Excursion 4

"Minette Oolitic Ironstone"

Site: Giele Botter (Differdange/Luxemburg)

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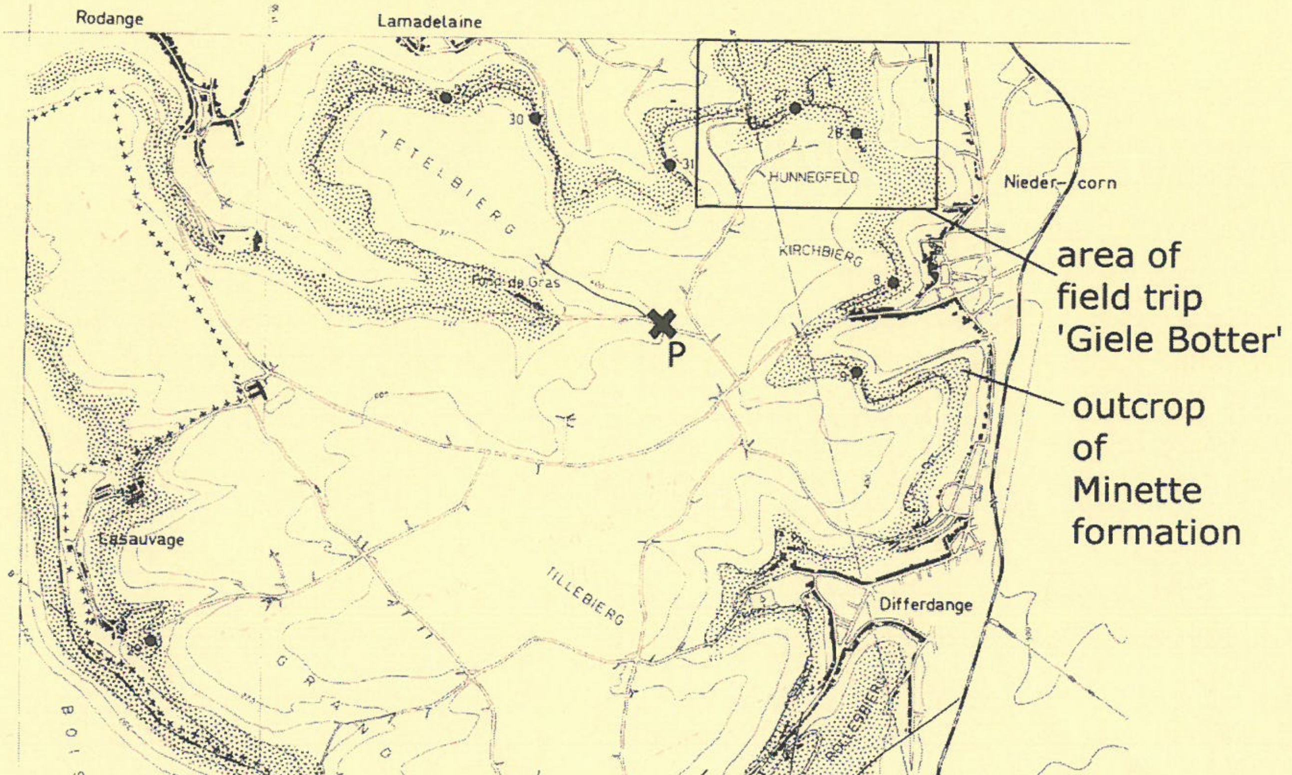
Guide:
Jean Thein
Bonn University - Geological Institute
Nussallee 8
D-53115 Bonn, Germany



1. Introduction

The Upper Liassic, the Aalenian and Lower Bajocian are in Middle and Western Europe a period of maximum sedimentation of oolitic ironstones. These so called minette-type deposits are wide-spread and generally bound to the near shore areas, surrounding the small continent masses in the shallow European shelf sea (Fig.1).

One of the largest ironstone deposit of the world is the "Minette" formation, formed in two separate sedimentation areas in the northeastern Paris Basin, in northern Lorraine, Luxemburg and Belgium. The larger Basin of Briey contains more then 10 billion tons of iron. It crops out through all southern Luxemburg, at the base of a prominent cuesta, topped by the reefal limestones and bioclastic carbonates of the Lower and Middle Bajocian. The ferriferous formation, mined for more then hundred years up to the end of the 20th century, is spread over an area of more then 1000 km^2 and reaches > 60 m thickness in the central part (Fig.2). Stratigraphically it is positioned in the upper Toarcian and Aalenian. It is underlain by the bituminous Posidonia shales, and the clays and sandstones (Fallaciosus Formation) of Toarcian age. It is overlain by marls (Micaceous Marls, Sonninia Marls) and subsequent biodetritic, ferruginous limestones (Limestone of Haut Pont) of the Lower to Middle Bajocian (Figs.3, 4). The youngest Bajocian sediments are formed by thick biodetritic limestones, containing bioherms of coral reefs (Limestone of Audun le Tiche), mined for cement fabrication in southeastern Luxemburg near Rumelange.

2. The Minette Formation: Facies, Geochemistry, Paleogeography

The Minette formation includes oolithic ironstones at several horizons in the upper part of up to 15 detrital coarsening upwards cycles. In Luxemburg the deposit is subdivided into a western part, the Basin of Differdange-Longwy, where 9 lower cyles are developed (Fig. 5) and an eastern part, the Basin of Esch-Ottange with well developed upper cycles. A marked regional and vertical facies variation can be observed: in the lower and western part silicate ores, built up by iron-rich chlorites (berthierine) predominate, while in the upper and eastern parts calcareous goethitic ores are more important. These varying mineral contents give characteristic colours to the rocks: from green over grey, to yellow and red after wich the mined ores have been given names.

The ironstone facies ("couches" or "Lager") consists mainly of cross-bedded iron oolites and bioarenitic limestones of a high energy environment (Fig. 6). Geochemically this facies is characterized by iron and a number of correlated siderophilic elements like V, Ni, Co, Mn, but also As and P, and by Ca and Sr in the higher cycles (Figs. 7, 8) The high phosporous content was the reason, why the Minette ores could not be smelted (they gave a steel of bad quality) until the invention of the thomas-process at the end of the 19th century. The intercalated, strongly bioturbated finegrained mud- and siltstone facies ("intercalaires" or "Zwischenmittel"), deposited in a lower-energy environment, is marked by a group of lithophilic elements (Si,Ti, K, Cu, Al) brought in by a finegrained siliciclastic detritus. The alternation of the two facies builds up a sequnce of shallowing upwards cycles. Coarse grained lithoclasts and large biomorpha (belemnites, ammonites, etc.) indicate a transgressive event at the base of each cycle. The bioturbated siltstones grade, with increasing iron-rich particle content into the ironstone facies, which is capped by a cross-bedded biorudstone ("lumachelle") on the top, indicating the highest energy ot the cyclothem. The Minette sediments were deposited in a nearshore shallow marine environment in the subsiding gulf like bay of Luxemburg surrounded by the lowlands of the hercynian Rhenish Massive (Ardennes, Eifel, Hunsrück) with its mesozoic cover, both deeply weathered (Fig. 12). The paleogeographic setting is similar to that of many other phanerozoic marine ironstones: a shallow inland sea at low paleolatitudes. Teyssen (1984) and Siehl & Thein (1989) interpreted the Minette series as subtidal to intertidal sediments. On wave and current dominated offshore shoals, elongated in NE/SW direction, the ironstones were deposited. The system is strongly influenced by tidal currents, leading to an ebb-dominated NE-SW trending current system, yielding the typical cross-bedding features observed in the layer facies (Figs. 10, 11). In SW direction, with increasing water depth, the bars interfinger with bioturbated mud and siltstones.

3. Origin of oolites

The source, transportation and accumulation modes of iron and especially iron ooids are still discussed. The extremely low solubilty of Fe, Al and associated elements (Ti, V, Cr, Zr, etc.) suggest a transport into the sea by terrigenous particles of various grain size. The classic opinion still adopted by Bubenic (1961) for the Minette is, that dissolved iron precipitates together with the associated elements in the mixing zone of fresh river water and saline marine or brackish water with the change of physico-chemical parameters (Eh, pH, salinity). The clastic grains of the Minette, so of many other marine deposits, however contain obvious structural features like those observed in hydromorphic soils (latosols) in which in situ formation of concentric grains (oolites, pisolites) is a normal process. The chemical composition of such formations is identical to that of Minette and other ironstones including the very diagnostic substitution of Al in goethite (Fig. 9). Siehl & Thein (1989) assume after comparision of many mesozoic to recent ironstones in marine, fluvial, lacustrine and soil environments that erosion, reworking and subsequent fluviomarine redeposition of soil derived ooids is a major process of generating minette-type ironstones. Postdepositional diagenetic changes may convert the aluminous, silica rich ferric ooids into berthierine in reducing environment, like observed in the Minette deposit. Finally iron ooids may form in various environments where appropriate Eh and pH fluctuations can produce coated grains, even on marine hardgrounds (Fig.13). The loci of ooid formation and sedimentation may be quite different.

4. The site "Giele Botter"

The abandonded open pit mine Giele Botter, which is a natural reserve since some years, allows to study in a unique way the western lower Minette sequence as well as the Bajocian cap rocks.

The site is reached over Differdange/Niedercorn, following the road to La Sauvage. On the top of the cuesta a road turns to the right in direction of Fond de Gras, Titelbierg (see Map on cover page). From the parking place a small road leads to the north where you reach after about 500 m walk the informatory sign of the natural reserve Giele Botter. The best access to the vast mine area and its geological content is following the path indicated in counterclock direction. Usefull informations are given on several boards, installed at the important points.

The outcrop covers the stratigraphic section typical for the Basin of Differdange, from the Couche Grise (Grey Cycle) to the Calcaire Superieur (Upper Calcareous Cycle) in the Minette Formation, so covering the upper Toarcian and the Lower Aalenian. The upper part is missing, probably due to erosion (see Fig. 4). The Giele Botter is in Luxemburg certainly also the best place to study the strata covering the Minette, from the Marnes Micacées to the Calcaire de Haut- Pont.

The Minette ores have been mined underground (you still can see the entry of the main mine) and in the open pit. In the open cast the ironstone was exploited in two sections, extracting separately the basal siliceous ores and the upper calcareous ores, both having metallurgically different properties. The two mining faces can be followed many hundreds of meters, over all the outcrop. In the lower part the siliceous facies of the Grey, Yellow and Red Cycles can be observed. Fig 5 gives a schematic N-S longitudinal section, in which the vertical profiles 27, 28, 8 mainly represent the area of the mine. The typical coarsening upwards sequences, developing from a flaser bedded muddy iron poor siltstone into the cross bedded ironstone facies (see Fig. 6) can well be observed in the Red Cycle. The Grey Cycle ores are formed mainly by berthierine, giving the ironstone facies a dark grey, blackish coulour. The cross-bedded ore-facies reaches up to 4 m thickness; the iron concentration can be as high as 40 %. The polished, mostly lense shaped ooids and ferriclasts can well be observed. Friable oolite-rich parts intercalate irregularly with stronger carbonatic layers, with a higher content of bioarenitic clasts. It is capped by a very marked thin layer with a large pelecypode called *gryphaea ferruginea.* The layer can be followed allmost over all the basin of Differdange and is suggested to be a stormlayer. The Yellow Cycle is just 1-2 m thin, varying rapidly in thickness. The Red Cycle, reaching almost 4 m thickness, displays the classical cyclothem development. In the ironstone facies large scale sandwave foresets with distinct tidal bundles are developed. Harder coarser grained calcareous banks grade upwards into a softer ooid-rich fine grained facies. The top part of the lower wall face is build up by the basal siltstone of the following Lower Calcareous Cycle, mined on the next terrasse. The ichnofauna can well be observed in the large blocks fallen from the walls. The flaser-bedded muddy siltstones are highly bioturbated by sediment feeders, like *rhizocorallium*, *phycodes* and *planolites,* whereas *arenicola* and *scolithos* are typical suspension feeders in the ironstone facies.

In the Giele Botter the Lower Calcareous Cycle is well developped with an ironstone facies of almost 5 m thickness. Very largescaled, low-angle dipping foreset-beds are cut by a sedimentary unconformity at the top of the sand wave. The foreset beds are developped in regular banks displaying numerous small scale cross-bedding features. Especially in the upper part the banks are grading into an nodular structure, produced by secondary carbonate dissolution. The ooids are goethitic , the ore facies is very rich in bioarenite, so reaching only low iron concentrations with a mean of 20 %. The Cycle is capped by a thick biorudstone (lumachelle)

With an irregular erosion surface the siltstone facies of the Upper Calcareous Cycle, with a well developped basal transgressive bed with numerous biomorpha, forms the upper part of the wall. The ironstone facies of the cycle is generally missing on the Giele Botter. The Minette Formation ends here with a hardground, wich is spread all over Luxemburg. The surface can be observed in the Giele Botter only in some remnants on the plateau above the Minette Formation. Dissolution molds, thin goethite crusts, burrows of *lithophagus,* some *ostreae* and *serpulidae* so as reworked Minette clasts can still be found. The overlying marls of the Concavus Zone, much thicker in the eastern Basin of Esch-Ottange, with a rich ammonite fauna are not developped in the excursion site.

Detailled information about the Minette of the Basin of Differdange and the sedimentological features is given in the atlas of IRSID (1967), Thein (1975) and Teyssen (1983,1984)

The overlying Bajocian sediments start with a transgressive shelf marl, the "Marnes Micacées", more then 13 m thick grey unconsolidated clays to mudstones. The carbonate content is very low and mainly concentrated in rare nodular banks. A prominent feature is the content of small muscowite flakelets, in fresh outcrops also diagenetic pyrite. The sediments are impermeable for water and form an important hydrogeologic barrier in the underground mining. In the open casts these marls were and are still responsible for mass slides, injuring the extraction activities.

In the upper part the clays grade into the "Sonninia Beds", a sequence of marls in which an increasing number of limestone banks are intercalated to the top, to form finally bedded limestones with marly interbeds, the so called "Calcaire d'Ottange". A hardground, similar to the one above the Minette is developed at the top of the Marnes Micacées. Large burrowed intraclasts of limestone, coated with goethite cruts form the "Sonninia Conglomerate". The carbonatic Sonninia Beds are generally micritic to fine grained bioarenitic limestones, with abundant echinoderm remains. Large burrows of rhizocorallium are very characteristic. The Calcaire d'Ottange series reaches a thickness of almost 6 m.

It is separated with a rather sharp boundary from the cross-bedded "Calcaire de Haut-Pont", which crops out in the Giele Botter with a thickness of about 10 m. As "hardrock" it forms a steep wall again in the upper part of the Giele Botter site. The sequence resembles very much the calcareous ironstone facies of the Minette. Cross-bedded bioarenitic carbonates show thin intercalations of marls in the basal part, the top beeing mainly bioarenitic pack- to grainstones of a high energy environment. Echinoderm fragments are very common. The content of siliciclastic particles is generally low; iron ooids are frequent in some layers which can reach Fe-concentrations up to 20 %.

The overlying coral reef facies of the "Calcaire d'Audin le Tiche" is no more exposed in the Giele Botter, but crops out on the Plateau south of the mine.

In total the Bajocian sequence shows a similar development than that of the Minette Formation and its underlying sediments, from low energy deeper shelf facies over subtidal facies to sediments of a high energy environment.

The Bajocian sequence exposed on the Giele Botter is described in detail by Köwius (1977)

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Maps: Carte Géologique du Luxembourg, èchelle 1 :25.000, Feuille No **12**, Esch/Alzette.

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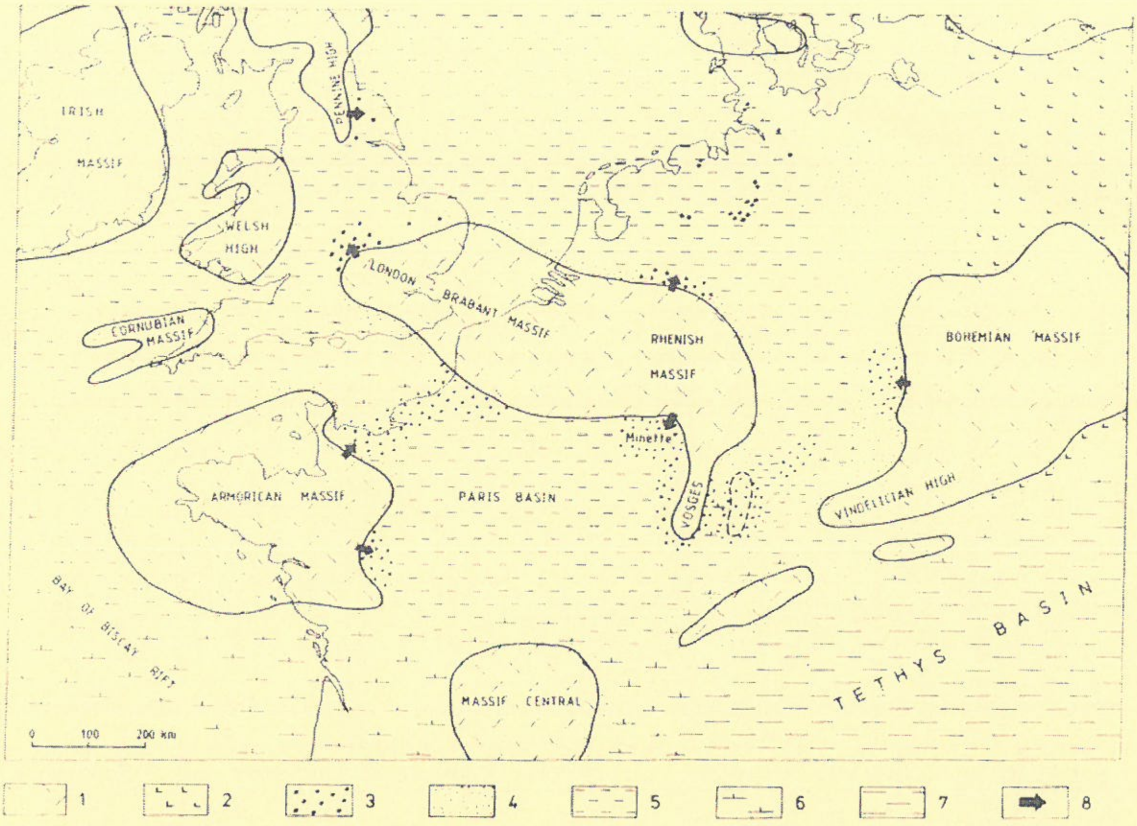


Figure 1

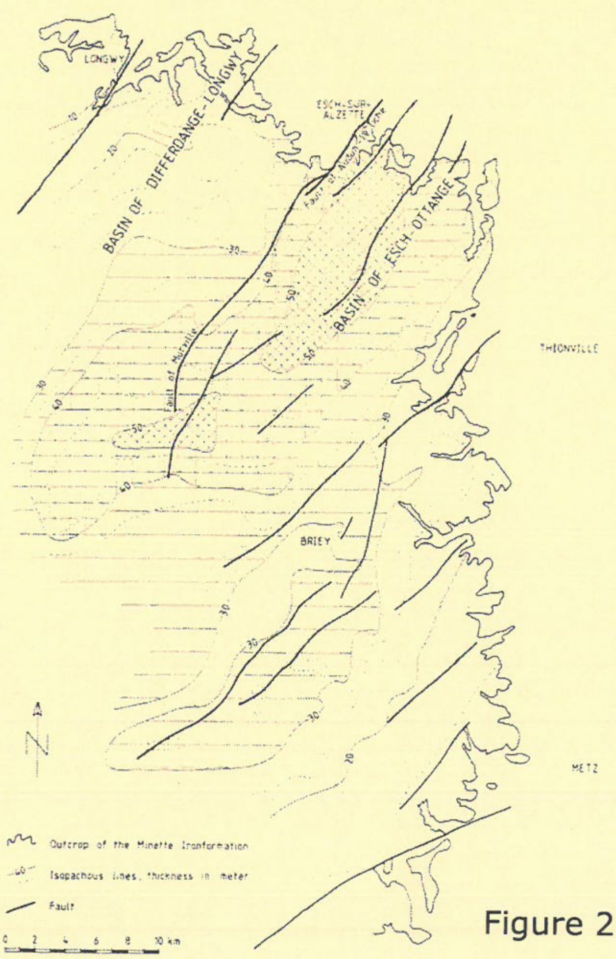
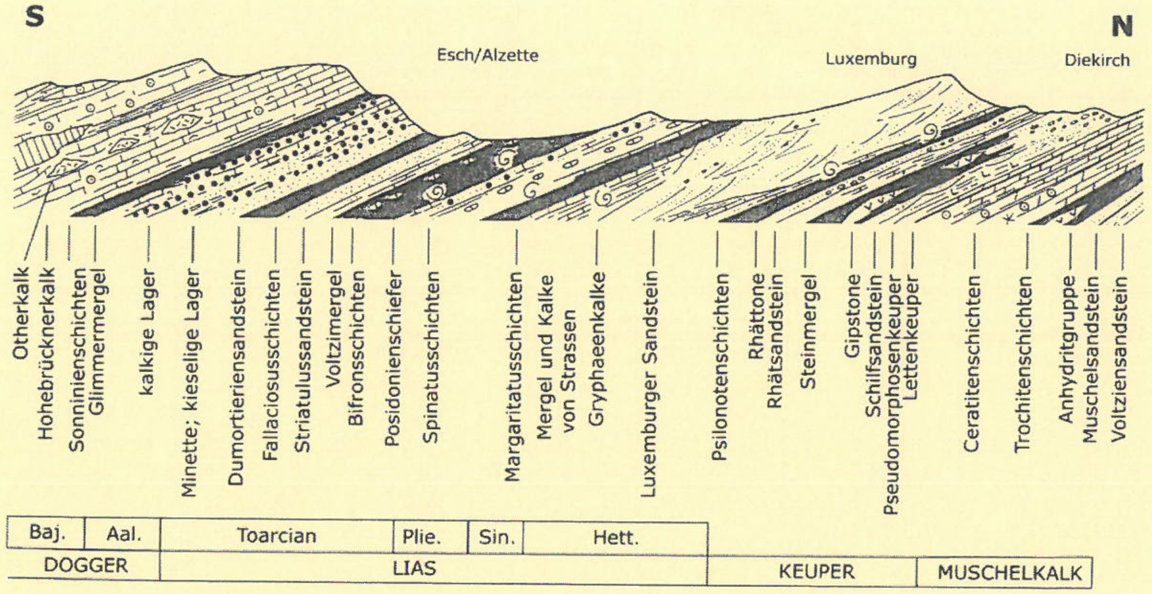


Figure 2

Fig. 1: Paleogeographic situation of western and middle Europe during the deposition of Minette Ironstone. 1. areas of non deposition, 2. continental and lacustrine sediments, 3. oolitic ironstones, 4. deltaic, coastal and shallow marine sands, 5. shallow marine shales, 6. carbonates, 7. deeper marine shales, 8. terrigenous clastic influx. (Fig. from Teyssen 1983)

Fig. 2: Thickness of the Minette Ironstone Formation in the Basin of Briey. Maximum thickness in the central subsidence zone of the subbasin of Esch-Ottange reaches > 60 m. The excursion site “Giele Botter” is located at the northern edge of the subbasin of Differdange-Ottange. Some faults are syngenetically active. The major fault of Murville/Audun-le-Tiche separates the rather siliceous facies in the West from the calcareous facies in the East. (Fig. from Teyssen 1984)

Figure 3



Subdivision cartographique de la minette et des couches sus-jacentes

Figure 4

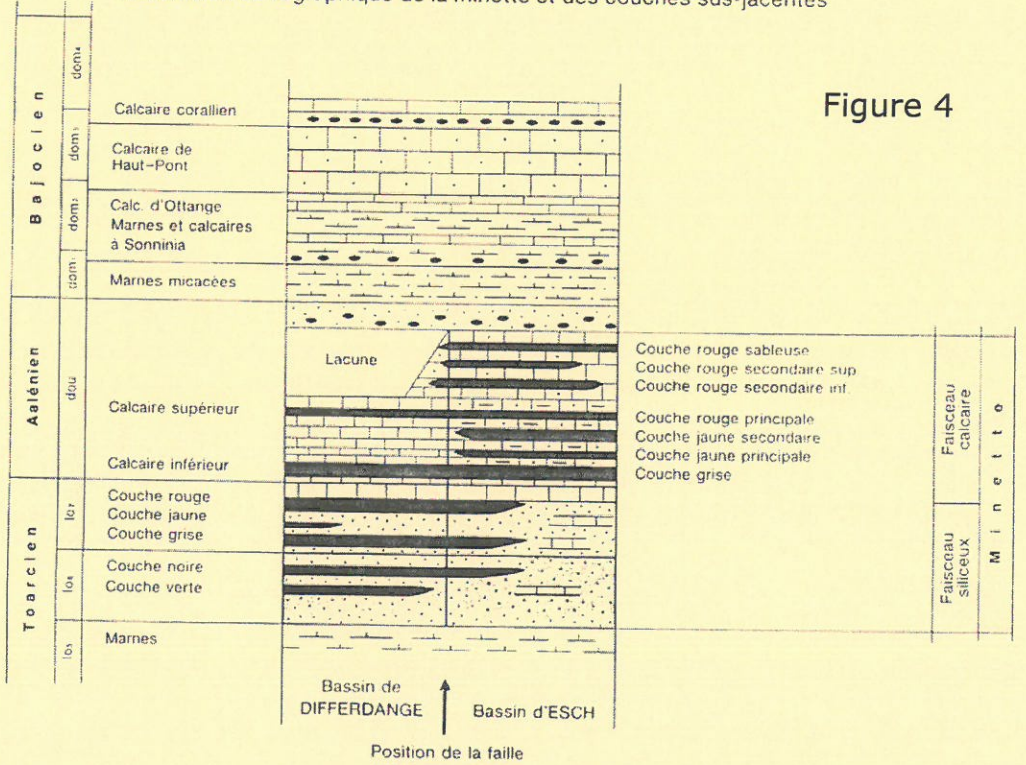


Fig. 3: Schematic cross-section through the Luxemburg Basin. The section illustrates the facies development from the upper Buntsandstein to the Middle Bajocian reefal and oolitic limestones. Important formation names are indicated. The hercynian basement of the Oesling crops out some kilometres north of the section. Strata are generally dipping with a faint angle in SW direction towards the central Paris Basin. Note the lense of the Luxemburg Sandstone, grading basinwards into the normal facies of Hettange. (unscaled) (Thein & Siehl, unpubl.)

Fig. 4: Stratigraphic normal section of the Minette Ironstone Formation and its cap rocks. Note the different development of the ironstone layers in the basins of Differdange and Esch, separated by the syngenetic Fault of Audun-le-Tiche. Upper Aalenian marls transgrades over a hardground developed in both areas. The section in "Giele Botter" covers the part from the "couche grise" to the Calcaire de Haut-Pont (Fig. from Carte Géologique 1:25.000, Feuille12, Esch/Alzette)

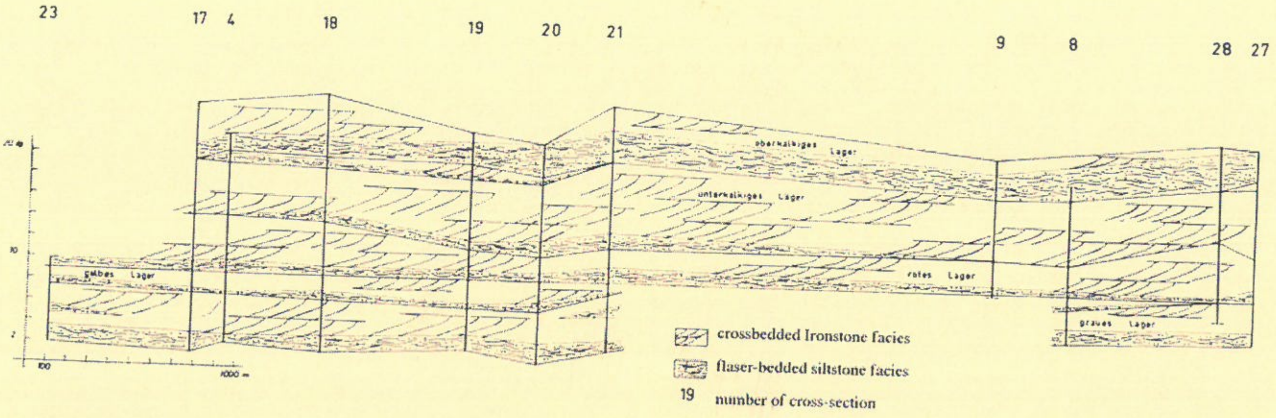


Figure 5

Figure 6

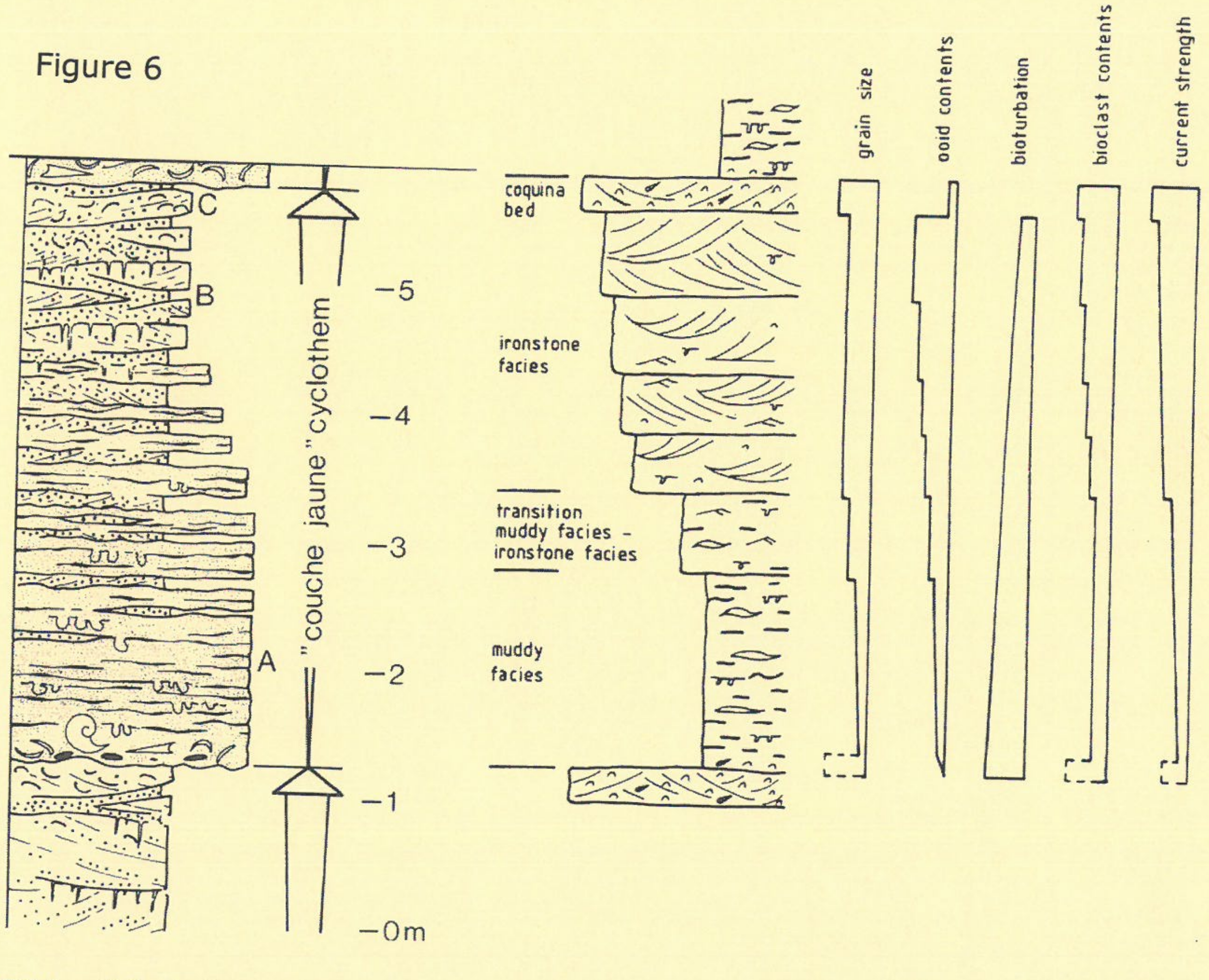


Fig. 5: Schematic longitudinal N-S section through the western part of the basin of Differdange-Longwy. The section is indicated in the cover map. Sections 27 and 28, as the northernmost are situated in the excursion area. Note the variations in thickness of the different sequences. The typical cyclothem shown in Fig. 6. must not necessarily be complete, due to erosion or non sedimentation. (vertical exaggeration: 5 x) (Fig. from Thein 1975)

Fig. 6: Asymmetric coarsening upwards sequence of a typical shoaling Minette cyclothem. The basal transgressive bed contains abundant biomorpha of marine fossils (ammonites, belemnites, pelecypoda) and conglomerate-sized intraclasts. The overlying linsen- to flaser-bedded muddy siltstone facies witch is poor in ooids, is strongly bioturbated by sediment feeders. A ripple-bedded transition zone grades into the large scale cross-bedded ironstones, rich in ooids and bioarenitic particles. Last are enriched in bred shaped carbonate-rich lenses, which are a product of diagenetic alteration. The ironstone facies is disturbed by vertical burrows of suspension feeders. Mostly the cycle ends with a cross-bedded biorudite. Grain size, content of ooids and bioarenite depend from the current strength rising from bottom to top. (Figs. from Siehl & Thein 1989, Teyssen 1984)

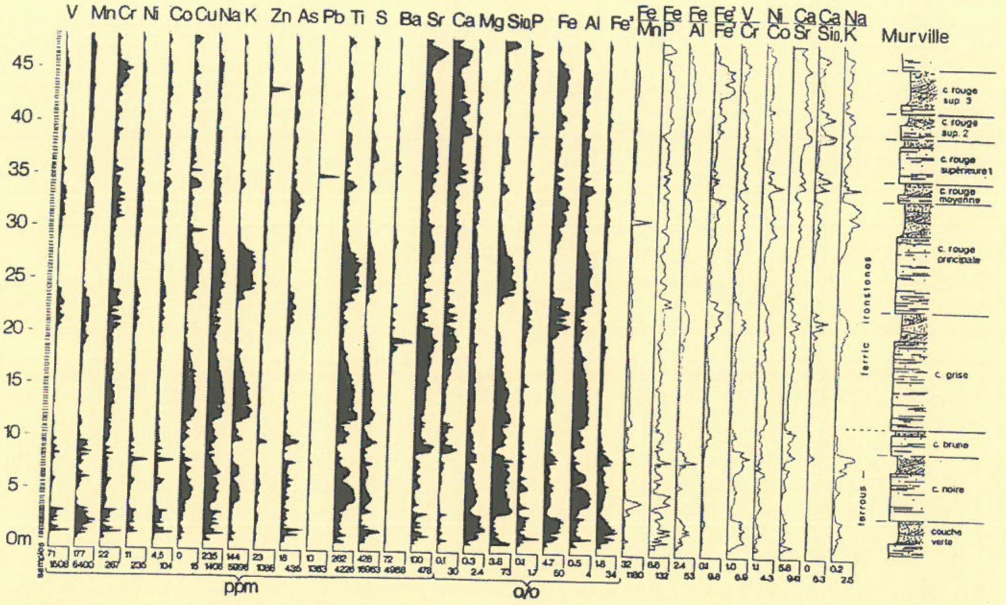


Fig. 7: Geochemical section through the Minette sequence at Murville, in the central basin of Briey. The ironstone stratigraphy corresponds to the eastern subdivision. Couche grise = Lower Calcareous cycle in Basin of Differdange-Longwy! The cyclic repetition of rock types is reflected by the rhythmic variation of three correlated element groups, representing the main lithologic facies: *muddy siltstones, ironstone, limestone* (see also Fig. 4) A long term trend is shown by the Fe^3/Fe^2 and Ca/SiO_2 ratios: development from siliceous berthierine bearing ores in the lower to calcareous goethitic ores in the upper part of the section. (Fig. from Siehl & Thein 1989)

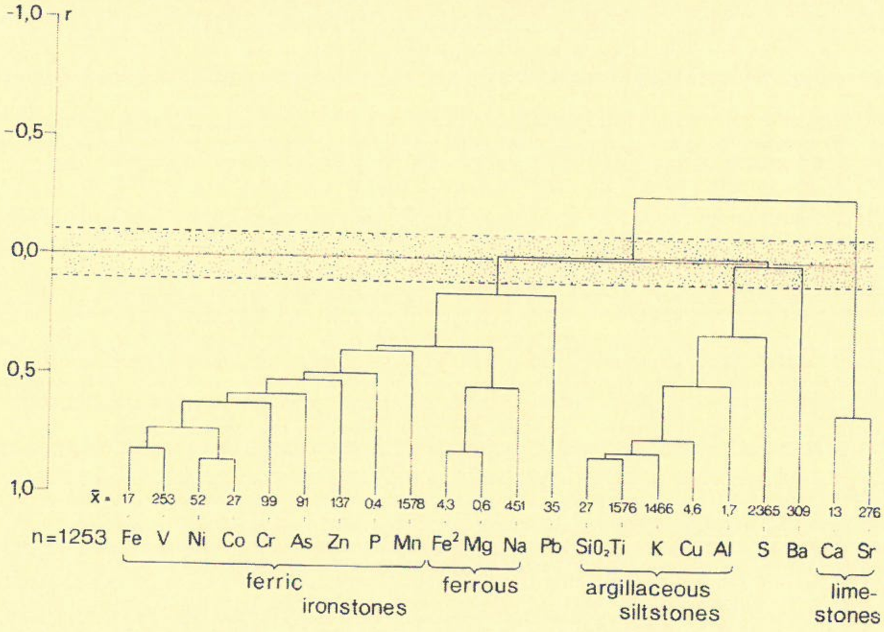


Fig. 8: Cluster analysis dendrogram of 1253 geochemical analyses of Minette Ironstone. Major clusters correspond to the main lithofacies: *ironstones* with siderophilic elements Fe, V, Ni, Co, As, Zn, P, Mn (the siliceous ores form a special group); *argillaceous siltstones* with the lithophilic elements Si, Ti, K, Cu, Al; the *limestones* with the biogenic Ca, Sr group. (x = mean values in % and ppm, stippled area: non significant correlation) (Fig. from Siehl & Thein 1989)

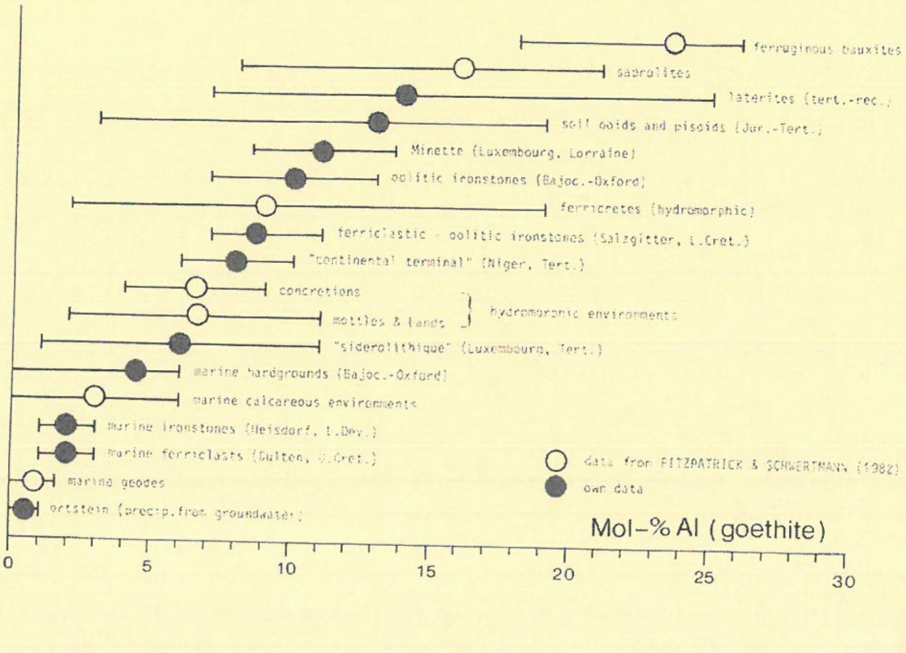


Fig. 9: Aluminium substitution in goethites of different formation environments. Mol%-values were determined by means of X-ray diffraction analysis (*d*(111) spacing of goethite) (Fig. from Siehl & Thein 1989)

Figure 10

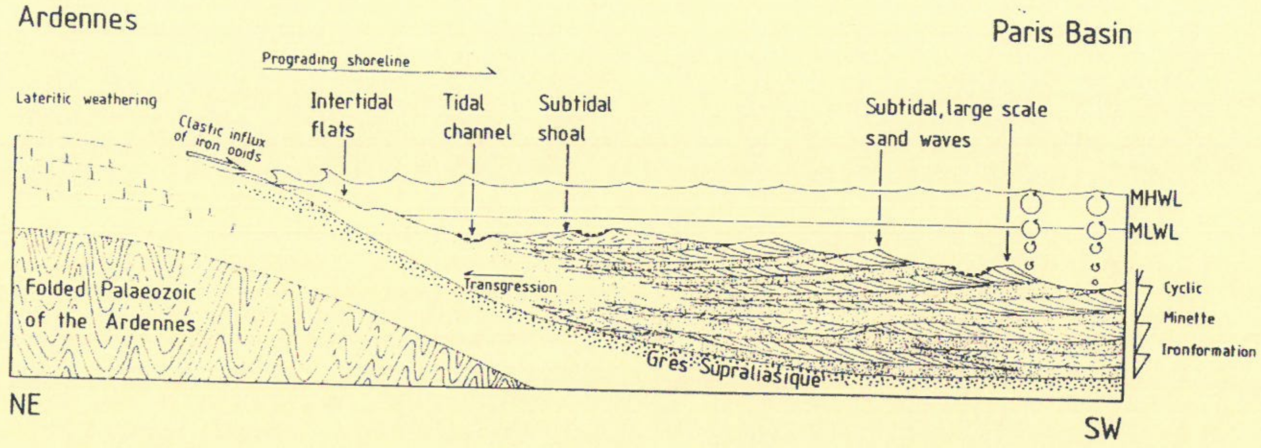


Figure 11

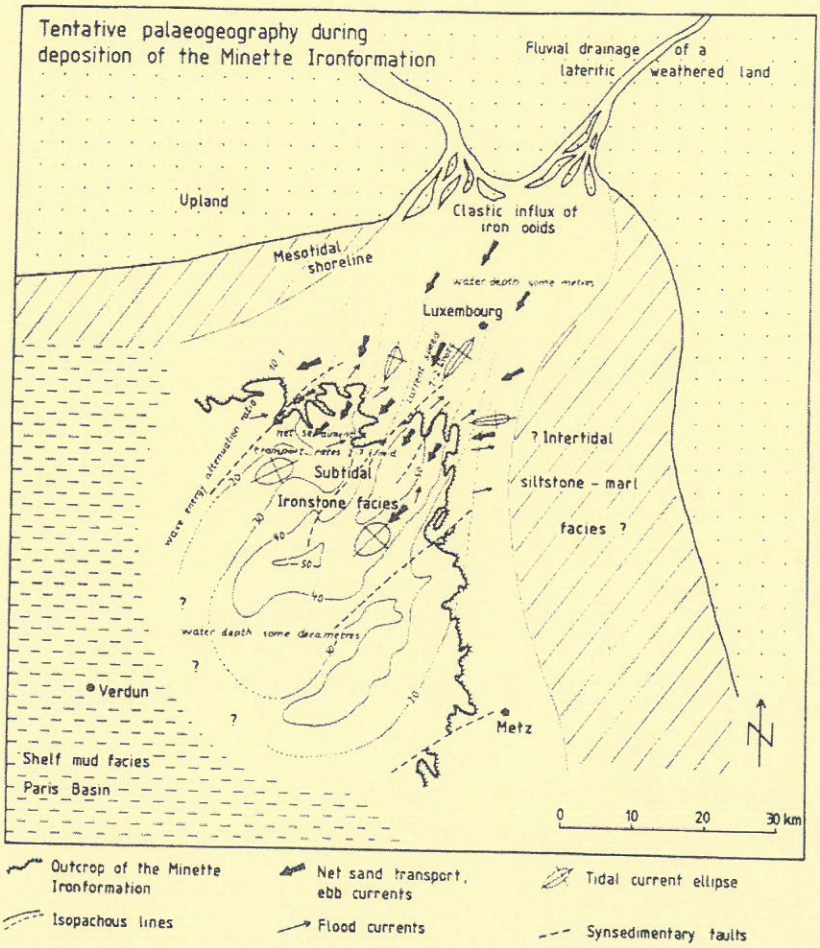


Fig. 10: Schematic section of the Minette depositional basin (not to scale). Ironstone facies and muddy siltsone facies are deposited in a subtidal environment, the coarser grained oolitic and bioarenitic sediments form shoals in a higher energetic milieu, the mud facies forms either in deeper shelf areas or represents an intertidal siltstone-marl facies. Ooids and other goethite grains are derived from the weathered continent and are redeposited in sand shoals by tidal currents. (Fig. from Teyssen 1984)

Fig. 11: Tentative paleogeography during deposition of Minette Ironstone Formation. Derived from the study of sand wave internal structures and wave ripple marks. The ironstone facies is winnowed to sand waves by tidal currents with a dominating NE-SW ebb-current. The lateral equivalents of the Minette in the more central Paris Basin are interpreted as shelf muds. The position of shore lines and of intertidal zones is hypothetical, since recent erosion makes direct observation impossible. (Fig. from Teyssen 1984)

Figure 12

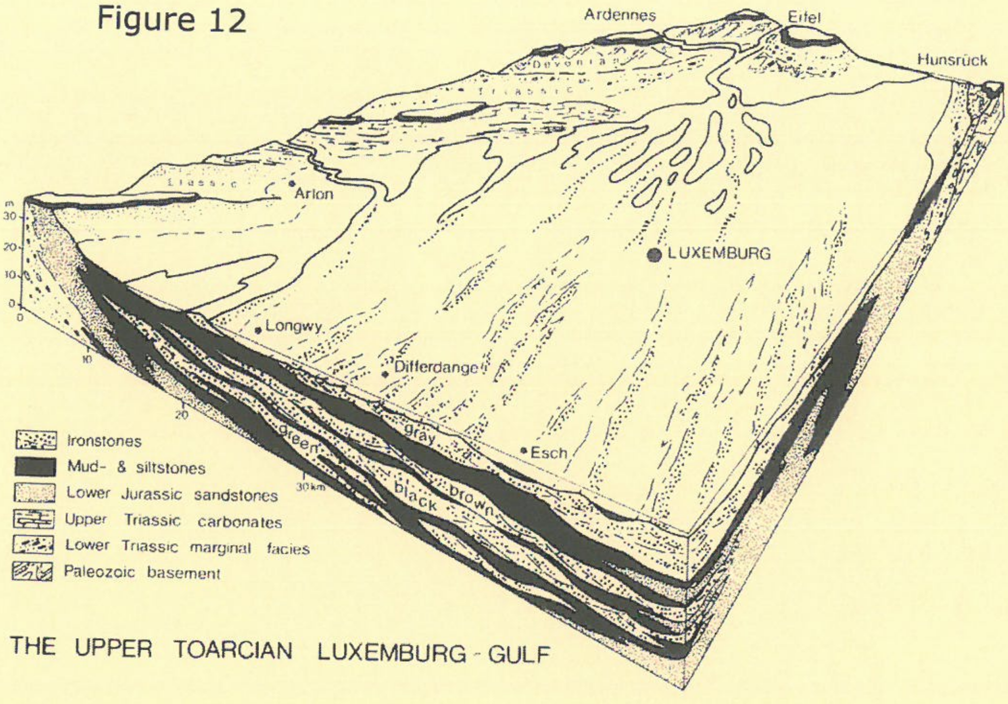


Figure 13

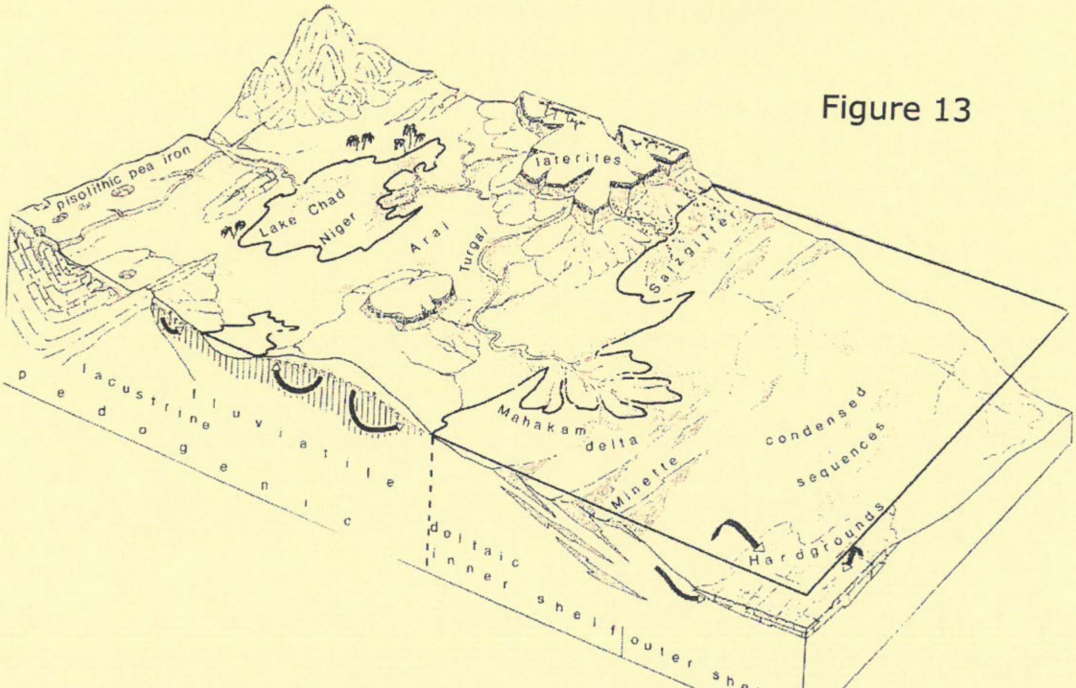


Fig. 12: Sketch diagram displaying the paleogeographic situation of the Luxemburg Gulf during deposition of the grey layer. The hercynian basement of Ardennes, Eifel, Hunsrück and the older Mesozoic cover are peneplained and covered with a thick weathering crust of lateritic nature. Rivers transport the eroded hydromorphic soils containing ooids, pisoids and ferriclasts into the shallow sea where they are accumulated together with siliciclasts and bioclasts in elongated sand bars. They interfinger laterally with muddy siltstones of quiet water areas. (Fig. from Siehl & Thein 1989)

Fig. 13: Environments of iron ooid and pisoid formation and loci of sedimentation and accumulation. Names indicate type cases for pedogenic, fluviatile, lacustrine and marine ironstones. (Fig. from Siehl & Thein 1989)