Field Excursion – Rheinisches Schiefergebirge (IGCP 596)

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Rheno-Hercynian - Introduction:

The Central-European part of the Variscan Orogen is one of the most significant type areas for the continent-continent collision between Laurussia and Gondwana that resulted in the formation of the supercontinent Pangaea. Traditionally, the Central-European Variscides have been subdivided across strike from NW to SE into three zones, the Rhenohercynian, the Saxothuringian, and the Moldanubian zones, respectively (Kossmat, 1927). Later, Brinkmann (1948) included a separate Mid-German Crystalline zone to this model, which is interpreted as a structural high between the Rhenohercynian and Saxothuringian zones (Fig. 1). This concept has been adapted to modern plate tectonic views in which the Variscan Orogen resulted from the accretion of peri-Gondwanan terranes or microplates by the closure of several oceans, among which the Rheic Ocean has been considered the most important.

Fig. 1: Structural units of the Mid-European Hercynian
The Rhenohercynian zone, which crops out preferentially in the Rheinisches Schiefergebirge, constitutes a classical fold-and-thrust belt and is one of the structural units of the European Variscides interpreted as a collage of microplates (e.g. Matte, 1986; Franke et al., 1990; Franke and Oncken, 1990, 1995; Franke, 2000).

It is now widely accepted that the Rheinisches Schiefergebirge is part of the Avalonia terrane, which separated from Gondwana in the Early Ordovician and drifted northwards (e.g. Oncken et al., 2000; Tait et al., 2000; Thorsvik and Cocks, 2004, Linnemann et al., 2008, 2010; Romer and Hahne, 2010; Eckelmann et al., 2013; Fig. 2). This resulted in the opening of the Rheic Ocean. In Late Ordovician, around 450 Ma, Avalonia collided with Baltica, which led to the closure of the Tornquist Sea. The ensuing collision of both Baltica and Avalonia with Laurentia closed the intervening Iapetus Ocean at about 420 Ma. As a result the continent Laurussia (= Old Red Continent) was formed (Kroner et al., 2007; Linnemann et al., 2008; Nance et al., 2010). According to Sánchez Martínez et al. (2007) and Nance et al. (2010), the closure of the Rheic Ocean began in the Late Silurian – Early Devonian and continued until the Early Carboniferous by successive advancing from west to east (Fig. 2).

Several plate tectonic models exist for the Variscan orogeny. The two-plate model involves the collision of Laurussia (Baltica+Avalonia+Laurentia) with West Gondwana (Amazonia+WestAfrica+Cadomia) as a result of the closure of the Rheic Ocean (e.g. Linnemann et al., 2004; Kroner et al., 2007; Linnemann et al., 2010). The multi-plate model accounts for the existence of a number of terranes and narrow oceans between the principal plates of Laurussia and Gondwana (e.g. Franke, 2000; Tait et al., 2000; Torsvik and Cocks, 2004; von Raumer and Stampfli, 2008). Different microplates are assigned to the “Amorican Terrane Assemblage (ATA)” by Franke et al. (1995) and are composed of Bohemia, Saxothuringia, Iberia and the Amorican Massif. ATA is believed to have separated from Gondwana during the Ordovician, following Avalonia in northward direction. Between Avalonia and ATA, an island arc has been proposed, which formed during the closure of the Rheic Ocean and was accreted to Avalonia during the Early Devonian (Franke and Oncken, 1995; Franke 2000). This arc is documented by magmatic rocks of Silurian age in the “Northern Phyllite zone” and in the “Mid-German-Crystalline zone (MGCZ)” (Altenberger et al., 1990; Sommermann, 1993; Dombrowski et al., 1995; Reischmann et al., 2001).

One model for the Rhenohercynian proposes successive rifting of a passive southern margin of Laurussia during Devonian times caused by the opening of a Rhenohercynian Ocean (e.g. Franke, 2000; Tait et al., 2000; Doublier et al., 2012). Conversely, Floyd (1982), Flick and Nesbor (1988), Ozlon (1994), Smith (1996), von Raumer and Stampfli (2008), and Zeh and Gerdes (2010) interpreted the
Rhenohercynian as an active continental margin whereby a northward dipping subduction zone triggered the opening of a Rhenohercynian back arc ocean (Fig. 2).

The MGCZ, a NE-SW trending basement wedge, represents the Variscan collision zone and separates the Rhenohercynian zone (Avalonia) from the Saxothuringian zone (Armorica; Zeh and Gerdes, 2010; Zeh and Will, 2010). However, Zeh and Gerdes (2010) presented provenance data that the MGCZ was not completely Armorican, but was partly Avalonian as indicated by certain rock units of the Ruhla Crystalline complex. Accordingly, the Spessart and the Böllstein Odenwald can be interpreted as belonging to Avalonia as well.

According to Plesch and Oncken (1999), the final Variscan continental collision occurred along two suture zones, one separating the external Rhenohercynian zone from the Saxothuringian zone, the other separating the latter the Teplabarandium part of the internal Moldanubian zone. However, collisions occurred earlier between the different microcontinents of the ATA. For example, Bohemia and Saxothuringia collided with the Armorican Massif and consequently became part of Armorica during the Late Devonian (Schäfer et al. 1997; Dörr and Zulauf, 2010). The final stage of the Variscan orogeny is primarily characterized by diorites and granites, usually of calc-alkaline composition (Altherr et al., 1999; Stein, 2001) and with a distinct subduction signature (Henes-Klaiber, 1992). But the rock pile was also overprinted by regional HT/LP metamorphism and segmentation in folds and thrusts (Oncken, 1997; Kroner et al., 2007). Within the Rheinisches Schiefergebirge, deformation combined with very low to low-grade metamorphism progressed from the SE (330 Ma) to the NW (300 Ma) in the Late Carboniferous (Ahrendt et al., 1978, 1983). The Variscan orogeny led to a crustal shortening there of, on average, about 50% (Behrmann et al., 1991; Oncken et al., 1999). This is also suggested for the allochthonous units (Doublier et al., 2012).

**Plate tectonic development of central Europe (Fig. 2)**

The following figures show the plate tectonic development of Central Europe based on earlier reconstructions by Torsvik and Cocks (2004) and recent investigations (Eckelmann et al., Gondwana Research, in press) from the Ordovician to the Late Carboniferous (from the top to the bottom: 480 Ma, 420 Ma, 380 Ma, 360 Ma, 330 Ma, and 300 Ma).

Furthermore, a plate tectonic model is presented for the Rheinisches Schiefergebirge, particularly for the southeastern part. Further explanations will be given in the field.
Based on the distribution of zircon age populations the provenance of autochthonous to par-autochthonous sediments of the southeastern Rheinisches Schiefergebirge exhibits a typical Baltica signature and weak Avalonian signals whereas those of the allochthonous units were derived from a Gondwanan source.

Sediments of the same age of autochthonous to par-autochthonous and allochthonous units show profound differences in their composition and facies development. The allochthonous units such as the Lohra-, Steinhorn-, and Hörre nappe are characterized by the absence of volcanic rocks. At the base of the Gießen nappe metabasalts with MORB-type affinities occur as tectonic slices.

Subduction-related volcanism lasted from the Early Devonian to the Early Carboniferous with a source area outside the Rheinisches Schiefergebirge. Intraplate volcanism was confined to the autochthonous to par-autochthonous units of the Rheinisches Schiefergebirge.

The existence of different magmatic arcs is mirrored in the frequency distribution of zircon grains. Based on both, the provenance analysis as well as geochemical results the evolution
of arcs is easy to reproduce and hence a subduction to the north as well as to the south is plausible (Eckelmann et al., in press)

- The plate tectonic model presented (Fig. 2) suggests the existence of a wide Rheic Ocean and an active continental margin to the north which resulted in the opening of the Rhenohercynian Ocean. This was associated with extension and subsidence of the continental crust of North Avalonia (= southern shelf area of Laurussia), which was accompanied by an intensive intraplate volcanism.

- In contrast to earlier publications (e.g., Kroner et al., 2007; Linnemann et al., 2010) the data presented suggest the existence of the Rheic Ocean until the Early Carboniferous.
1st day: Arrival in Frankfurt – travel to the Eifel area
(Eifel Synclines – Middle Devonian)
Frankfurt (A 3/ A 48) – Kerpen (Stop 1.1, Stop 1.2) – Üxheim-Ahütte (Stop 1.3, Stop 1.4) – Meyen – Gondorf – Alken

Introduction to the Eifel area:

The Eifel area, in particular the Middle Devonian sequences of the Eifel carbonate synclines, contains well-known fossil localities which have been investigated for many decades (Goldfuss 1826–1844; Römer 1844; Steininger 1848). As a result of this long-term research, a large number of publications are available on the brachiopods, stromatoporoids, rugose corals, echinoderms (crinoids) and trilobites of the Middle Devonian of the Eifel Synclines, as well as on the stratigraphy (Tab. 1) and regional geology. The Eifel area (Eifel Synclines) is the dominant structural unit interpreted as a N–S trending axial depression of the RSG (Fig. 3). The grade of diagenesis in the entire area is very low (e.g., Königshof and Werner, 1994; Helsen and Königshof 1994).

Fig. 3: Simplified geological map of the Rheinisches Schiefergebirge and the Ardennes (after Wehrmann et al., 2005)
Siliciclastic sediments were delivered from the north during the Early Devonian and early Middle Devonian (Eifelian) but diminished during Givetian times when shallow subtropical carbonates were established over much of the region. Struve (1963) established a depositional model for the Eifel area with a N–S trending basin surrounded by landmasses, which he considered as the so-called ‘Eifel Sea Street’. In contrast to this model, Winter (in Meyer et al. 1977) defined three facies belts in the Eifel Synclines (Fig. 4).

Fig. 4: Idealized facies model of the Middle Devonian of the Eifel (modified from Winter in Meyer et al. 1977). Facies type A: facies dominated by clastic input; facies type B: facies characterized by carbonate platforms and biostromal reefs (including the Mid-Eifelian High); facies type C: facies characterized by reduced clastic input and increasing carbonate.

Facies A in the northern synclines mainly represents the accumulation of siliciclastics in a marginal marine setting. Facies B, typical of the eastern Eifel Synclines, is characterized by carbonate platform facies and biostromal reef deposits (including the Mid-Eifelian High) with interbedded siltstones and mudstones. Further to the south, Facies C is mainly composed of marls and shales due to the increasing clay content. Faber (1980) subsequently modified this model, based on detailed
microfacies studies which provided evidence of rhythmic development of a carbonate platform during the early Eifelian and of a flat shelf lagoon during the late Eifelian and early Givetian, affecting the eastern part of the Eifel Synclines. Paproth and Struve (1982) distinguished between N-, W- and S-Eifel biofacies based on faunal differences. During the Givetian this facies differentiation broke down to some degree and mainly stromatoporoid/coral biostromes extended over the entire area. Krebs (1974) characterized this environment as a broad shelf lagoon bordered to the south by a carbonate rim or barrier.

1.1: Weinberg quarry west of Kerpen, Hillesheim syncline, mapsheet 5606 Dollendorf

Stratigraphic units and age:
Late Eifelian: Late Junkerberg Fm. to Ahbach Fm.
What to see: Detritic reefal and crinoid limestones, marls and dolomites; carbonate buildup-facies within the *otomari* Interval.
Mud mound development above crinoidal detrital limestones.
What to collect: rugose and tabulate corals, brachiopods, trilobites, crinoids.
1.2: Rauheck quarry, west of Kerpen, Hillesheim syncline, mapsheet 5606 Dollendorf

Stratigraphic units and age:
Early Givetian, Loogh Fm.

What to see: About 20 m thick bioherm, composed of stromatoporoids and corals; above the massive limestones thin-bedded, wavy layered greyish detrital limestones occur.
What to collect: stromatoporoids, tabulate and rugose corals as well as solitary rugosa.

1.3: Western part of Ahlbach section, Hillesheim syncline, mapsheet 5606 Dollendorf
(Lunch at Nohner Mühle)

The section consists of three abandoned railway cuts (see Bultynck et al. 1988). In case the section is still exposed we expect to see the higher part of the Eifelian and the lower part of the Givetian.

Stratigraphic units and age:
The section originally was described as the Nohn Mill railway section, (the easternmost part, higher part of the Junkerberg Fm.), the Katzenley Railway cut (Ahbach Fm.), and the Dreimühlenwald Railway cut (Loogh Fm.).

What to see: detritical reefal limestones with variable marly limestone intercalations of shallow marine neritic to subtidal deposits.
What to collect: tabulate and rugose corals, stromatoporoids, brachiopods, trilobites (rare) and conodonts.
Tab. 1: Stratigraphy in the Eifel area, after Stuve et al., 1997.

1.4: Müllertchen quarry, Hillesheim syncline, mapsheet 5606 Dollendorf

Stratigraphic units and age:
Ahbach Fm; all beds belong to the *Po. xylus ensensis* conodont biozone.

What to see: Abandoned quarry east of the cement plant is composed of marly limestones, crinoidal limestones, and bioclastic limestones.

What to collect: brachiopods, corals, conodonts, rare trilobites.
Introduction
During Devonian time the Old Red Continent delivered siliciclastics into the southern shelf area where the Rheinisches Schiefergebirge belongs to. Marine Devonian sediments in the Rheinisches Schiefergebirge are traditionally assigned to two facies settings, the “Rhenish” facies and the “Hercynian” facies (Erben 1962). The Rhenish facies is characterized by thick siliciclastic successions which are referred to deltaic shallow marine environments in the northern part of the Rheinisches Schiefergebirge (e.g. Stets and Schäfer 2002, Wehrmann et al. 2005). Typical sediments of the “Hercynian” facies are pure limestones and argillaceous shales whereas sandstones are rare. Starting with the Early Devonian, the Rhenohercynian Basin developed as a narrow (about 250 - 350 km) but rather elongate (more than 2 000 km) trough south of the Old Red Continent. Towards the south, the trough was confined by the Mid-German High during the Gedinnian and Siegenian. Detrital supply had been delivered from northern (Wierich 1999) as well as from the southern source areas (Hahn 1990, Hahn and Zankl 1991). Transport along the axis of the basin from the northeast may have supported to fill the basin (Haverkamp 1991; Fig 5). During the Early Emsian, the Mid-German High disappeared caused by erosional processes, tectonic activity, and sea-level rise. Lower Devonian sequences in the southern part of the Rheinisches Schiefergebirge are characterized mainly by sandstones and siltstones which were rapidly deposited in sedimentary troughs (“depocenters”) and on swells (e.g., Meyer and Stets 1980, 1996, Mittmeyer 1982) based on a rift stage which started during the Gedinnian, and went on during the Siegenian, and in the early Emsian. High subsidence rates are documented by more than 10,000 m in thickness of this time interval of about 19 Mio years (DSK 2002). In the Late Emsian the subsidence rate was reduced; about 1,000 m thick sediments were delivered in basinal settings, such as the Mosel-Lahn trough (Meyer and Stets 1980) attributed to a post rift-stage. Middle Devonian successions in the Rheinisches Schiefergebirge are predominantly composed of shales, platy limestones and reef limestones. Siliciclastic sedimentation changed to predominantly carbonaceous when reef development began to flourish during Middle Devonian. Where water depth was suitable, barrier-type reefs grew in short distance to the shore line from the western Rheinisches Schiefergebirge (Eifel area) to Harz Mountains, and Moravia in eastern Central Europe. In the open shelf area further to the south only islands could sustain reef growth. There, responding to extensional tectonics an intensive submarine volcanism of continental intraplate geochemistry provided local opportunities for the development of reefs. These are concentrated in the Lahn-Dill
area in the southeastern Rheinisches Schiefergebirge, but can still be found in the Harz Mountains further northeast. The dominating reef-building organisms are tabulate corals and stromatoporoids. In deeper marine settings Middle to Late Devonian cephalopod limestones in pelagic facies occurred simultaneously.

Fig. 5: Palaeogeographic setting of the Rhenohercynian Basin during the Siegenian stage (after Ziegler, 1990, Stets and Schäfer 2002)

Upper Devonian sediments are developed in “Hercynian” facies characterized by siltstones, argillaceous shales, often red shales, platy and nodular limestones, and sandstones. Reef growth continued into the lower part of the Upper Devonian and stopped in the course of the Kellwasser Crises. Beginning with the Late Devonian, the Mid-German Cristalline Rise (MGCR; Brinkmann 1948, Zimmerle 2000) came into being by convergence and subduction towards the south. Thus, another high is met just in a similar palaeogeographic position during the Late Devonian and Early Carboniferous as it had been in the Early Devonian. Caused by collapse of the thickened crust and a renewed extension it was burried beneath the more than 7,000 m thick sedimentary pile of Upper

Carboniferous sediments mainly occur in the N, NE, and E Rheinisches Schiefergebirge (see day 3 and day 4). The Lower Carboniferous is composed of cherts, alum shales, argillaceous shales, and greywackes which is called the “Kulm facies”. The greywackes are regarded as turbidites which are derived from the Mid-German Crystalline Rise (MGCR; Brinkmann 1948, Zimmerle 2000). The Upper Carboniferous of the Ruhr area (NW Rheinisches Schiefergebirge) is characterized by cyclic sediments ranging from coals to marine shales. During the Carboniferous, the area of the Rheinisches Schiefergebirge was affected by the Variscan orogeny prograding from SE to NW. Deformation features in the Rheinisches Schiefergebirge, east of the river Rhine are strongest in the SE (Taunus area) and becoming less intense towards the NW (e.g. Sauerland area). The Devonian sedimentary pile underwent folding and thrusting. As a consequence, a huge anticlinal structure originated for in the northern part of the Middle Rhine transect called East Eifel Main Anticline (Osteifeler Hauptsattel, Meyer 1994). It consists of two minor anticlines that are the Ahrtal Anticline (Ahrtal-Sattel) and the Hönningen-Seifen Anticline (Hönningen-Seifen-Sattel). Whereas the Ahrtal Anticline contains a steep, in places overturned northwestern flank and a gently dipping southeastern flank, the Hönningen-Seifen Anticline shows neither asymmetry nor overturn. Toward the south, this anticline is delimited by the major thrust fault system of the Siegen Main Thrust (Siegener Hauptüberschiebung). It separates the East Eifel Main Anticline in the north from the huge Mosel Syncline in the south. This main synclinal structure in the center of the mountain belt is built up of several imbricate structures. Farther toward the south, imbrication is dominant building up several imbricate fans controlled by major thrust fault systems. During the latest Carboniferous and Permian, the Rheinisches Schiefergebirge was eroded. Sediments were accumulated in adjacent sedimentary troughs, such as the Saar-Nahe Trough. After the Variscan orogeny, most parts of the Rheinisches Schiefergebirge remained above the sea-level – only small parts were flooded during the Triassic, Late Cretaceous and Tertiary (e.g. K. Fuchs et al. 1983). In the Late Tertiary, the Rheinisches Schiefergebirge started to be lifted; synchronously, the rivers Rhein, Lahn, and Mosel cut into the deposits forming deep valleys. The rivers have left a system of terraces that were predominantly formed during the early Pleistocene (see stop Loreley).

Columnar sections of larger outcrops have been investigated along the Middle Rhine valley and the neighbouring tributaries during the last years. Rock sequences, some of them more than 150 m thick, have been analyzed as individual case studies by Stets and Schäfer (1990, 2002). Some of them will be shown during this field trip. The columnar sections of these rock sequences are rather small with respect to the more than 10,000 m thick Lower Devonian siliciclastic successions in the centre of the
Rhenohercynian Basin that had been the cradle of the Rhenohercynian fold-and-thrust belt. Nevertheless, these columns give evidence of the depositional environments with adequate precision even if they repeat again and again within one section due to thrusting and folding. Most of the area visited during our field trip underwent only relatively low deformation during the Variscan (Hercynian) orogeny. Thus, sedimentological features can well be recognized and thoroughly be studied already in the field. The understanding of the different palaeoenvironments can easily be performed using lithology, grain-size, distinctive primary depositional structures, and biogenic remains. Using these parameters, three different facies belts (Stets and Schäfer 2002) had been defined within the Rhenohercynian Basin along the Middle Rhine transect from the northwest toward the southeast (Fig. 6, Fig. 7):
Fig. 7: Simplified paleogeographical map of the western and central part of the Rhenohercynian Basin during the Gedinnian to Lower Emsian (incl.); the three main facies belts are indicated: NFB: Northern Facies Belt, CFB: Central Facies Belt, SFB: Southern Facies Belt; maximum thicknesses are given in thousands of metres; hatched areas illustrate ancient land masses; map without palinspastic adjustment modified after Meyer & Stets 1996, Stets & Schäfer 2002; abbreviations: (SMT): later Siegen Main Thrust, (BDT): later Boppard-Dausenau Thrust, (TKT): later Taunuskamm Thrust.

- The **Northern Facies Belt (NFB)** situated in front of the Old Red Continent is characterized by the sedimentary palaeoenvironments of distal meandering fluvial systems that gradually passed into a huge delta complex. It consisted of a system of elongate bird foot type deltas oriented toward the south (Stets and Schäfer 2002, 2008); the subsidence of the basin and the detrital input from the Caledonian Old Red Continent in the north had been in balance with each other during the Early...
Devonian; no severe coastal onlap or offlap was evident during this time; long-term continuous subsidence and a high and continuous sediment supply into the delta system controlled a consequent prograding toward a shelf sea in the south.

- Towards the southeast, the **Central Facies Belt (CFB)** represents a shelf sea setting characterized by subtidal intra-shelf conditions starting with the Hunsrückschiefer facies; the sedimentary freights that had passed through the Northern Facies Belt and that came down from the delta as well as from other sources respectively did not fill this part of the Rhenohercynian Basin completely during the rift stage; not until to the end of the early Emsian, the delta prograded farther towards the south; even in the Mosel area, the land-sea transitional deltaic environment occurred during the uppermost lower Emsian Nellenköpfchen Formation that reflected the beginning of the post-rift stage and started with the Emsquartzite Formation (Emsquarzit) at the beginning of the Late Emsian. Due to sea-level rise, conditions changed again and subtidal marine environments occurred throughout the entire Central Facies Belt. These conditions persisted until to the end of the Late Devonian spanning a time of about 40 Mill. years or even longer. During the post-rift stage, special environmental conditions prevailed within a small-scale arrangement of basins and swells that are the predecessors of the later large-scale tectonic structures.

- In the **Southern Facies Belt (SFB)**, sedimentary conditions started with continental alluvial environments (Bunte Schiefer, Late Gedinnian) north of the Mid-German High. Later on, open marine coastal to nearshore conditions followed (Hermeskeil Formation, Lower Siegenian) that consequently developed to inner offshore environments (Taunusquartzite Formation, Middle and Upper Siegenian). They graded forward to form outer offshore to intrashelf basinal environments (Hunsrückschiefer, early Emsian).
Tab. 2: Stratigraphic column for the Early Devonian (after Wehrmann et al., 2005)

2. 5: Mosel valley, Alken quarry

Stratigraphic units and age:
Early Devonian, rocks of the uppermost Lower Emsian (see Wehrmann et al., 2005)
What to see: About 90m thick section of shallow marine setting (tidal flat). Two distinct fossiliferous units contain abundant terrestrial plant remains and a diverse mixed terrestrial to marine fauna.

What to collect: Plant remains, euryperids (rare), brachiopods. For details see attached paper by Wehrmann et al. 2005.

2. 6: Rheineck beneath the castle, mapsheet 5509 Burgbohl (optional)

Stratigraphic units and age:
Early Devonian, Lower Siegen-Group, Northern Facies Belt

What to see: About 250m thick columnar section (Fig. 9) belonging to the Early Devonian and comprises several sedimentary cycles (after Stets and Schäfer 2002). Within the ancient quarry near to the chapel built in 1976, the uppermost cycle of this columnar section can be studied in more detail (Fig. 9).

What to collect: Plant remains of the *Psilophyton*-flora preferentially occur in the fine-grained mudstones. They contain *Taeniocrada decheniana*, some specimens showing even fructifications, *Zosterophyllum rhenanum*, and *Drepanophycus spinaeformis*. Besides that, *Crassirhensselaeria crassicosta* and *Modiolopsis obliqueducta* have been found indicating a non-marine palaeoenvironment (Schweitzer 1983, 1994).

The entire section contains two types of depositional subenvironments (Fig 8). The high-energy lateral accreting sand packages contrast with the low-energy vertical accreting siltstones and mudstones. The latter comprise the majority of the entire column with a bulk content up to 60 % and even more.
Fluvial sedimentation seems to be obvious. Muds have been deposited on wide mud flats containing perennial lakes and pools or on flood plains vegetated by plants in various places (Schweitzer 1994). The muds contained former siderite nodules and calcretes. Desiccation cracks indicate that the flats
felt dry occasionally. Channels up to ten meters deep had been cut into the muds. The channel facies of the Rheineck columnar section is documented by three larger channels, several tens of meters in width as well as several smaller ones. The channel fills are characterized by rapid fining-up grain-size trends starting with medium- to fine-grained sands containing mud pebbles occasionally.

2. 7: Section Friedrichssegen near the town Lahnstein, mapsheet 5611 Koblenz

Fig. 10: The Friedrichssegen road cut illustrating the Emsquartzite palaeoenvironment; a: cross section, b: interpretation sketch of the southern part of the outcrop: asymmetrical channels cutting down into a shoreface environment, c: depositional model; HTL high-tide level, LTL low-tide level (from Stets & Schäfer 2002).
Stratigraphic units and age:
Early Devonian, rocks of the Emsquarzite Formation (basal Late Emsian, Lahnstein substage)

What to see: A 15m thick sequence (Fig. 10) of the Emsquartzite Formation is exposed forming a vertical cliff. Along the road from Lahnstein to Friedrichssegen, up to 15 m of the Emsquartzite Formation are exposed forming a vertical cliff. This outcrop is located near to the top of the Oberlahnstein anticline (Oberlahnsteiner Sattel: Ehrendreich 1959), i.e. a special anticline in the center of the Mosel syncline. The well-bedded quartzites gently dip toward the southeast.

According to the regional geological setting, they follow on top of the Nellenköpfchen Formation. The rocks show a high degree of silicification (Holl 1995). The high content of quartz is due to a primary enrichment by reworking during the sedimentation. Another aspect is a preferred recrystallisation of SiO₂ along the boundaries of the quartz grains. Minor enrichments of crinoid fragments within the Emsquartzite Formation and rich faunas in the Hohenrhein Formation above indicate an open marine environment.

2.8: Loreley, mapsheet 5812, St. Goarshausen

The plateau just above the river Rhine provides a pleasant view down to the canyon and allows a short report on the genesis of the Middle Rhine valley (Fig. 11; Meyer & Stets 1998, 2007).

What to see: During Late Palaeozoic and Mesozoic times, the Rhenish Massif that had been a highland following the Variscan orogeny underwent erosion and denudation nearly down to the sea-level. Parts of the Rhenish Massif had even been flooded during the Late Cretaceous and Tertiary (K. Fuchs et al. 1983). During the Late Tertiary (Miocene), uplift started. Beginning with the Late Miocene, the river Rhine crossed the Rhenish Massif coming down from the Upper Rhine Graben and Mainz Basin in the south. As the uplift endures since the Late Tertiary, and even accelerated during the Pleistocene, the river and its tributaries were forced to cut their valleys down into the Lower Devonian strata. The interaction of the Late Tertiary to recent tectonic uplift and the heavily changing climatic conditions during the ice ages produced the famous staircase of an valley-in-valley fluvial terraces system that can be visited at stop 1.8.

The cyclic river terraces can be subdivided into several stages (Fig. 11):

- During the Trough Valley stage, a broad-floored valley of up to 10 km with and even more originated containing a rather flat floor with up to three steps (late Miocene to Pliocene),
- the **Plateau Valley** stage that is also a broad-floored valley several kms wide in places too contains an up to five steps staircase, and

- the narrow **Canyon** or **Channel Valley** stage consisting of up to six steps also.

As the Trough and Plateau valleys originated from mainly laterally working erosion (SE) that brought about the wide and broad-floored valleys down to a depth of about 100 m in 4.5 My, the Canyon valley originated by predominantly down-cutting erosion (TE) of about 100 - 150 m within 0.8 My.

The hiatus of uplift can clearly be observed at the limit between the Plateau and the Channel valley. Here, a sharp morphological edge (K) has been worked out by the river, as the broad older terraces down to tR5 meet the inclined terraces of the Canyon valley. Here, at the edge of the Younger Main Terrace (Jüngere Hauptterrasse, tR5), the Loreley terrace (tR6, Gurlitt 1949) intervenes between both types. We used this geomorphological marker to quantify the tectonic uplift of the Rhenish Massif (Meyer and Stets 1998, 2002, 2007). It reached an amount of about 135 m within 0.8 My at the Loreley near St. Goarshausen, i.e. a velocity of about 17 cmka⁻¹. The approximate age of the marker has been determined using the palaeomagnetic data of Fromm (1984).
2. 9: Unkel anticline, wine yards just below Stuxhöhe. Mapsheet, 5309 Königswinter

**Stratigraphic units and age:**
Early Devonian, Upper Siegen-Group, Northern facies Belt

**What to see:** About 85m thick columnar section (Fig. 8) belonging to the Upper Siegenian.

**What to collect:** The fauna consisting of brachiopods, bivalves, corals, and crinoids suggests an open marine environment. The intercalated siltstones represent ambivalent brackish to marine shallow-water conditions that are indicated by *Modiolopsis* sp. and *Ctenodonta* sp. as well as by allochthonous plant remains (*Taeniocrada* sp., *Drepanophycus* sp.), equivalent to those of the Wahnbach Formation. Plant remains of the *Psilophyton*-flora preferentially occur in the fine-grained mudstones.

**Depositional environments:**

**Mud flats.** The mainly fine-grained detritus was deposited in a muddy lagoonal to foreshore environment. The muds show bioturbation in places, and desiccation cracks indicate temporary subaerial exposure. Limonitic crusts and nodules suggest former anaerobic conditions within the muds. Delicate shells of brachiopods (*Chonetes* sp.) and bivalves prove casual marine ingressions. Thin sandy layers intercalated within the muds are widespread showing both fining-up and coarsening-up trends at a scale of up to 3 m. In places, fine-grained sands and coarse-grained silts show current ripple lamination developed as herringbone cross-stratification indicating intertidal conditions.

**Barrier sands.** Barrier sands that are characteristics of a shore-face subenvironment are represented by the medium-grained sandstones containing large-scale trough cross-bedding. Tidal bundles have been found in many places.
Fig. 8: Details of the columnar section Unkel (Stop 1) illustrating the barrier sand (a, d) and mud flat (b, d) environments; the transport direction of the psammitic detritus (a) toward the west is indicated in a diagram (c); abbreviations: U silt, fS fine-grained sand, mS medium-grained sand. (from Königshof and Linnemann (eds.), 2008)
3rd day: Northern and northeastern Rheinisches Schiefergebirge (from shelf to basinal facies settings)
Frankfurt (A 45/ A 46, A1, A44, B252, B3, A5) – Plettenberg (Stop 3.10 optional) – Iserlohn/Lasbeck) (Stop 3.11) – Brilon – Madfeld (Stop 3.12) – Korbach (Stop 3.13) – Vöhl – Edersee (Stop 3.14 optional) – Frankenau (Stop 3.15 optional) - Marburg

3.10: Ordovician rocks in the northern Rheinisches Schiefergebirge, mapsheet 4713
Plettenberg (optional)

Stratigraphic units and age:
Ordovician (Lanvirnian to Caradocian), small roadcut.

What to see: Depending on the outcrop situation I will try to show you the oldest sedimentary rocks of the Rheinisches Schiefergebirge. They are mainly composed of shales. In terms of plate tectonics they have been deposited close to Gondwana (Perigondwana, see plate tectonic reconstruction in the introduction). For a stratigraphic overview of the area see table 3.

What to collect: The fauna is mainly composed of trilobites and graptolites, such as Pricyclopyge binodosa, Didymograptus bifidus, Climacograptus scharenbergi.

3.11: Quarry in the Lasbeck Valley, W of Lasbeck at the Lenne river, mapsheet 4611
Hohenlimburg

(around 12:00, registration)

Stratigraphic units and age:
Middle Devonian, late Eifelian (Brandenburg Fm)

What to see: Nearshore environment of the clastic shelf facies with sandstones, siltstones and redish silt and sandstones. Occasionally limestone lenses occur. Significant sedimentary structures are cross- and flaser-bedding, ripple- and wavy bedding as well as slumping, and ball and pillow structures. Also desiccation cracks occur. Bioturbated horizons can be recognized within the siltstones, often limited to the upper part of the thicker beds. The environmental setting is generally supposed to be within a deltaic complex.

The overall thickness reaches 600m which have been exposed in two quarries.

What to collect: The fauna occurs in distinct layers in siltstones. Fauna is reduced in diversity, but rich in monospecific individuals. Many bivalves, ostracodes, fish fragments have been found. In silt- and sandstones plant are quite common (in distinct layers), often as trunk-like pieces and washed together.
Das Unterdevon mit den wichtigsten Formationen des Sauerlandes
3.12: Burgberg quarry, west of Beringhausen, mapsheet 4518 Madfeld

**Stratigraphic units and age:**

Middle Devonian to Early Carboniferous including F/F boundary

**What to see:** For-reef facies close to the Brilon reef (Figs. 12, 13, 14).

**Fig. 12:** Location of the Burgberg quarry (from Pas et al., 2013)

**Fig. 13:** Simplified depositional environment during the Frasnian (Bender et al., 1977)
The section has a thickness of about 130m and is composed of siliciclastics, such as sandstones, shales, siltstones and carbonates. The entire section can be divided in different facies settings or units (Fig. 14; see paper by Pas et al., 2013).

Fig. 14: Schematic lithological log showing different sedimentary units and MF with T/R trends (Pas et al., 2013)
3.13: Roadcut north of Korbach, close the village of Dingerichausen, mapsheet 4718 Goddelsheim

Stratigraphic units and age:
Lower Carboniferous rocks of the “Kulm” facies

What to see:
The quarry exhibits typical rocks of the “Kulm” facies (Late Tournaisian to early Viséan), composed of black and light shales. Occasionally, turbiditic limestones occur. The sequence represents a typical basinal facies setting. Ash tuffs occur frequently in these sediments due to subduction related volcanism at that time. In terms of plate tectonics, these kind of sequences document that the Rheic Ocean wasn’t closed at that time as suggested by recent papers (e.g., Linnemann 2010).

What to collect:
The fauna is mainly represented by planctic, pseudoplanctic organisms, such as goniatites, orthocone cephalopods and pelecypods (Pterinopecten, Posidonia), radiolarians, and conodonts.

3.14: Freshwater Reservoir Edersee (optional)

This reservoir is one of the biggest reservoirs in the eastern Rheinisches Schiefergebirge. During the second world war the wall of the reservoir was destroyed by the British army in the night from May 16th to 17th, which cause a huge flood. The hills around are mainly composed of greywackes of Carboniferous age.
3.15: Abandoned quarry “Im Hüstengrund” along the road B252, mapsheet 4919 Frankenau (optional)

Stratigraphic units and age:
Lower Carboniferous rocks (Visean)

What to see:
The quarry exhibits typical greywackes with intercalated shales and conglomerates, and proximal turbidites. The sequence belongs to the southeastern part of the Rheinisches Schiefergebirge (Sauerland), see fig.15.

What to collect:
The fauna is mainly represented plant fossils.

![Fig. 15: Facies development of the Rheinisches Schiefergebirge, east of the river Rhine.](image)

Overnight stay: Marburg / Lahn
4th day: Southeastern Rheinisches Schiefergebirge (Lahn Syncline and allochthonous units)

Introduction

The Rheinisches Schiefergebirge is part of the Rhenohercynian zone of the Variscan orogen (Fig. 1). In its eastern part, several autochthonous, parautochthonous (e.g. Wachendorf, 1986; Meischner, 1991; Schwan, 1991; Bender and Königshof, 1994) and allochthonous units (e.g. Engel et al., 1983; Oczlon 1992, 1994; Franke, 2000; Salamon, 2003; Huckriede et al., 2004; Salamon and Königshof, 2010) have been defined, the latter having been recognized by Kossmat (1927) who was the first to propose a nappe tectonic concept for the Rhenohercynian zone. In the eastern Rheinisches Schiefergebirge, samples were taken from different structural units: the Lahn-Dill area in the southeast, and in the Kellerwald area, a partly separated region in the northeastern Rheinisches Schiefergebirge. The Lahn-Dill area can be subdivided into the autochthon, known as Lahn syncline and Dill-Eder syncline, which are separated by the allochthon of the Hörre nappe. Southeast of the latter, more allochthonous units occur, such as the Steinhorn nappe and the Lohra nappe as a part of the Frankenbach imbrication zone, and the Gießen nappe (Fig. 16). Additionally, there are several parautochthonous units, which can be found imbricated within the above mentioned autochthon and allochthon as a result of strong deformation and thrusting. Except for the Lahn syncline all of these structures extend into the Kellerwald area. The deformation over the entire area shows distinctive differences: the allochthonous and parautochthonous units have experienced more intense folding and thrusting, as compared to the autochthonous areas.

In the following the main tectonic units are described:

Lahn- and Dill-Eder synclines

The geological record of the Lahn syncline and the Dill-Eder syncline generally extends from about the Middle Devonian to the end of the Early Carboniferous and the onset of the Variscan orogeny. Sedimentation in this area was generally controlled by basin development and volcanism, both reflecting the thinning of the crust due to extensional tectonics. In terms of depositional development, the Lahn and Dill-Eder synclines represent a single unit with the Dill-Eder syncline in the north being more influenced by arenaceous siliciclastic sediments derived from the Old Red Continent.
Fig. 16: Regional geology in the southeastern Rheinisches Schiefergebirge

Intensive intraplate volcanism started in the early Givetian, lasting with interruptions for about 50 Ma into the Carboniferous (Nesbor et al., 1993; Nesbor, 2004). The Devonian volcanic successions allowed for overgrowth by reef limestones (so-called “Massenkalk”), which flourished during the Givetian and Frasnian. Depending on their depositional setting, reef structures are variable in their...
morphology and thicknesses (e.g., Königshof et al., 1991, 2007; Buggisch and Flügel, 1992; Braun et al., 1994; Königshof et al., 2010). Volcanic activity and reef development led to considerable submarine relief in the Lahn-Dill and Kellerwald areas, resulting in widespread facies variations during the Upper Devonian. Further Upper Devonian sedimentation in the Lahn and Dill-Eder synclines produced slates and nodular calcareous slates in numerous basins, and condensed limestones on the swells. The slates were supplemented by thick sandstone sequences, especially in the Dill-Eder-syncline (e.g., in the Thalenberg Formation: Pirwitz, 1986; Wierich, 1999), whereas these are rare in the Lahn syncline. Locally, minor amounts of primitive basaltic melts ended the Devonian volcanic cycle.

Crustal thinning on the southern shelf of Laurussia continued into the Early Carboniferous resulting in a moderate increase of water depth in the eastern Rheinisches Schiefergebirge. This resulted in a special facies realm called the “Culm facies” that caused reduced sedimentation initially characterized by black shales and cherts. This sedimentation was later associated with intensive activity of the Carboniferous volcanic cycle. The volcanic activity was followed by argillaceous sedimentation and, subsequently, by graywackes at the end of the Lower Carboniferous. The latter can reach thicknesses of hundreds of metres and represent the final stage of deposition prior to the Variscan orogeny in the area of interest (for overview and references see Bender and Stoppel, 2006; Bender 2008; Königshof et al., 2008; Nesbor, 2008; Königshof et al., 2010).

**Hörre nappe**

The sedimentary development of the Hörre nappe began in the early Famennian. It differs profoundly from that of coeval strata in the Lahn and Dill-Eder synclines (e.g., Bender, 1978; Bender and Homrighausen, 1979; Bender, 1989, 2008). For example, volcanic rocks are notably absent in contrast to the entire Rhenohercynian zone where repeated intense and sometimes explosive volcanism occurred. It is important to note, however, that ash layers are intercalated in the sedimentary pile of some formations of the Hörre nappe, such as the Gladenbach Formation (Early Carboniferous). The succession of the Hörre nappe starts with shales overlain by sandstones and graywackes (Ulmbach Formation). Occasionally detrital limestones are intercalated. The overlying Weitershausen Formation is mainly composed of shales and detrital, thin-bedded carbonates. These rocks are overlain by shales, quartzitic sandstones and thin-bedded graywackes of the Endbach Formation of Early Carboniferous age. The overlying Gladenbach Formation is mainly composed of siliceous shales, alum black shales, cherts and turbiditic limestones. These sediments are succeeded
by the Bischoffen Formation consisting of shales with intercalations of graywackes, and finally the Elnhausen Formation composed mainly of shales and thick-bedded graywackes (Bender 2008).

**Bicken-Ense and Wildenstein imbrication structures**

The Bicken-Ense and Wildenstein imbrication structures have long been regarded as parts of the Dill-Eder syncline bordering the Hörre unit (e.g., Bender, 1997), whereby the Wildenstein imbrication structure is imbricated with rocks of the Hörre nappe. Because of differences in their sedimentological records compared to adjoining rock units of the same age and their tectonic contact (Bender et al., 1997), they are to be considered to be parautochthonous units. The Bicken-Ense imbrication structure consists almost entirely of the Bicken Formation, which is mainly composed of shales and fossiliferous, pelagic carbonates (e.g. cephalopod limestones) of Early Devonian (Emsian) to Early Carboniferous age (Bender, 1997). The Wildenstein imbrication structure is composed of reddish and gray shales and siliceous shales of the Wildenstein Formation, which is assumed to be mainly of Late Famennian age.

**Kammquartzite imbrication structure**

The Kammquartzite imbrication structure can be traced for more than 300 km throughout the Rhenohercynian zone. This and the dominance within the unit of quartzitic sandstones of Early Carboniferous age have been the focus of geological investigation for a long time (Koch, 1858; Kockel, 1958; Schriel and Stoppel, 1958; Homrighausen, 1979; Wierich and Vogt, 1997; Jäger and Gursky, 2000; Huckriede et al., 2004). Originally regarded as part of the Hörre unit, the Kammquartzite imbrication structure is now considered a separate tectonic unit since it can be found within the Dill-Eder syncline, the Wildenstein imbrication structure, the Hörre nappe, the Frankenbach imbrication zone, and beneath the Gießen nappe. Reflecting its intensive deformation, the quartzitic sandstone slices range in a size from 100 m to less than 1 cm, embedded in a melange composed of very strongly deformed dark gray and siliceous shales.

**Frankenbach imbrication zone**

The Frankenbach imbrication zone, as defined by Bender (2006), has a stratigraphic range from Early Devonian to Early Carboniferous. It is generally strongly deformed and exhibits numerous imbricate
structures. The zone consists, on the one hand, of slices of authochthonous rocks typical for the Lahn- and Dill-Eder synclines, although massive reef limestones (“Massenkalke”), which are common in the Lahn syncline and the northern part of the Rheinisches Schiefergebirge (e.g., Pas et al., 2013 and references therein), are absent. On the other hand, allochthonous units of the Lohra and Steinhorn nappes, as well as slices of the Hörre nappe, are intercalated in the Frankenbach imbrication zone. The paraauthochtonous Kammquartzite is also imbricated locally into this zone.

**Lohra nappe**

The Lohra nappe represents an isolated allochthonous unit in the Kellerwald area, whereas to the southwest in the Lahn-Dill area, it is tectonically integrated into the Frankenbach imbrication zone (Fig. 16). The Lohra nappe consists of the Famennian Lohra unit composed of shales and cherts, with intercalations of sandstones and graywackes, and the Kehna unit of Lower Carboniferous age composed of graywackes and shales.

**Steinhorn nappe**

The Steinhorn nappe is here defined as a new tectonic unit with an isolated allochthonous setting in the Kellerwald area. Comparable to the Lohra nappe, it can be traced into the Frankenbach imbrication zone as part of the Lahn-Dill area. The Steinhorn nappe consists primarily of Early Devonian sandstones, graywackes (“Erbsloch-Grauwacke”), shales and carbonates (e.g., the Greifenstein and Schönau limestones), which exhibit Bohemian faunal affinities (e.g. Flick, 1999). Middle/Upper Devonian sequences are represented by shales, alum shales, cherts and graywackes. Those of Early Carboniferous age are composed of shales, cherts and a melange unit of Devonian and Lower Carboniferous rocks. The entire sedimentological record differs from other structural units described in this paper, and is here used to define a new tectonic unit.

**Gießen nappe**

The long-disputed Gießen nappe (Fig. 16) was the first allochthonous unit established in the Rheinische Schiefergebirge (e.g. Eder et al., 1977, Engel et al., 1983), and covers an area of about 250 km². The rocks of the Gießen nappe consist of shales, clayish sandstones, cherts and graywackes, with the latter predominating. At its base, condensed phyllitic shales and radiolarian cherts are
imbricated with tectonic slices of MORB-type metabasalts (Wedepohl et al., 1983; Grösser and Dörr, 1986). The Gießen nappe sequence spans the Early Devonian to Early Carboniferous and can be subdivided into two structural units containing graywackes of different age (Birkelbach et al. 1988; Dörr, 1990). Graywackes of the smaller northern unit are of Frasnian age, whereas those of the larger southern unit are Early Carboniferous (for a detailed stratigraphic and lithologic description see Dörr, 1986).

4.16: Greywacke quarry southwest of Marburg, mapsheet Gladenbach 5215.

Stratigraphic units and age:
Lower Carboniferous rocks (Visean) of the allochthonous unit of the Hörre nappe.

What to see:
The quarry exhibits typical greywackes with intercalated shales. The sequence belongs to the allochthonous units of the southeastern Rheinisches Schiefergebirge (see Eckelmann et al., 2013). This formation (Elnhausen Formation) is the youngest sequence of the Hörre nappe. The quarry exhibits famous load- and flute casts.

What to collect:
The fauna is mainly represented plant fossils.

4.17: Cliffs at the entrance to the active quarry at Rinkenbach, SW of Oberscheid, mapsheet 5215 Oberscheid.

Stratigraphic units and age:
Lower Carboniferous volcanic rocks (Visean).

What to see:
The basalts of the Lower Carboniferous phase 1 produced tholeiitic magmas in contrast to the ones of the Devonian cycle (alkali-basaltic). This indicates higher partial melting in its mantle source during that time due to higher heat flow. Because of a lower viscosity of tholeiitic magmas, the shape of the pillows could ideally develop (Fig. 17). The generally dark-green meta-basalts contain former olivine micro-phenocysts. To the end of the Carboniferous cycle, around the Carboniferous 2/3, again small amounts of primitive alkali-basaltic magmas rose directly from the mantle to the surface representing the Lower Carboniferous phase 2 (Nesbor, 2004, 2007, 2008).
4.18: Quarry south of Philippstein, mapsheet 5516 Weilmünster

Stratigraphic units and age:
Middle Devonian volcaniclastic rocks and iron ore.

What to see:
Alkali-basaltic sheet flows, pillow lavas, pillow fragment-breccias, and synsedimentary iron ore of the Lahn Dill type (Fig. 18).

The pillow lavas are rich in vesicles whereby these trace the outlines of the tubes. They show a characteristic development. The outer ones, rather numerous, are quite small and filled with chlorite. To the interior they become bigger, their number diminishing, and are filled with calcite.

The pillow breccias consist of pillow fragments of different size whereas the pillow-fragment breccias show a rather heterogeneous composition. The matrix is made up of vesicle-poor hyaloclastites where the fragments of the pillow rims are embedded besides irregular shaped mini-pillows. Such pillow-fragment breccias make up a great portion of the so-called “Schalstein” of the Lahn-Dill area. Due to a later slaty cleavage they tend to break off in plates where they are exposed on cliffs – thus they were termed “Schalstein”.

Fig. 17: Pillow basalts of Lower Carboniferous
A hematitic iron ore deposit developed on top of the volcanic succession. This lies almost vertical on the top bench at the east wall of the quarry cut by several small thrusts. Massive coarse debris flows continue the profile to the top containing quite a few reworked iron ore clasts.

Fig. 18: Sedimentary log of the upper part of the Philippstein quarry (after Königshof et al. 2008 and Königshof et al., 2010)
4.19: Road cut southwest of Weilburg (optional), mapshet 5515 Weilburg

Stratigraphic units and age:
Middle Devonian to early Late Devonian volcaniclastic rocks (ash tuffs), Late Devonian carbonates

What to see:
This section shows the famous ash tuff (phyroclastic fall out deposits), which is an indication of subaerial volcanism. Occasionally, iron ore is intercalated (reworked material) in these rocks. Later these island where covered at some places by bioherms or reefs (Stop 4.20). This section is covered by platy carbonates, deposited on a submarine swell.

What to collect:
Conodonts (very rich in the carbonates – “Plattenkalke”)

4.20: Abandoned quarry southwest of the former railway station in Villmar

Stratigraphic units and age:
Middle Devonian (Givetian) reef limestones, central part of a reef

Fig. 19: Central reef facies, Villmar (after Königshof et al., 1991)
What to see:
The section represents a central reef complex of Middle Devonian age. The main reef builders are stromatoporoids followed by tabulate corals (*Heliolites*) and occasionally rugose corals. According to Pedder (1977) the last appearance of *Heliolites* lies within the Upper *varcus*-subzone. This age is also confirmed by conodont data (*varcus*-Zone) which have been found nearby (Königshof et al. 1991). The outcrop represents a most spectacular one based on the partly polished cut walls, showing a huge variety of different morphotypes of stromatoporoids, such as tabular, domical columnar and bulbous types (Königshof et al. 1991, Braun et al. 1994, Königshof 2007, Fig 19), as it has been described elsewhere in comparable settings (Königshof and Kershaw 2006).

The section is placed in situ which can be proved by geopedal fabrics. The outcrop can be studied in a 3-dimentional view (!) and has been mapped at a scale 1:10 (Braun et al. 1994). The number of stromatoporoids in life position, larger than 30 cm has been estimated to be up to 60% of the population. Of special interest is interaction between stromatoporoid growth-forms and sedimentation (e.g., ragged morphotypes resulted from episodic flanc sedimentation) which took place coevally. Mapping and evaluation demonstrate that the stromatoporoids and their different morphotypes are not equally distributed within the reef. Growth centres can be found, where larger stromatoporoids form a frame work. Individuals can reach a size of up to 1.5 m, but most are typically smaller than 1 m. One limiting factor for stromatoporoid size in a high energy environment is the stability of the sediment. The limiting size is due to wave action, which allowed only a certain height of stromatoporoids on a gravel floor. If stromatoporoids were turned over it was still possible, that they continue to grew in a new position. Massive stromatoporoids of that size lived in shallow water down to 10 meters depth.

The main components of the background sedimentation are crinoids, stromatoporoids, and accessory debris from corals and to a less content brachiopod shells. Parts of the matrix have been dissolved due to pressure solution. Another type of internal sediment is characterized by intensely red, middle- to coarse grained ruditic sediment layers, which are underlain by a compact stromatoporoid breccia. These layers mark the palaeomorphology of the reef surface and may have been caused by seasonal events (tropical storms). At least three redish layers occur.Depressions between growth centers have been filled with sediment during storm events. These layers have been covered again by a new generation of stromatoporoids.

Based on mapping data a palaeogeographic reconstruction of the entire area is provided (Fig. 20).
Fig. 20: Attempt of a palaeogeographic reconstruction of the area visited during the last day of the excursion.

What to collect:
No samples - protected area (Geosite)

References:


Pirwitz, K., 1986. Die Sandsteinfächer des höchsten Oberdevons der Dillmulde (Thalenberg-Formation) am SE-Rand des Siegerländer Blocks – Stratigraphische, petrographische und


