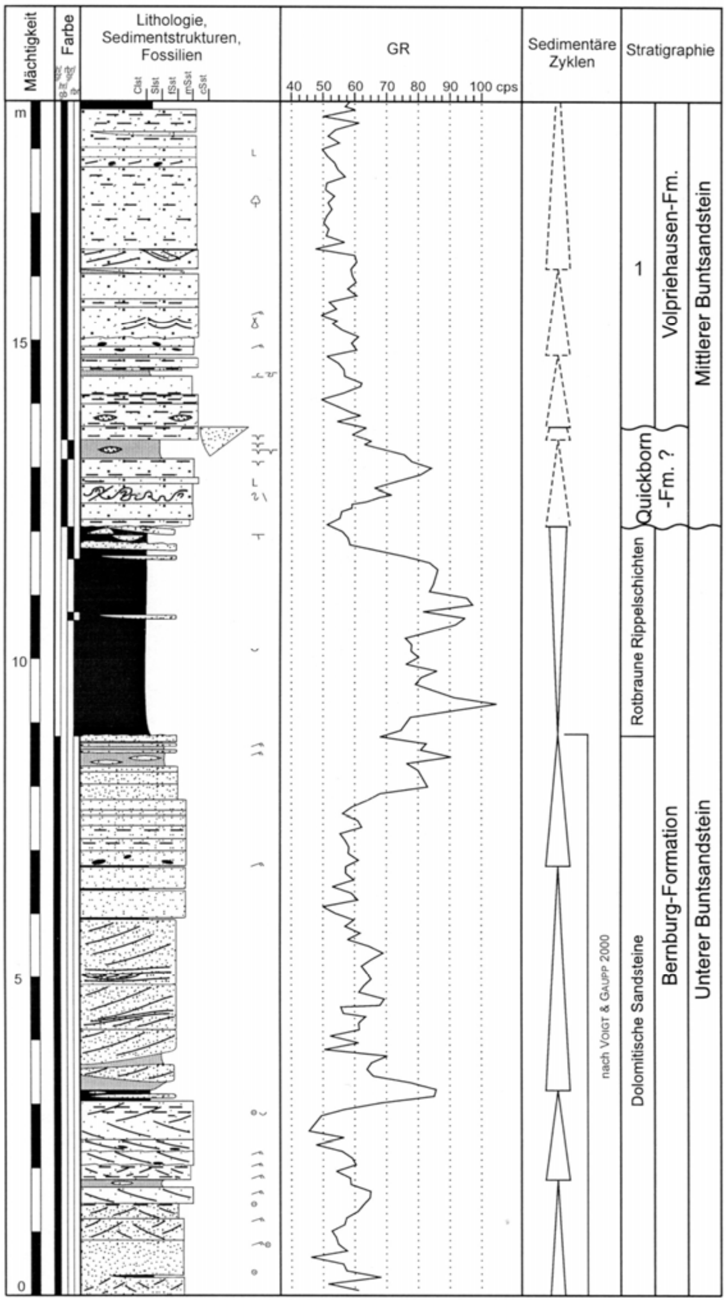


Fig. 11: Großwangen section, after ROMAN (2003).

Main features to be observed:

- White to grey, sandy oolitic limestones in the lower quarry walls reflect the beach and nearshore of a large lake or marginal sea, completely dolomitized
- Transition Bernburg to Volpriehausen Formation: red clays with intercalated thin sandsheets, dessication cracks, ripples, mud-clasts
- Basal Volpriehausen Formation:medium-grained, poorly sorted sandstones, clay-partings with mud cracks, linsen- and flaser-bedding, rare channels
- Superbly exposed synsedimentary half-graben with associated fault scarps, water escape structures, described in detail by SCHÜLER et al. (1989)

Facies sequences:

- Probably shallowing from a marginal lake to a lagoonal and playa environment
- Shallowing-upward from oolitic limestones of shoreline to lagoonal sediments, terrigenous deposition is indicated by the overlaying sandstone unit
- Both increasing quartz-content of oolitebeds and intercalation of sandstone beds with increasing thickness in the red-brown clay bed point to basinward shifting of the lake shoreline
- Formation of large floodplain areas dissected by shallow channels with temporary fluvial deposition (sheet-floods) and minor eolian redeposition (Volpriehausen Formation)

Facies geometries:

- Comparisons of single units across the large quarries on both sides of the Unstrut valley and with boreholes in the centre of the Querfurt syncline (Radzinski 1995) indicate the regional distribution of marker beds. A regional correlation for the oolitic limestone horizons was established by PAUL & KLARR (1987) and RADZINSKI (1995)
- Regional distribution of the red-brown lacustrine claystones with rippled sandsheets indicates low-relief morphology
- Changing thicknesses and facies of marker beds indicate a much more complicated depositional pattern than previously expected
- The good correlation of the single units across the Germanic Basin is most likely not the expression of synchronous events but evidence for migrating facies belts depending on fluctuating lake level

Sedimentology:

- Sandy oolitic limestones in lower quarry walls
- Red clays with conchostracans, mud cracks and sand layers
- Basal Volpriehausen Formation: medium-grained, poorly-sorted sandstones
- Large, gentle hummocks, second order structures: rippled beds, low angle bedding, scours
- Shallowing to green clays with thin sand-oolite-sheets and oscillation ripples, increasing sand content
- Cyclicity (2-5 m) with fining- and thinning-upward tendencies in the oolitic sequence, top with mud cracks

Points of discussion:

- Tidal influence during deposition of the oolitic limestones
- Correlation of oolitic horizons in the Germanic Basin (timelines, marker horizons or migration of facies belts?)
- Lack of fossils in the oolitic limestones
- Correlation with the marginal (sandy) Lower Buntsandstein to the southeast
- Timing of dolomitisation
- Cycles and sequences in the Lower Buntsandstein
- Facies sequence (simple transition from marine to terrestrial deposition or basin reorganisation)
- Seismic features in clastic sequences – evidence for basin development
- Facies of the basal Volpriehausen Formation (sandplain with salt crusts, eolian deposition or terminal sandy fan)

- Conchostracan-biostratigraphy (facies dependence or evolutionary trend)
- Reasons for lake level shifts, climate, tectonics or global sea-level?

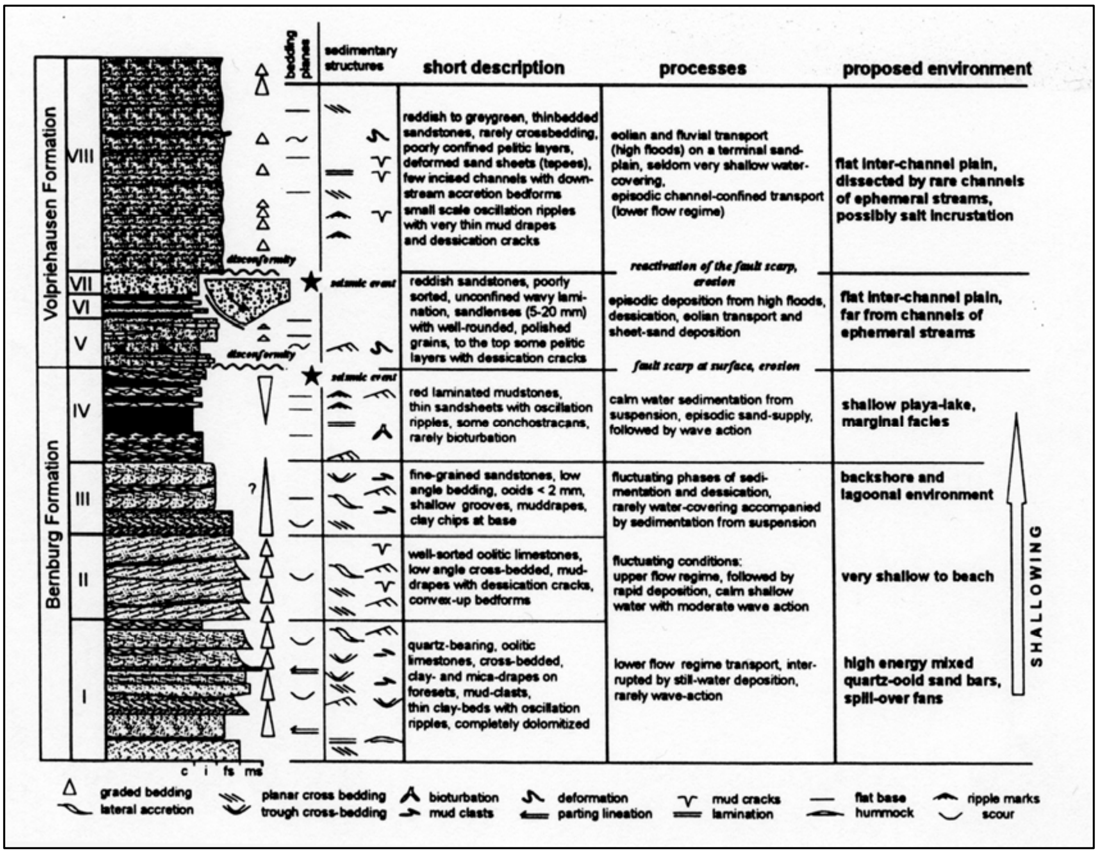


Fig. 12: The Wangen section exposes the boundary of the Lower and Middle Buntsandstein. In general, the section marks the transition from a marginal marine (lacustrine?) depositional system with oolite shoals to a sandy plain with fluvial and eolian deposition.

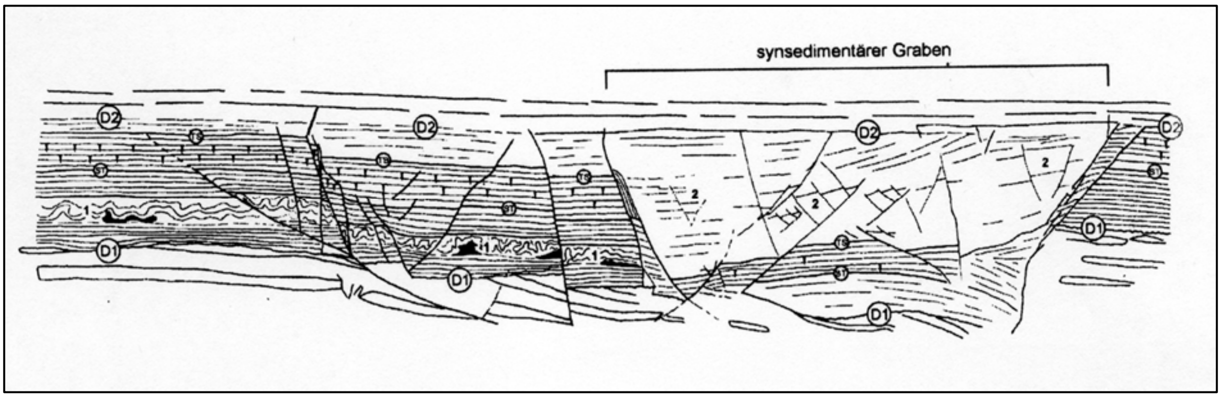


Fig. 13: sketch showing quarry wall of Großwangen section.

Stop 7: Middle Buntsandstein in the Quarries west of Nebra

Gaupp, Voigt & Roman

Locality:

Large quarry wall and cliffs 400 m west of Nebra

Stratigraphy:

Uppermost part of Hardegsen Formation and Solling Formation

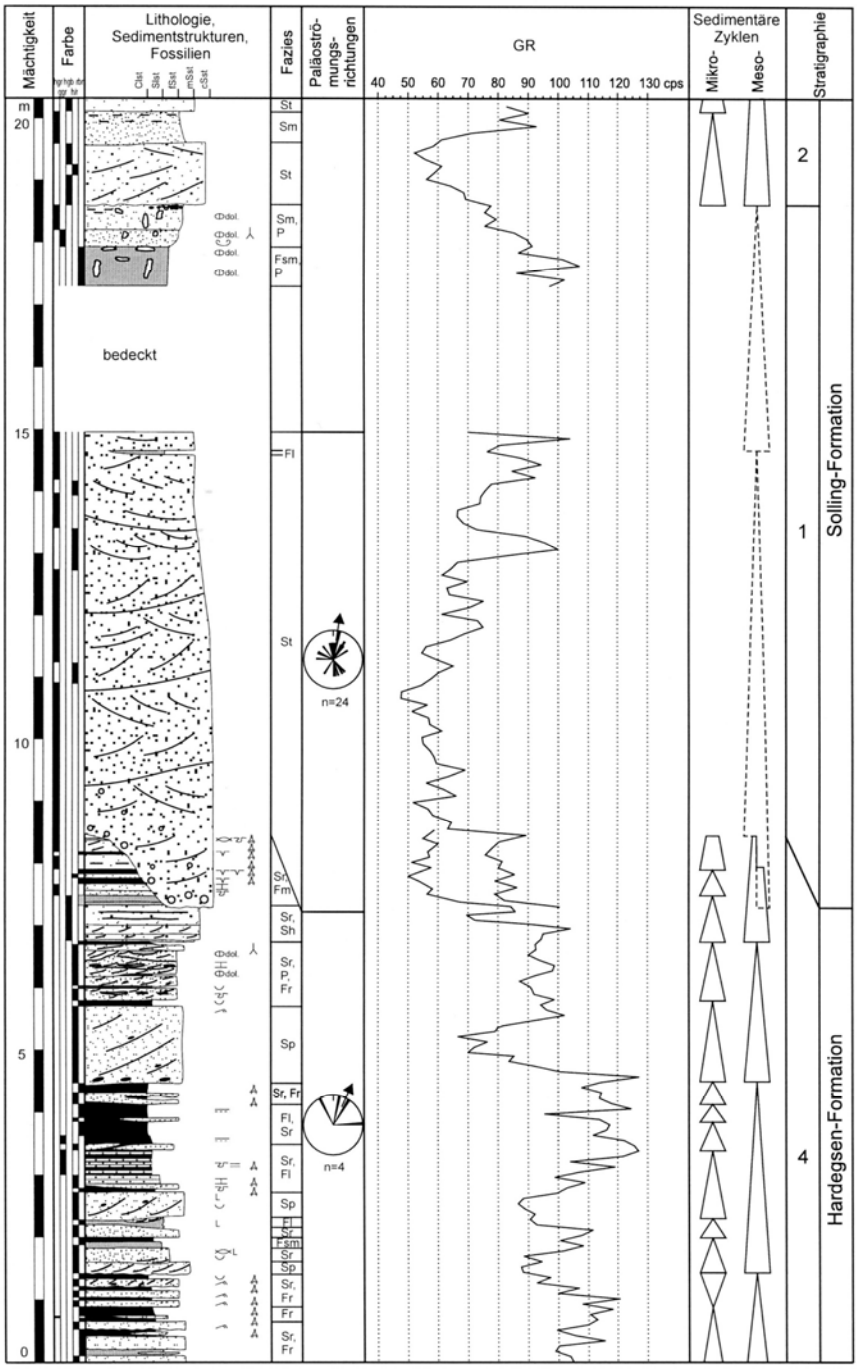


Fig. 14: Nebra section, after ROMAN (2003).

Main features to be observed:

- Top of Hardegsen Formation: thin bedded floodplain or terminal fan deposits with various sedimentary structures, bioturbation, conchostracans
- Base of the Solling Formation: coarse-grained, pebbly sandstones with cross-bedding at the base of largescale channels, cutting into floodplain deposits
- Reworked calcretes and carbonates cementation at the base of channels
- Soil formation in the floodplain deposits of the upper parts of the Solling Formation (columnar, nodular and platy calcretes), redeposition of reworked calcretes in overlying fluvial sandstones
- Bioturbation, plant remnants and conchostracans

Sedimentoloy:

- Carbonate cementation in the channelsandstones of the Solling Formation
- Lateral accretionary bedding and trough cross-beds (downstream accretion) within the channelfills

Facies sequence and stacking patterns:

- Top Hardegsen floodplain deposits are eroded to different levels by the ovelying Solling sandstone channels
- No unconformity between the Hardgsen and Solling Formation was deduced on a regional scale within the Thuringian Basin, but an angular unconformity is evident at the western margin, where some hundred meters of pre-Solling deposits were eroded (Eichsfeld Swell)

Points of discussion:

- Timing and factors controlling the formation of the Solling unconformity
- Trends in sedimentary structures and channel architecture, changes in accommodation potential (reorganisation of the basin tectonics, relief enhancement or climatic change)

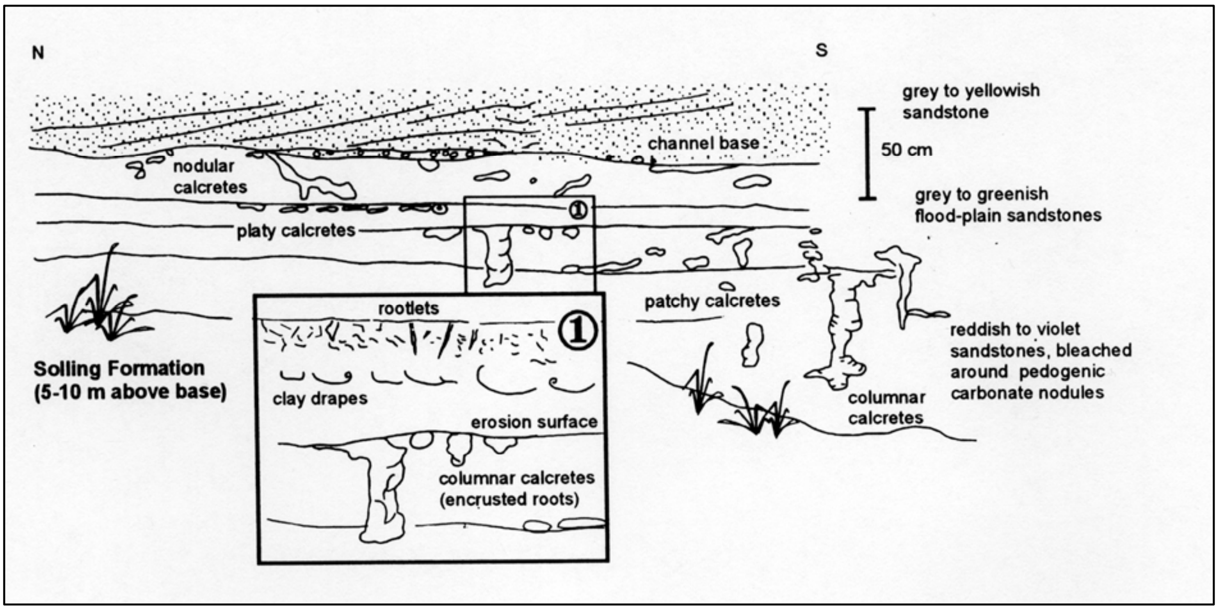


Fig. 15: The middle part of the Solling Formation in the quarries west of Nebra is characterized by the predominance of floodplain deposits. Calcretes and rootlet beds point to soil formation under a semiarid climate.

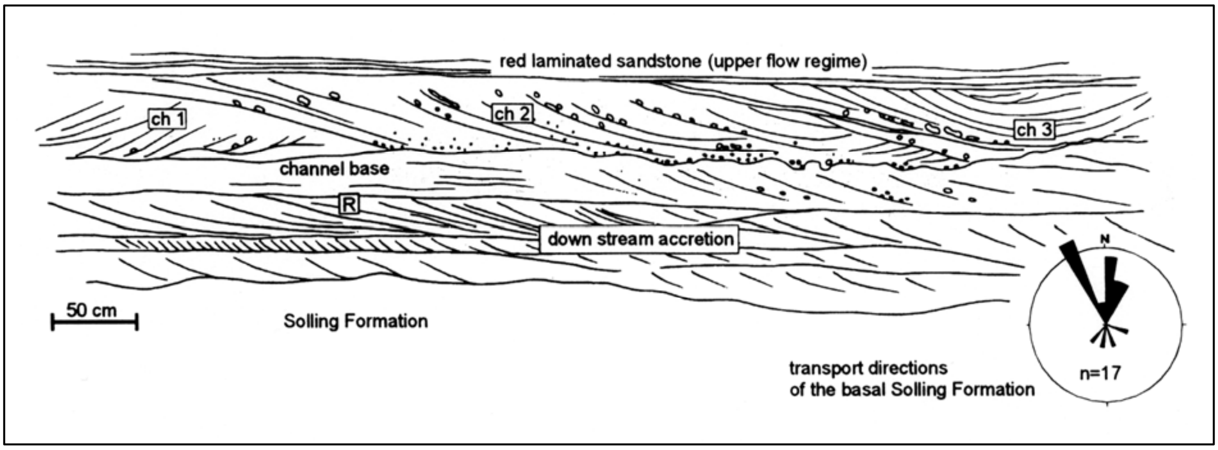


Fig. 16: Large scale cross-beds of downstream accretion bedforms represent the fills of large incised channels of the Lower Solling Formation. Note dip directions of cross-beds to the north and reworked calcretes at channel bases.

Stop 8: Outcrop at the Unstrut River near Dorndorf

Exner

Locality:

Cliffs 1 km west of village Dorndorf

Stratigraphy:

Uppermost part of Göschwitz Subformation and complete section of the Glockenseck Subformation (Type section)

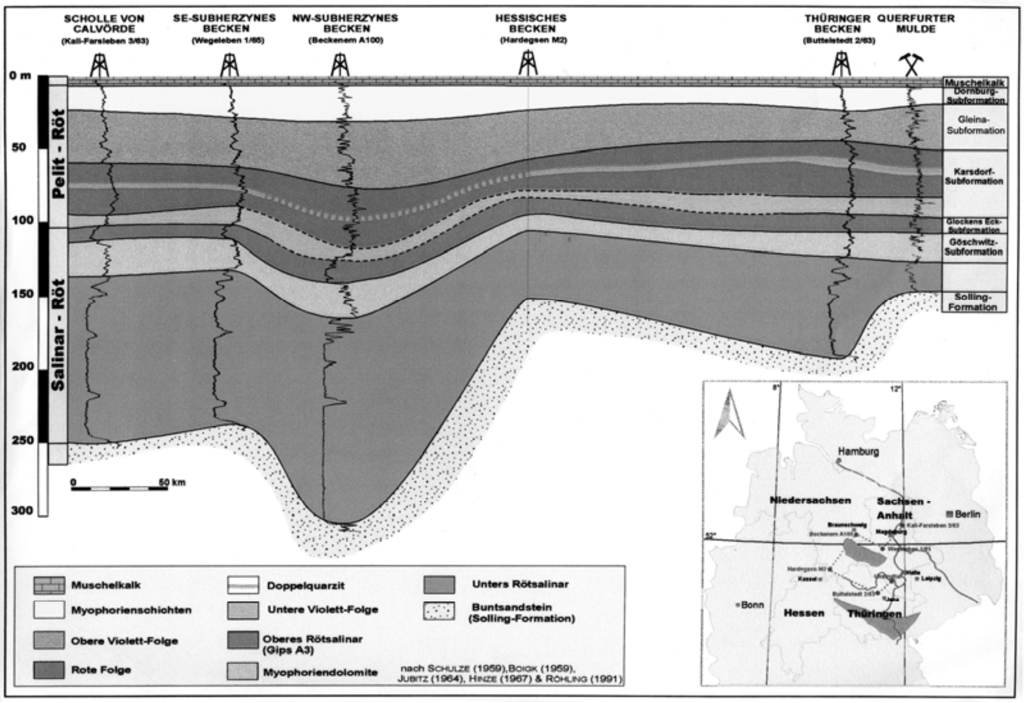


Fig. 17: Correlation of the Röt Formation in middle part of Germany, after EXNER (1999).

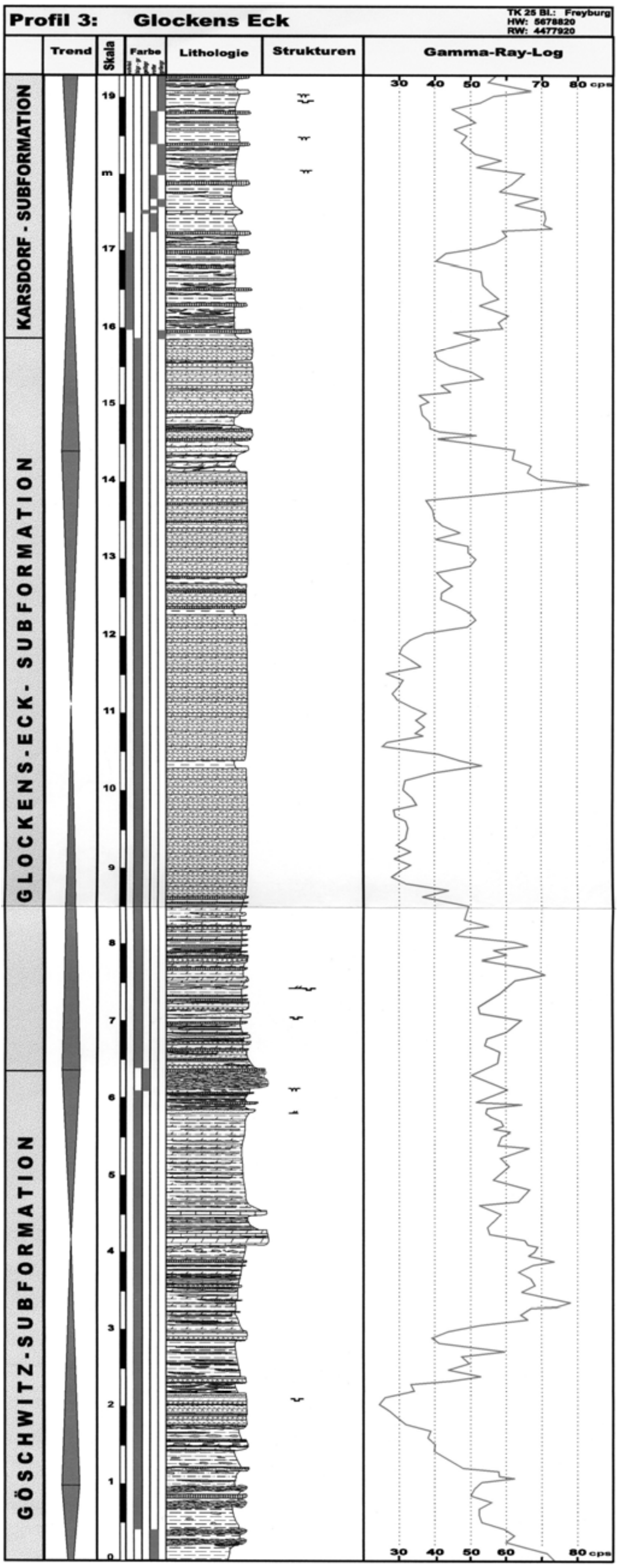


Fig. 18: Glockenseck section, after EXNER (1999).

Main features to be observed:

- Transition of lacustrine environment of the Göschwitz Subformation to the hypersaline environment of the Glockenseck Subformation (Oberes Rötsalinar)

Points of discussion:

- Importance of Glockenseck Subformation for basinwide correlation (fig. 19,20)
- Origin of the sulphate sediments

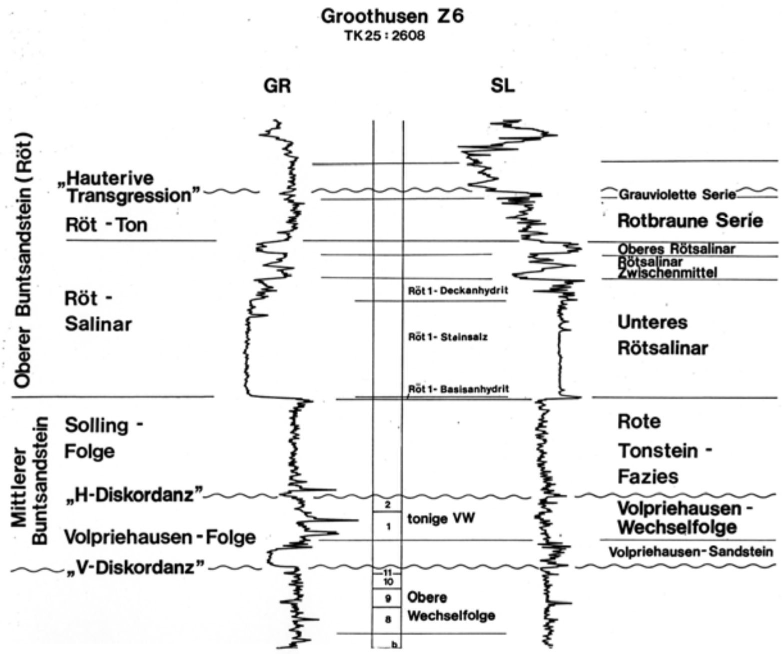


Fig. 19: Subdivision of the Röt Formation in western Germany, after RÖHLING (1991).

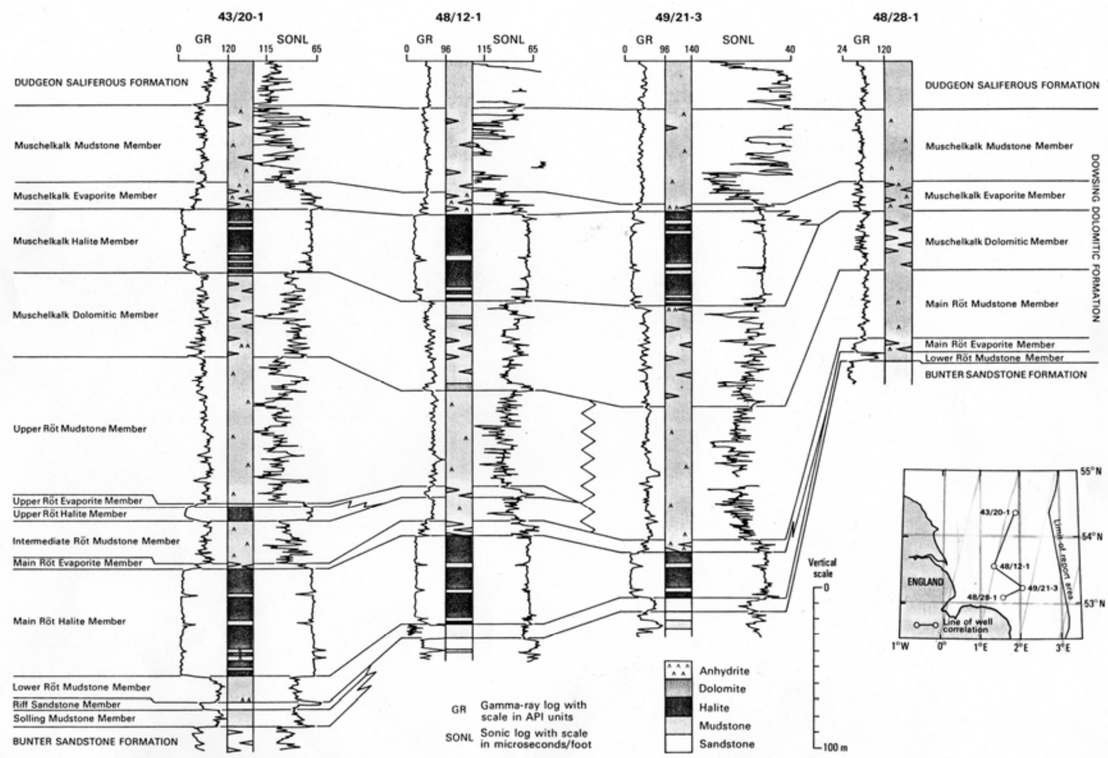


Fig. 20: Correlation of the Dowsing Dolomitic Formation in the Southern North Sea Basin, after CAMERON et al. (1992).

Stop 11: Steudnitz

Complete Lower Muschelkalk section and base of Middle Muschelkalk

Anette Götz, Thomas Voigt

Locality:
Quarry of the "Dornburg Zement" factory at Steudnitz (Fig. 3)

Stratigraphy:
Röt Formation (Myophorien Member), Jena (Wellenkalk) Formation (including Oolithbank Member, Terebratelbank Member and Schaumkalk Member), Middle Muschelkalk (Orbicularis Member)

Main features to be observed:

- Marlstones and micritic limestones with diagenetic bedding
- Various types of bioclastic storm layers within the micritic subtidal background deposits
- Amalgamated beds with hardgrounds, shell-debris and ooids (Oolithbank Member, Terebratelbank Member, Schaumkalk Member)
- Fossils (bivalves, brachiopods, scaphopods, crinoids) of the Anisian
- Marls, dolomites and stromatoliths at the base of the Middle Muschelkalk
- Synsedimentary deformation (slumps, slides, debris flows, ball and pillow structures)

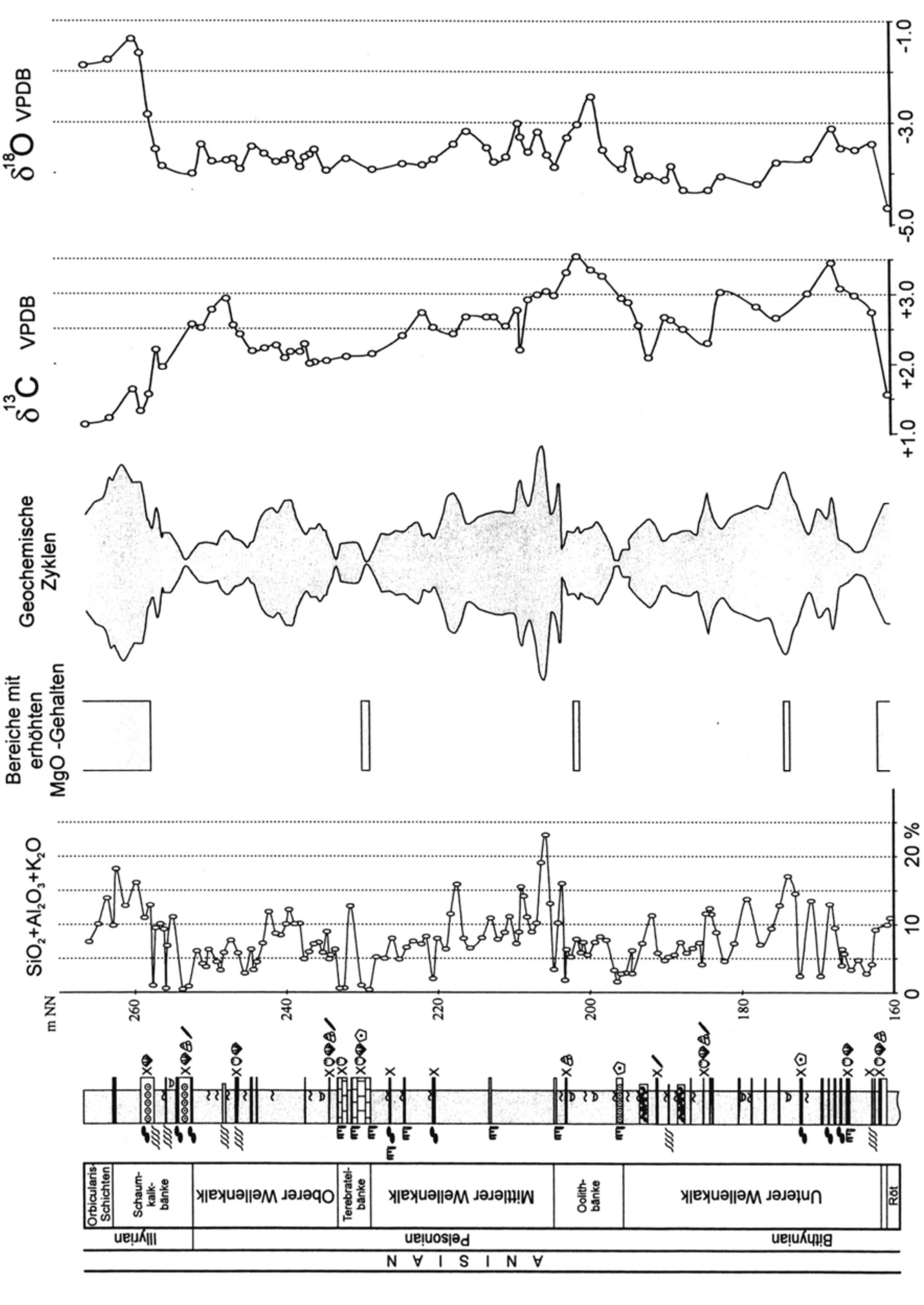
Sedimentology and Facies

- Transition from intertidal stromatolitic limestones to micritic limestones of a storm-dominated shallow shelf (Wellenkalk facies)
- Various types of current-induced sedimentary structures indicating shallowing at the level of the Oolithbank and Schaumkalk Members and, perhaps, at the Terebratelbank Member
- Transition to evaporitic sedimentation at the top of the Lower Muschelkalk
- 2-6m thick shallowing-upward cycles

Points of discussion:

- Regional facies and faunal trends
- Sedimentary structures and stacking patterns
- Sequence stratigraphy of the Triassic in the Germanic Basin
- Depositional cycles of the Lower Muschelkalk – autocyclic or allocyclic (MITCHUM & VAN WAGONER 1991, STRASSER 1991, GÖTZ 1996)
- Early cementation and nodule-formation within marls (diagenetic bedding)
- Origin of synsedimentary-deformed horizons

Fig. 23: Profile and geochemical data from the Steudnitz-outcrop.



Stop 12: Krähenhütte (Bad Sulza)

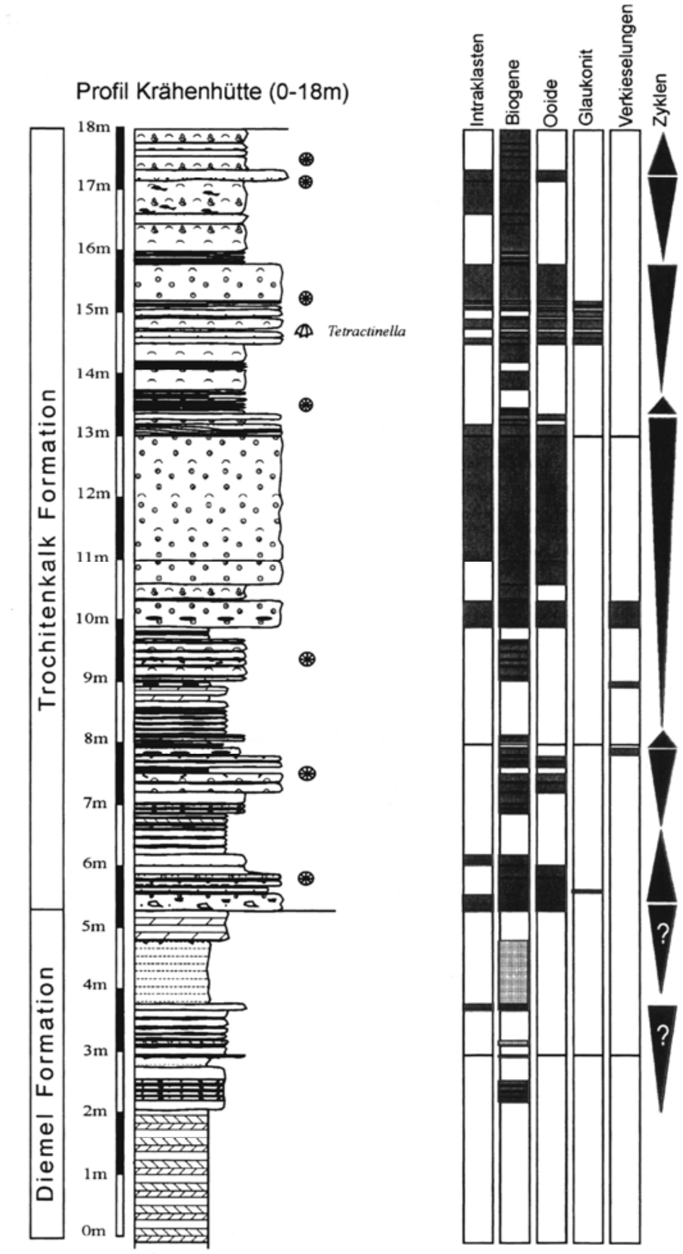
Locality: Quarry is located above the railroad station of Bad Sulza.

Stratigraphy: Middle Muschelkalk (Diemel Formation) – Upper Muschelkalk (Trochitenkalk Formation)

Section: The Middle Muschelkalk consists of dolomicrites with tempestite-layers (hcs-stratification). At and near the top bioclastic horizons (gastropods) occur. The Upper Muschelkalk is represented by an intercalation of bioturbatic biomicrites (with coarsening upward tendencies) and marls.

Literature: VOIGT et al. (2001)

Fig.24:



Profil und zyklostratigraphische Interpretation des Trochitenkalks im Steinbruch Krähenhütte (Bad Sulza). (Aufnahme: Katzschmann, Stötzer, Voigt; 2000, Stötzer 2001).

VOIGT et al. (2001)

Stop 13: Troistedt (near Weimar)

Locality:

From Autobahn A 4, Nohra exit, on county road to the southeast towards Weimar-Troistedt; after 0.7 km left into the active quarry of "Rena Recycling und Naturstein GmbH".

Stratigraphy:

The quarry shows a section of the Upper Muschelkalk from its base to the *cycloides*-Bank (Trochitenkalk Formation, Meißner Formation). The section is typical for a basinal position in the southern part of the depocentre. The carbonate facies is dominated by deeper water "Tonplatten" (interbedded thin marlstone/limestone beds and tempestites).

Main features to be observed:

- Sediment structures (individual beds): Thickly-bedded crinoidal and skeletal limestones with biohermal structures; stylolithic bedding planes. Stratigraphically significant blackish chert layers at the Upper Muschelkalk base. In the "Tonplatten" there are proximal to distal tempestites with erosive bases and rippled tops, gutters, sole marks, bioturbation as well as concretionary limestone nodules, occasionally containing fossils (decapod arthropods, fish, reptile bones).
- Sediment structures (cycles): Different types of metre-scale asymmetrical shallowing-upward cycles. Asymmetrical transgressive/regressive stacking pattern. However, the regressive branch of the Upper Muschelkalk, dominated by marlstones with abundant bonebeds, dolomicrites and a few thick limestone marker beds (Warburg Formation), is not exposed at this outcrop.
- The *cycloides*-Bank, a basinwide ecostratigraphical marker bed in typical position (biostratigraphically correlated). The *Spiriferina*-Bank is hard to identify; its marker fossil, the brachiopod "*Spiriferina*" (*Punctospirella fragilis*), has been found in other nearby Upper Muschelkalk outcrops.
- Biostratigraphy: Ceratite zones of the Lower and Middle Ceratite Beds (*atavus* biozone to *enodis* biozone). In the Troistedt section there are many excellent specimens of the otherwise very rare early ceratites (*Paraceratites atavus* and *P. flexuosus*), which had invaded from the western Tethys via the Burgundy Gate.
- Paleoecology: Different soft ground fossil communities (e.g. *Bakevellia costata/Hoernesia socialis* fossil community, shell ground and hard ground communities (body fossils, ichnofossils); abundant *Germanonautilus* steinkerns, often with incrusters. Terquemiid/ Encrinid-Bioherms with in situ crinoid roots in the uppermost crinoidal bed.
- Transgressive/Highstand Systems Tract and Maximum Flooding interval of Upper Muschelkalk sequence.

Points of discussion:

- Cycle diversity
- Regional subsidence patterns (no shallow water carbonates during *compressus* to *evolutus* and *nodosus* to *semipartitus* biozones)
- Origin of marlstone (maximum deposition of marlstones during Upper Ceratites Beds)
- Biological response (accumulation of skeletal and crinoidal debris) on shallow ramp.
- Parasequences versus High Frequency Sequences: sedimentological versus paleoecological evidence.
- Position of maximum flooding.
- Ceratite standard profile and Ceratite evolution (contribution Ockert & Rein in Abstract Vol.)

Literature: The Troistedt section has not been published before because the quarry was opened only a few years ago.

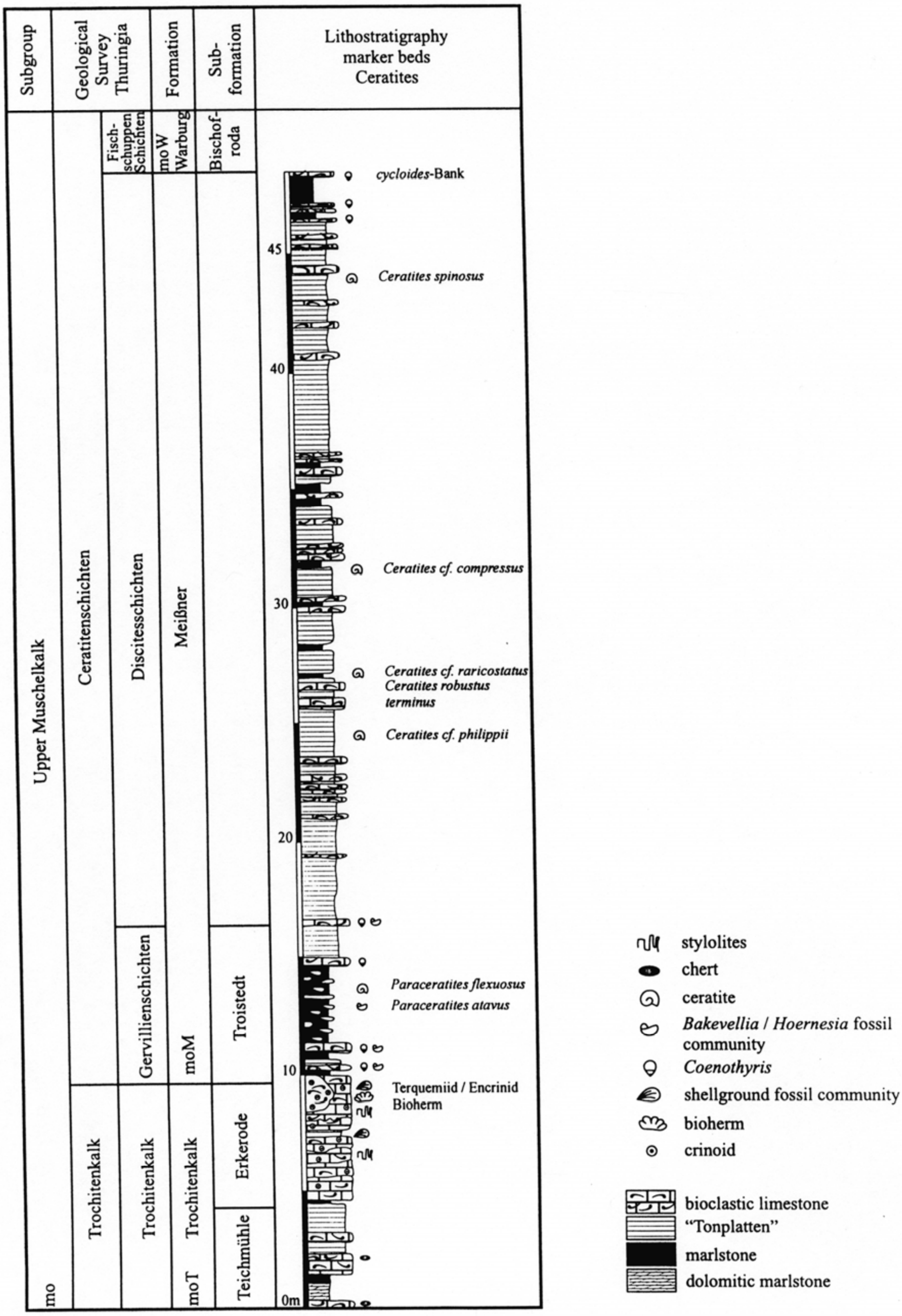


Fig. 25:

Lithological log and ceratites of Troistedt quarry. Traditional (Geological Survey of Thuringia) and new lithostratigraphy. Section measured and interpreted by H. HAGDORN.

Day 4 (18. July 2005)

Stop 14: Egstedter Trift (in the gorge S of Erfurt-Melchendorf)

Gerhard Beutler & Joachim Schubert

Locality:

Gorge S of Erfurt-Melchendorf, about 500 m SE from Stop 5,

Stratigraphy:

Lower Keuper (Ladinian): Section from the uppermost part of Upper Muschelkalk to the basal beds of the Grabfeld Formation (Type section of the Erfurt-Formation); Fig. 8

Main features to be observed:

- Cyclic sedimentation of the Erfurt Formation according to the fining-upward scheme
- Six microcycles can be distinguished
- Sandstones are characterised by poor textural maturity (greywacke sandstones)
- Shales are very variable, from dark, finely-laminated to multicoloured unlaminated
- Microcrystalline dolomites are the most abundant carbonate rocks.
- In the upper part a thin layer of clayey coal (so-called "Lettenkohle") occurs and also some layers with haematite nodules .

Points of discussion :

- Palaeogeography of the Erfurt Formation
- Lithostratigraphy in comparison to southern and northern Germany
- Origin of the clastic materials
- Sedimentary environments

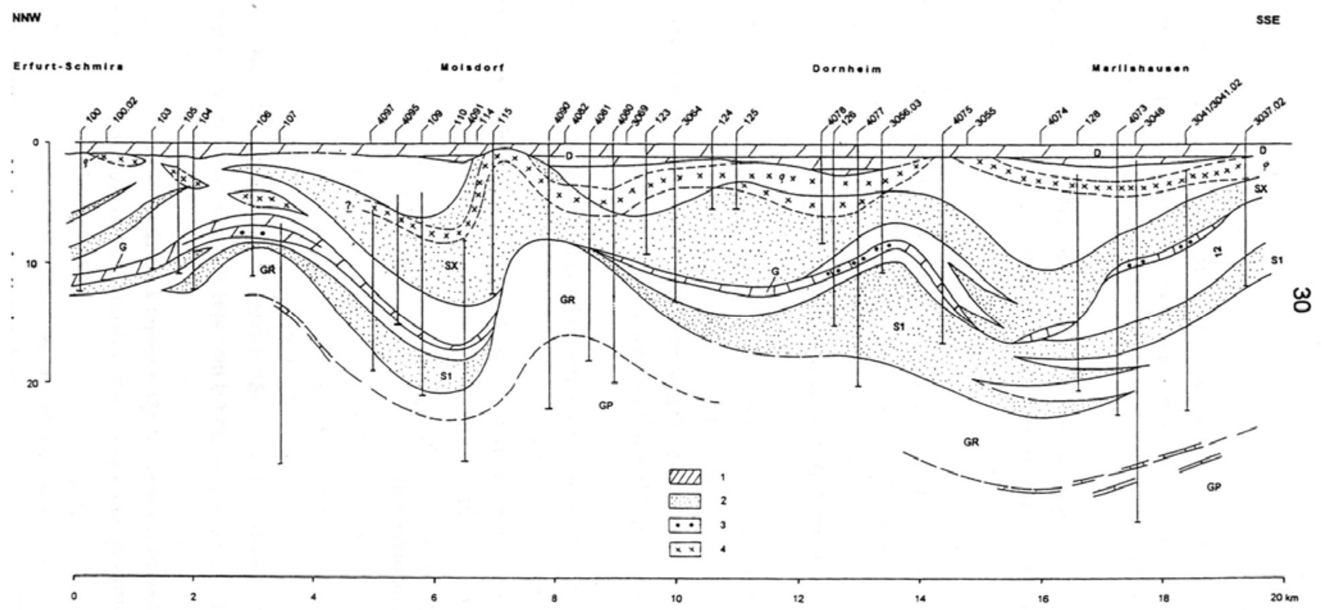


Fig. 26: Different facies of the Lower Keuper. 1 – dolomitic limestone, 2 - fine sandstone, 3 – carbonatic pebbles, 4 – red color (JUNGWIRTH et al. (1996).

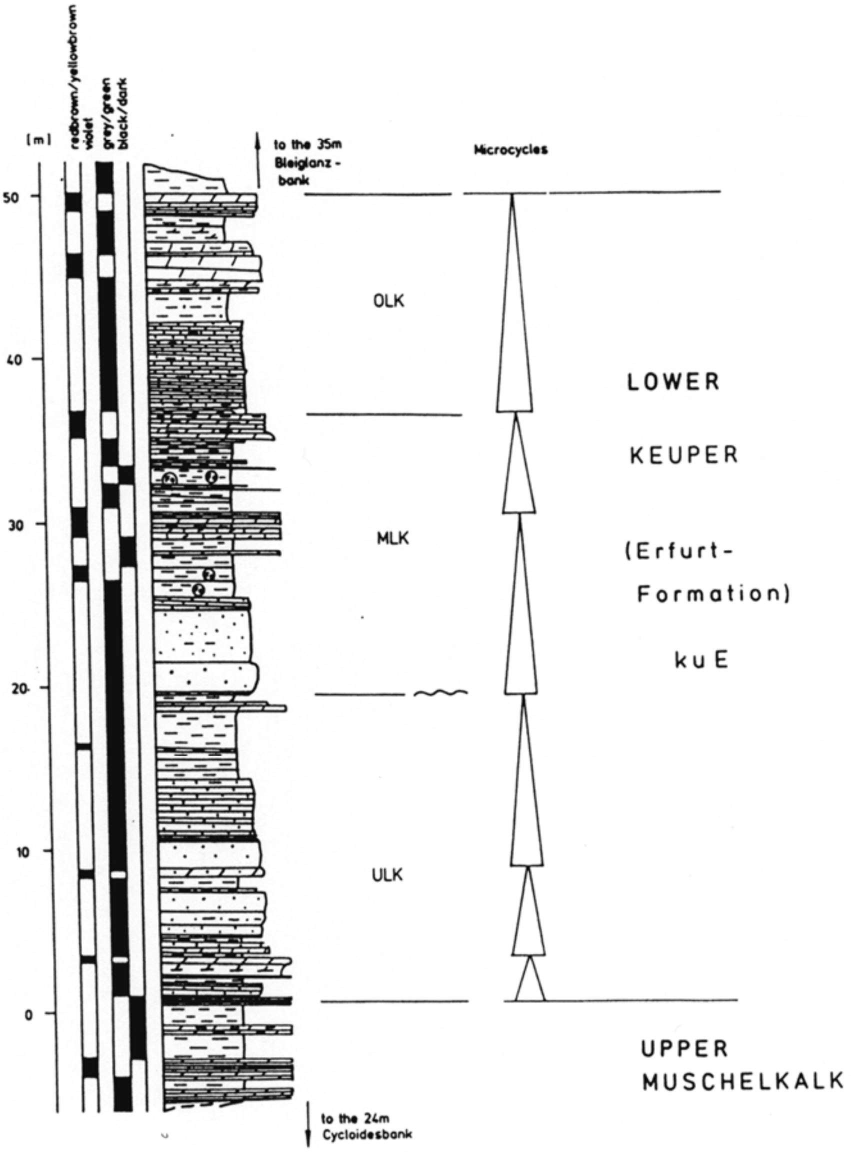


Fig. 27: Section of the Lower Keuper (Erfurt Formation), in the gorge "Egstedter Trift" at Erfurt-Melchendorf. Proposed type section of the Erfurt Formation.

Literature: RICHTER (1936), BEUTLER & GRÜNDEL (1963), DOCKTER et al. (1970)

Stop 15: Petersberg Erfurt (slope below the Petersberg Castle)

Locality:

The Petersberg Castle is located in the centre of Erfurt, on the north side of the Domplatz. From the castle there is a nice view of the old town of Erfurt. The outcrop is situated below the wall in a slope cutting (SE side). Natural monument!

Stratigraphy:

Middle Keuper (Carnian – Norian); exposed is the middle part of the Weser Formation (Oberer Gipskeuper), with the uppermost part of the "Rote Wand" and the Lehrberg Beds.

Main features to be observed:

- Redbeds of the Rote Wand
- Grey, partly fossiliferous dolomites, intercalated with green claystones
- Gypsum nodules, partly dissolved

Points of discussion:

- Transition from playa mudflat to lacustrine deposits
- Distribution of the Lehrberg Beds in Germany
- Origin of the faunal elements

Literature:

DOCKTER et al. (1970)

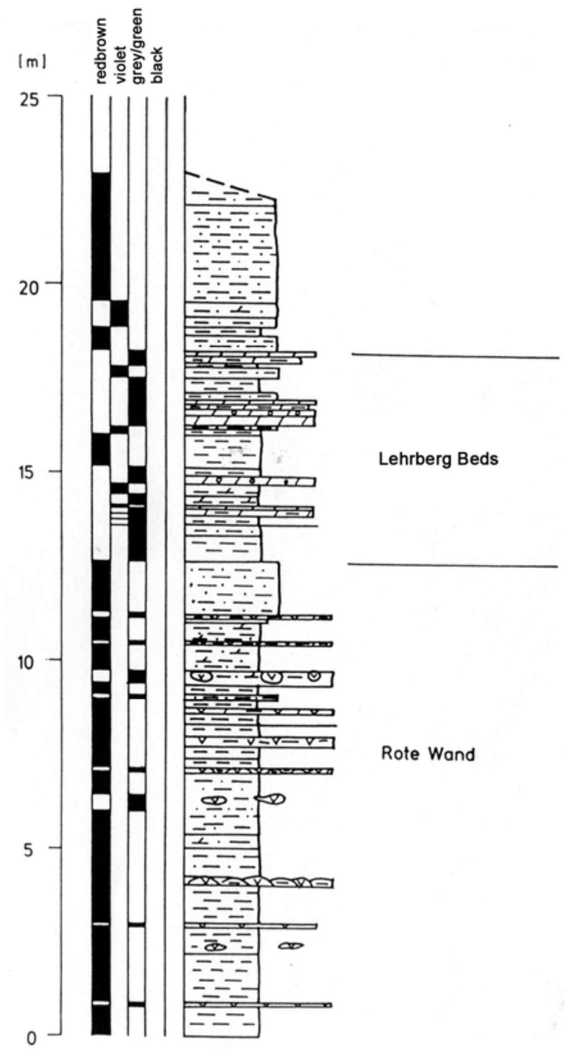


Fig. 28: Middle part of the Weser Fm, including typical "Lehrberg Beds". Road cut below the wall of the Petersberg castle.

Stop 16: Erfurt-Gispersleben (brick pit)

Locality:
Northern slope of the "Roter Berg", about 6 km N of the centre of Erfurt (Domplatz). B 4 to north, at exit Gispersleben to the E (1.5 km), Mittelhäuser Straße to N (1.5 km), then enter the brick pit at the east side of the road.

Stratigraphy (from top to bottom):
Middle Keuper (Carnian): Lower part of the Weser Formation, and upper part of the Stuttgart Formation (Schilfsandstein); Fig. 6

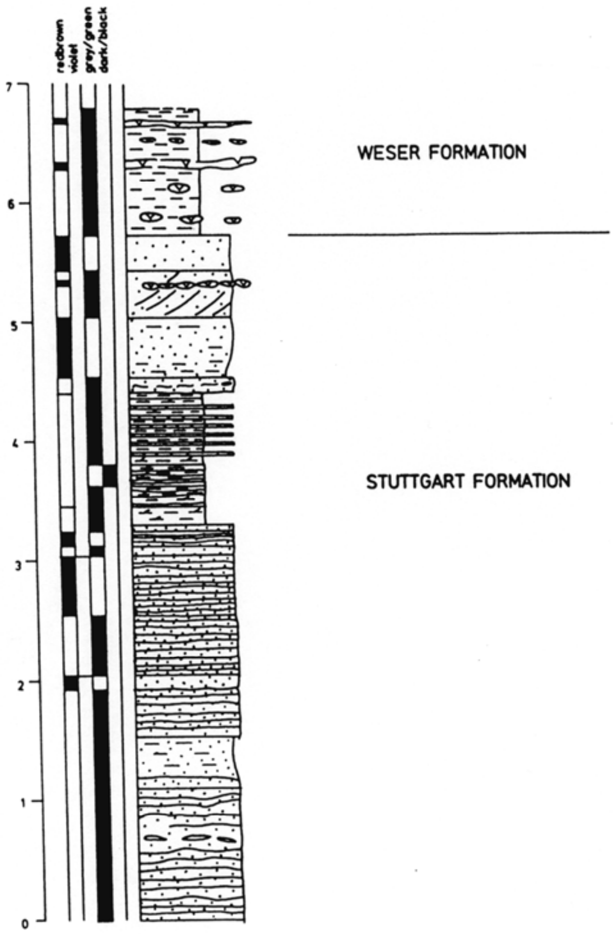


Fig. 29:
Transition from the Oberer Gipskeuper (Weser Formation) to the Schilfsandstein (Stuttgart Formation) in the brick pit Erfurt-Gispersleben.

Main features to be observed:
- Red-brown claystone in the lower part of the Weser Formation, containing some layers of nodular gypsum (chicken-wire type)
- At the top of Stuttgart Formation: Brown sandstone with light-red coloured nodular gypsum
- Siltstone and claystone in red-bed facies, rock colour changes between red-brown and violet-brown, greenish colours are rare
- Sandstone, red-brown, some meters thick with remarkable cross-bedding, erosional base (channel fill)
- Oxidized root horizons in the middle part of the section (indications of paleosoils)

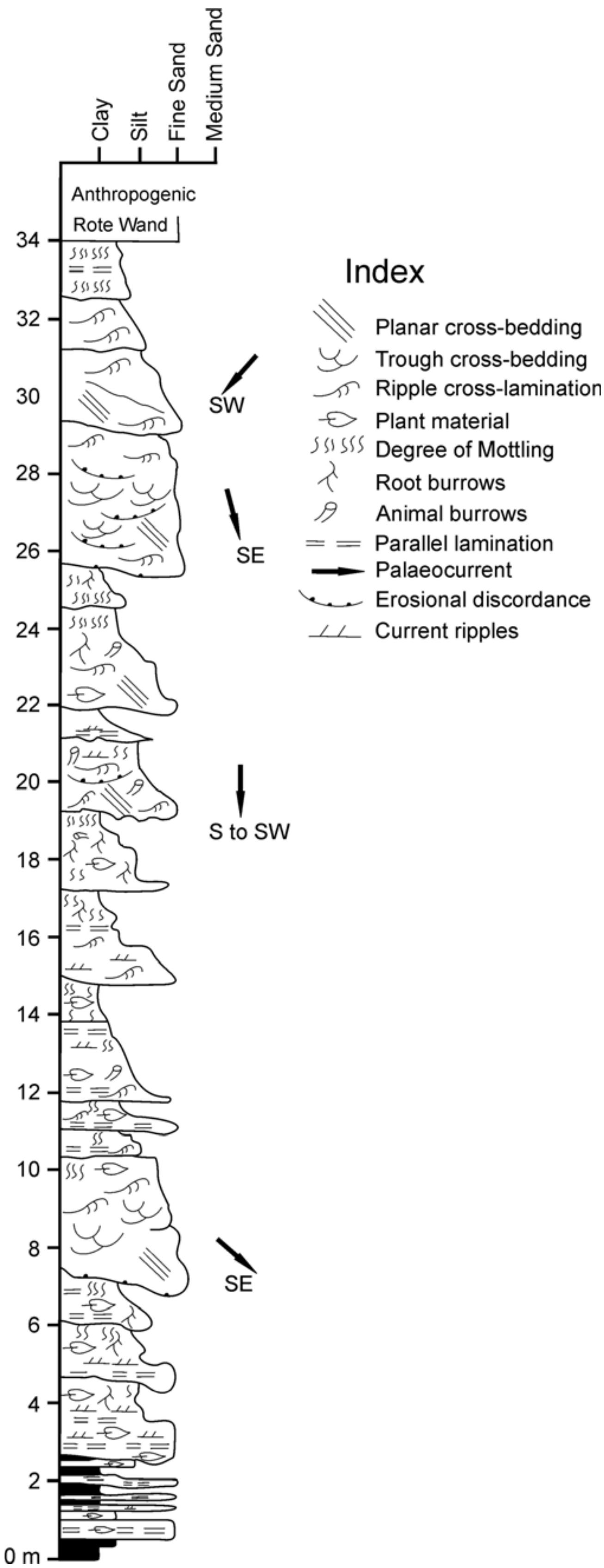


Fig. 30: Litholog of Stuttgart Fm. In the Gispersleben quarry showing major lithofacies and general palaeocurrent trends (from U. SHUKLA, unpubl.).

Stop 17: Heldburggips at the Schwellenburg (protected area)

Locality:

1 km S Eisleben, 200 m W of road B4, abandoned gypsum quarry

Stratigraphy:

Weser Formation, uppermost part consisting of the Schwellenburg Subformation and the Heldburggips Subformation

Section:

On the way to the top of the hill about 30 m multicoloured shales with intercalations of sandstones (thin beds) in the lower part, intercalations of thin dolomites and gypsum beds are exposed. Uppermost 10 m are dominantly grey. The top of the hill is an outcrop with 10 m gypsum, which is strongly dissolved (Heldburggips). In boreholes a maximum thickness of 18 m was recorded. The Heldburggips is a marker horizon of the Middle Keuper.

Literature: Seidel (1966)

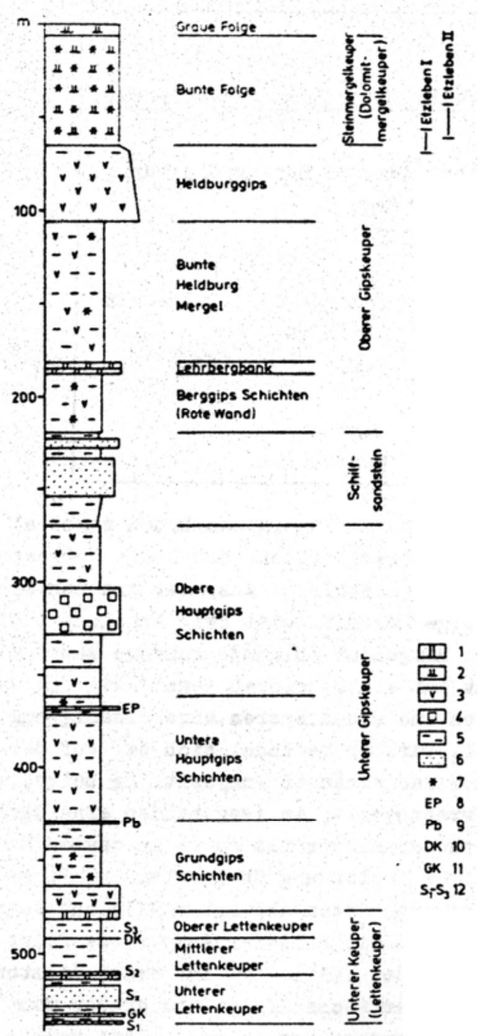


Fig. 31:

Profil der Bohrung Schillingstedt 1 (n. DOCKTER u.a. 1970)

Legende: 1-Dolomit, 2-Dolomitischer Tonstein, 3-Gips, 4-Halit, 5-Tonstein, 6-Sandstein, 7-rote Farben, 8-Aquivalent Engelhofer Platte, 9-Bleiglanzbank, 10-Dietendorfer Kalk, 11-Guthmannshäuser Kalk, 12-Sandsteine des unteren Keupers

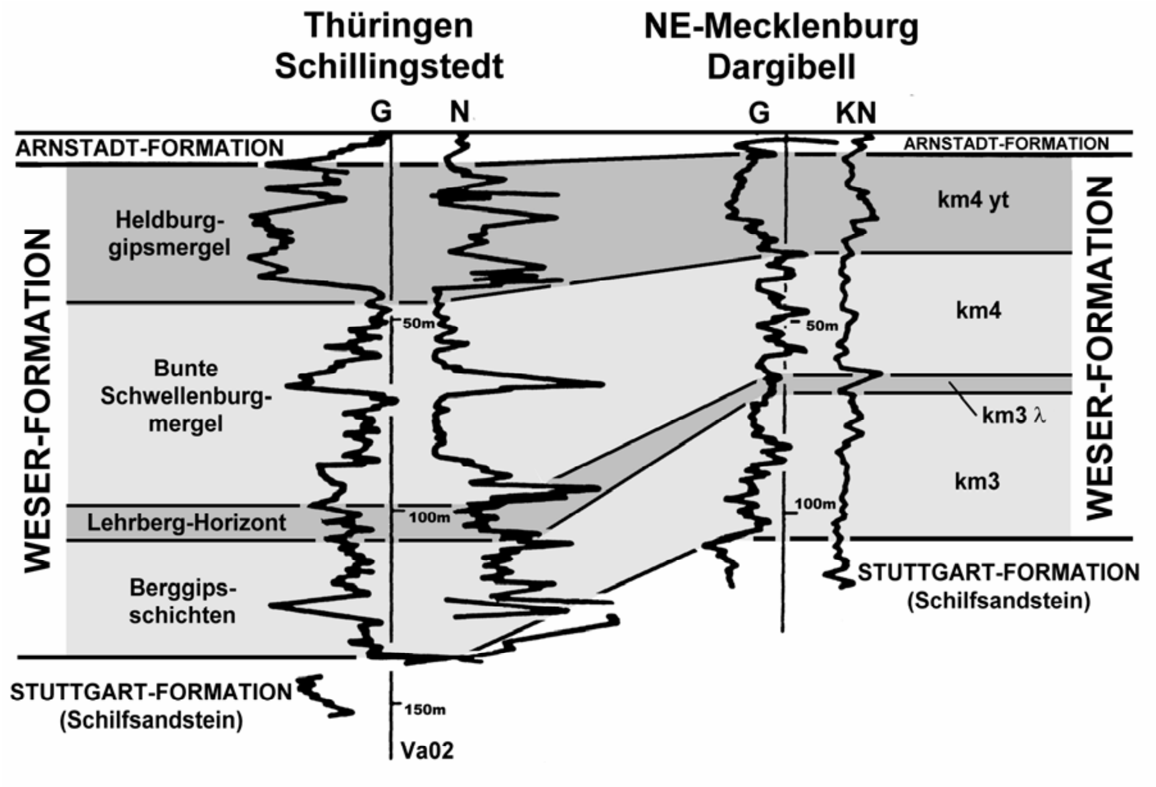


Fig. 32: Log-correlation between Schillingstedt (Thuringia) and Dargibell (NE-Germany).

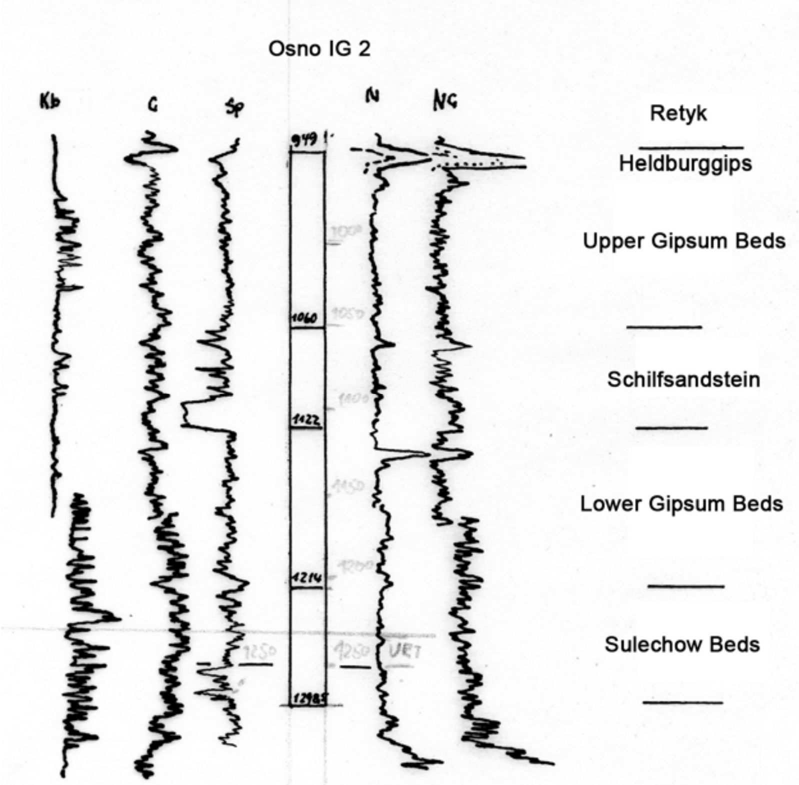


Fig. 33: Osno IG 2 with logs. Subdivision after Polish Stratigraphic Commission.

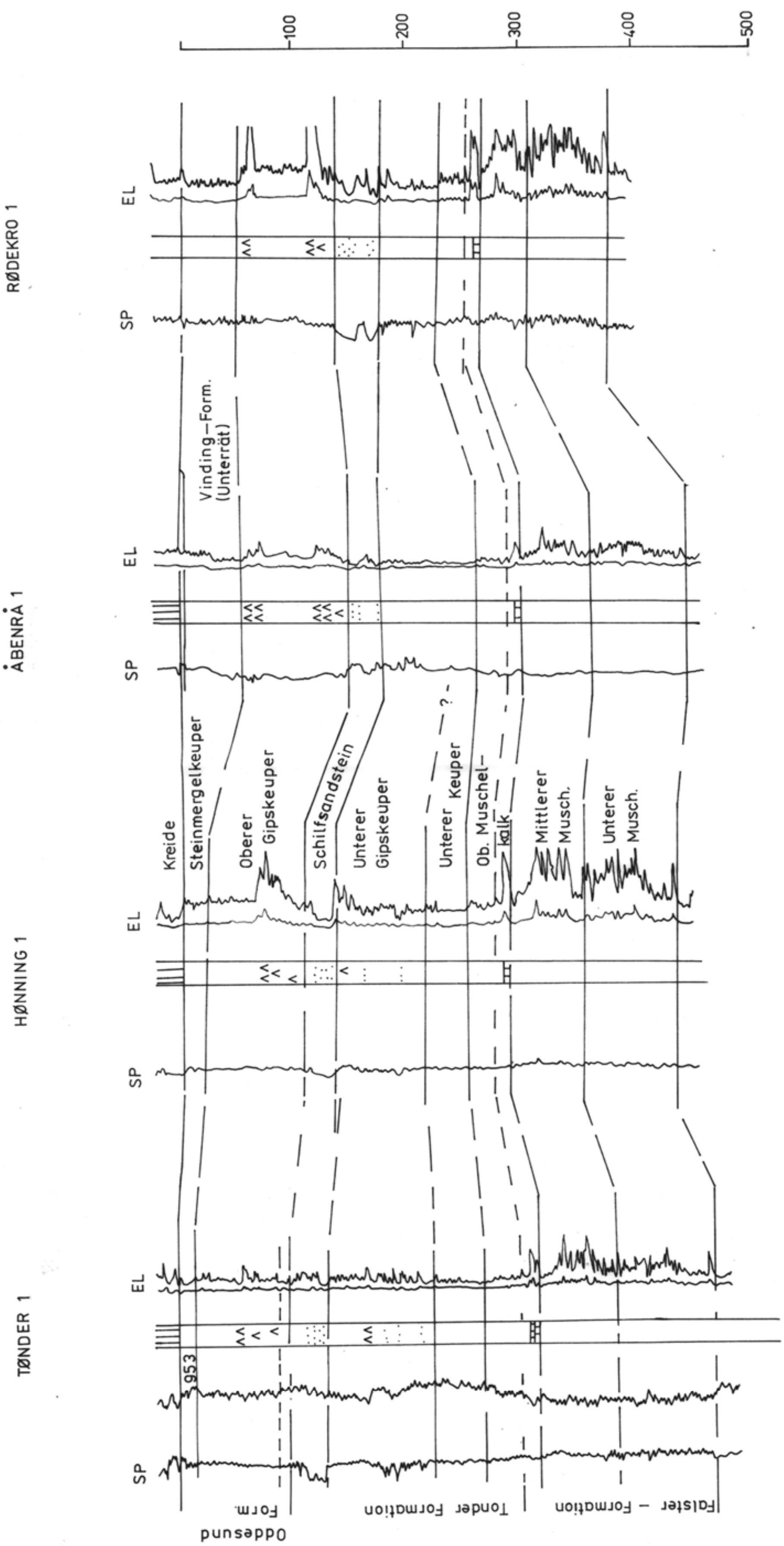


Fig. 34: Log-correlation between the Tønder 1 and Røderkro 1 of the southern Jutland area (Denmark), after BERTELSEN (1980).

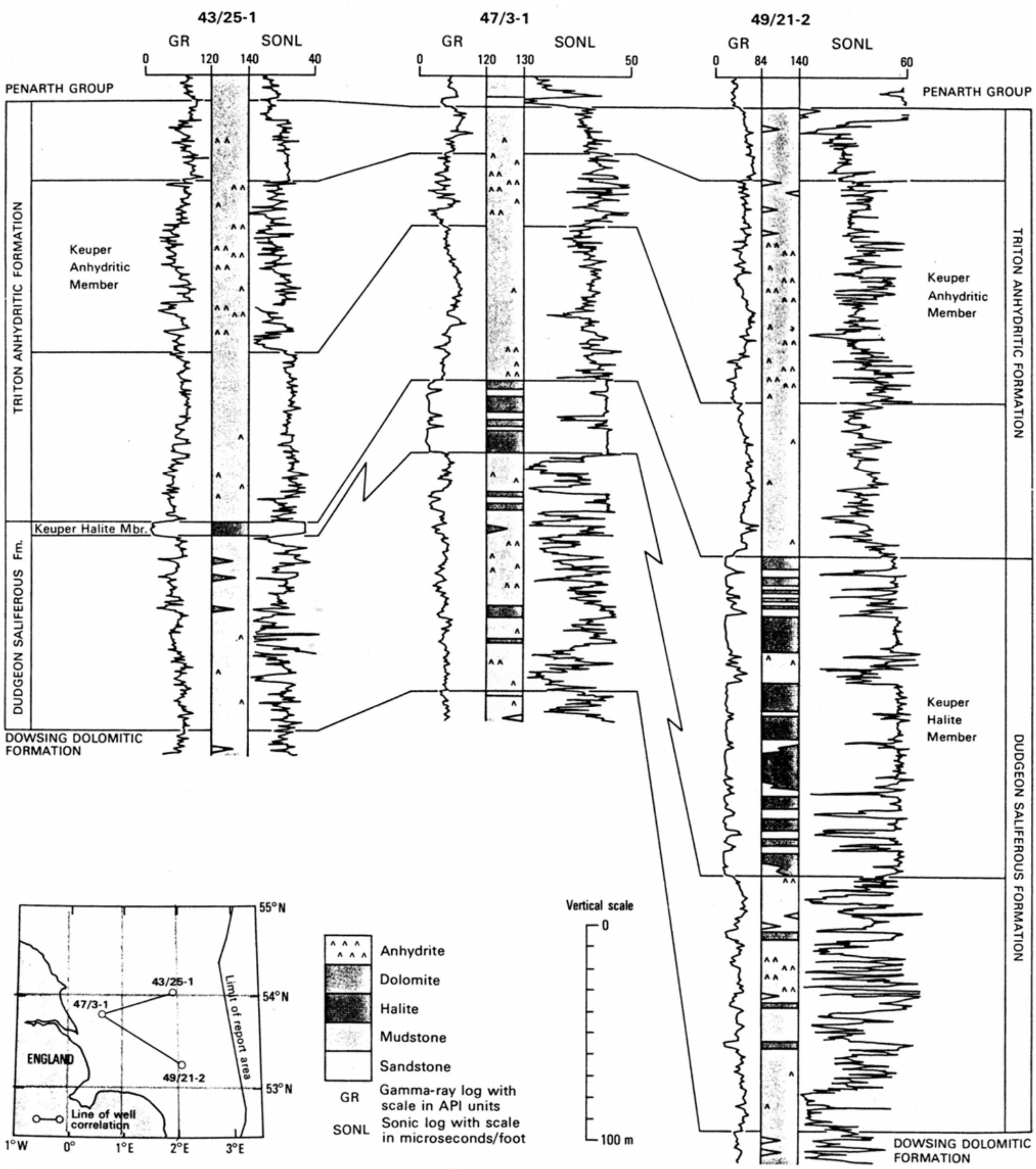


Fig. 35: Correlation of the Dudgeon Saliferous and Triton Anhydritic formations between three offshore wells (southern North Sea area).

Stop 18: Groß Monra

Locality:
Quarry 2.5 km W Groß Monra.

Stratigraphy:
Middle Keuper (Stuttgart Formation)

Section:
Quarry section comprising greenish-grey to red coloured cross-bedded sandstone.

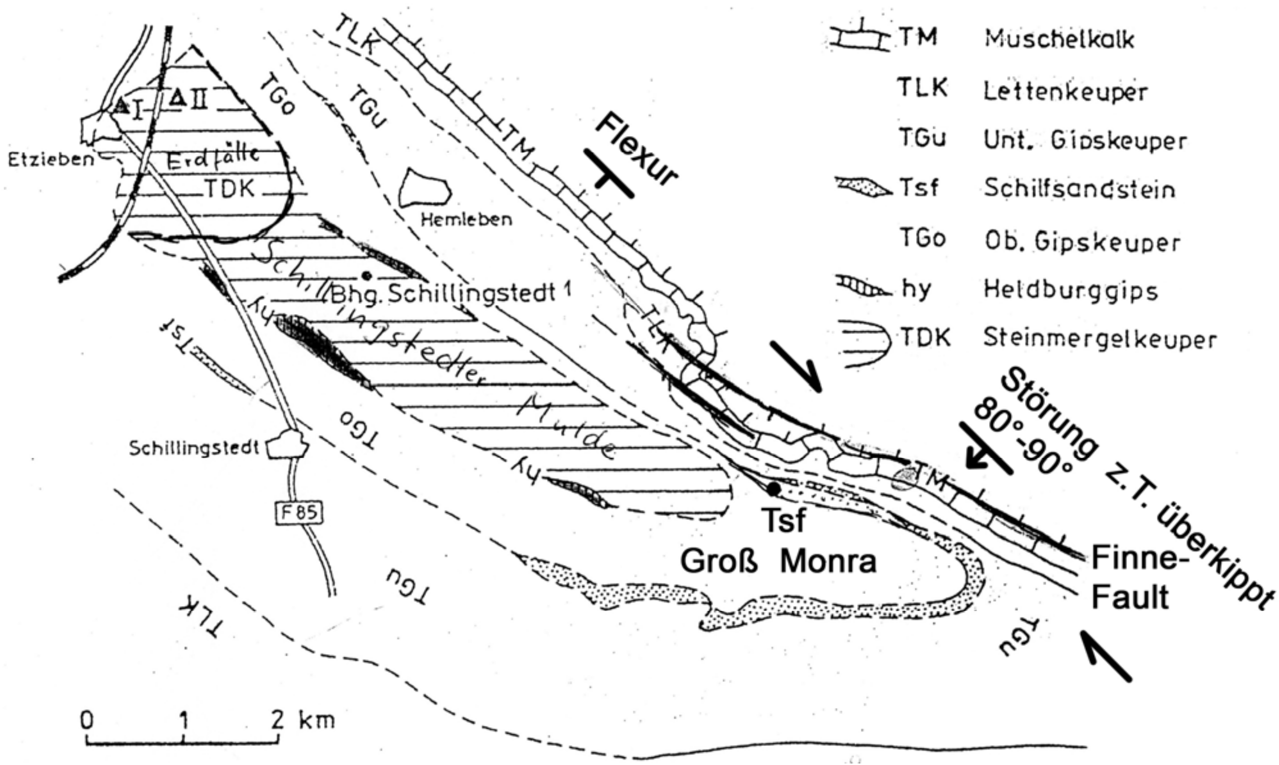


Fig. 36: Geological map with the position of the Groß Monra quarry.

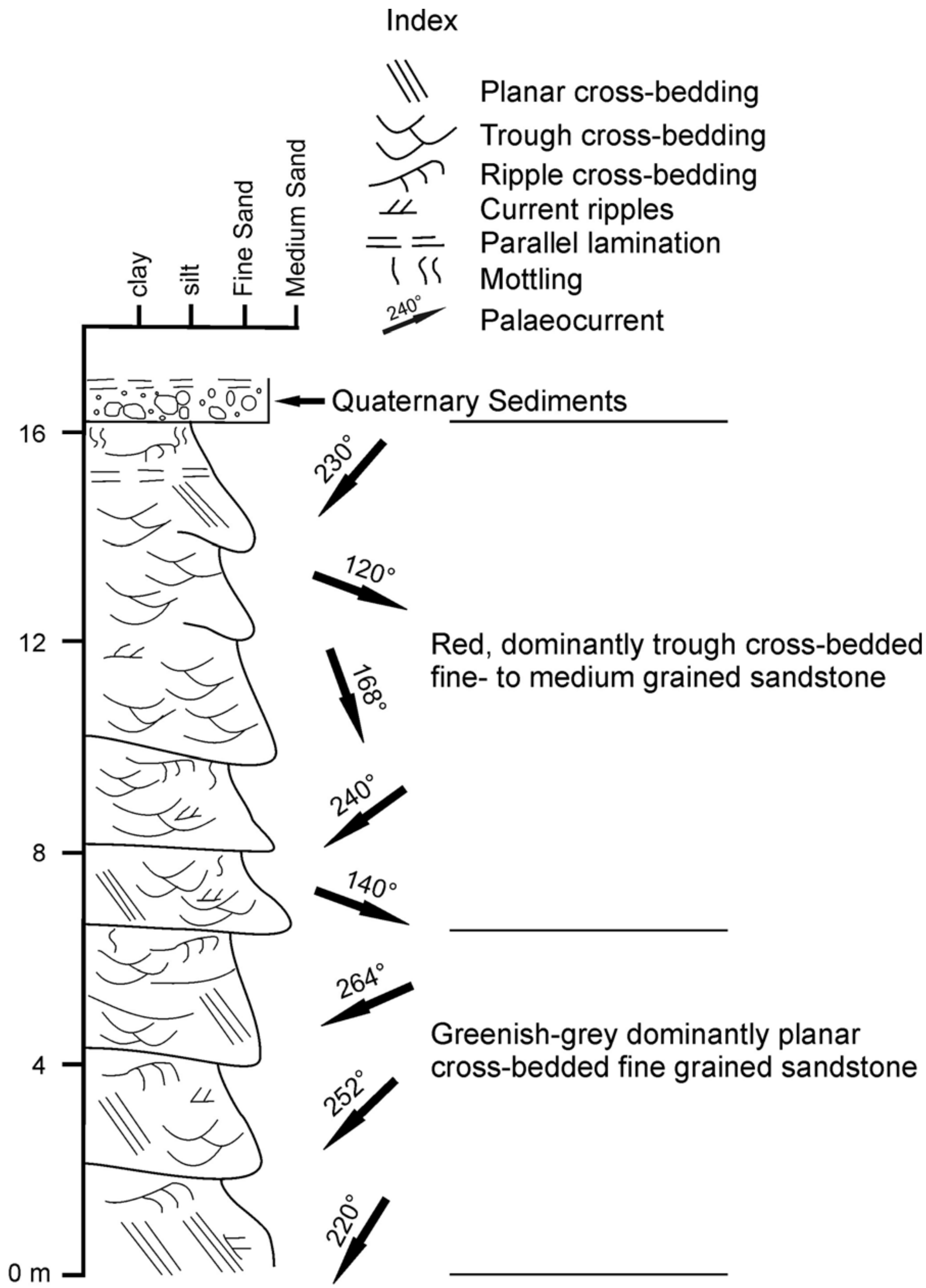


Fig. 37: Litholog showing distribution of lithofacies and palaeocurrent directions in the Stuttgart Fm. at Groß Monra (from U. SHUKLA, unpubl.).

Day 5 (19. July 2005)

Stop 19: SW-Hang Wachsenburg

Locality:

Badlands of the SW slope of the Wachsenburg hill, 5 km NW Arnstadt, 800 m NW of village Holzhausen. Nature reserve!

Stratigraphy:

Upper part of Middle Keuper (Norian): Arnstadt Formation (Steinmergelkeuper); exposed are “Mittlere Graue Folge” and “Untere Bunte Folge”, also the underlying “Heldburggips” of the Weser Formation. This section is part of the proposed type section.

Main features to be observed:

- Red shales in the lower part and grey to black shales in the upper part
- Cyclic intercalations of grey dolomites
- Two sandstone horizons, partly with cross-bedding, erosional bases
- Gypsum beds (Heldburggips) below the Arnstadt Formation (6-8 m thick)

Point of discussion:

- Sedimentary environment (playa mud flat, fluvial deposits, lake sedimentation, pedogenic influence)
- Origin of the clastic materials, connection to Southern Germany
- Palynostratigraphy of the Arnstadt Formation

Literature:

NAUMANN (1911), KELLNER (1997)

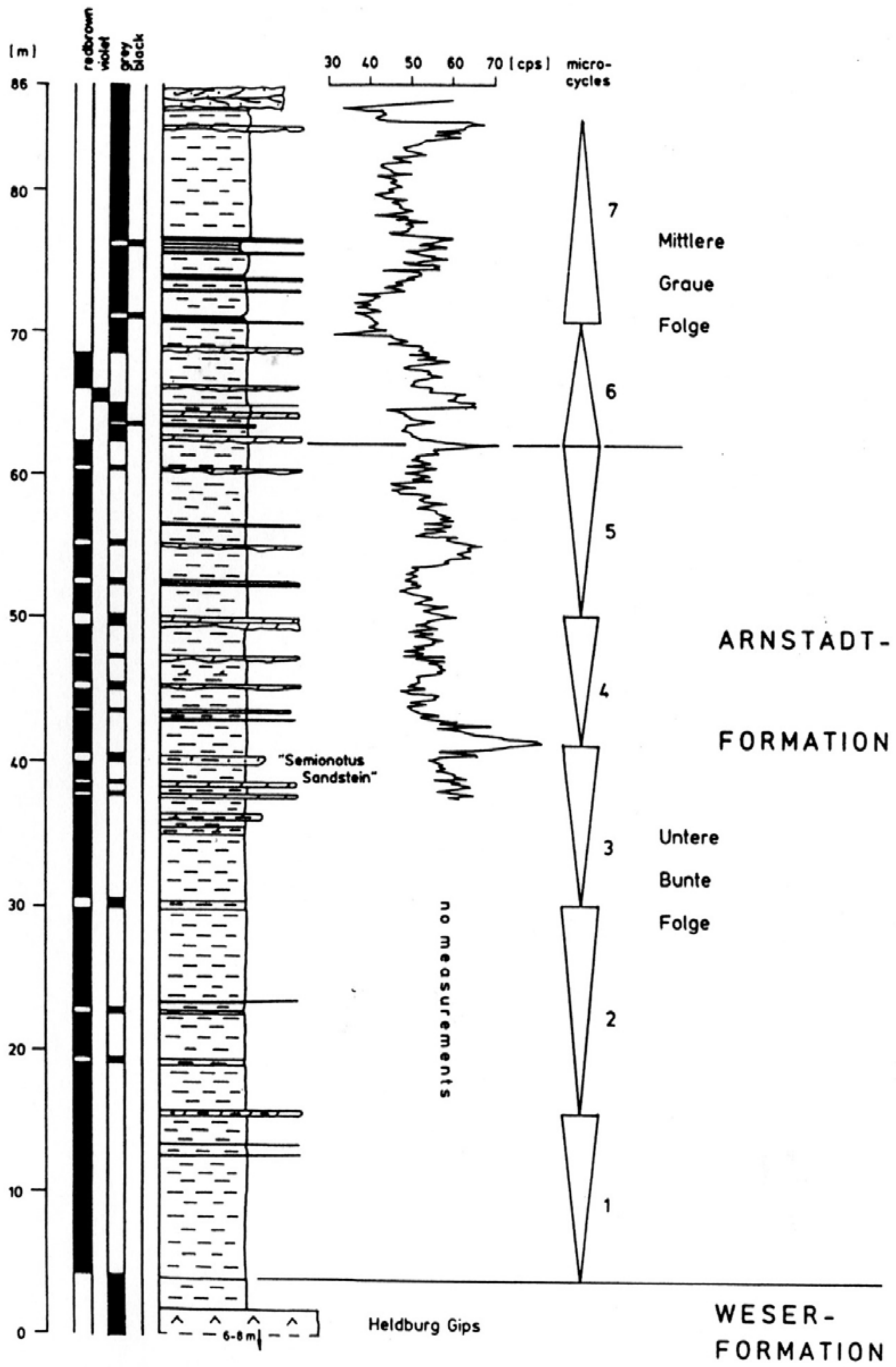


Fig. 38: Profile and Gamma-log at the Wachsenburg outcrop.

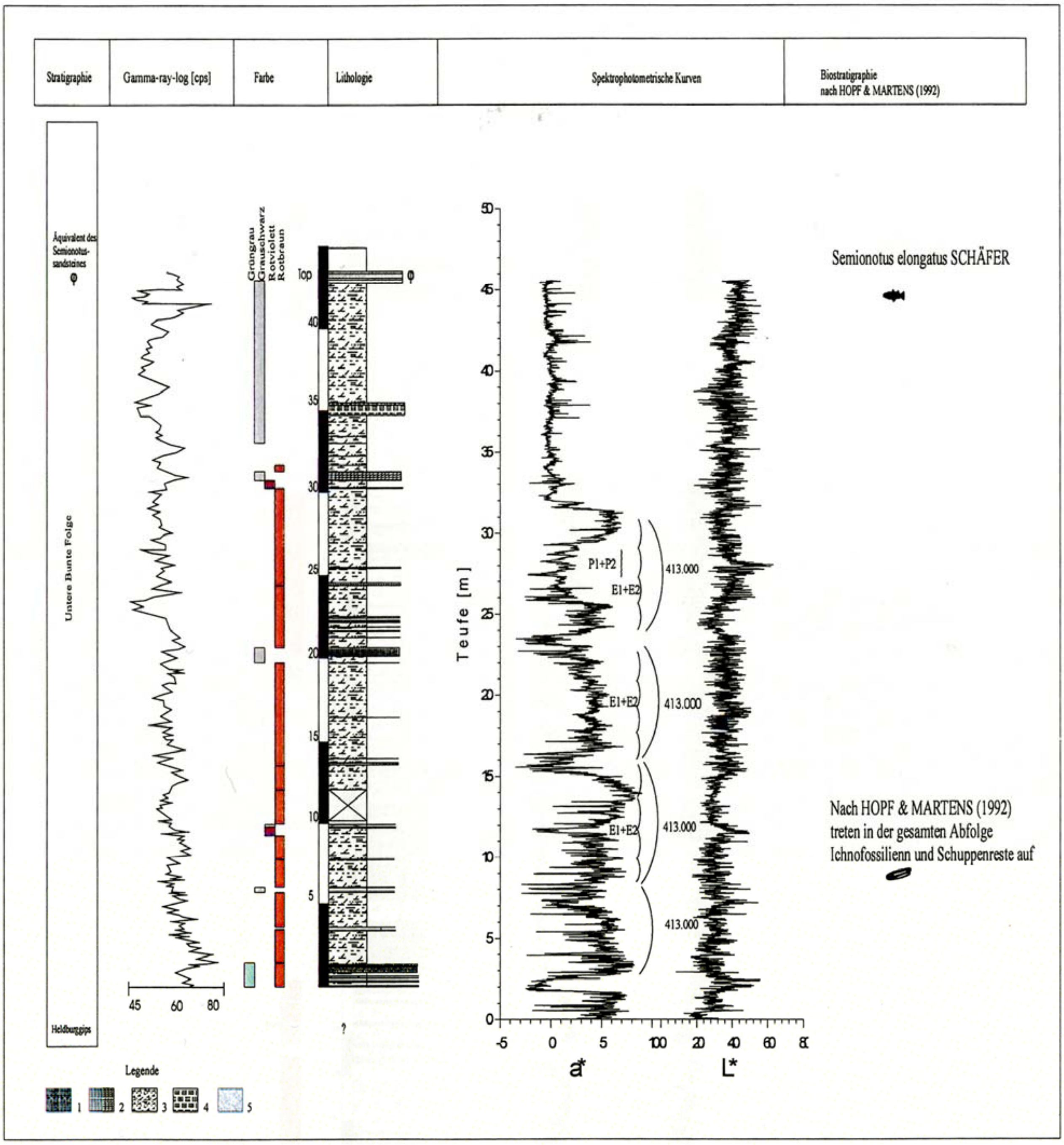


Fig. 39: Profile of the Wachsenburg outcrop.

Stop 20: Burg Gleichen

Locality:
Badlands at the southern slope of Burg Gleichen, 700 m east of Mühlberg/ Wandersleben exit. Access by a path from the parking lot at the road to Wandersleben.

Stratigraphy:
Upper part of Middle Keuper (Steinmergelkeuper; proposed type locality of Arnstadt Fm)

Main features to be observed:

- Subdivision in multicoloured and grey shales (Lower Bunte Folge, Middle Graue Folge, Upper Bunte Folge)
- Bedded vs. nodular dolomite beds
- Small-scale shale-dolomite cycles

Point of discussion:

- Depositional environments
- “Transgressive/regressive” vs. “wetter/drier“ facies pattern (lacustrine vs. playa)
- Cyclicity
- Apparent rarity of gypsum (relics)
- Lacustrine vs. pedogenic origin of dolomite beds
- Evaporite pumping model (Hsu & Siegenthaler, 1969) for dolomite beds
- Rapid variation of sedimentation causing lithostratigraphic correlation problems
- Transition to alluvial facies in Southern Germany
- Norian/Rhaetian correlation problems

Literature:
NAUMANN (1911), KELLNER (1997), E.SCHRÖDER (1955)

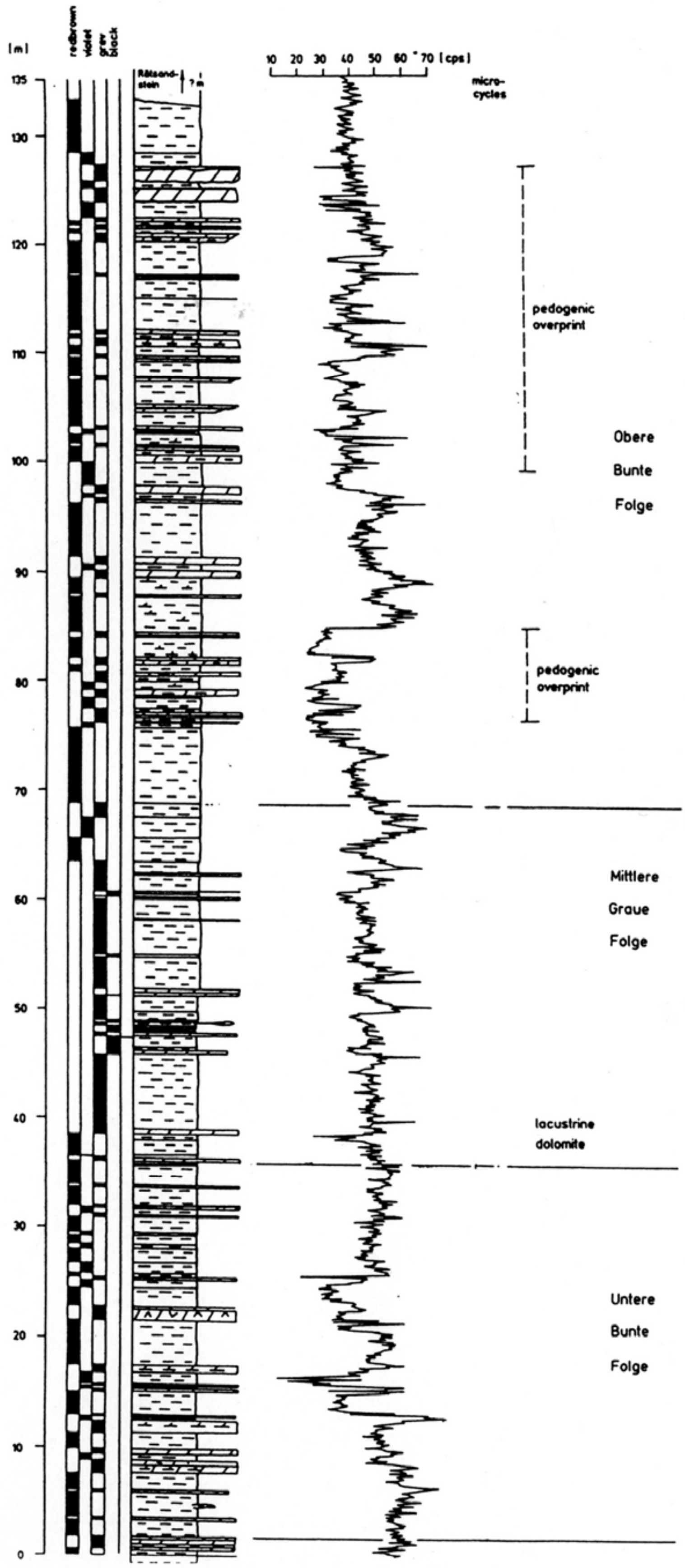


Fig. 40: Profile of the Burg Gleichen outcrop.

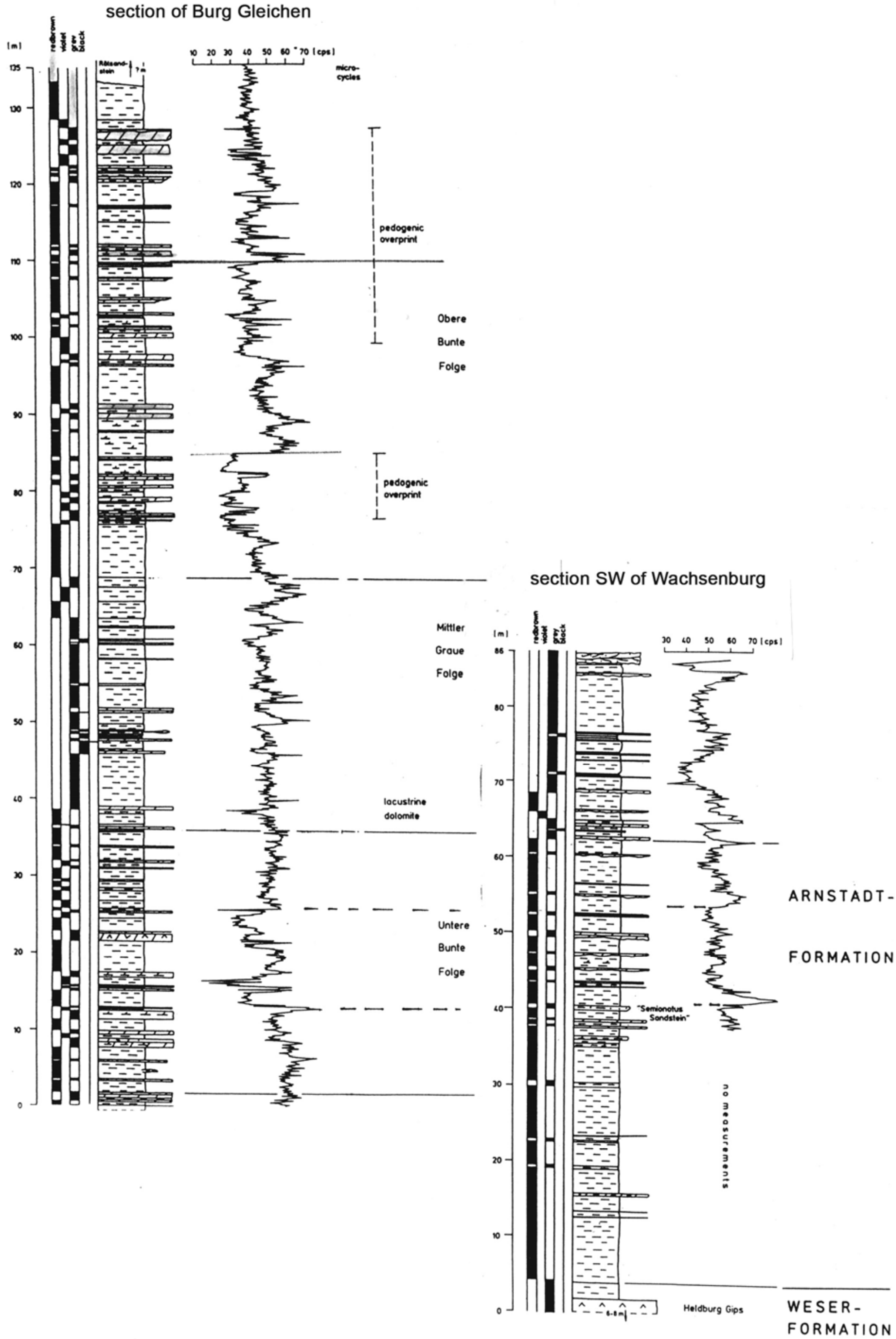


Fig. 41: Correlation of the Burg Gleichen section with the Wachsenburg section.

Stop 21: Kammerbruch

Locality:

From Topfleben, 2 km SE from Gotha, on the road to the top of the Großer Seeberg about 3 km to the east. On top of the hill are several active quarries in which building stones are produced. This is an historical working site because the sandstone was used for numerous historical buildings, such as the Wartburg, the Erfurter Dom and many others.

Stratigraphy:

Liassic (Lower Hettangian, Psilonoten Beds) to Exter Formation (= Rätkeuper, comprising Triletes Beds, Contorta Beds and Postera Beds). Reference section of the Exter Formation.

Main features to be observed:

- Lithology: Dark to black shales with poorly preserved fauna *(Psilonotum sp.* several species)
- Microflora: Very common Acritarchs, *Hystrichosphaeridium langii* Wall
- Mica-rich sandstone interbedded by grey claystone, rarely with plant remains, at the base dominated by claystone (so-called Töpferton), type strata (Stratum typicum) of *Cornutisporites seebergensis* Schulz 1962 and *Semiretisporites gothae* Schulz
- Massive sandstone horizons, fine grained quartz-sandstone, partly cross-bedded, ripple marks at the palaeosurface. Thin intercalations of black and grey claystone containing plant fossils and palynomorphs (for instance *Rhaetipollis germanicus*).
- About 3 m below the ripple-marked surface there is a coarse-grained sandstone with small caves ("Kavernöse Quarzschicht").
- Sedimentary structures, ripple marks, desiccation cracks, mud pebbles.

Point of discussion:

- Stratigraphy (Triassic/Jurassic boundary)
- Palaeogeography of the Rhaetian in the Germanic Basin.
- Sedimentary environments, marginal facies.
- Origin of the clastic material.

Literature:

KLAUA (1969), DOCKTER et al. (1970), ERNST (1994), SEELING (1999)

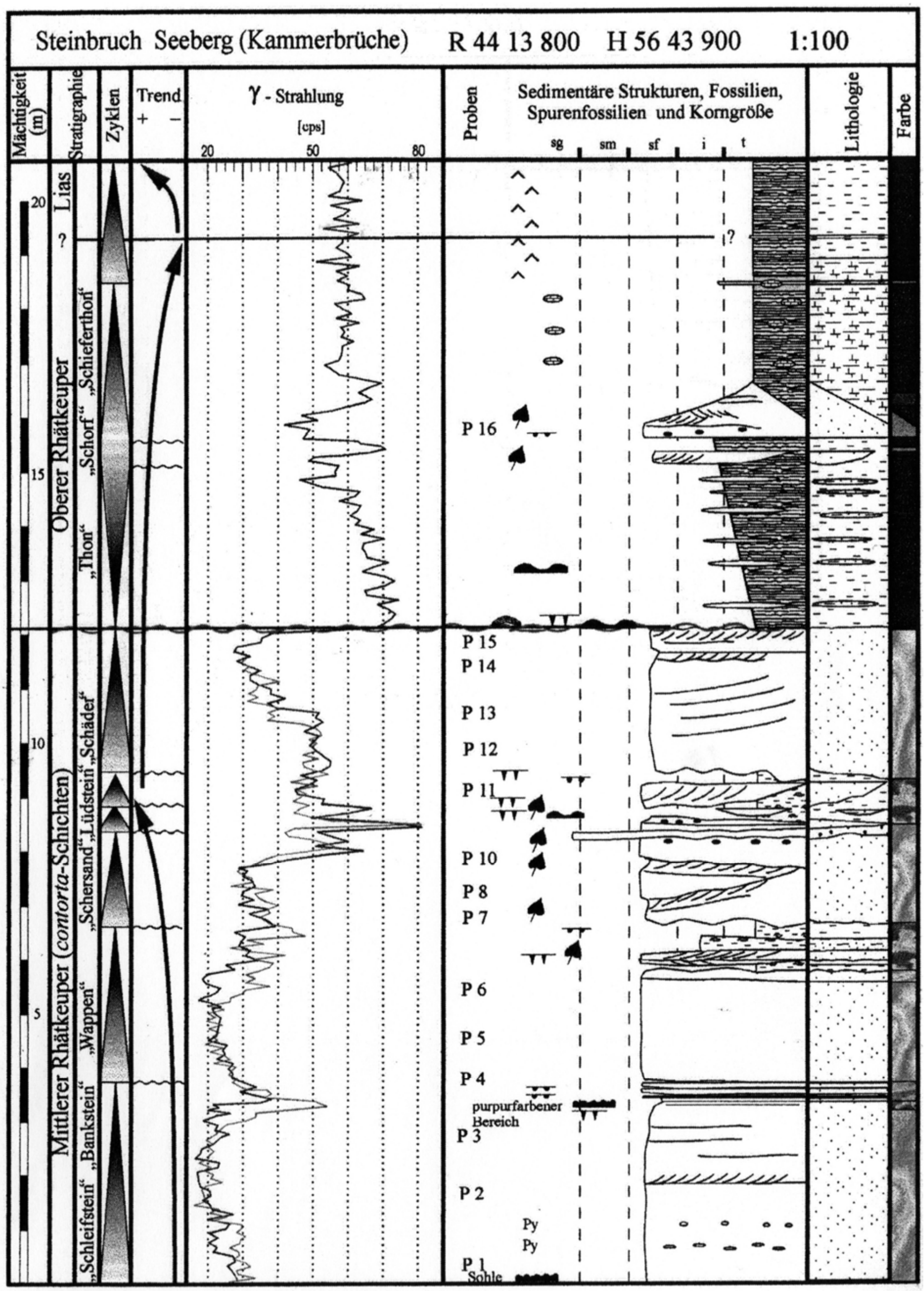


Fig. 42: Profile and Gamma-log of the Seebergen outcrop (SEELING 1999).

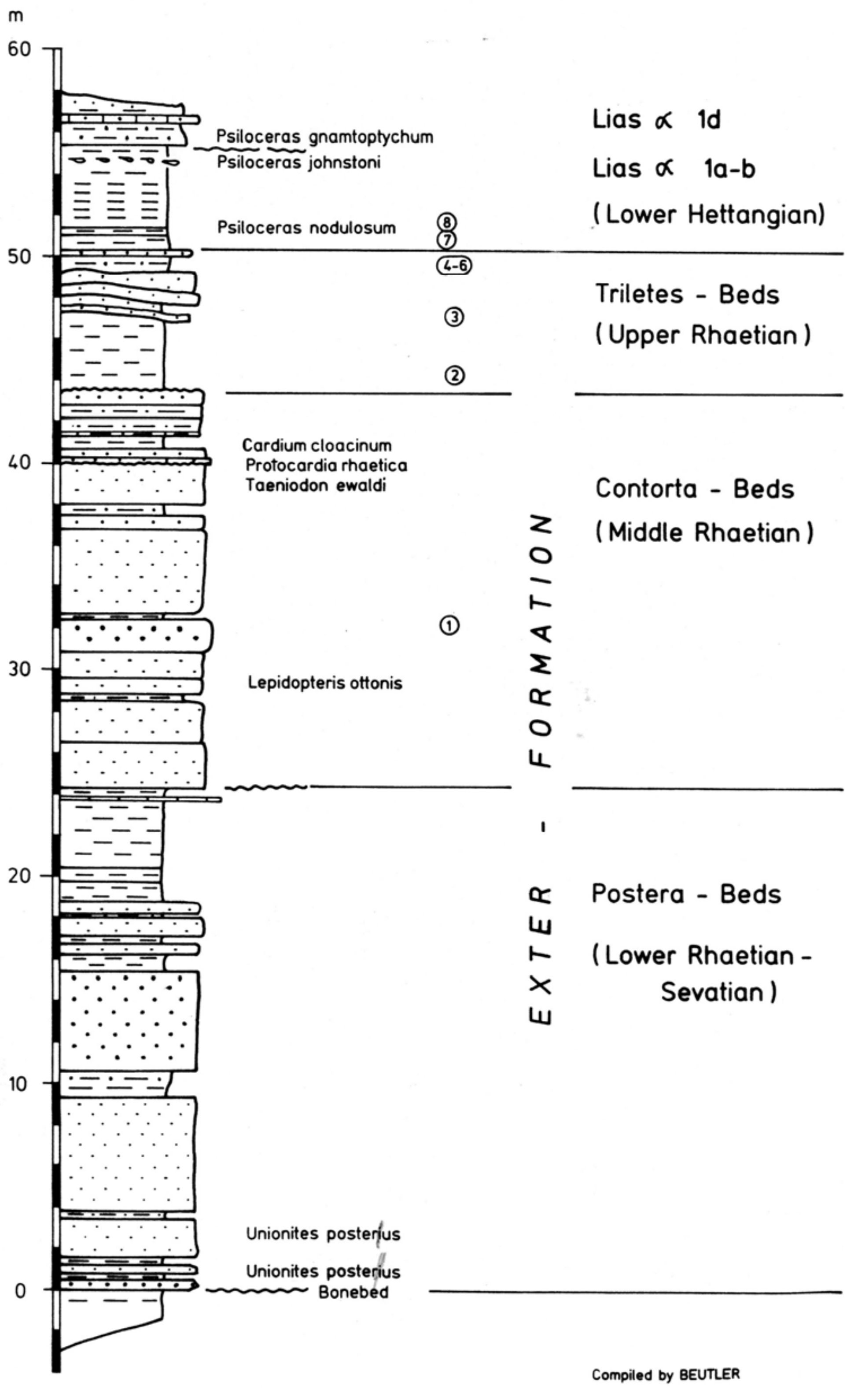


Fig. 43: Profile of the Seebergen outcrop.

Literature

AIGNER, T. (1985): Storm depositional systems. Dynamic stratigraphy in modern and ancient shallow marine seyuences. – Lecture Notes in Earth Sci., **3**: 1-174.

AIGNER, T. & BACHMANN, G.H. (1992): Sequence-startigraphic framework of the German Triassic. – Sedim. Geol., **80**: 115-135.

ALBERTI, F. V. (1834): Beitrag zu einer Monographie des Bunten Sandsteins, Muschelkalks und Keupers und die Verbindung dieser Gebilde zu einer Formation. – 366 S.; Stuttgart (Cotta).

BACHMANN, G.H. & KOZUR, H.W. (2004: The Germanic Triassic: correlations with the international chronostratigraphic scale, numerical ages and Milankovitch cyclicity. – Hall. Jb. Geowiss., **B26**: 17-62.

BEUTLER, G. (1979): Verbreitung und Charakter der altkimmerischen Hauptdiskordanz. – Z. geol. Wiss., **7**: 617-632.

BEUTLER et al. (2005) - Deutsche Stratigraphische Kommission (Hrsg., 2005): Stratigraphie von Deutschland, Keuper. Courier Forsch.-inst. Senckenberg, Frankfurt.

BEUTLER, G. & SCHÜLER, F. (1979): Über Vorkommen salinarer Bildungen in der Trias im Norden der DDR. – Z. geol. Wiss., **7** (4): 903-911.

BERTELSEN (1980): Lithostratigraphy and depositional history of the Danish Triassic. - Geological Survey of Denmark, Series B, No.**4**: 52 pp.

BOIGK, H. (1956): Vorläufige Mitteilungen über eine neue Gliederung des Mittleren Buntsandsteins im Raume Südhannover. – Geol. Jb., **72**: 325-340.

BOIGK, H. (1959): Zur Gliederung und Fazies des Buntsandsteins zwischen Harz und Emsland. – Geol. Jb., **76**: 597-636.

BRENNER, K. (1973): Stratigraphie und Paläontologie des Oberen Mittelkeupers in Südwestdeutschland. – Arb. Inst. Geol. Paläont. Univ. Stuttgart, N. F. **68**: 101-222.

CAMERON, T.D.J., Crosby, A., Balson, A., Jeffrey, P.S., Lott, D.H., Butlat, G.K. & Harrison, D.H. (1992): United Kingdom offshore regional reports. The geology of the southern North sea. MHSO for the British Geological Survey, **152**.

DITTRICH, D. (1989): Beckenanalyse der Oberen Trias der Trier-Luxemburger Bucht. Revision der stratigraphischen Gliederung und Rekonstruktion der Paläogeographie. – Publ. Du Serv. Geolog. Du Luxembourgh, **26**: 223 S.

DOCKTER, J., LANGBEIN, R., SEIDEL, G. & UNGER, K.P. (1970): Die Ausbildung des unteren und mittleren Keupers in Thüringen. – Jb. Geol., **3**: 154-194.

DOCKTER, J, PUFF, P., SEIDEL, G. & KOZUR, H. (1980): Zur Triasgliederung und Symbolgebung in der DDR. – Z. geol. Wiss., **8 (8)**: 951-963.

DUCHROW, H. (1984): Keuper. – in: KLASSEN, H. (Ed.): Geologie des Osnabrücker Berglandes. – 221-334; Osnabrück.

EMMERT, U. (1994): Hat Leopold von Buch den Formationsbegriff „Keuper“ wirklich definiert? – Geol. Bl. NO Bayern, **44** (3-4): 261-266.

ERNST, W. (1994): Über den Rhät/Lias- Graben am Apfelstädt-Fluß zwischen Wechmar und Wandersleben (Kreis Gotha). – Veröff. Naturkundemuseum Erfurt, **13**: 49-59.

EXNER, M. (1999): Zyklische Stratigraphie und Fazies des Oberen Buntsandsteins (Röt) im Unstrut-Tal (Sachsen-Anhalt). – 85 pp., Diploma Thesis Univ. Halle.

GÖTZE, J. (1998): Geochemistry and provenance of the Altendorf feldspathic sandstone in the Middle Bunter of the Thuringian Basin (Germany). – Chem. Geol.

GWINNER , M. P. (1980): Eine einheitliche Gliederung des Keupers (Germanisiche Trias) in Süddeutschland. – N. Jb. Geol. Pal., Mh., 229-234.

HAUBOLD, H. & PUFF, P. (1976): Zur Genese der Solling-Folge (Untere Trias, Buntsandstein) in Thüringen. – Schriftenr. Geol. Wiss. Berlin, **6**: 63-80.

HAUSCHKE, N. & SZURLIES, M. (1998): Excursion B: Stratigraphy, Sedimentary Environment and Cyclicity of Buntsandstein and Lower Muschelkalk in the Central European Basin (North of the Harz Mountains), in: G.H. Bachmann, G. Beutler, I. Lerche (Eds.), Excursions of the International Symposium on the Epicontinental Triassic, Halle (Saale) September 1998, Hallesches Jb. Geowiss. **B6**: 86-98.

HOFFMANN, F. (1825): Ueber die geognostischen Verhältnisse des linken Weserufers bis zum Teutoburger Wald. – Ann. Physik, **79**: 1-42.

HOPPE, W. (1959): Zyklische Gliederung des Unteren und Mittleren Buntsandsteins in Thüringen. – Ber. Geol. Ges. DDR, **4**: 3-58.

HOPPE, W. (1966): Die regionalgeologische Stellung der Thüringer Trias. – Ber. deutsch. Ges. geol. Wiss. A, Geol. Paläont., **11**: 7-38.

HOPPE, W. (1974): Buntsandstein: - in: Hoppe, W. & Seidel, G. (Ed.): Geologie von Thüringen. – 568-605; Gotha, Leipzig.

JUBITZ, K.-B. (1959): Die Trias Ostthüringens als Rohstoffbasis. – Exk.führer Thüringer Becken, Jahrestag. Geol. Ges. DDR in Weimar: 99-138.

JUNGWIRTH, J., P. PUFF, G. SEIDEL (1996): Zur Ausbildung des Oberen Muschelkalkes zwischen Erfurt und Arnstadt (Thüringer Becken). - Geowissenschaftliche Mitteilungen von Thüringen, **4**: 19-34.

KELLNER, A. (1997): Das Typusprofil des Arnstadt-Formation (ehem. Steinmergelkeuper, Obere Trias) Thüringens. - 71 pp., Dilpoma Thesis Univ. Halle.

KLAUA, D. (1969): Sedimentpetrographische Untersuchungen der Rhätsandsteine Thüringens. – Geologie, Jg. **18**, Bh. **64**: 18-82.

KNAUST, D. (1996): Die Kalkstotzen-Fazies im Muschelkalk (mittlere Trias) von Thüringen. – Zbl. Geol. Paläont., Teil 1, 1/2: 189-204.

KNAUST, D. & HAUSCHKE, N. (2004): Trace fossils versus pseudofossils in Lower Triassic playa deposits, Germany, Palaeogeogr., Palaeoclimatol., Palaeoecol., **215**: 87-97.

KOZUR, H.W. (1999): The correlation of the Germanic Buntsandstein and Muschelkalk with the Tethyan scale, Zbl. Geol. Paläont. Part I 1998, **7-8**: 701-725.

KOZUR, H.W. & BACHMANN, G.H. (2005): Correlation of the Germanic Triassic with the international scale, Albertiana, **32**: 21-35.

NAUMANN, E. (1911): Beitrag zur Gliederung des Mittleren Keupers in Thüringen. – Jb. Preuß. Geol. L. Anst., **28** (3): 549-580.

PAUL, J. & KLARR, K. (1987): Feinstratigraphie und Fazies des Unteren und Mittleren Buntsandsteins in der Bohrung Remlingen 5. – GSF-Bericht, **8/87**, 118 S.

PUFF, P. (1976): Gliederung der Solling-Folge (Trias, Buntsandstein) im südlichen Thüringen mittels Violetter Horizonte. – Schriftenr. Geol. Wiss., **6**: 81-96.

PUFF, P. (1995): Buntsandstein. – in: SEIDEL, G. (Ed.): Geologie von Thüringen. – 302-315; Stuttgart.

RADZINSKI, K.-H. (1995): Zum Unteren und Mittleren Buntsandstein im Unstruttal bei Nebra (Südwestrand der Querfurter Mulde). – Mitt. Geol. Sachsen-Anhalt, **1**: 83-105.

RÖHLING, H.-G. (1991): A lithostratigraphic subdivision of the Lower Triassic in the Nordwest German Lowlands and the German sector of the North Sea , based on Gamma-Ray and Sonic logs. – Geol. Jb., **A 119**: 3-24.

RÖHLING, H.-G., STOLLHOFEN, H. & TIETZE, K.-W.(2002): Trias-Exkursion I. Buntsandstein zwischen Hannover und Würzburg, in: B. Niebuhr (Ed.), Geo2002 - Planet Erde: Vergangenheit, Entwicklung, Zukunft, Schriftenreihe Dt. Geol. Ges., **22**: pp. 5-28.

ROMAN, A. (2003):Sequenzstratigraphie und Fazies des Buntsandsteins im östlichen Teil des Germanischen Beckens (Polen, Deutschland). 144 pp., Dissertation Univ. Halle.

ROMAN, A. (2004): Sequenzstratigraphie und Fazies des Unteren und Mittleren Buntsandsteins im östlichen Teil des Germanischen Beckens (Deutschland, Polen), Thesis Univ. Halle: 144 pp.

RÜFFER, T. (1996): Seismite im Unteren Muschelkalk westlich von Halle. – Hallesches Jb. Geowiss., B, **18**: 119-130.

SCHOTT, W. (1944): Die Gliederung im nordwestdeutschen Rätbecken. – Ber. Reichsamt f. Bodenf., **63**: 61-77.

SCHRÖDER, B. (1982): Entwicklung des Sedimentbeckens und Stratigraphie der klassischen Germanischen Trias. – Geol. Rdsch., **71**: 783-794.

SCHÜLER, F., Beutler, G. & Franzke, H.J. (1989): Über synsedimentäre Bruchtektonik an der Grenze Unterer/Mittlerer Buntsandstein auf der Hermundurischen Scholle. – Hall. Jb. Geow., **14**: 49-54.

SCHWARZ, H.-U. (1972): Sedimentary structures and facies analyses of shallow marine carbonates (Lower Muschelkalk, Middle Triassic, Southwestern Germany).- Contrib. Sedim., **3**: 100 pp.; Stuttgart.

SEELING, M. (1999): Fazielle und sequenzstratigraphische Untersuchungen im Rhätkeuper (Exter-Formation) Thüringens und des nördlichen Harzvorlandes. – 116 S., Diploma Thesis Univ. Halle.

SEIDEL, G. (1965): Zur geologischen Entwicklungsgeschichte des Thüringer Beckens. – Geologie, Beih. **50:** 1-119.

SEIDEL, G. (1966): Zur Ausbildung der Trias auf dem Südteil von Blatt Walschleben (Thüringer Becken). – Ber. Deutsch. Ges. geol. Wiss., A Geol. Paläont., **11** (4): 503-520; Berlin.

SEIDEL, G. (1974): Muschelkalk. – in: HOPPE, W. & SEIDEL, G. (Ed.): Geologie von Thüringen. – 568-605; Gotha.

SZULC, J. (1993): Early Alpine Tectonics and lithofacies successsion in the Silesian part of the Muschelkalk Basin. – in: Hagdorn, H. & Seilacher, A. (Ed.): Muschelkalk. Schöntaler Symposium 1991. – Sonderbde. Ges. Naturk. Württemberg, **2**: 19-28; Stuttgart.

SZURLIES, M. (1997): Magnetostratigraphie und zyklische Stratigraphie im Unteren Buntsandstein des nördlichen und nordöstlichen Harzvorlandes (Sachsen-Anhalt), Dipl. Univ. Hannover: 85 pp.

SZURLIES, M.(1999): Zyklenstratigraphie und Gamma-Ray-Log-Korrelation im Unteren Buntsandstein (Untere Trias) des nördlichen Harzvorlandes, Hallesches Jb. Geowiss., **B21**: 35-53.

SZURLIES, M.(2001): Zyklische Stratigraphie und Magnetostratigraphie des Unteren Buntsandsteins in Mitteldeutschland, Thesis Univ. Halle: 116 pp.

SZURLIES, M., BACHMANN, G.H., MENNING, M., NOWACZYK, N.R. & KÄDING, K.-C.(2003): Magnetostratigraphy and high-resolution lithostratigraphy of the Permian-Triassic boundary interval in Central Germany, Earth Planet. Sci. Lett., **212**: 263-278.

THÜRACH, H. (1888/89): Übersicht über die Gliederung des Keupers im nördlichen Franken im Vergleiche zu benachbarten Gebieten. – Geogn. Jh., **1**: 1-162, **2**: 1-90; Cassel.

TRUSHEIM, F. (1961): Über Diskordanzen im Mittlerem Buntsandstein Nordwestdeutschlands zwischen Ems und Weser. – Erdoel-Z., **77**: 361-367.

USDOWSKI, H. E. (1961): Die Entstehung der kalkoolithischen Fazies des norddeutschen Unteren Buntsandsteins. – Beitr. Min. Petrogr., **8**: 141-179.

VOIGT, T. & LINNEMANN, U. (1996): Resedimentation im Unteren Muschelkalk – das Profil am Jenzig bei Jena. – Beitr. Geol. Thüringen, N.F., **3**: 153-167.

VOIGT, T., BACHMANN, G.H. & GAUPP, R. (2001): Buntsandstein und Muschelkalk im Thüringer Becken. – in: GAUP, R. & VAN DER KLAUW, S. (Ed.) Sediment 2001.- Schriftenr. Der DGG, H 13: 137-169; Hannover.

VOIGT, T., BACHMANN, G.H. & GAUPP, R.(2002):, Buntsandstein und Muschelkalk im Thüringer Becken, Jber. Mitt. oberrhein. geol. Ver., N.F., **84**: 151-189.

WALTER, R.(1995): Geologie von Mitteleuropa, Schweizerbart: 566 pp.

WICHER , C.A. (1951): Zur mikropaläontologischen Gliederung des nichtmarinen Rät. – Erdöl Kohle, **4** (12): 755-760.

WICHER , C.A. (1957): Die mikropaläontologischen Gliederung des nichtmarinen Keupers. – Erdöl Kohle, **10** (1**)**: 3-7.

WILL, H.-J. (1953): Paläontologische Untersuchungen zur Stratigraphie des Oberkeupers in Nordwestdeutschland. – Diss. Univ. Tübingen, 288 S., (unpubl.).

WILL, H.-J. (1969): Untersuchungen zur Stratigarphie und Genese des Oberkeupers in Nordwestdeutschland. – Beih. Geol. Jb., **54**: 240 S.

WURSTER, P. (1964): Geologie des Schilfsandsteins. – Mitt. Geol. Staatsinst. Hamburg, **33**: 227 S.

WURSTER, P. (1965): Krustenbewegungen, Meeresspiegelschwankungen und Klimaänderungen der deutschen Trias. – Geol. Rdsch., **54**: 224-240.

WYCISK, P. (1984): Faziesinterpretationen eines kontinentalen Sedimentationstroges (Mittlerer Buntsandstein/ Hessische Senke). – Berliner Geowiss. Abh., **A 54**: 104 S.

ZIEGLER, P.A. (1990): Geological Atlas of Western and Central Europe. – 239 pp.; The Hague (Elsevier & Shell Intern. Petrol. Maatschappij B.V.).