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NEW LITHOSTRATIGRAPHICAL, SEDIMENTOLOGICAL, MINERALOGICAL AND PALAEONTOLOGICAL DATA ON THE MESOZOIC OF BELGIAN LORRAINE: A PROGRESS REPORT

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(9 figures, 2 tables & 3 plates)

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In memory of Pierre-Louis Maubeuge (1923-1999)

ABSTRACT. A multidisciplinary study of some extensively cored boreholes together with the new 1/25.000 geological mapping of Wallonia led us to propose a new lithostratigraphic canvas for Belgian Lorraine. This area is located on the N-E border of the Paris Basin, south of the Ardennes; the studied stratigraphic interval covers the Keuper to the Toarcian. Each of the new lithostratigraphic units is interpreted by macroscopic and microscopic sedimentological observations. Detailed palynological and claystratigraphical analyses were also performed, providing additional stratigraphical, palaeoecological and sedimentological data. The Habay Formation (conglomerates and red mudstones) is a fluvial unit, with immature channel conglomerates and paleosoils. The Attert Formation (dolomitic marls with gypsum and pseudomorphs) exhibits an evaporitic trend. The Mortinsart Formation (sands and marls) corresponds to a restricted marine unit, evolving towards an alluvial plain (Levallois Member). The second cycle begins with the Jamoigne Formation (bioturbated marls and limestones), a marine subtidal restricted unit, evolving towards a more sandy series (Metzert Member). The base of the third cycle corresponds to the rest of the Luxembourg Formation, composed by a superposition of sand waves. The Ethe Formation (laminar mudstones and marls) marks a deepening of the basin and the outset of marine dysaerobic conditions. The Aubange Formation (bioturbated marls with sandstones and limestones) is characterized by the reappearance of a normal benthic fauna. The Grandcourt Formation (laminar mudstones and marls) marks a return to open marine dysaerobic conditions. The Mont-Saint-Martin Formation (marls, sandy marls and oolitic ironstone) is a highly regressive unit, while the Longwy Formation (limestones) marks the initiation of a carbonate platform.

KEYWORDS: Lorraine, Triassic, Jurassic, boreholes, lithostratigraphy, palaeontology, palynology, petrography, clay mineralogy.

1. Introduction

The Mesozoic formations of Belgian Lorraine, outcropping on approximately 800 km^2, are a north-eastern dependence of the Paris Basin. In spite of their limited extension and their marginal localization, the study of these formations is of undeniable interest for palaeogeography and dynamic reconstruction of the sedimentary basin. The nature and the complex geometry of sedimentary bodies indeed indicate a littoral environment characterized by a mixed sedimentation with a siliciclastic predominance (Muller, 1987). The sequential evolution of deposits was integrated in a globally retrograding sedimentary prism. As the general rise of relative sea level was sufficient to escape significant erosion unconformities, the littoral zones were particularly able to record in detail relative sea level changes.

Since Dumont's precursory report (1842), studies in Belgian Lorraine have been almost exclusively devoted to lithostratigraphy and biostratigraphy. Only the Sinemurian sand body and the Aalenian "Minette" have been detailed sedimentologically (i.e., Berners, 1983; Mertens *et al.*, 1983; Teyssen, 1984; Muller & Steingrobe, 1988; Guerin-Franiatte *et al.*, 1991). This situation contrasts with the amount of work carried out by French geologists in Paris Basin, integrating biostratigraphy, sedimentology and sequential stratigraphy (i.e., Vail *et al.*, 1987; Bourquin & Guillocheau, 1993). These works are mainly based on oil exploration data.

Recent hydrological studies of boreholes performed by the Geological Survey of Belgium in Belgian Lorraine (Boulvain & Monteyne, 1993; Boulvain *et al.*, 1995, 1996) as well as the new geological mapping program supported by the Région Wallonne unravelled the deficiencies of the existing stratigraphic canvas, partly based on biostratigraphy (Maubeuge, 1954) and implying the use of controversial marker beds (Mergen, 1984, 1985).

The aim of this paper is to present in a schematic way the lithology of the main boreholes performed in Belgian Lorraine, to propose a lithostratigraphic re-interpretation and to present the new stratigraphic canvas in a coherent way. Preliminary petrographical, mineralogical and palaeontological observations are provided. Some sedimentological data supplement this progress report.

2. Boreholes

Except for some famous sections, mainly located in the sandy Sinemurian (i.e., section of the Côte Rouge, Maubeuge, 1967), boreholes constitute the principal geological data source for Belgian Lorraine (Fig. 1). Figure 2 presents the synthetic logs of the main boreholes drilled during the last 20 years. Detailed lithological descriptions are provided in the following publications:

- Arlon borehole 219E254: Gulinck *et al.* (1973);
- Latour borehole 225E189: Boulvain & Monteyne (1993), Boulvain *et al.* (1995);
- Neulimont borehole 222W253, Saint-Mard borehole 225W145, Toernich borehole 219E614, Aubange borehole 223E493: Boulvain *et al.* (1995);
- Villers-devant-Orval borehole 221E87: Boulvain *et al.* (1996).

The other logs correspond to previously unpublished descriptions, made by F. Boulvain from cuttings. Descriptions are available in the GeoDoc databank of the Geological Survey of Belgium (Devleeschouwer & Boulvain, 1997).

The lithostratigraphic canvas is summarized below.

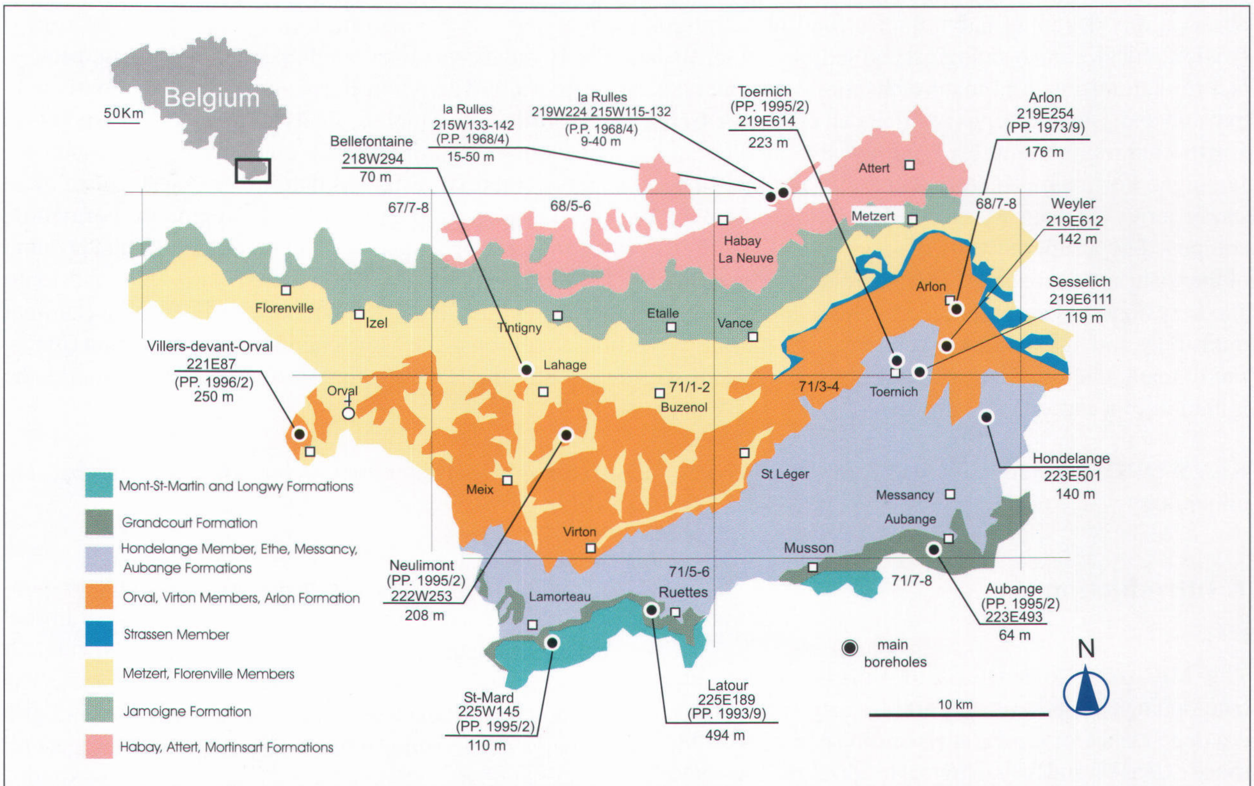

Figure 1. Simplified geological map of Belgian Lorraine.

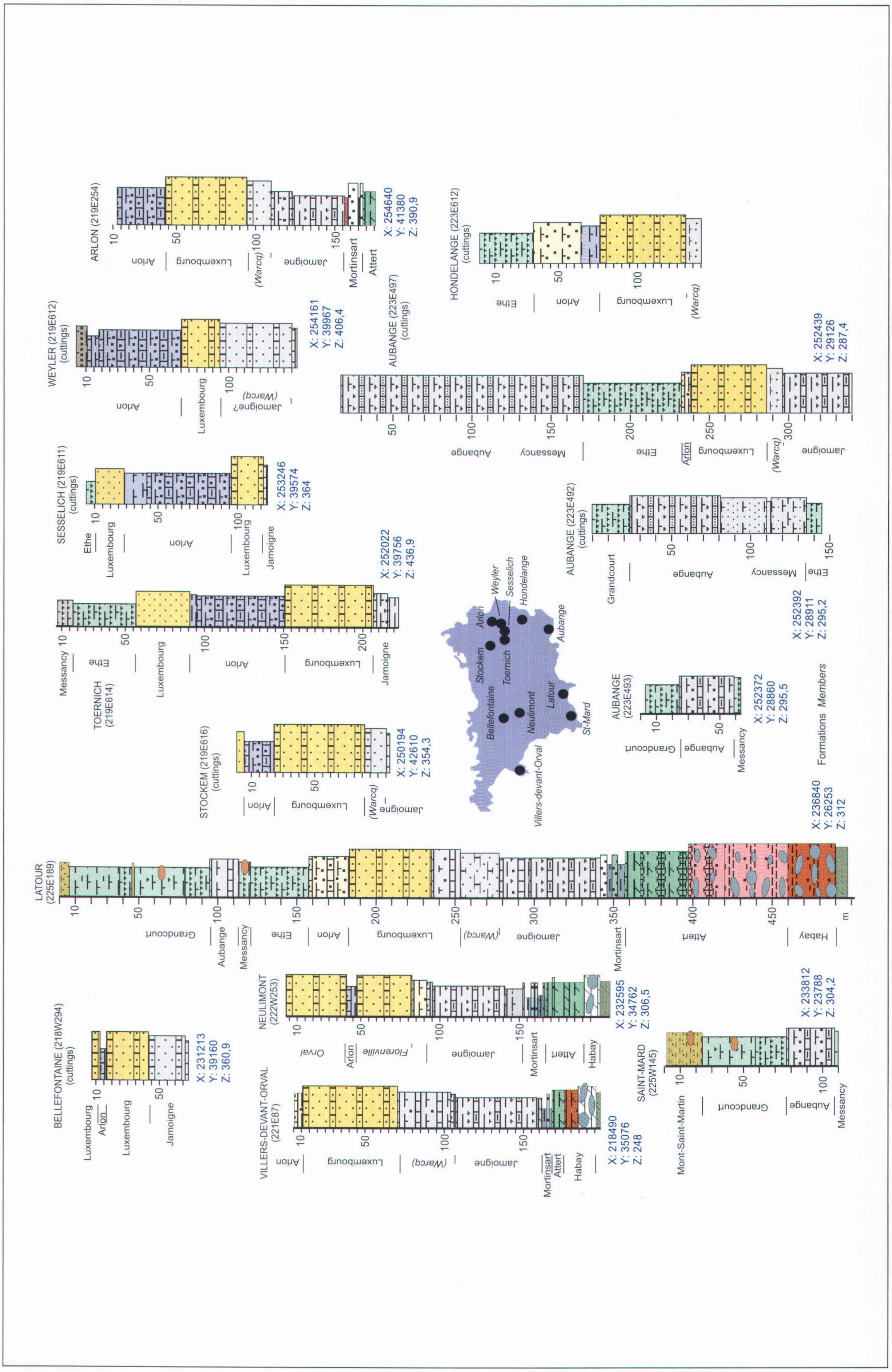

Figure 2. Logs and stratigraphic interpretation of some important boreholes from Belgian Lorraine.

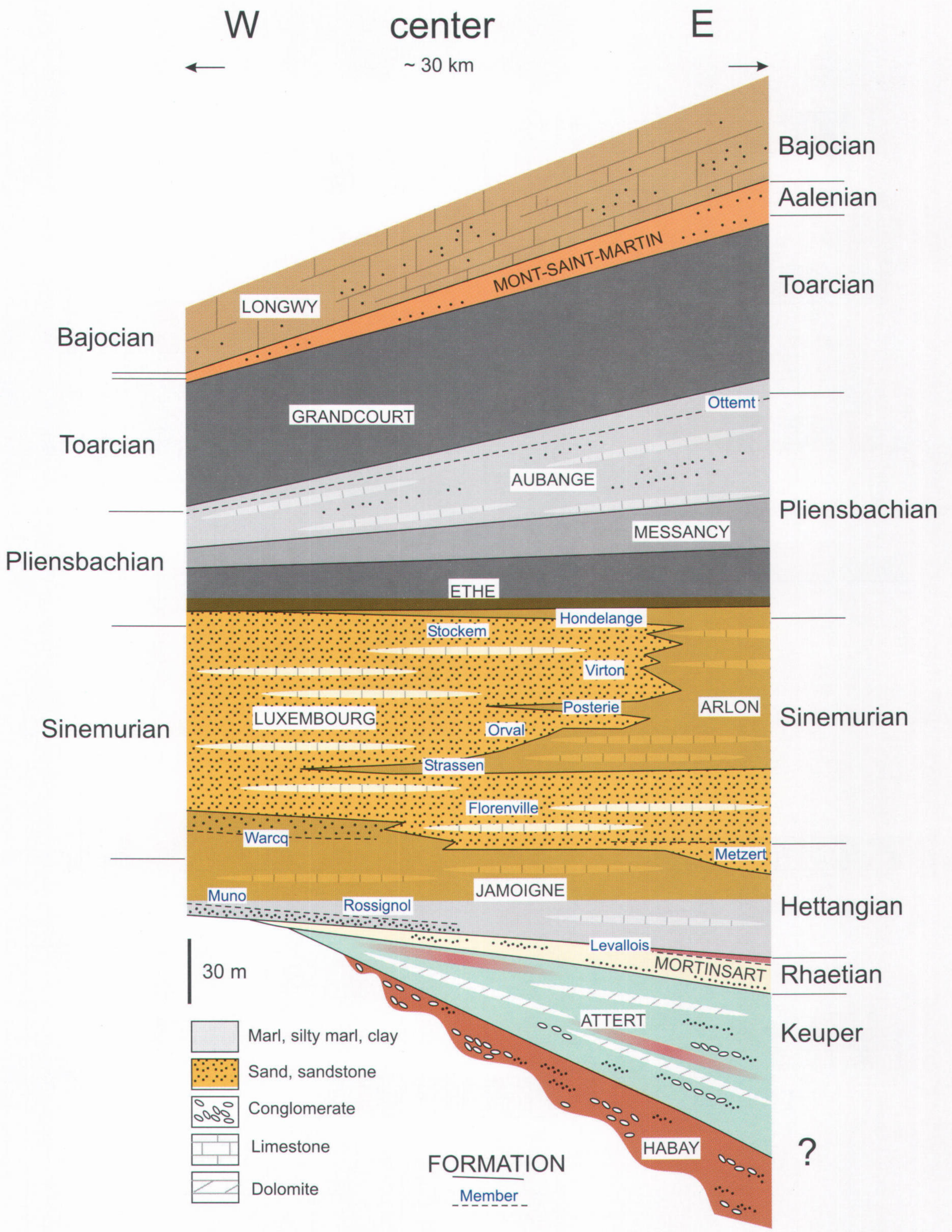

Figure 3. E-W schematic lithostratigraphic section of Belgian Lorraine.

3. Lithostratigraphy

Contrary to the opinion of Mergen (1984), we estimate that in spite of lateral variations and geometrical complexity of the sedimentary bodies, it is both possible and necessary to propose a renewed lithostratigraphic canvas for the sedimentary units outcropping in Belgian Lorraine (Hedberg, 1970) (Figs 3 and 5). Figure 4 presents in a diagrammatic way the historical evolution of a portion of the stratigraphic canvas.

3.1. Habay Formation

Alternation of conglomerate (Pl. 1: A), sand, clayey sand, conglomeratic dolomite and clay, generally brick-red, sometimes greenish (Fig. 5A-B). This unit, with a marked continental character, rests unconformably on the Devonian basement. Its thickness is, consequently, locally variable. The formation outcrops in the north of Belgian Lorraine. It still appears westerly of the Rossignol meridian, down to the Chiny Forest. Its thickness increases gradually towards the east and the south to reach about 30 m at the meridian of Attert. Near the French border, the formation displays about the same thickness in subsurface (Latour borehole).

Until now, no dating method has provided a specific age of the formation. Depending on the authors, it is assigned a Permian or a Triassic age.

3.2. Attert Formation

Greenish or purplish marls and dolomitic marls ("marnolithes") interbedded with decimetric white dolomitic lenses (Pl. 1: C) with some clays, conglomeratic clayey sandstone, and occasionally conglomerates with dolomitic cement (Fig. 5A-B). In boreholes, gypsum layers (Pl. 1: B). The formation outcrops in the north-eastern part of Belgian Lorraine. Its thickness seems to increase regularly from west to east, and from north to south, to reach a maximum of some 50 m in the neighborhoods of Attert. In the central area, at Habay, the formation is only 30 m thick. It then disappears west of Marbehan. In subsurface, in the Latour borehole, the Attert Formation reaches a hundred meters, bearing increasing conglomeratic facies.

The Attert Formation is dated from Late Triassic. This Formation is laterally equivalent to the upper "Marnes irisées" in the Paris Basin or to the upper "Bunte Mergel" in Luxemburg (Hary & Muller, 1967). These formations are usually interpreted as an "organic desert" and are characterized as an important blank for palynology (Roche, 1994). The first miospore-rich bed below the Rhaetian sandstone shows a Carnian assemblage, as described in the "Grès à roseaux" (Biard, 1963; Van der Eem, 1974 *in* Schuurman, 1977). The vertebrate fauna discovered in the upper Bunte Mergel at Medernach favors a Late Triassic age (?Late

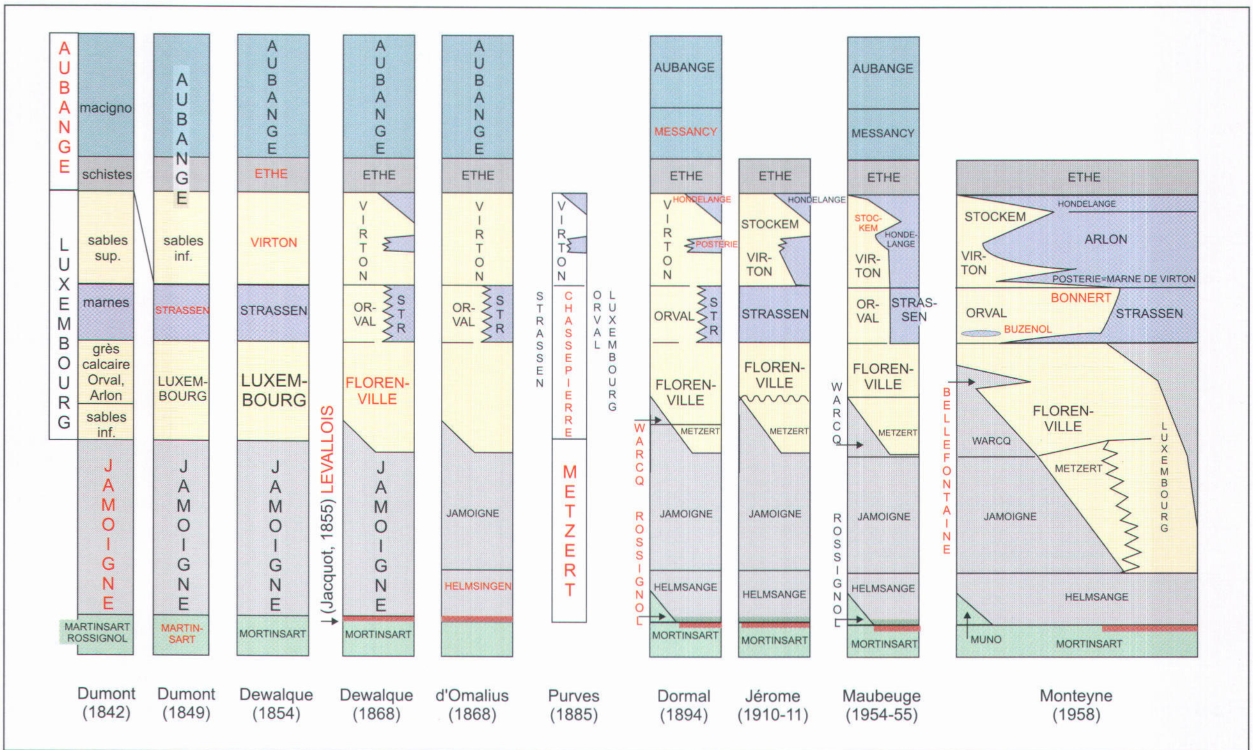

Figure 4. Evolution of stratigraphic concepts in Belgian Lorraine.

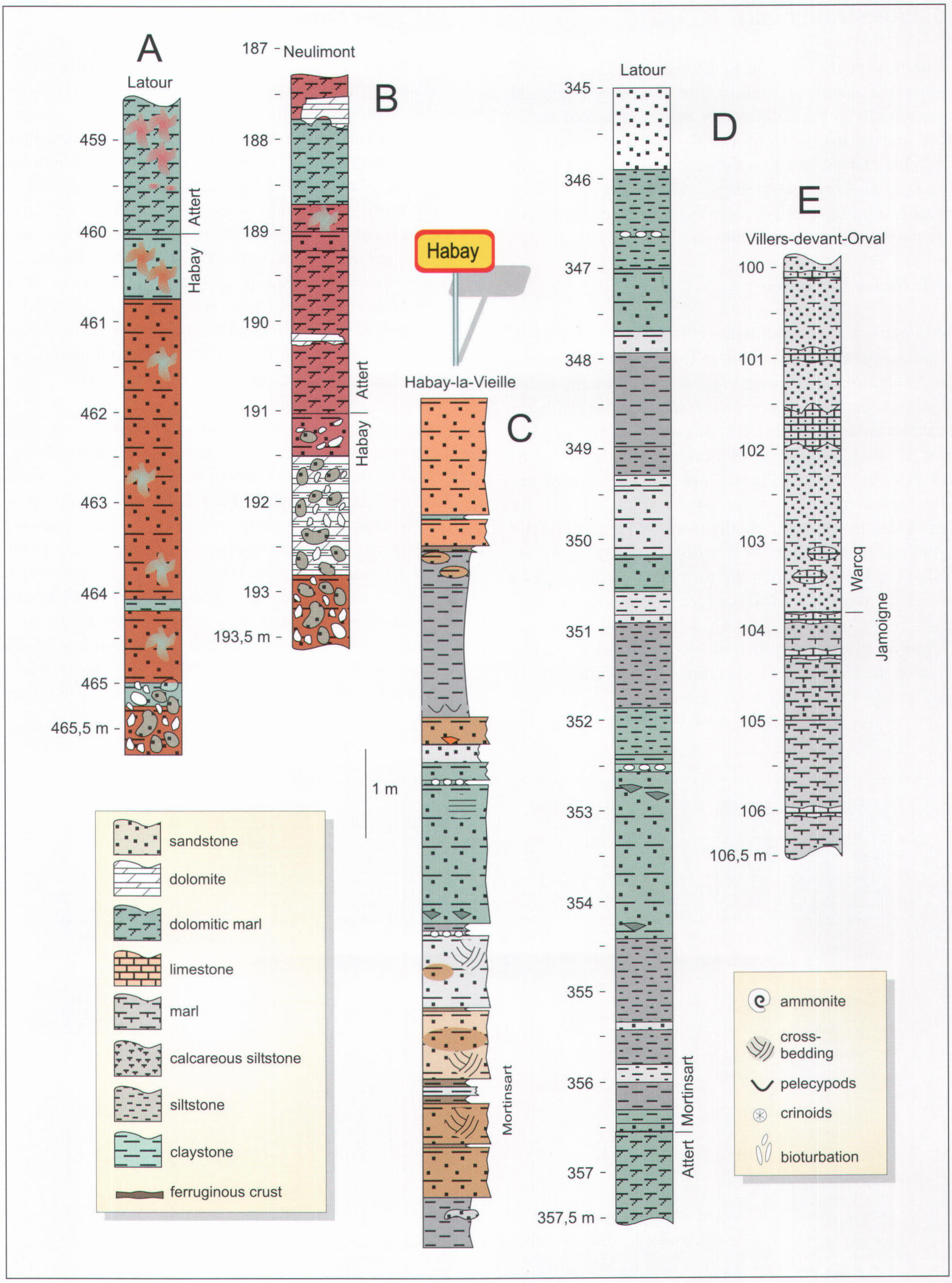

Figure 5a. Examples of lithologies of Belgian Lorraine formations and boundaries of these units in some selected boreholes. Boundary between Habay and Attert Formations in Latour (A) and Neulimont (B) boreholes; C: section of Mortinsart Formation in the new trench of I.r.Sc.nat.B. near Habay (see Pl.3:A); D: boundary between Attert and Mortinsart Formations in Latour borehole; E: base of Warcq Member in Villers-devant-Orval borehole

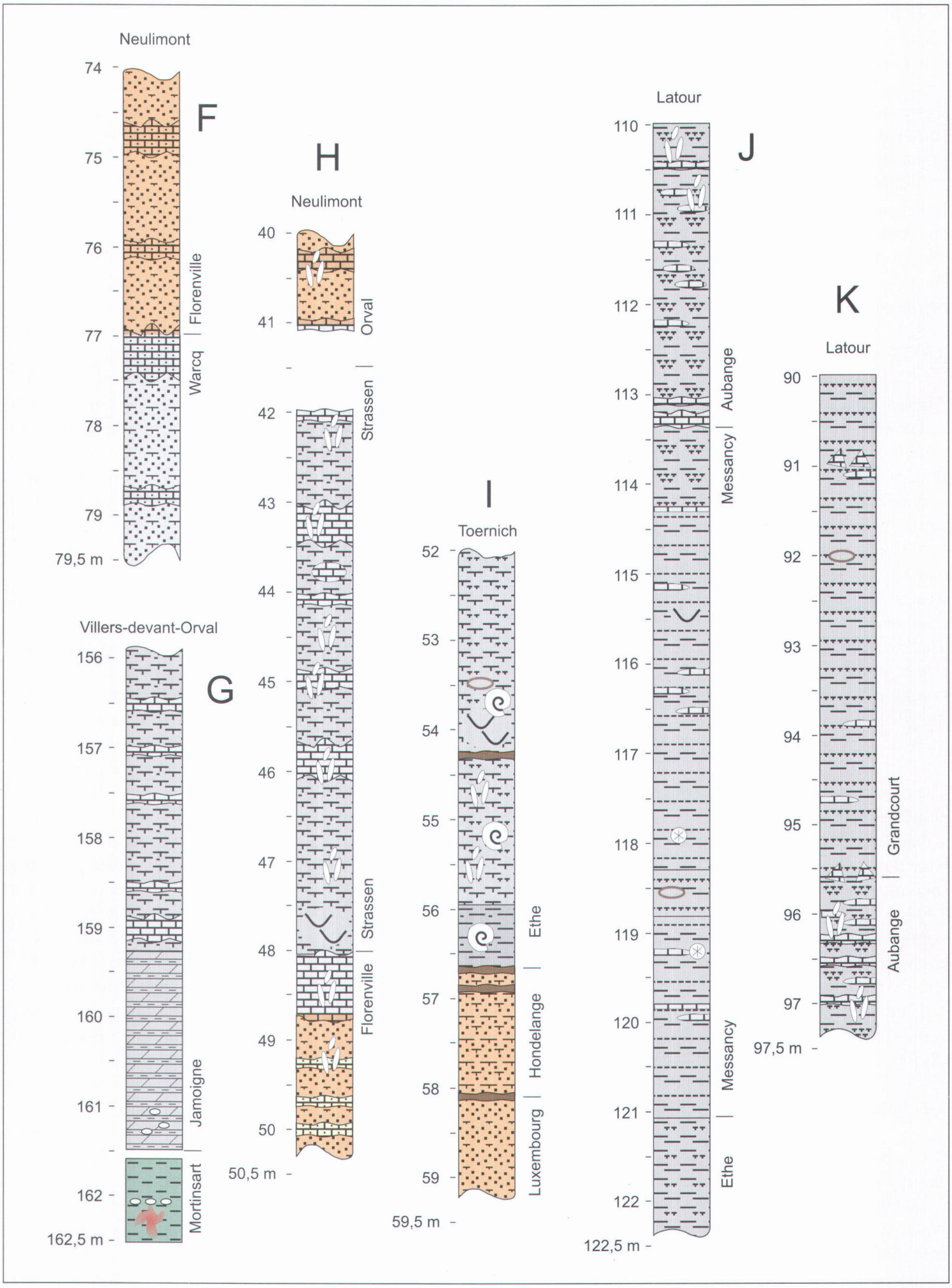

Figure 5b. Examples of lithologies of Belgian Lorraine formations and boundaries of these units in some selected boreholes. F: base of Florenville Formation in Neulimont borehole; G: base of Jamoigne Formation in Villers-devant-Orval borehole; H: relations of Strassen Member and Luxembourg Formation in Neulimont borehole; I: base of Ethe Formation in Toernich borehole; J: base and top of Messancy Formation in Latour borehole; K: base of Grandcourt Formation in Latour borehole.

Norian), as this assemblage closely resembles those found in the Knollenmergel in Germany (Duffin, 1993; Cuny *et al.*, 1995).

In subsurface, in the Campine Basin, the Gruitrode, Bullen and Bree Members consist of sandstone, conglomerate and siltstone with a continental facies. The "Muschelkalk" and the "Keuper" are characterized by limestone, dolomite and evaporite. Upwards, the Sleen and Aalberg Formations, dated from Rhaetian to Lias, consist of dark clay and marl with some clayey limestone levels (Dusar *et al.,* 1987; Wouters & Vandenberghe, 1994).

3.3. Mortinsart Formation

Alternation of grey to greenish sandstone, sand, silt and black or greenish clay (Pl. 1: D; Pl. 3: A). Locally, some dolomite, gravelly beds, bone-beds and lignite (Fig. 5C-D). This unit is capped in the east of Belgian Lorraine by wine-colour clay ("Argiles de Levallois"), and in the western part of the area by a pebbly horizon. The formation is a dozen meters thick near Habay and Attert (Fig. 5C) (central area). In the western area, west of Rossignol, it is transgressive on the Paleozoic basement and is characterized by a reduced thickness. Thickness does not increase strongly towards the south since, close to the French border, in the Latour borehole, it remains less than 20 m (Fig. 5D). The "Argiles de Levallois" disappear westerly of a NNE-SSW line passing through Lischert (Maubeuge, 1992).

The formation is dated Rhaetian sensu lato, on the basis of the presence of pelecypod *Rhaetavicula contorta*, a characteristic fossil of the Mortinsart Formation. Rhaetian sensu lato on the basis of palynomorphs (Schurmann, 1977; Adloff & Doubinger, 1982; Roche, 1994; Rauscher *et al.*, 1995) and of vertebrates. The marine components of the vertebrate assemblage discovered in the Mortinsart Formation at Habay-la-Vieille (Duffin *et al.*, 1983) and Attert (Duffin & Delsate, 1993) closely resemble the typical Rhaetian vertebrate fauna from Holwell (Duffin, 1980) and Aust (Storrs, 1994) in England.

3.4. Jamoigne Formation

Bioturbated dark grey marl with decimetre-thick clayey-sandy limestone or sandstone beds (increasingly frequent towards the top of the unit) (Pl. 1: E). The Warcq Member, capping the formation at the contact with the Luxembourg Formation, consists of light grey clayey sand or sandstone (Fig. 5E-F). Locally, micaceous sandstone and gravel beds are observed at the base of the Jamoigne Formation (Fig. 5G). Fauna and bioturbation are quite abundant. The formation outcrops in Belgian Lorraine with a rather constant thickness of about 45 m. The thickness gradually increases towards the south to reach 70 m in boreholes close to the French border. In the west, the Jamoigne Formation is transgressive on the Rhaetian (Rossignol Member) and on the Palaeozoic basement (Muno Member) with a more arenaceous and fossiliferous facies.

The Jamoigne Formation is only Hettangian in age in eastern Belgian Lorraine, covering the *Psiloceras planorbis, Alsatites liasicus* and *Schlotheimia angulata* ammonite Zones; in the western part, the formation also includes the Warcq Member (*Arietites bucklandi* Zone) and thus extends to the Lower Sinemurian (Maubeuge, 1954; Mergen, 1984; Guérin-Franiatte & Muller, 1986).

This formation was subdivided as various "Assises" by Dumont and later authors on a biostratigraphic basis: namely the Helmsingen or Helmsange, Ansart, Jamoigne ss. and Warcq Assises. Some are not included here because of criteria for their definition; the Member of Warcq is redefined on a pure lithostratigraphic basis.

3.5. Luxembourg Formation

Alternation of sandy limestone and sand with cross-bedded stratifications; locally, homogeneous sand, massive sandstone and lumachelles (Figs. 5F-H; Pl. 2: A). The formation, a hundred meters thick, comprises four members: at the base, the Metzert Member (Pl. 1: F), a grey to yellow sandy unit (locally sandstone: "Clairefontaine facies"); then, above a slight angular unconformity, the Florenville, Orval and Virton Members, consisting of alternating yellow to orange sand and sandy limestone. These members are differentiated from one another only when separated by marl horizons (respectively, the Strassen and Posterie Members, Fig. 5H). West of the meridian of Prouvy, these marl horizons become thin layers that are very difficult to correlate. On the other hand, at the east of the meridian of Arlon, the same marl horizons thicken quickly and pass to the Arlon Formation. The Stockem Member, which consists of clear sand, is probably a weathering facies of Virton or Hondelange Members.

The Luxembourg Formation is clearly diachronic (Maubeuge, 1965; Guérin-Franiatte & Muller, 1986; Guérin-Franiatte *et al.,* 1991). In eastern Belgian Lorraine, it encompasses the Upper Hettangian and the base of the Sinemurian, from *Schlotheimia angulata* to *Arietites bucklandi* ammonite Zones; in the western part of the area, this formation extends from the Lower to the Uppermost Sinemurian, from *Arnioceras Semicostatum* to *Echioceras raricostatum* ammonite Zones.

This formation was introduced in Belgium by Dumont (1842). Because of its diachronic character, it was later subdivided in various "Assises" on a biostratigraphic basis. The unitary character of the formation was redefined by Guerin-Franiatte *et al.* (1991). Some units, partially corresponding to old "assises", were redefined as members with new lithostratigraphic limits (Members of Metzert, Florenville, Orval, Virton, Stockem). The other "assises" are abandoned.

3.6. Arlon Formation

Grey marl, silty marl, bioturbated clayey-silty to sandy limestone (Pl. 2: B). Abundant fauna. The formation has a thickness of about 60 m close to Arlon. More to the west, its thickness decreases very quickly, the formation being represented only by marl beds in the Luxembourg Formation (corresponding successively to Strassen and Posterie Members, Pl. 2: C). A late western extension of the marly-sandy facies constitutes the Hondelange Member (Fig. 5I), which overlies the Luxembourg Formation.

In eastern Belgian Lorraine, in Arlon area, the Arlon Formation extends from the Lower Sinemurian (*Arnioceras semicostatum* ammonite Zone) to the top of the Lower Pliensbachian (*Prodactylioceras davoei* Zone) (Maubeuge, 1954; Mergen, 1984). To the west of the region, the Arlon Formation is exclusively Pliensbachian in age. In the Rabais-Ethe area, it covers the *Uptonia jamesoni* and *Tragophylloceras ibex* Zones (Mergen, 1984).

All authors have highlighted the difficulty to establish, east of Arlon, in this sandy-clayey-limestone unit (Lorraine facies), subdivisions other than biostratigraphic ones. We thus use the name Arlon Formation here as a global unit and subdivide it into members whenever possible to do so on a lithostratigraphic basis (see intercalations in the Luxembourg Formation)

3.7. Ethe Formation

Grey marl and silty clay, often laminar (Pl. 2: D). Locally, limonitic nodules (Fig. 5I-J). The thickness of the formation varies between 20 and 25 m in the west of the Belgian Luxembourg. In Eastern area, it can reach about 50m.

The Ethe Formation is limited to Pliensbachian, and generally corresponds to the *Prodactylioceras davoei* Zone (Maubeuge, 1954).

3.8. Messancy Formation

Grey silty or silty-sandy laminar marl (Fig. 5J). The boundary between Ethe and Messancy Formations corresponds to the first sandy bed. In the area of Messancy, the formation reaches approximately 35 m in thickness. In the west of Belgian Lorraine, Messancy and Aubange Formations together total between 35 and 40 m. In Latour borehole, Messancy Formation has a thickness of 8 m.

The Messancy Formation is dated Upper Pliensbachian *Amaltheus margaritatus* ammonite Zone (Maubeuge, 1954, 1971).

3.9. Aubange Formation

Grey sandy marl with centimetric to pluri-decimetric lenses of limestone and clayey-sandy limestone (Fig. 5J-K). Locally, limonitic crusts or conglomerate (Pl. 2: E). Fauna is relatively abundant and bioturbation generally high. A pluri-decimetric coquina bed is almost always present near the top of the formation, under the Ottemt Member. The extreme top of the formation is locally constituted by bluish marl with blue-grey limestone nodules (Ottemt Member, see Boulvain *et al.*, 1995), or by blue-grey marly limestone beds (Saint-Mard) towards the west. In the western part of Belgian Lorraine, the thickness of Aubange and Messancy Formations varies between 35 and 40 m. It reaches approximately 45 m for Aubange Formation alone towards the east. In Latour borehole, the formation seems to be reduced in favour of Ethe, Messancy and/or Grandcourt Formations.

The Aubange Formation is dated from Upper Pliensbachian to Lower Toarcian *Pleuroceras spinatum* Zone to *Dactylioceras tenuicostatum* Zone (Maubeuge, 1954, 1971; Delsate, 1990).

3.10. Grandcourt Formation

Generally bituminous grey clay and marl with a thin silty-calcareous lamination (Fig. 5K; Pl. 2: F) and laminar limestone nodules ("Schistes Cartons" Member), passing to the top to sandier laminated marl, rich in septaria. Occurrences of centimetric to decimetric limestone beds. The formation outcrops in the south of Belgian Lorraine, with a thickness of approximately 40 m in the western area. It thickens towards the east to reach about 60 m near the Luxembourg border.

The Grandcourt Formation is Toarcian, from *Harpoceras falciferum* Zone to *Grammoceras thouarcense* Zone (Delsate, 1990; Laenen, 1991).

3.11. Mont-Saint-Martin Formation

Clayey sandstone ("Supraliasic Sandstone"), followed by ferruginous marl including several iron oolite beds, and ending with sandy marl. Locally, coquina beds.

The formation crops out in the extreme south of Belgian Lorraine. It presents a thickness of approximately 40 m in the eastern area, but is strongly reduced towards the west.

The Mont-Saint-Martin Formation is dated from Upper Toarcian to Lower Bajocian *Grammoceras thouarcense Zone* to *Hyperlioceras discites* Zone (Maubeuge, 1947, 1972).

3.12. Longwy Formation

Orange yellow sandy limestone, followed by shelly limestone with locally conglomeratic layers with bioclastic limestone clasts. The base of the formation corresponds to the first limestone deposit superposed on Mont-Saint-Martin or, towards the west, on Grandcourt Formations. Its top coincides with the base of the "Marnes de Longwy". Longwy Formation crops out in the extreme south of Belgian Lorraine. The formation is about 50 m thick in the eastern area. Its thickness gradually thins towards the west, with no possibility of giving any value.

The Longwy Formation is dated from Lower Bajocian *Hyperlioceras discites* Zone to *Stephanoceras humphriesianum* Zone (Maubeuge, 1951, 1954).

4. Petrography

This synthesis is based on the microscopic study of more than 150 thin sections from the Latour (Fig. 6), Neulimont and Villers-devant-Orval boreholes (Fig. 7). The classification used is from Dott (1964). For carbonate rocks, we refer to Dunham's classification (1962). As thin sections were obtained from the most hardened sediments, their description can therefore induce a certain skew in characterizing the clayey formations.

4.1. Habay Formation

Lithic conglomerate or graywacke with a predominate dolomitic or clayey-silty matrix. The coarse fraction is ill-sorted, with subangular pebbles and grains of quarzite, quartzophyllade, quartz, schist, and clayey sandstone. The majority of grains are covered by an iron-oxide coating. Pedogenetic structures are relatively frequent: rhizomorphs (Pl. 3: B), dolomite with cellulous structure, microcodiaceae, lithoclasts, glaebules, "mottles" (see Wright, 1994).

4.2. Attert Formation

Sandstone (seldom litharenite), with occasionally conglomerate with a gypsum or dolomitic cement (Latour) passing to sandy dolomite. Locally, bioturbated claystone with silty or sandy laminae are observed (Neulimont). The coarse fraction, always ill-sorted, includes subangular to subrounded quartz grains, quarzite fragments and uncommon schist debris. The other grains comprise lithoclasts (dolomitic mudstone) and peloids. Some pedogenetic structures are observable. Anhydrite occurs as fractured nodules with a gypsum filling.

4.3. Mortinsart Formation

Fine grained sandstone, quartzwacke and siltstone with clay-dolomitic matrix (Pl. 3: C), as well as sandy and silty dolomite. The sorting of the detrital fraction is medium to good. Bioturbation (rhizomorphs?) deforms the detrital laminae. Lithoclasts and peloids are frequent.

4.4. Jamoigne Formation

At the base of the formation, the Rossignol Member is characterized by well-sorted sandstone with subrounded quartz grains. This member is overlain by a homogeneous series of locally dolomitic clayey-silty limestone (packstone), comprising well-sorted subangular to subrounded detrital quartz with an average diameter of 60 µm. In addition to many peloids, an abundant fauna of crinoids and pelecypods is characteristic. Bioturbation is ubiquitous. The average diameter of quartz increases gradually upward.

Warcq Member: this unit is characterized by a large scale coarsening upward (60 to 150 µm) associated with an increase of the detrital fraction. The matrix of the sandy limestone and limestone (packstone) is generally microsparitic, sometimes sparitic, seldom clay-dolomitic. The abundant peloids are accompanied by some pelecypods and crinoids.

4.5. Luxembourg Formation

Florenville, Orval, Virton Members: not easily discriminated petrographically, these units are characterized by calcareous sandstone and sandy limestone in which subangular to subrounded quartz is well-sorted with an average diameter of about 200 µm. Calcareous grains include peloids, pelecypods and bioclasts. Crinoids are less common. Locally, some oolites and proto-oolite- rich beds are observed (Villers-devant-Orval, Pl. 3: D and Neulimont). These sandy limestone (grainstone) are generally cemented by a clear equigranular sparitic calcite, often syntaxic developed on crinoids. Many fossils (gastropods, pelecypods) were partially dissolved before cementation; they often form coquina beds. Locally, a first generation of fibrous cement is preserved (especially in Villers-devant-Orval borehole). Instead of a cement, a

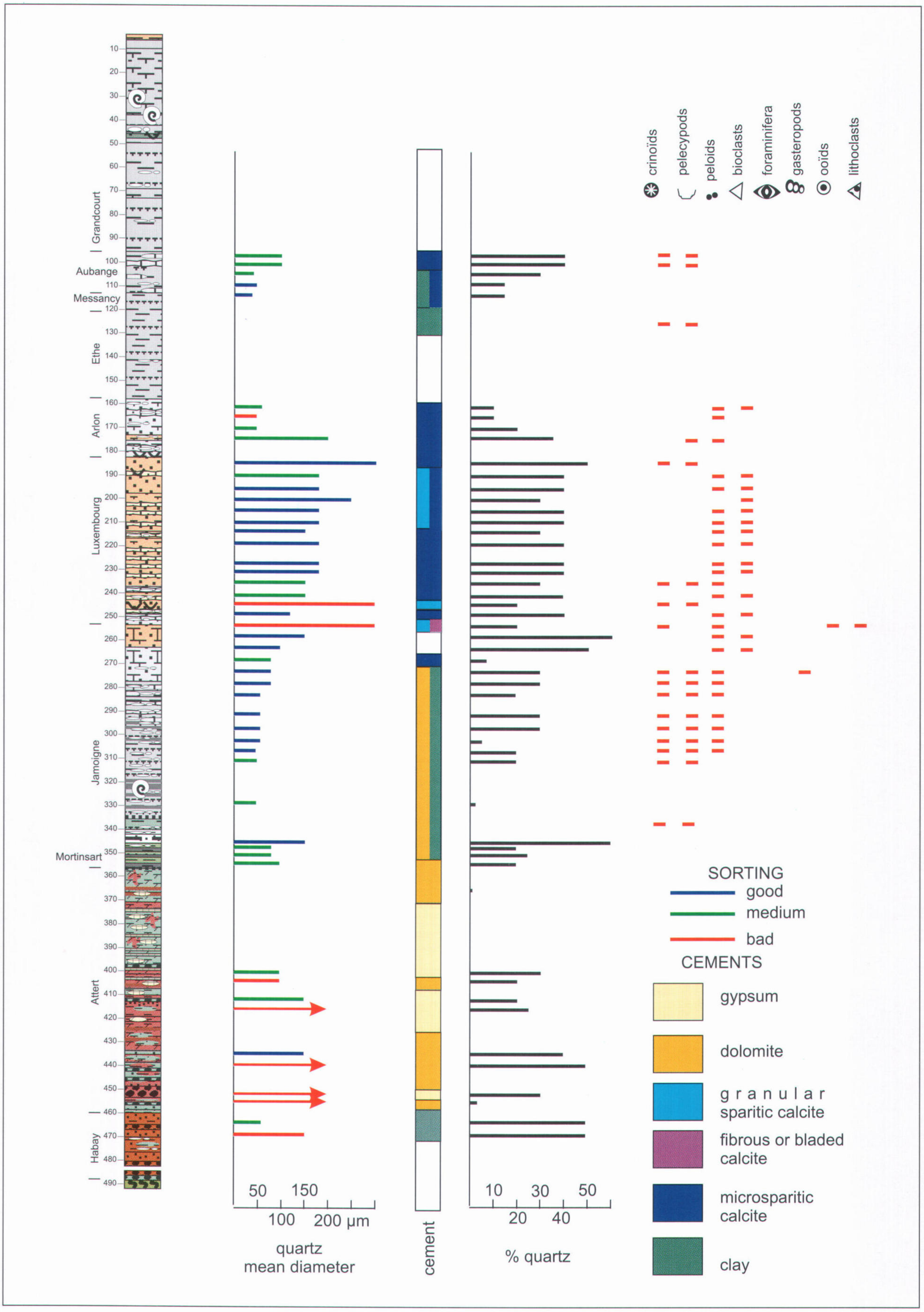

Figure 6. Petrography of Latour borehole.

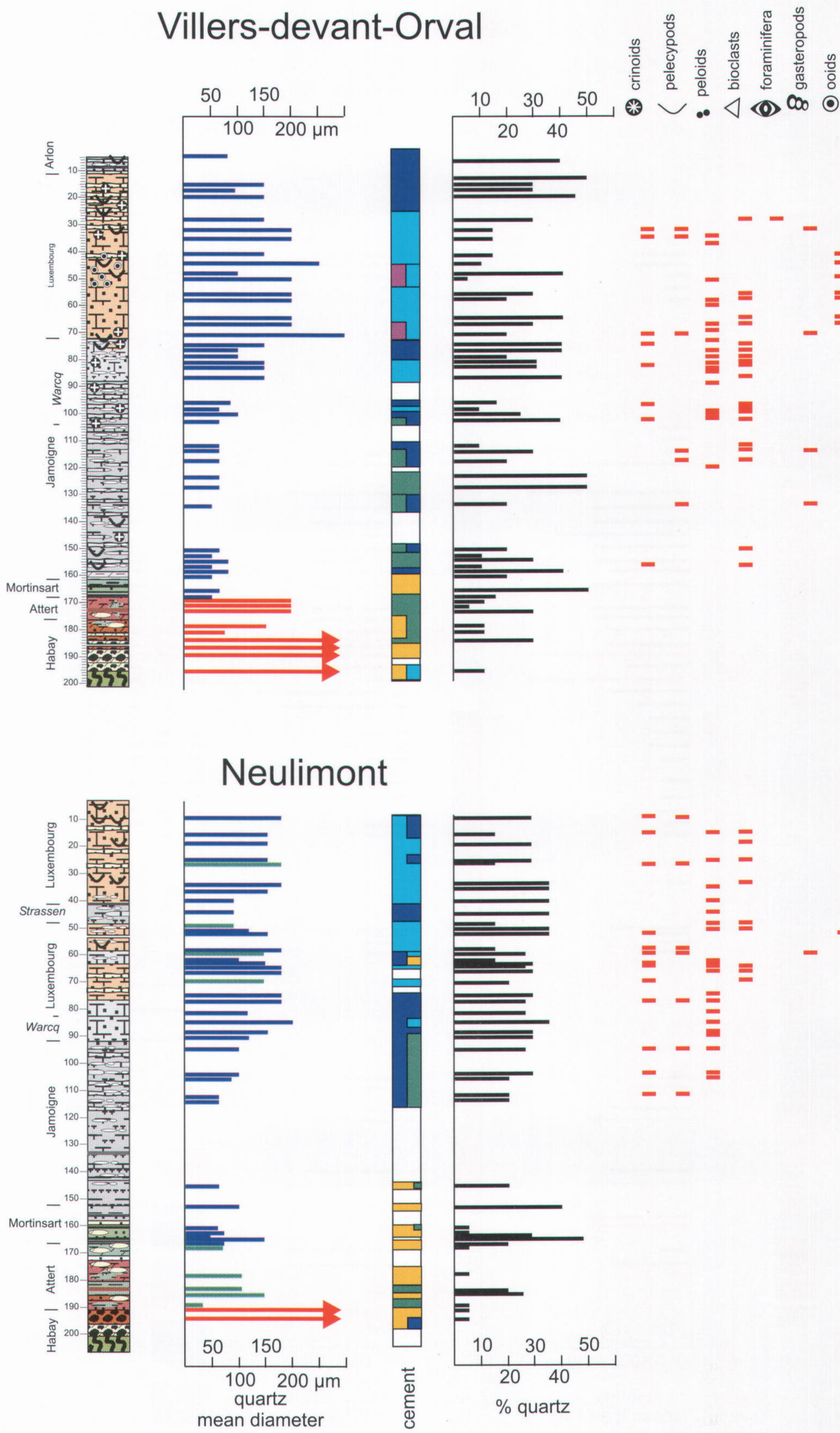

Figure 7. Petrography of Neulimont and Villers-devant-Orval boreholes.

microsparite indicating a less permanent water agitation (packstone) is also observed: this is especially the case in Latour borehole. At the base of Florenville Member or at the top of Warcq Member, one notes the occurrence of beds composed by a coarser sandy fraction, sometimes ill-sorted, and accompanied by fragments of quarzite (Neulimont) or by lithoclasts with oolites (Latour, whereas oolites are lacking as individual grains).

4.6. Arlon Formation

In the Hondelange Member, a progressive decreasing of abundance and of grain size of quartz is observed: sandy limestone pass upward to clayey-silty limestone. The sorting of the detrital fraction is not as good as in Luxembourg Formation, whereas the content of opaque fragments (coaly debris) increases. The bioclastic fraction is dominated by peloids and pelecypods. The microsparitic matrix is clayey. The peloid-rich bioturbated microsparitic packstones of the Strassen Member are characterized by a 90 µm diameter sandy fraction.

4.7. Aubange Formation

The hardened layers show a rather homogeneous microfacies consisting of clayey-silty limestone, often laminar, wherein quartz (15 to 30% of grains, with an average diameter near 40 µm) is accompanied by micas, opaque minerals and glauconite. Locally, the detrital fraction may be coarser and is accompanied by bioclasts (crinoids, pelecypods). Frequent burrows deformed silty laminae.

5. Palynology

The physicochemical processing includes the following stages:
- acid attack with HCl (30%); dissolution of carbonates; rinsing by two centrifugations;
- acid attack with HF (40%); dissolution of silicates; rinsing by two centrifugations;
- cleaning of the maceration in a diluted solution (20%) of hot HCl;
- filtration by millipore system on a metal sieve with a 12 µm mesh;
- for some samples: moderate oxidation (5 to 10 ') in HNO3 and additional filtration to 12 µm.

The addition of a given amount of a marker (spores of lycopod) after HF attack makes it possible to estimate the concentration of miospores per gram of sediment.

As for the petrographic study, the results are synthesized, formation by formation. The 175 samples come from Latour (Fig. 8), Villers-devant-Orval, Neulimont, Toernich, Aubange and Saint-Mard boreholes.

5.1. Mortinsart Formation.

Rhaetipollis germanicus-rich assemblage characteristic of Rhaetian. Rare occurrence of the typically Rhaetian *Rhaetogonyaulax rhaetica*. Palynofacies is dominated by continental organic matter, carbonaceous debris and miospores; rare phytoplankton, represented by *Rhaetogonyaulax rhaetica* and acanthomorph acritarches. In Neulimont borehole (157,9 m and 157,10 m), the upper part of the formation is characterized by more aquatic palynofacies (*Rhaetogonyaulax rhaetica*), open to continental supplies and favourable for conservation of lipidic organic matter.

5.2. Jamoigne Formation

Miospores assemblage typical of Hettangian-Sinemurian: predominance of *Classopollis* with significant presence of *Heliosporites reissingeri*. No significant cysts of dinoflagellate. Alternation of palynofacies with amorphous organic matter, phytoplankton and carbonaceous remnants, and palynofacies bearing a more continental influence, dominated by carbonaceous fragments. Near the base of the formation occurs a palynofacies of sapropelic type (Villers-devant-Orval: 150,9 m, Neulimont: 142,5 m), which evolves upwardly towards a facies with a marked oxidizing character. Presence of reworked carboniferous miospores.

5.3. Luxembourg Formation

Diversified miospore assemblage with bisaccates, *Cerebropollenites, Quadraeculina* and *Classopollis*. No significant cysts of dinoflagellate. Palynofacies low in organic matter, dominated by carbonaceous fragments and miospores associated with acanthomorph acritarchs and rare polygonomorphs. Presence of reworked carboniferous miospores.

5.4. Arlon Formation

Miospore assemblage with bisaccates, *Cerebropollenites, Quadraeculina* and *Classopollis*. No significant cysts of dinoflagellate. Palynofacies rich in carbonaceous fragments with rare miospores, associated with some acanthomorphs acritarchs. Alternating with this facies, occurs a palynofacies richer in palynomorphs wherein organic matter is better preserved. Reworked carboniferous miospores are particularly abundant at certain levels. Globally, the unit exhibits a detrital palynofacies dominated by oxidized woody fragments.

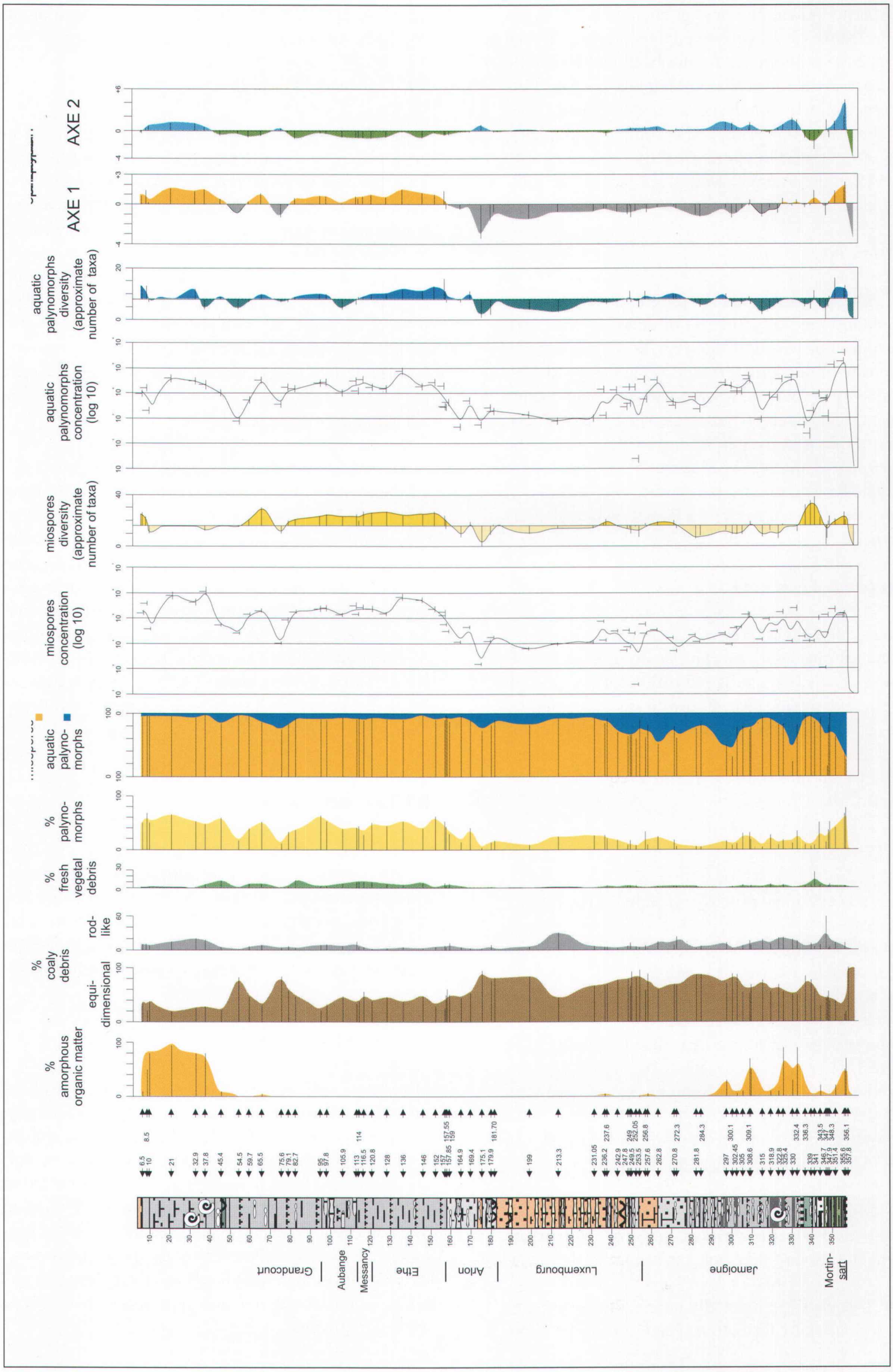

Figure 8. Palynology of Latour borehole.

5.5. Ethe Formation

Miospore assemblage with bisaccates, *Cerebropollenites, Quadraeculina*, *Classopollis* and *Chasmatosporites*. No significant cysts of dinoflagellate. This palynofacies is very rich in lipidic organic matter of continental origin: extremely high concentrations in miospores and particularly bisaccates; diversified assemblage of miospores, rich in triletic ornamented spores. The continental fraction also includes unaltered woody fragments as well as black and brown carbonaceous remains. The aquatic fraction is represented by a diversified assemblage of acritarchs including acanthomorphs, prismatomorphs and punctually by netromorphs and *Tasmanaceae* and *Botryococcus*.

5.6. Aubange Formation

Miospore assemblage with bisaccates, *Cerebropollenites mesozoicus, Quadraeculina anellaeformis, Classopollis*. spp., *Chasmatosporites* spp. and *Retitrilites* spp. Abundant *Nannoceratopsis* spp. Palynofacies with well preserved organic matter and abundant pyrite. As for the Ethe Formation, organic matter of continental origin dominates through high concentration of miospores, particularly of bisaccates, various assemblage of miospores rich in trilete ornamented spores. The continental fraction also includes unaltered woody fragments, black and brown carbonaceous remains and rods of pyrofusinite. Aquatic organic fraction is represented by a diversified assemblage of acritarchs including acanthomorphs (*Micrhystridium* spp. and *Baltisphaeridium* sp.), prismatomorphs (*Veryhachium irregulare*), cysts of dinoflagellates (*Nannoceratopsis*) and *Botryococcus*. The Ottemt Member is characterized by a palynofacies associating carbonaceous fragments with abundant degraded acanthomorph acritarchs (monospecific assemblage?) associated with degraded miospores (*Classopollis* spp., bisaccates, *Cerebropollenites mesozoicus* and *Chasmatosporites* spp.). Reworked carboniferous miospores are particularly abundant.

5.7. Grandcourt Formation

The “Schistes cartons” are characterized by an assemblage of *Spheripollenites* spp., *Cerebropollenites mesozoicus*, *Chasmatosporites* sp. and *bisaccates* sp. The aquatic palynomorphs are represented by *Tasmanites* sp. Chitinous basal structures of foraminifera are observed. This palynofacies is characterized by dominant amorphous organic matter associated with *Tasmanites* sp. and *Spheripollenites* spp. Fragments of pyrofusinite and other miospores (*Cerebropollenites mesozoicus, Chasmatosporites* spp.) are also present. In the upper part of the formation (“Marnes de Grandcourt”), one notes an evolution of the palynofacies by a progressive reduction in amorphous fraction and, correlatively, by an enrichment in continental elements.

6. Vertebrates

Tables 1 and 2 show the distribution of vertebrate fossils in the different Mesozoic formations from Belgian Lorraine.

6.1. Mortinsart Formation

Several important bone-beds distributed within this formation yield particularly diversified vertebrate micro-remains. The mixing of marine and terrestrial components suggests a deltaic sedimentation. The fauna is dominated by marine components, with a typical Rhaetian facies association: a similar mixing of hybodonts and early neoselachian sharks can also be observed, among others, in the British Rhaetian localities of Holwell (Duffin, 1980) and Aust (Storrs, 1994). The composition of the bony fish assemblage remains uncertain, as isolated teeth are rarely diagnostic in this group: the only Osteichthyes that can be recognized with an acceptable degree of certainty is Semionotidae *Sargodon tomicus*. Fossils of marine reptiles are rare and non-diagnostic. The terrestrial component is very diversified, including teeth of pterosaurs (*Eudimorphodon),* ornithopod and prosauropod dinosaurs, carnivorous archosaurs, sphenodontids, cynodonts and early mammals (among the oldest in the world). The remains of terrestrial vertebrates all belong to small animals, not exceeding one meter in length, that probably did not suffer from the Rhaetian transgression, which induced a diminution of surface of the emerged land.

6.2. Jamoigne Formation

Terrestrial vertebrates are not represented in Jurassic formations of Belgian Lorraine (with the single exception of one theropod tooth from the Grandcourt Formation at Aix-sur-Cloie).

In the Jamoigne Formation, fossils of vertebrates include teeth of hybodont and neoselachian sharks, carnivorous, pholidophoriform and semionotiform actinopterygians and isolated bones of ichthyosaurs and plesiosaurs.

6.3. Luxembourg and Arlon Formations

Hybodont sharks and holocephalans (chimaerae) are particularly diversified in the Luxembourg Formation of Belgian Lorraine, although neoselachian sharks are minor. Marine reptiles are represented by forms well adapted for life in open sea, including the medium-sized ichthyosaur *Ichthyosaurus*, the very large ichthyosaur

Taxa	Mortinsart Fm (1)	Jamoigne Fm (2)	Luxembourg Arlon Fm (3)	Aubange Messancy Fm	Grandcourt Fm (1)	Longwy Fm (5)
Selachii						
Lissodus minimus	•					
Lissodus cfr.pattersoni			•			
Lissodus sp.		•				
Hybodus delabechei			•			
Hybodus reticulatus		•	•			
Hybodus cf. raricostatus			•			
Hybodus cf. medius			•			
Hybodus cf.hauffianus				•		
Acrodus nobilis			•			
Acrodus anningiae			•			
Polyacrodus cloacinus	•					
Polyacrodus holwellensis	•					
Pseudodalatias barnstonensis	•					
Vallisia coppi	•					
"Hybodus" minor	•			?		
Nemacanthus monolifer	•					
Synechodus rhaeticus	•					
Synechodus occultidens			•	•		
Synechodus enniskilleni			•	•		
Synechodus sp.					•	
Sphenodus sp.					•	
Synechodontiformes indet.		•		•		
Welcommia terencei				•		
Protospinax sp.					•	•
Squalogaleus sp.					•	
Heterodontus sarstedtensis					•	
Palaeobrachaelurus cf .alisonae					•	
Annea maubeugei					•	
Agaleus sp.			•			
cf. Chiloscyllium					•	
Orectolobiformes indet.						•
Pseudocetorhinus pickfordi	•					
Scyliorhiniformes indet.		•				
Jurobatos cappettai					•	
cf. Spathobatis					•	
Batomorphii indet.						•
Chimaeropsis foussi			•			
Halonodon warneri			•			
Myriacanthus paradoxus			•			
Actinopterygii						
"*Birgeria*" type of teeth	•					
"*Saurichthys*" type of teeth	•					
"*Gyrolepis*" types of teeth & scales	•					
"*Colobodus*" type of teeth	•					
Acidorhynchus sp.					•	
Sargodon tomicus	•					
Lepidotes sp.				•	•	
Dapedium sp.		?			•	
Tetragonolepis sp.					•	
Pycnodontiformes indet.	•					
Leptolepis normandica					•	
Pholidophoriformes indet.		•			•	
Pachychormiformes indet.					•	
Saurostomus sp					•	
Dipnoi indet	•					

Table 1 - Distribution of selachian and actinopterygian fossils in the different Mesozoic formations from Belgian Lorraine. Main references: (1) Duffin *et al.* (1983); Duffin & Delsate (1993); Delsate (1995). (2) Lepage *et al.* (1984); Delsate & Lepage (1990). (3) Casier (1959); Duffin (1984); Delsate & Duffin (1993); Duffin & Delsate (1995). (4) Casier (1965); Delsate *et al.* (1989); Delsate (1990, 1999); Delsate & Lepage (1991); Godefroit & Nolf (1991); Thies (1993); Delsate & Godefroit (1995); Delsate & Thies (1995);. (5) Delsate (1993a, b, 1994).

Taxa	Mortinsart Fm (1)	Jamoigne Fm	Luxembourg Arlon Fm (2)	Ethe Fm (3)	Grandcourt Fm (4)	Mt-St-Martin Fm (5)
Marine reptiles						
Ichthyosaurus communis			•			
Temnodontosaurus platyodon			•			
Leptonectes cf. tenuirostris				•		
Stenopterygius sp.					•	
Ichthyosauria indet.	•	•				
Elasmosauridae indet.			•		•	
Pliosauridae indet.			•			
Plesiosauria indet.		•			•	
Sauropterygia indet.	•					
Steneosaurus sp.					•	•
Terrestrial diapsids						
Eudimorphodon ranzii	•					
Ornithischia indet.	•					
Prosauropoda indet.	•					
Carnivorous archosaurs indet.	•					
Carnivorous dinosaurs indet.					•	
Clevosaurus sp.	•					
cf. Diphyodontosaurus sp.	•					
Therapsids - mammals						
Lepagia gaumensis	•					
Gaumia longiradicata	•					
Gaumia ? incisa	•					
Pseudotriconodon sp.	•					
Microscalenodon nanus	•					
Habayia halbardieri	•					
Thomasia woutersi	•					
Thomasia antiqua	•					
Mojo usuratus	•					

Table 2 - Distribution of tetrapod fossils in the different Mesozoic formations from Belgian Lorraine. Main references: (1) Wouters *et al.* (1984); Hahn, Lepage & Wouters (1987); Hahn, Wild & Wouters (1987); Hahn *et al.* (1988); Butler & MacIntyre (1994); Delsate (1995); Duffin (1995); Godefroit (1999). (2) Godefroit (1993, 1995a, 1995b); (3) Godefroit (1992); (4) Godefroit (1994); (5) Godefroit (1994).

Temnodontosaurus, large long-necked (elasmosaurids) and short-necked (pliosaurids) plesiosaurs.

6.4. Ethe, Aubange and Messancy Formations

Vertebrate fossils are uncommon and fragmentary in Pliensbachian formations from Belgian Lorraine. Only one fragmentary paddle of the large ichthyosaur *Leptonectes* has been discovered in the Ethe Formation. Shark teeth are more diversified in the upper part (Toarcian) of Ottemt Member of Aubange Formation, with both hybodont and neoselachian representatives, together with semionotiforms and indeterminated carnivorous actinopterygian teeth.

6.5. Grandcourt Formation

Numerous, diversified and well-preserved actinopterygian fishes have been discovered in the "Schistes cartons" of Grandcourt Formation: this ichthyofauna is currently being studied by D. Delsate. This level also contains fragmentary fossils of marine reptiles: medium-sized ichthyosaur *Stenopterygius*, elasmosaurid plesiosaurs and marine crocodiles. Shark teeth are particularly diversified in the thin *Coeloceras crassum* phosphatized layer of Grandcourt Formation. A very important phase of evolutive radiation can be observed at this level for the neoselachians, leading to a complete turn-over of the selachian faunas at least in the north-eastern part of Paris Basin (Delsate, 1993a).

6.6. Mont-Saint-Martin and Longwy Formations

Vertebrates are not frequent in these formations. Only several fragments of snout belonging to marine crocodiles have been discovered in the Mont-Saint-Martin Formation. Shark teeth have been occasionally discovered in the Longwy Formation.

7. Clay mineralogy and mineralostratigraphy

A detailed XRD analysis of the raw material and of the clay fraction (the less-than-two microns) of 180 samples was carried out by Teerlynck (1998) and Dosquet (1999) from three boreholes (Latour, Neulimont and Toernich). The investigated samples were the most clayey in composition, and systematically duplicate the samples studied for their palynological content by M.Roche. The stratigraphical intervals range from Attert Formation to Grandcourt Formation.

The samples were investigated in parallel in two forms : as random powder of the raw material and as the clay fraction, which was extracted after decarbonatation (with cold 0,1N HCl) and, when needed, after desulphatization (by washing with hot water). The clay fraction was then prepared as oriented aggregates, following the sedimentation-onto-slide method. No chemical pre-treatment was applied in order to preserve the original in situ clay composition. The oriented aggregates were analysed in sequence and in three forms: as air dried, N , glycolated, EG, and heated (500°C) samples. Complementary but combined cation saturation with LiCl and KCl were added for clay mineral analysis, and the requested x-ray record in sequence of the following states : LiN- Li300 -Li300Gl (glycerol), and KN-K110-K110EG. These post-treatments were indicated for obtaining a more accurate qualitative identification as well as to give genetic information about swelling clay components like smectite, illite-smectite and, in some levels, chlorite-smectite mixed layers. Punctually, an acid attack with boiling 4N HCl confirmed occurrence of kaolinite mixed with chlorite.

Figure 9 provides the mineralogical results obtained by XRD analysis of both types of preparation. The following minerals in the bulk samples were identified: quartz (3-66%), feldspars as plagioclase and orthoclase (0-8%), calcite (combined cement/matrix and non extracted fossils) (0-90%), dolomite (lacked generally but occurred up to 50% at the uppermost part of Attert Formation); gypsum (absent or present, but only in traces in some samples) and total clay and phyllosilicate content (4-88%).

The quantitative estimation of the clay components in the oriented aggregates was based on the intensity of diagnostic basal reflections without introducing any correction factors : here- only the quantitative trend supported by clay minerals throughout the entire series was considered, and not their absolute percentages.

The overall clay mineral composition concerned: (a) illite (I) (10-70%) occurring either as well-crystallized illite-mica with an acuate (001) reflection at 10A (Ial) or as a more or less degraded mineral characterized by distended interlayers and better corresponding to an illite with enlarged foot (Il); (b) kaolinite (K) (0-78%); (c) undifferentiated or total smectite (Smt) (3-50%) ; (d) random mixed layer illite-chlorite (10-14c) with illite layers and distended interlayers behaving like a chlorite (3-22%); (e) generally a Fe-chlorite (C), but this variety was substituted for Mg-chlorite in some samples from Attert Formation; here the latter variety became associated with a more or less ordered chlorite-smectite mixed layer; this mixed layer comprised between 45 and 55% of smectite layers, probably of saponite, and was often associated with palygorskite.

The smectite was further detailed. The v/p ratio (Biscaye, 1965) and Retkke's (1981) diagramme indicated a smectite component ranging between 35 and 75%, confirming thus mainly an occurrence of random RO illite-smectite mixed layers in place of a true smectite mineral; this assumption was also supported by the "crystallinity" classification of the smectite sensu lato (Thorez, 1976), which showed mainly E class, whilst some samples or intervals or formations were characterized by B, C or D crystallinity classes (Fig. 9). Combined Li- and K-saturation allowed to partition the smectite component between, on the one hand, a detrital, neoformed variety mixed less frequently with a transformation montmorillonite (10-14M)17A, which was brought during the general transgression process from external sources, and on the other hand, neoformed beidellite (10-14Bei)17A, which was episodically recycled from coastal vertisols; the latter material was cannibalised during transgressive events or possibly developed on new coastal settings. Recycling of both mixed layers are general, except in some intervals, and their relative contribution in the smectite fraction was highly variable.

The stratigraphic distribution of clay assemblages, including data about bulk smectite "crystallinity", and the quantitative trends showed by feldspars permitted to mineralogically differentiate most of the crosscut formations in the three investigated cores. However, only data related to Latour borehole are presented in Figure 9.

7.1. Attert Formation

It can be subdivided into three parts or intervals, based on clay assemblages and feldspar content (the latter being comprised between 0 and 10%):

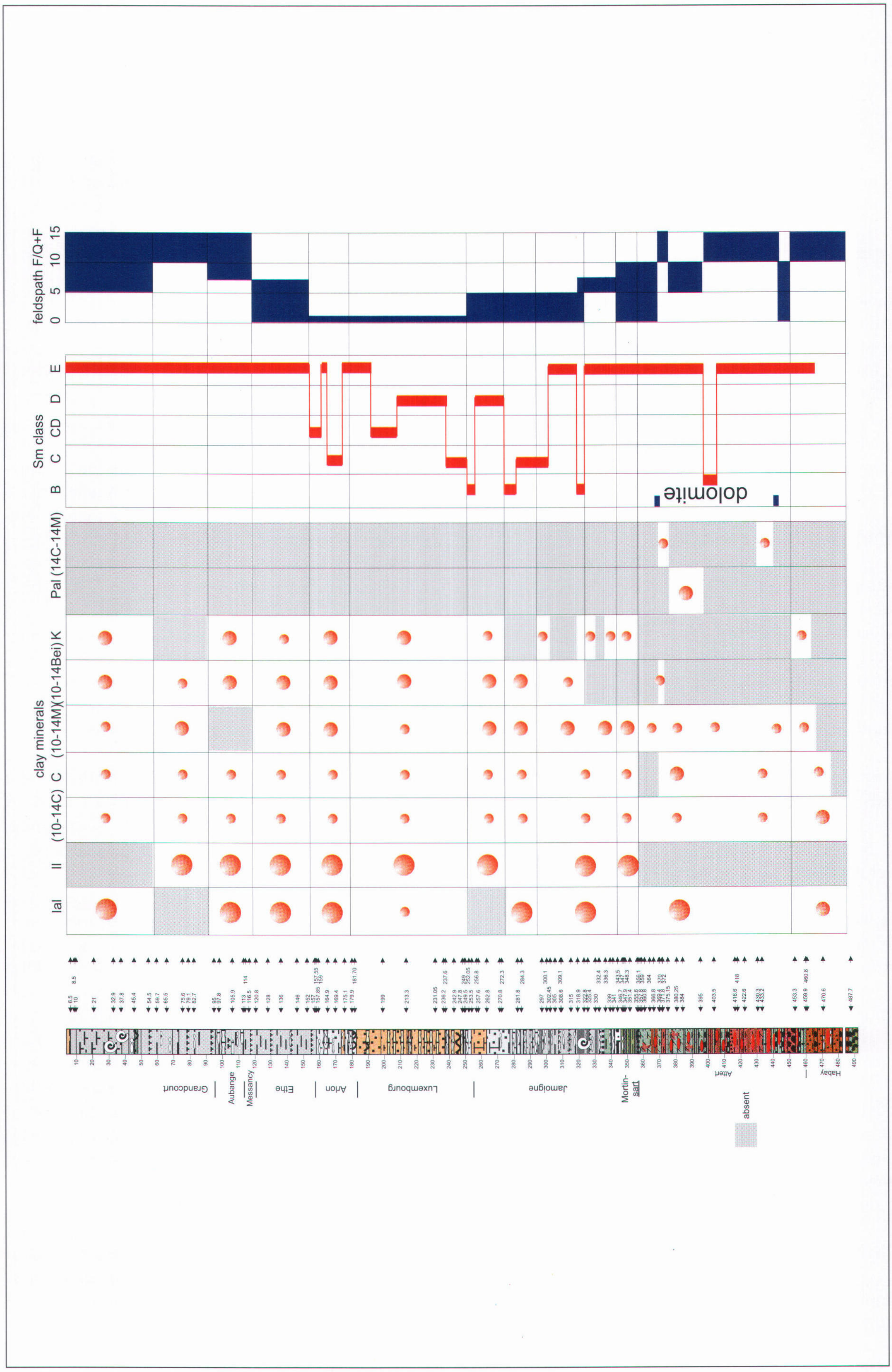

Figure 9. Mineralogy of Latour borehole.

- lower interval: characterized predominantly by an illite with acuate peak (Iap), and by (10-14M)17A mixed layer (E class), with a lack or only traces of chlorite and very locally vermiculite (the latter as a weathering product of a parent chlorite); one sample contained a feldspar content reaching 23%;

- medium interval: characterized by illite with acuate or enlarged 10A peak, and by (10-14M)17A (E class), with a lack on kaolinite, but occurrence of chlorite and of more or less ordered chlorite-smectite (14C-14M) (a montmorillonite composition was obtained by Li-saturation although a saponite composition would have been met (further investigation is needed); this mixed layer is regularly found in Trias of Luxembourg;

- upper interval wherein illite with enlarged peak or a degraded (open) illite associated with (10-14M)17A (E class); kaolinite and chlorite are lacking in the clay assemblages.

7.2. Mortinsart Formation

An illite with enlarged foot and (10-14M)17A (E class) is predominantly observed. Kaolinite is weakly represented but in one single sample; its absence contrasted with its occurrence in Attert Formation. The feldspar content was around 5-6%.

7.3. Jamoigne Formation

The formation can be subdivided in three sections or intervals on the basis of the clay minerals and feldspar content:

- lower interval ; characterized by an illite -mica or an illite with acuate peak ; (10-14M)17A (B and C classes) were predominant in the clay assemblages. Kaolinite occurred in mean to abundant relative proportion. The feldspar content was around 5-7%;

- medium interval : illite with acuate peak; predominance of (10-14M)17A (B, C and E classes); feldspar content comprised between 0 and less than 5%;

- upper interval (cf. Warcq Member) ; illite with acuate peak ; mixing of (1014M)17A and (10-14Bei)17A (B and D classes). Abundant kaolinite with absence of this mineral in some samples. The feldspar content remained weak overall.

7.4. Luxembourg Formation

Predominance of illite with an enlarged peak, and of (10-14M)17A (C and CD classes predominant upon E class). Very abundant kaolinite, whereas some levels did not contain kaolinite. Feldspar was absent or very weak in content.

7.5. Arlon Formation (Hondelange Member)

Illite with acuate or enlarged peak; illite-smectite mixed layer (C, CD or E classes). Feldspar content from 0 to 6%.

7.6. Ethe Formation

Illite with acuate or enlarged peak; mixing of (10-14M)17A and (10-14Bei)17A (E class). Kaolinite mediumly represented with fresh Fe-chlorite. Feldspar content comprised between 7 and 15%.

7.7. Messancy And Aubange Formations

Illite with acuate or enlarged peak. Mixing of illite-smectite mixed layer (E class) with predominant (10-14M)17A. Kaolinite generally in small amounts. Feldspar content comprised between 10 and 15%.

7.8. Grandcourt Formation

This formation can be subdivided into two intervals:

- lower interval: illite with enlarged peak ; (10-14M)17A (E class); absence of kaolinite, and a feldspar content comprised between 5 and 15%;

- upper interval: illite with acuate or enlarged peak ; mixing of (10-14M)17A and (10-14Bei)17A (globally E class). Kaolinite well represented. Feldspar content comprised between 5 and 15%.

One remarkable feature throughout the entire stratigraphy concerned the quantitative distribution of feldspar in three successive intervals; the medium interval corresponded to Luxembourg Formation, but did not contain any feldspar, whereas the other intervals showed a content reaching 10% at the maximum.

The content in calcite as cement plus fossils was characterized by an oscillatory pattern (not shown in Fig. 9), in which a maximum coincided with the base of Luxembourg Formation. Other maxima, but less significant, occurred in Jamoigne and Arlon Formations, as well as in the basal part of Grandcourt Formation.

Dolomite, whether associated with palygorskite or not, was stratigraphically limited to the lower part of Latour borehole (between -360 and -450 m). Small amounts of dolomite were encountered around -25m in Grandcourt Formation.

The lack of kaolinite should be noted within some levels or samples in Jamoigne and Attert Formations as well as in the lower part of Grandcourt Formation. The (10-14Bei)17A was not represented in the clay assemblages of the basal part of Jamoigne Formation and in Attert Formation. This neoformed smectitic component clearly appeared as having been recycled from vertisols developed on the coastal plain. Its occurrence matched that of maxima in kaolinite and seemed linked to clayey material associated with retrogradation and progradation phases. (10-14M)17A was lacking in Aubange and Messancy Formations. (14C-14M) and palygorskite did not occur at certain levels of Attert Formation.

8. Sedimentological interpretation

We here propose a first global sedimentological interpretation, formation by formation. A detailed interpretation that exceeds the framework of this work is in progress, and is based on definition of lithofacies and on their geometry.

- Habay Formation: river environment with channels (Bock, 1989), floodplain and paleosoils, mainly calcrete.

- Attert Formation: installation of an evaporitic lagoon representing a transgressive trend. The area evolved to a confined fluvio-littoral system.

- Mortinsart Formation: very proximal restricted marine environment (bay, lagoon) with still a relatively marked evaporitic influence. Levallois Member characterizes a return to an alluvial sedimentation (flood plain).

A major sedimentary break separates Mortinsart Formation from Jamoigne Formation. It corresponds to a hiatus, followed by a significant marine transgression underlined in the west of Belgian Lorraine by the sandstone of Rossignol Member (Fig. 5). This break represents a transgression surface sensu Vail *et al.* (1987).

- Jamoigne Formation. This unit is mainly composed by marl, accumulated in a relatively protected subtidal coastal environment, but not completely protected from an open marine influence. The sediment is well-oxygenated (intense bioturbation). Organic sedimentation is dominated by oxidized and reworked material.

- Luxembourg Formation. The Metzert Member, representing the base of the sandy body, is separated from the Florenville Member by a clear angular uncon-formity. This unconformity, observed for instance in the small valley of Clairefontaine (Monteyne, 1958) was already highlighted by Jerome (1910). In several boreholes, this unconformity seems to be underlined by a grain size increase and presence of reworking features (Figs. 6 & 7). It obviously bears an important sequential significance and apparently corresponds to a major sequence base in Paris Basin, where it is dated 202 million years (Vail *et al.,* 1987). The upper part of the Luxembourg Formation mainly corresponds to an aggrading sandy body constituted by sand waves, the development of which was studied by Berners (1983) and Mertens *et al.* (1983) in subtidal coastal environment. According to these authors, these sands were accumulated by NNE-SSW tide currents. Despite of a great facies homogeneity, it is possible to laterally follow some interesting variations: if one considers the successive shorelines of the Liassic transgression, oriented NNE-SSW (Maubeuge, 1954, for instance), Villers-devant-Orval, Neulimont and Latour boreholes may be located back on a roughly proximal-distal transect. This difference in proximality seems indeed to be underlined by the following criteria: a progressive replacement of cement by a microsparitic matrix and disappearance of oolites.

- Arlon Formation. Within its interdigitations with Luxembourg Formation (Strassen, Posterie, and Hondelange Members) and in the area of its full extension near Arlon (Arlon and Toernich boreholes), this unit is characterized by a reduction in grain size and a relative proportion of detrital quartz grains. Facies evolved from an agitated environment to a quieter environment; the sea-bed, more stable, was again richer in endofauna. The palynofacies suggests a relatively protected environment, like a bay.

- The contact between Arlon or Luxembourg Formation and Ethe Formation is underlined by several centimetric ferruginous beds (Fig. 5). These may correspond to hardgrounds with a regional extension. After littoral conditions, which prevailed during the time of sandy deposition, a return to a muddy sedimentation in Ethe Formation indicates an obvious deepening of the basin. Silty-calcareous laminae, frequent in marls and clays, could correspond to distal tempestites preserved in an environment where bioturbation was poorly developed (weakly oxygenated sediment). The palynofacies suggests an opened environment, but with a deltaic influence.

- Messancy and Aubange Formations: after the suboxic episode of Ethe Formation, these formations are characterized by the reappearance of an endofauna and progressive re-establishment of a carbonate production. However, the environment remains subtidal, by remaining located under the fairweather wave level. The deltaic influence suggested for the preceding unit is always present. The contribution of reworked material is significant.

- Grandcourt Formation marks a passage to a definitely suboxic to anoxic facies. Undisturbed sea-bed ensure an optimal preservation of the organic matter. The general facies evolution from the base to the top of the formation emphasizes a progressive reduction in bathymetry and a return to a more marked continental influence.

9. Conclusions

The completed study of boreholes, associated with a new mapping program in the Trias-Lias of Belgian Lorraine, required the establishment of a formal lithostratigraphy. Units or formations used here were defined by Boulvain *et al.* (submitted). They follow classical subdivisions as much as possible, but avoid units with a biostratigraphic connotation. For each of these formations, preliminary petrographic, mineralogical and palaeontological results justify a first overall sedimentological interpretation. Some significant surfaces within the sequential architecture of these formations of Belgian Lorraine are highlighted, but the establishment of a complete canvas and its connection with the sequential subdivision of Paris Basin requires additional information.

10. Acknowledgements

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PLATE 1

Typical lithologies of Belgian Lorraine formations in boreholes.

A: Habay formation, Neulimont borehole, 196,0 m: conglomerates;
B: Attert Formation, Latour borehole, 376,6 m: argillite with anhydrite nodules;
C: Attert Formation, Neulimont borehole, 175,1 m: dolomitic layers (white) in dolomitic marls "marnolithes" (purple, green);
D: Mortinsart Formation, Neulimont borehole, 163,8 m: bioturbated sandstone and dolomitic sandstone;
E: Jamoigne Formation, Neulimont borehole, 105,5 m: sandy marls with bioturbated limestone lenses;
F: Luxembourg Formation, Metzert Member, Neulimont borehole, 80 m: bioturbated marly sandstone.

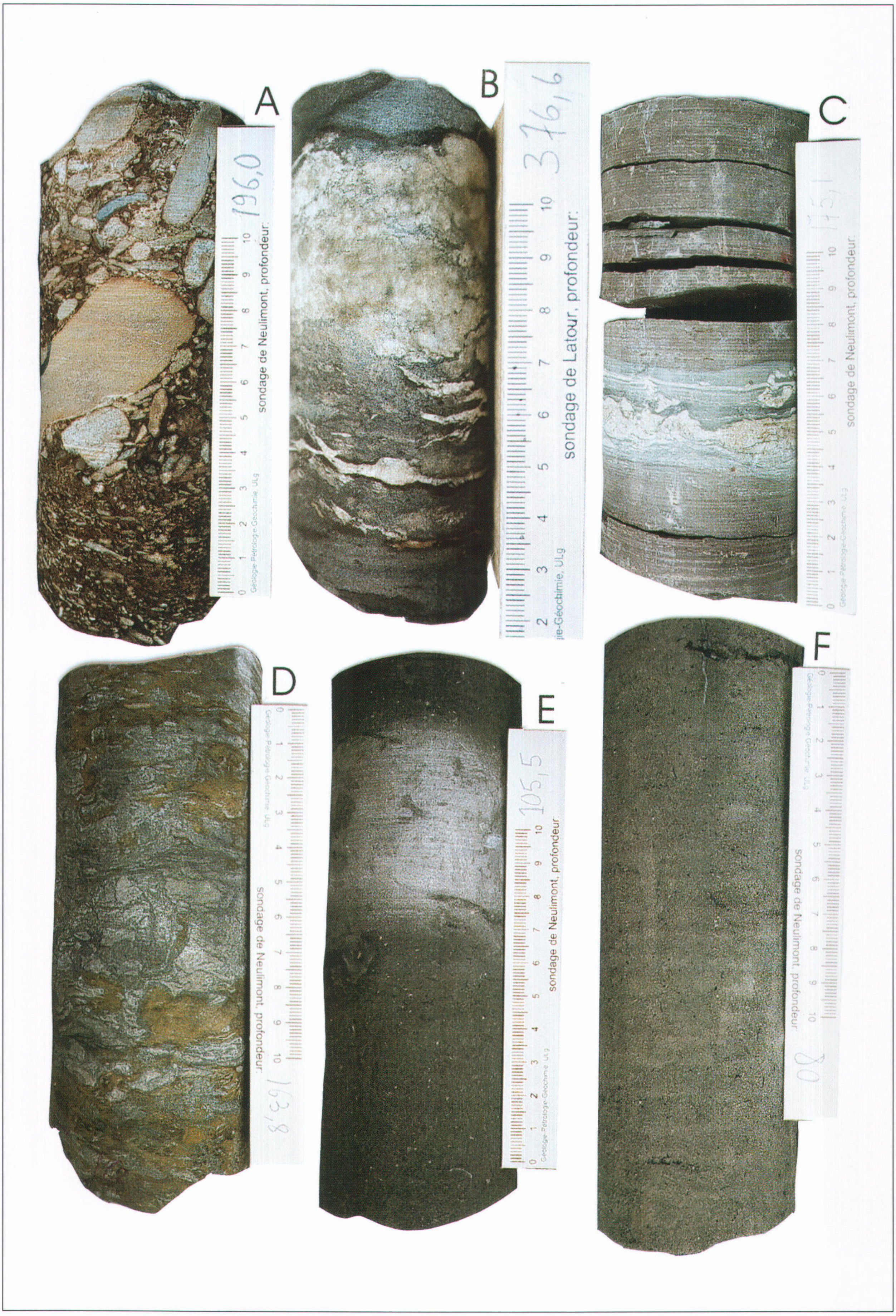
A
196,0
sondage de Neulimont, profondeur:
B
376,6
sondage de Latour, profondeur:
C
sondage de Neulimont, profondeur
D
163,8
sondage de Neulimont, profondeur:
E
105,5
sondage de Neulimont, profondeur
F
80
sondage de Neulimont, profondeur

PLATE 2

Typical lithologies of Belgian Lorraine formations in boreholes.

A: Luxembourg Formation, Neulimont borehole, 69,5 m: sandstone (dark yellow) and sandy limestone (grey);
B: Arlon Formation, Toernich borehole, 117,1 m: bioturbated silty to sandy marl (dark yellow) and sandy limestone (grey);
C: Arlon Formation, Strassen Member, Neulimont borehole, 42 m: bioturbated sandy marl;
D: Ethe Formation, Latour borehole, 154,5 m: laminar argillite with calcareous silt lenses;
E: Aubange Formation, Latour borehole, 104,5 m: conglomerate with a sandy marl matrix;
F: Grandcourt Formation, Latour borehole, 86 m: slightly bioturbated argillite with calcareous silt lenses.

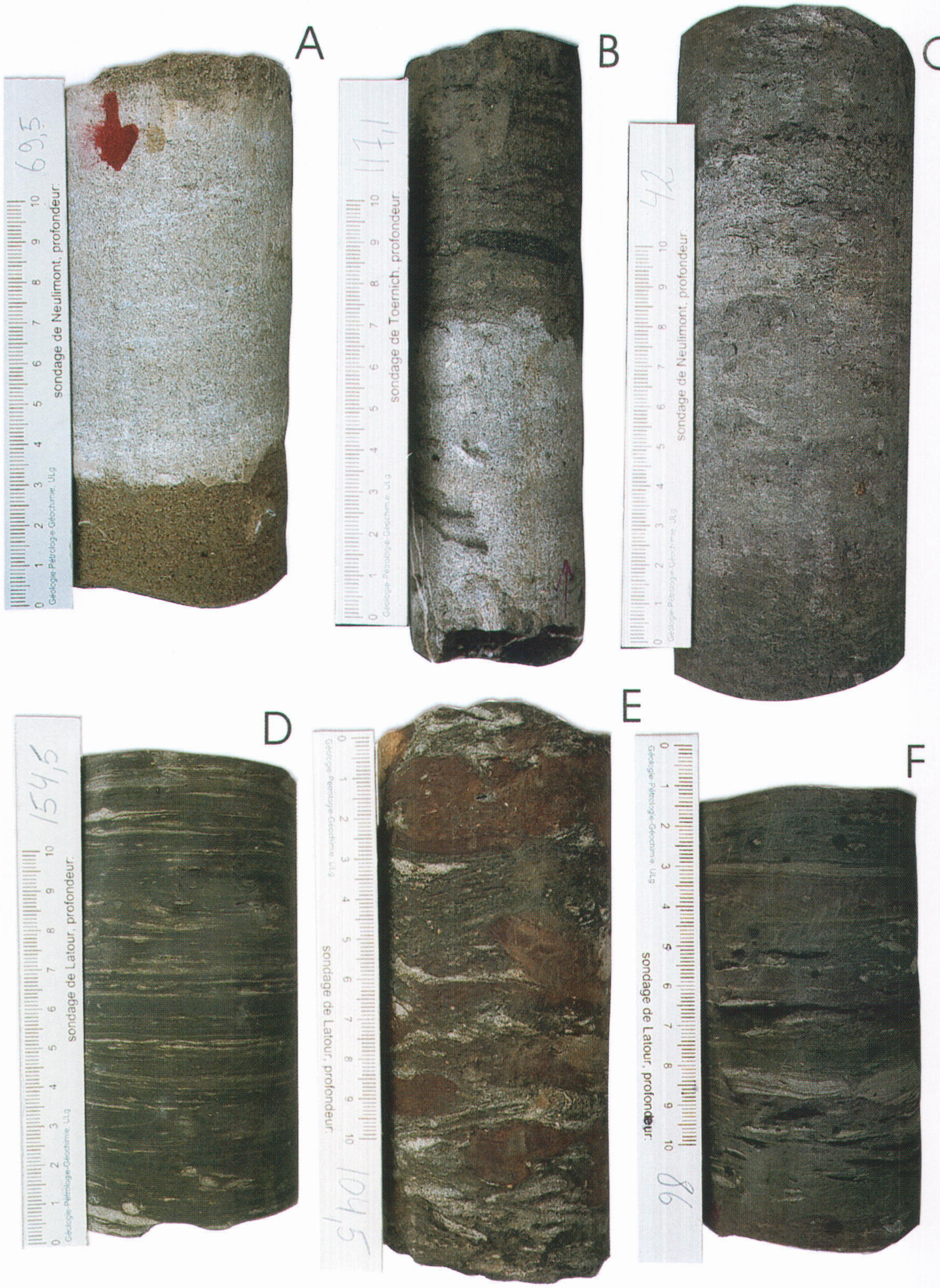
A
B
C
D
E
F
sondage de Neulimont, profondeur: 69,5
sondage de Toernich, profondeur: 117,1
sondage de Neulimont, profondeur: 42
sondage de Latour, profondeur: 154,5
sondage de Latour, profondeur: 104,5
sondage de Latour, profondeur: 98
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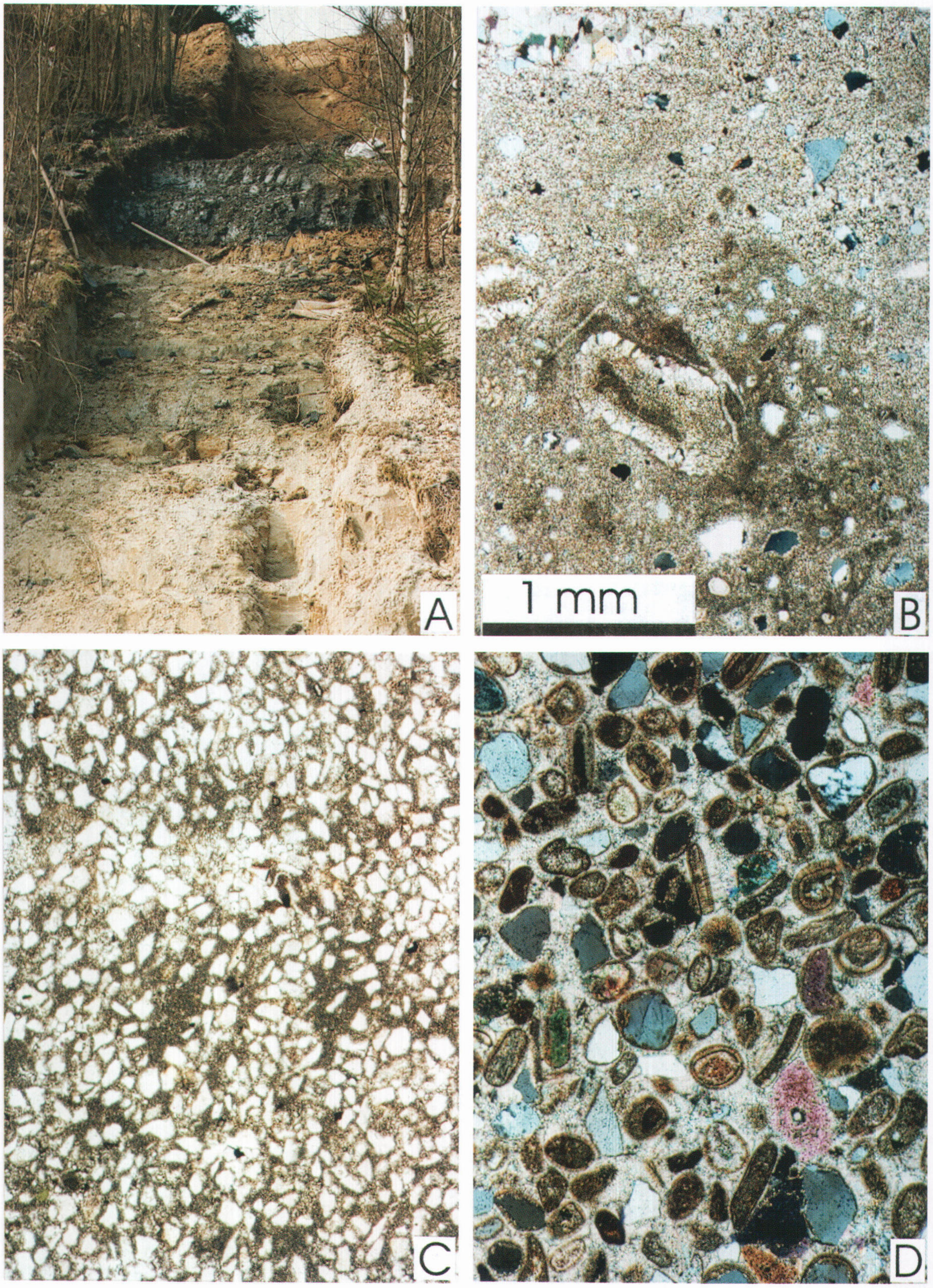
PLATE 3

A: Trench made by the I.r.Sc.nat.B. in the Mortinsart Formation, near the Brussels-Luxemburg highway exit of Habay. Alternation of silty sand and clay.

B: Dolomitic wackestone with poorly sorted quartz grains; rhizomorph near the centre of the picture. Habay Formation, Villers-devant-Orval borehole, 195,3 m. Crossed nicols.

C: Bioturbated sandstone with a dolomitic matrix. Mortinsart Formation, Villers-devant-Orval borehole, 164,5 m. Crossed nicols. Same scale as B.

D: Oolithic grainstone. Luxemburg Formation, Villers-devant-Orval borehole, 49,0 m. Crossed nicols. Same scale as B.


A
1 mm
B
C
D

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