2nd day: The Buntsandstein of Eastern Thuringia

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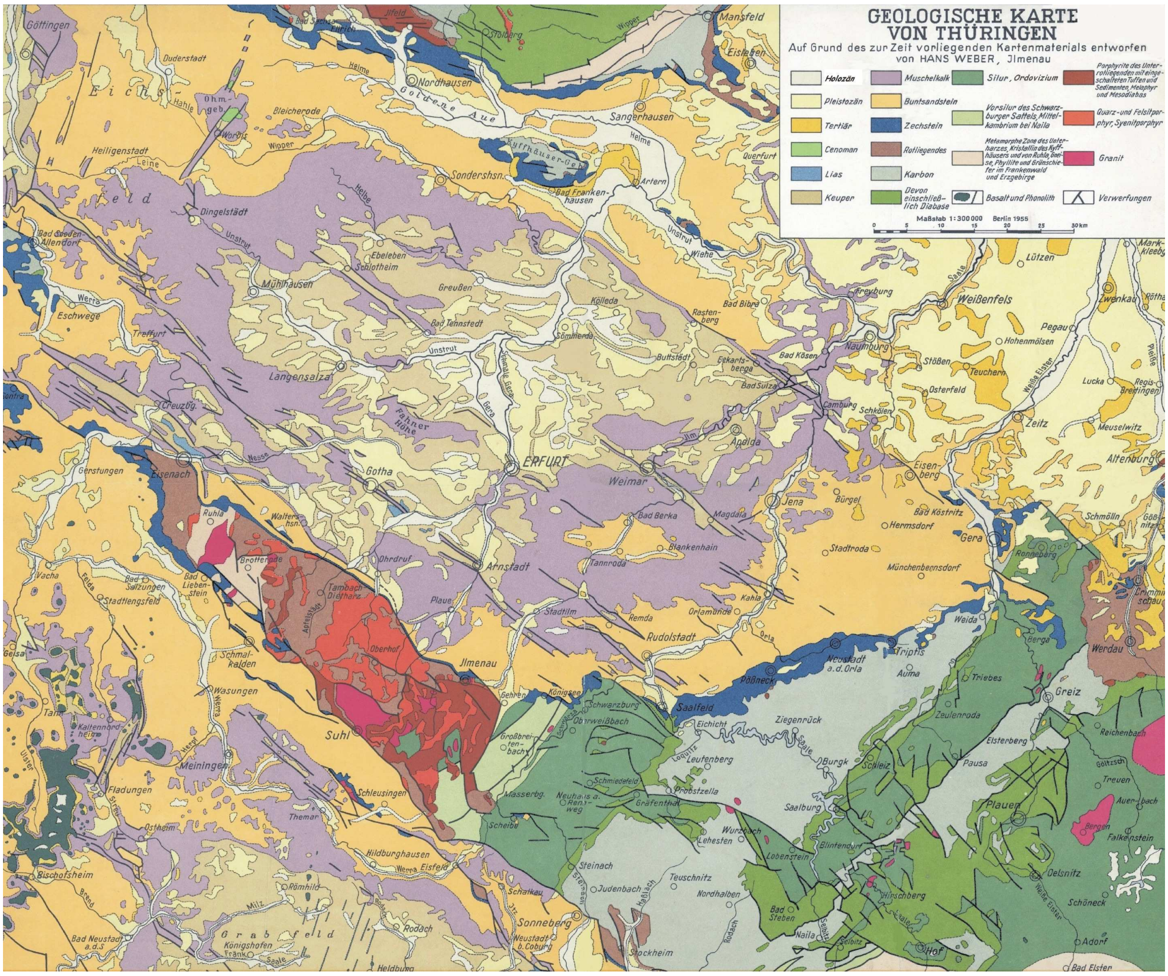

fig.1: Geological map of the Thuringian Syncline

Stratigraphy

The Buntsandstein of Germany is traditionally subdivided in three parts: The Lower Buntsandstein (200-400 m) consist of sandstones and claystones, partly with carbonate cements. The Middle Buntsandstein (200-250 m) is characterized by a predominace of sandstones which never contain carbonates; and the Upper Buntsandstein (100-150 m) is composed of evaporites and red claystones. This subdivision is possible in the central basin, but becomes diffuse and probably useless in the southern basin (southern Germany and western France), where the whole section is presented by a vast pile of stacked fluvial sandstones. As in the most continental successions, especially in those which were deposited under arid climate conditions, fossils are rare and become more abundant in the Upper Buntsandstein, which is partly of marine origin. Biostratigraphy in the continental units depends therefore mainly on conchostracans.

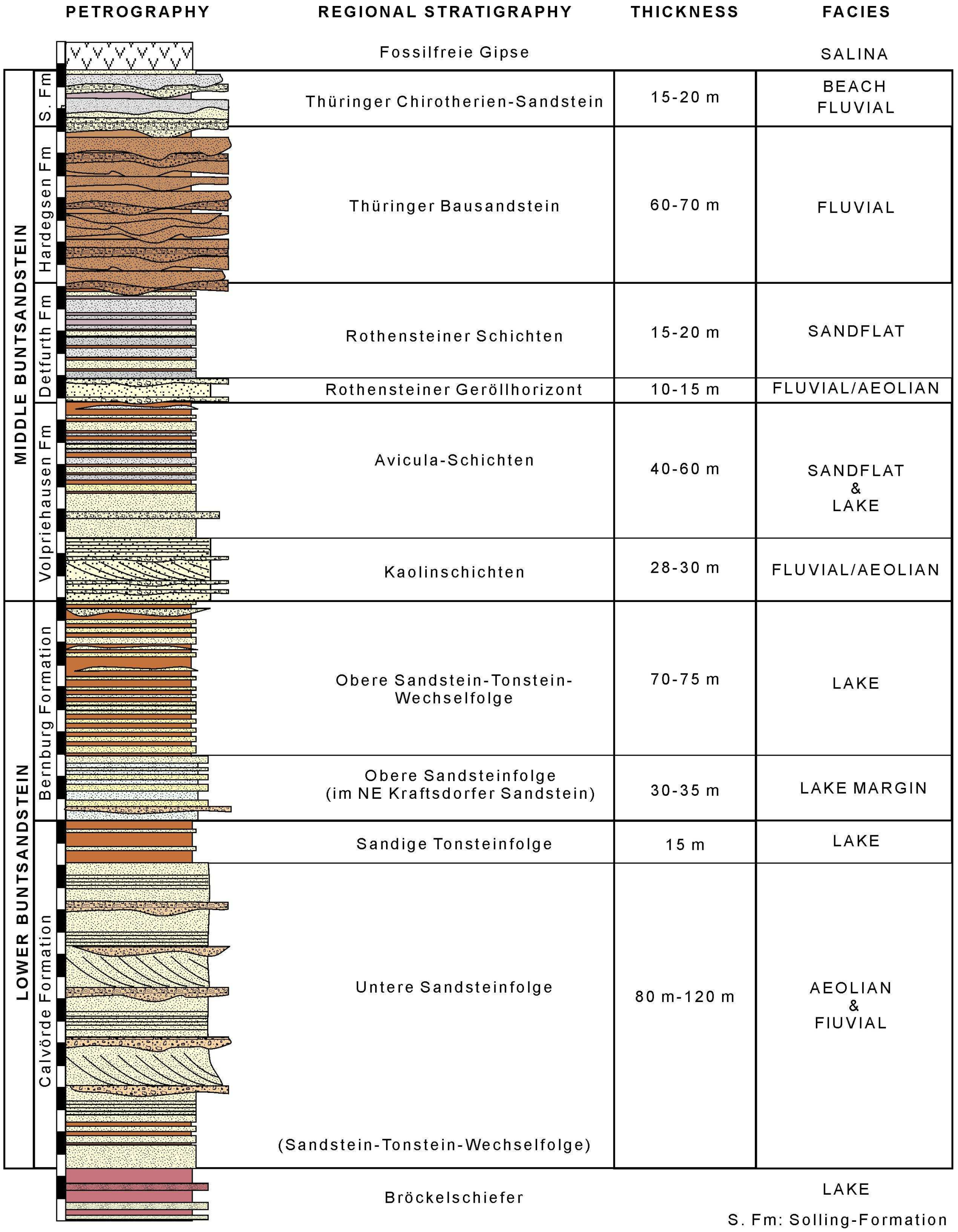

fig.2: Summarised regional stratigraphy of the Thuringian Buntsandstein

The tripartite lithostratigraphic subdivision is very crude according an average thickness of 600 to 1000 m of the whole Buntsandstein, and was therefore refined by the definition of smaller units of local extent (regional lithostratigraphy). In eastern Thuringia, this work was done by Kolesch (1911, 1919) during the second mapping campaign of the geological survey. The units that he distinguished are traceable at least in a regional scale, but he recognised also the gradual changes in facies over distances of more than a few kilometres.

In the fifties of the last century, Boigk (1959) established 6 formations in the Lower and Middle Buntsandstein of Lower Saxony on the base of borehole data. They start with a basal sand-rich unit with a sharp base (best seen in gamma-logs by a sudden retreat of radiation) and show a gradual transition to more clayey units to the top. Shortly after the first definition in the basin-centre it was widely used and applied to the more marginal parts. But in fact, some of the published correlations seem to be questionable.

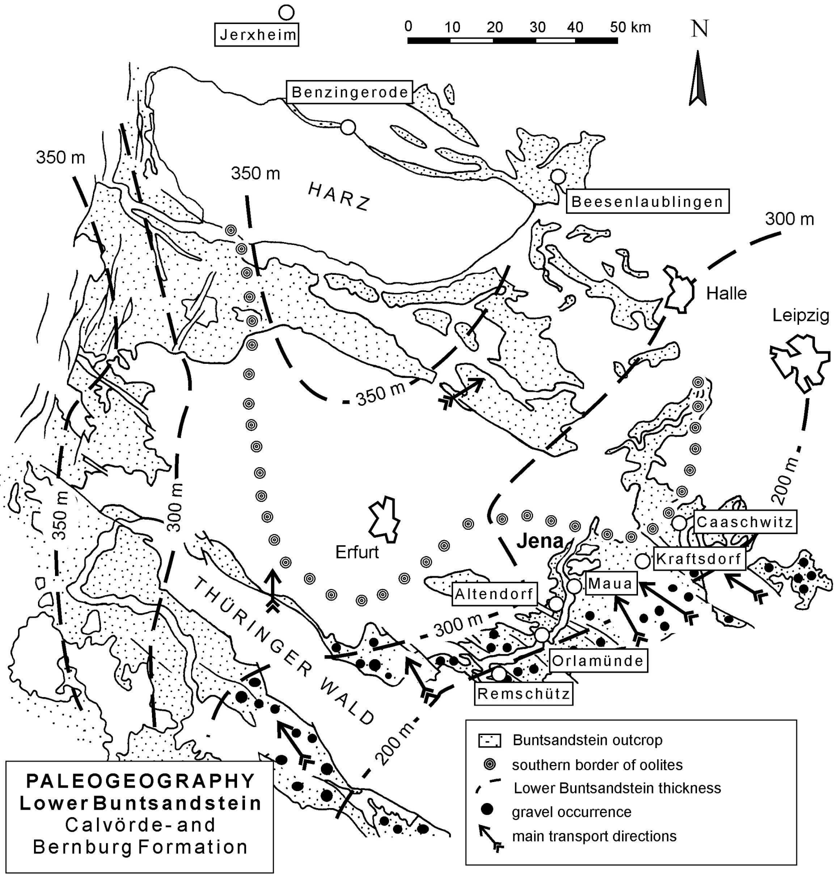

fig. 3: Thickness and facies of the Lower Buntsandstein with outcrop localities which will be visited

In Thuringia, which lies in the transition from the fluvial parts of the outer basin to the more lacustrine deposits of the inner basin, the application of the new lithostratigraphy was relatively easy (Hoppe 1959). But, the focus of investigations was more on the colour and grainsize of the deposits (pure description and lithostratigraphy) and the use for industrial purposes (ceramics, construction, sand, glass, and building stones) so that facies investigations started lately. More or less, this holds true for nearly whole Germany. As such, the whole succession was interpreted to be exclusively of fluvial origin, or to represent distal alluvial fans. New investigations revealed a great variety of different depositional systems, predominantely of lakustrine and eolian origin in the Lower, and of lakustrine to fluvial with a broad variety of channel- and floodplain deposits in the Middle.

During this day, we want to present an overview over different depositional systems of the Buntsandstein. We start in the Saale-valley about 40 km south of Jena and start with the oldest deposits. This is possible, because the Saale-river cuts into a large syncline between the basement uplifts of the Thuringian forest and the Harz mountains (Cretaceous inversion structures, very similar to Krkonose and Jizerske hory).

Figure 1 shows a geological map of the excursion area, fig. 2 gives an overview over the regional stratigraphy concerning the Lower and Middle Buntsandstein. Fig 3 and 4 display the main structural features of the Thuringian Syncline, namely the enhanced thickness in a N-S striking subsidence centre and a synsedimentary swell (Eichsfeld swell) which influenced both sedimentation during deposition of the Lower Buntsandstein and even led to erosion (400 m in maximum) before deposition of the Solling formation. Facies of the Upper Buntsandstein is displayed in fig. 5

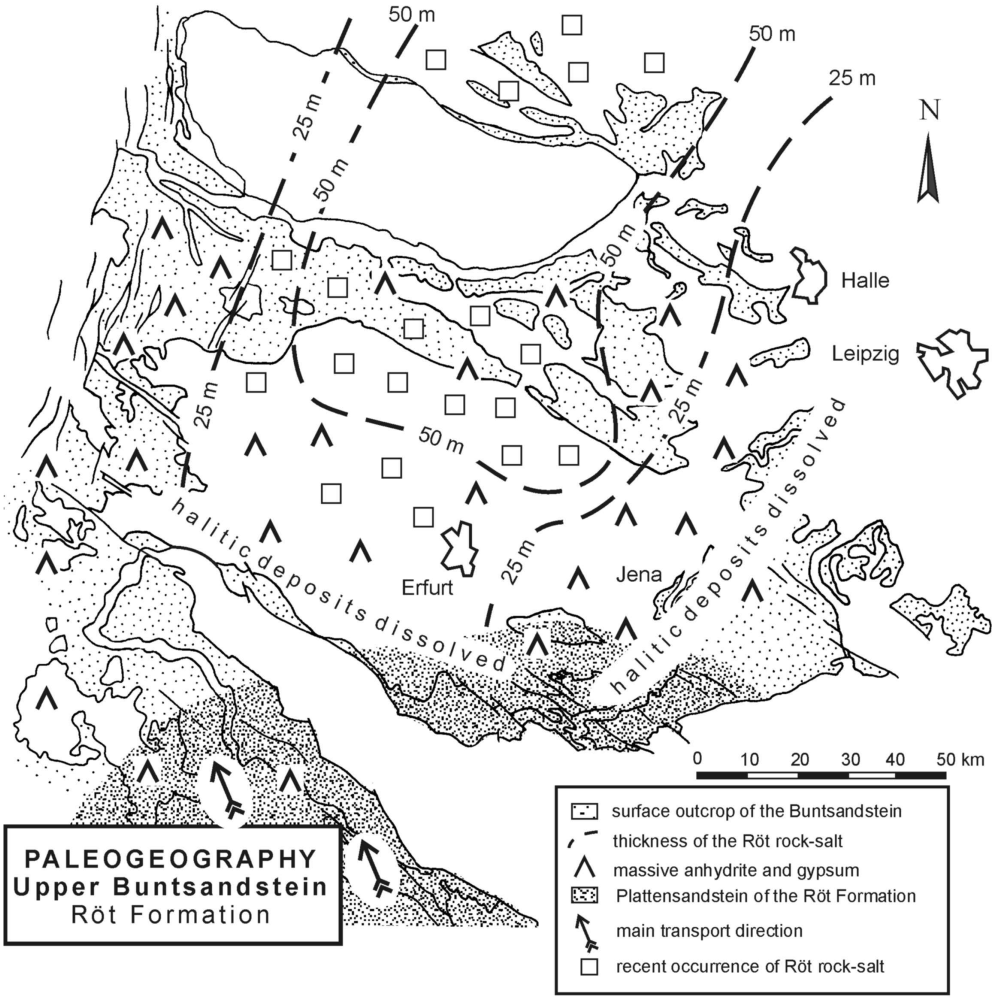

fig. 5: Facies-distribution of the Upper Buntsandstein and thickness of the salt at the base

Stop 1: Sandgrube Remschütz: Calvörde Formation

Aeolian and fluvial deposits

fig. 6: Early Triassic Calvörde Formation of the Remschütz sand pit.

The abandoned sand pit Remschütz exposes a 40 m thick succession of loosely cemented (friable) sands of the lowermost Buntsandstein. Together with 5 other sandpits of similar size along the outcrop of the Calvörde Formation, this pit was the base for the facies interpretation of Maaß & Voigt 2009, presented here. It is underlain by a basal succession of oolithic limestones carbonatic sandstones and claystones, which contains the Permian-Triassic boundary (not exposed). Sandstones are white to light-grey, some horizons are red to dark yellow. These beds are strongly cemented and contain mud clasts. Basal erosion and trough cross-bedding point to deposition in shallow fluvial channels. Most of the section is composed of bimodal-distributed sands with pin-stripe lamination. Each layer is less then one millimetre thick and is composed either of fine-grained or coarse-grained sand. Sand beds are not erosive but may fill shallow depressions in a conformable way. They are closely related to large scale cross-beds, up to 2 m thick with the same bedding type. Pin-stripe lamination is the result of migrating wind-ripples. The large scale cross-beds are the remains of much greater dunes. Their preservation depends on the groundwater level which presents the loose sand from further transport. Between the sand-units, green claystones and clayey sands are observed. These are interpreted as inter-dune deposits.

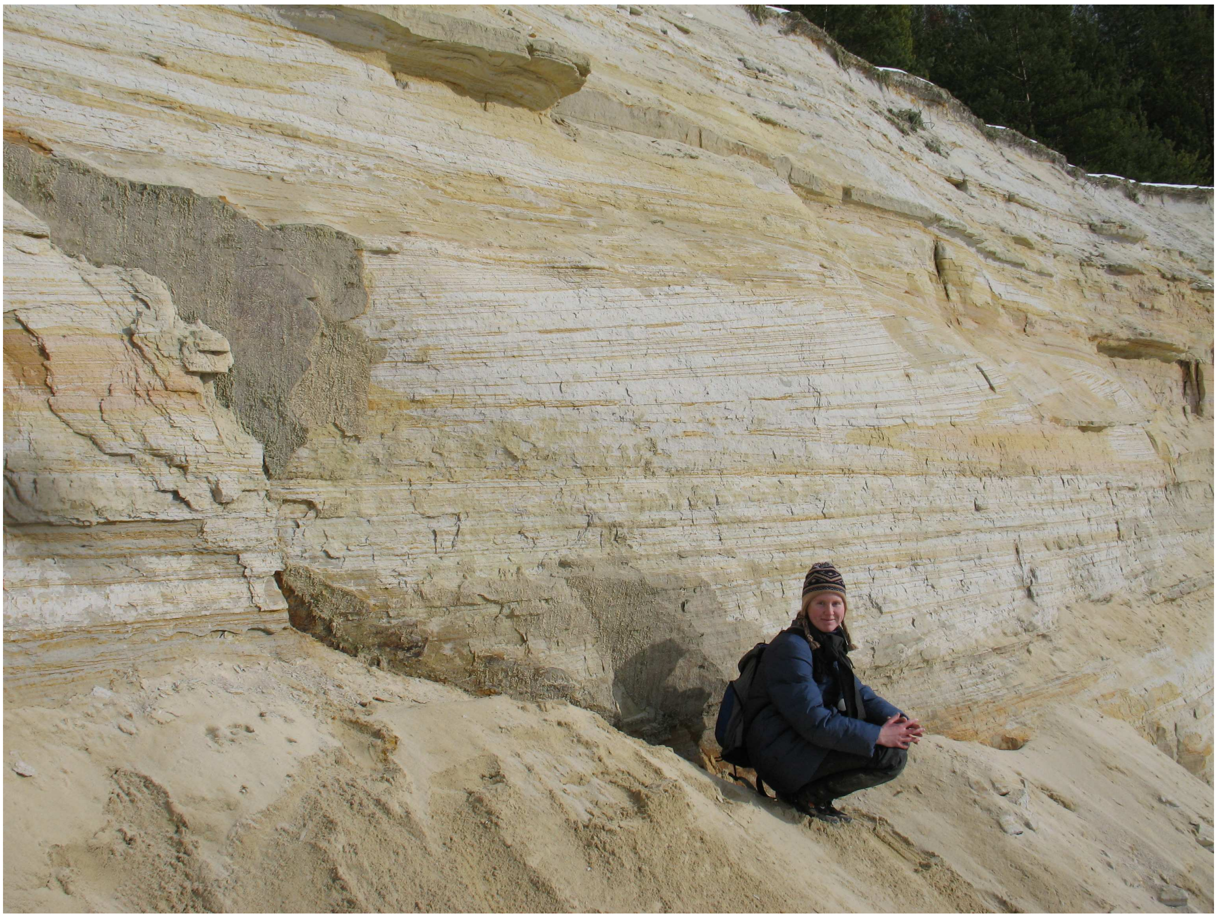

fig.7:Remains of large dunes and pin-stripe sands in the Remschütz section

After rainfalls, temporary lakes and wet sandflats may develop (probably with salt crusts). We assume an early diagenetic cementation of the eolian sands by gypsum or halite, because the sands show no evidence of compaction. These cements were dissoluted later, under the influence of meteoric water during basin uplift. As the fluvial sandstones form distinct horizons within the succession, formation during wet phases is assumed. A similar recent depositional system is known from the Atlantic coast of Namibia. After heavy rain in the hinterlands, some ephemeral rivers (mostly dry) cut through a dune belt and produce similar deposits like observed in this Buntsandstein-outcrop.

This facies belt of eolian sands in the Calvörde-Formation is characteristic of a 10-15 km wide, SW-NW striking belt. To the north, this unit is fully lacustrine (Stop1, next day) which transgress also over the eolian sands in this outcrop (upper Calvörde-Formation: “Tonige Sandsteinschichten”).

Stop 2: Orlamünde, Bernburg formation

Wet and dry sandflat, lake deposits, (terminal fan?)

fig. 9: Orlamünde section

This rock wall in the small town of Orlamünde with some picturesque cellars (formerly used for the storage of beer) is one of the most often visited excursion stops in Thuringia, due to the beautiful sedimentary structures (fig. 9). The red, white or yellow sandstones show cross-bedding, erosive surfaces, load casts and ripples on top. Together with bioturbation and desiccation cracks in the intercalated red mudstones, the whole suite of typical sedimentary structures in continental environments is present. Nevertheless, the interpretation of the depositional system needs some problems: Mostly attributed to a flood-plain environment, some features like the complete absence of major river channels in this stratigraphic unit and the occurrence of ooids in the sandstones point to another mode of formation. Some units, especially those with mud clasts and some, which cut as small channels into underlying deposits, were deposited in flowing water. Some units with steep cross-bedding and pin-stripe lamination may represent small dunes and other beds were deposited in temporary lakes (thick mudstones). In some cases, cross-beds with reactivation surfaces, which interfinger with red claystones point to small deltas prograding in a persistent waterbody. Such depositional systems with aeolian, fluvial and lacustrine processes are best described as sand-flats. In this case, no influence of salt is visible, so that a relatively wet environment can be assumed. Surprisingly, traces of life as rootled beds, vertebrate tracks, bivalve shells or fish-bones were never found, except some conchostracans and bioturbation (*Scoyenia*, *Corophoides*).

Although the existence of terminal fans in the fossil record was completely neglected by some authors, the interpretation of a river delta which ended in a large plain is the preferred interpretation of this environment. A good modern example is the Seravshan river in Usbekistan, which is sourced b the glaciers of the Western Tien Shan and enters the Kyzylkum desert. The Seravshan does not reach the Syrdarya, because all water is lost to the porous deposits in the subground. The delta (terminal fan) consists of hundreds of small channels and is about 30 km wide. In spring, during highest discharge, major areas are covered by shallow water for a short time (temporary lakes with mud deposition). In summer, the area runs dry and is affected by the wind which transports sand and forms small dunes (barchans). A similar depositional system would explain the rapid changes of lakustrine, fluvial and aeolian deposits which occurs in the this outcrop.

Stop 3 Roadcut Orlamünde, boundary Bernburg Formation (Lower Buntsandstein) to the Volpriehausen-Formation (Middle Buntsandstein)

fig. 10: Boundary of the Lower to the Middle Buntsandstein in Orlamünde

This outcrop is a good example how lithostratigraphy in the Buntsandstein works: The red, fine-grained and clay-rich deposits of the Lower Buntsandstein are overlain by medium to coarse-grained sandstones of the basal Volpriehausen-Formation with a conspicuous white colour. The depositional environment was interpreted to be fluvial in the basal parts and as aeolian in the other part, but there is room for discussion. The white sandstones are up to 30 m thick and show a gradual transition to lacustrine sandstones with some bivalves (*Avicula*) and gastropods (*Turbonilla*).

Stop 4: Sand pit Altendorf: Detfurth-Formation and base of Hardegsen-Formation:

Fig. 11: sandpit Altendorf: Detfurth-Formation overlain by strongly cemented Hardegsen sandstone.

The old sandpit in Alterndorf exposes the Detfurth Formation and the basal Hardegsen Formation. The Detfurth Formation is about 35 m thick of which 20 m are exposed. The sand of the pit was used for construction purposes. But, even of more importance was the “basal sandstone”, which was used for porcelain production in the nearby town of Kahla, due to its high content of feldspar. Exploitation started in large pits, but later it was even mined below the hills around Altendorf. The Detfurth Sandstone is about 10 m thick. It starts with 2 m of coarse-grained to conglomeratic sandstones with trough cross-bedding, followed by an aeolian unit of large-scale cross-bedded to pin-stripe laminated sandstones of about 6m thickness, very similar to the facies observed in the Remschütz sand pit. The top of this basal Detfurth sandstone is again formed by coarse-grained fluvial deposits and are exposed close to the sand pit’s entry.

The deposits of the higher Detfurth Formation may represent a sand flat (thinly-bedded, poorly-sorted sandstones and clay-drapes, abundant soil formation) with some small ephemeral channels (medium-grained, trough cross-bedded sandstones), one of which is exposed somewhere in the middle of the pit’s wall. A few metres below the Hardegsen Formation, which is conspicuous due to its brown colour, and the incision of its fluvial sandstones, a white aeolian sand-sheet is intercalated.

Stop 5: Rabenschüssel rock in Jena Maua: Hardegsen and Solling Formation

Fluvial deposits (channels of braided rivers and flood plains)

The "Rabenschüssel" is a rock wall close to Jena and consists of fluvial sandstones of the Hardegsen and Solling formations. The stacked channel fills show beautiful cross-beds, most of them are large troughs or compound cross-beds (re-activation surfaces), Deposition probably occurred in a sandy braided river of at least 4 m depth. As no traces of desiccation, aeolian reworking or soil formation are observed, a perennial river is assumed. Floodplain deposits are rare to absent, only near the top of the Hardegsen Formation, some thick clay beds, often associated with desiccation cracks, point to mud deposition in ephemeral lakes (abandoned channels?). Thickness of the Hardegsen Formation reaches 50-70 m, whereas the Solling Formation is only 15-20 m thick. Transport directions indicate that the river channel was running from the East to the West.

Fig. 12: fluvial sandstones of the Solling Formation near Jena Maua

Stop 6: Teufelslöcher in Jena: base of Upper Buntsandstein (Salinarröt)

The caves of the "Devil's Holes" are situated in the town of Jena. The large rock wall is composed of folded gypsum and marl. The most conspicuous feature is folding and the formation of secondary fibre gypsum which occurs in up to 10 cm thick layers. The folds are probaly related to a fault which runs NE-SW.

fig. 13: Basal Upper Buntsandstein in Jena (Teufelslöcher)

A small spring at the base of this unit marks the top of the Middle Buntsandstein (Solling Formation). The base of the Upper Buntsandstein is formed by green claystones with some thin sandstone beds, containing small dolomitized ooids. It is interpreted to mark the transgression of the sea on an arid coastal plain. This 1 m thick unit is overlain by a 20 m thick unit of gypsum and marlstones. The gypsum-beds are a few cm to 1 m thick and are strongly recrystallised (star-gypsum and porphyroblastic gypsum crystals).

This marks the transition to a salina-type sedimentation. Boreholes show that the complete sections contain a 20-50 m thick rock salt near the base of the succession. The salt and parts of the gypsum were dissolved near surface and was probably the reason for the formation of fibre gypsum.

Stop 7: Mönchsberg in Jena-Göschwitz: Upper Buntsandstein (Pelit-Röt)
Red playa deposits with soil formation (nodular gypsum)

The outcrop exposes a few meter of red claystones intercalated by some sandstone beds, with desiccation cracks and salt imprints at the bases. The section contains also fibrous gypsum, mostly oblique to bedding. To the top, this uniform succession of probably playa (salty mud flat) origin is overlain by a 1-2 m thick horizon of nodular gypsum. These nodules formed as a soil during a transgression of the Tethys (marginal salina?) from the east, which several times entered the eastern Germanic Basin. These horizons of nodular gypsum form some correlation horizons traceable at least in a regional scale.

fig. 14: Mönchsberg outcrop in Jena-Göschwitz

Stop 8 (optional): castle rock in Jena-Burgau: Solling Formation

The Solling Formation is characterized by strong lateral changes of channels, flood plain deposits and soils. The typical tripartite succession of basal coarse-grained river sandstones, followed by mudstones and homogenized sandstones with soil formation (calcretes and silcretes), and a top-sandstone which is again of fluvial origin, was not observed in the Rabenschüssel outcrop due to the predominance of river channels, but is beautiful exposed in Burgau. The middle part between the fluvial dominated basal sandstone and the top sandstone is composed of clayey sandstones and claystones of strongly varying colour (violet, greyish, red). It probably represents a time of non-deposition and long-term oil formation.

To the top, platy, thinly bedded sandstones with abundant ripples follow. They contain a variety of reptile tracks (Chirotherium) of up to 40 cm length. That is why the sandstone was named “Chirotherien- Sandstein”. Abundant wave ripples and deformation structures point to deposition in a salty sandflat, probably already influenced by the sea.

fig. 15: Chirotherium traces from the Solling Formation

Stop 9: Beer-garden at the Burgau bridge

(no further explanation necessary)

fig. 15: View from the beer garden in Jena-Burgau to the Saale-river and Muschelkalk hills.