

LIVIAN

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(4 figures)

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ABSTRACT. The Livian Substage is about 3-4 Ma long and was defined as corresponding to the Cf5 Foraminifer Zone by Conil *et al.*, 1977 (= MFZ12 Zone of Devuyst & Hance, in Poty *et al.*, in press). Its base is taken at the base of the “Banc d’or de Bachant”, a bentonite capping the Moliniacian Neffe Formation (Fm). The top of the substage corresponds to the top of the Bay-Bonnet Member (Mbr) of the Grands-Malades Fm, below the appearance of the first foraminifers marking the base of the Warnantian Substage, at the base of the Thon-Samson Mbr (Bonne River Fm). The substage comprises the Lives Fm, including the Haut-le-Wastia, Corphalies and Awirs Mbrs, and the Grands-Malades Fm including the Seilles-Maizeret and Bay-Bonnet Mbrs. It is mainly composed of shallowing-upward parasequences which were deposited by aggradation on the shelf as suggested by their lateral regularity. The Livian Substage comprises the third-order sequence 7 (from the base of the Lives Fm to the top of the Seilles-Maizeret Mbrs) and the TST of the sequence 8 (Bay-Bonnet Mbr) of Hance *et al.* (2001). The Livian corresponds to the RC5 γ Coral Subzone and the RC6 Zone. The Livian can be correlated with the British Holkerian Substage.

KEYWORDS: Livian, Middle Viséan, Carboniferous, Belgium, biostratigraphy, lithostratigraphy, palaeogeography.

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1. Name

Livian (English), Liviaan (Dutch), Livium (German), Livien (French).

2. Age

From 335 to 331 Ma (i.e. 4 Ma long) in a time scale with minimum ages and from 337.5 to 334.5 (i.e. 3 Ma long) in a time scale with maximum ages (Menning *et al.*, 2001).

3. Authors

Conil, R., Groessens, E. & Pirlet, H., 1977. Nouvelle charte stratigraphique du Dinantien type de la Belgique. *Annales de la Société géologique du Nord*, XCVI: 363-371.

The Substage corresponds to the Cf5 Foraminifer Zone of Conil *et al.* (1977), which is characterized by the appearance of *Koskinotextularia* and *Pojarkovella nibelis* (Conil *et al.*, 1977; Paproth *et al.*, 1983; Conil *et al.*, 1991). The base of the Substage is taken at the base of the « Banc d’or de Bachant », an argillaceous bed (bentonite L1 of Delcambre, 1989) separating the Lives Formation (Fm)

from the underlying Neffe Fm. Its top is below the entry of the foraminifers of the Cf6 Zone of Conil *et al.* (1977) at the base of the Thon-Samson Member (Mbr) (base of the Warnantian Substage).

4. Historical type area

Cliff and quarry situated at Lives, on the right bank of the Meuse valley, downstream from the Beez motorway bridge (Fig. 1). The base of the stage is exposed near the

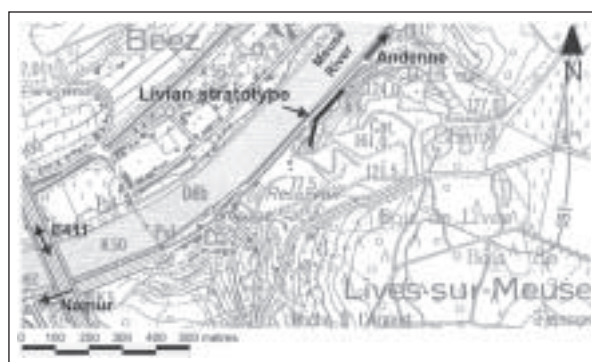


Figure 1. Location of the Livian stratotype.

foot of the cliff (Fig. 2) along the highway N90 (Hance, 1979).

Geological map n° 144 (Namur-Champion, 1901), under revision by Delcambre & Pingot (in preparation).

5. Description

In the stratotype, the underlying Neffe Fm is dolomitized and not well exposed. Only the lower part of the substage is visible, corresponding to the Lives Fm, including the Haut-le-Wastia Mbr (32 m thick), the Corphalie Mbr (19.6 m thick) and the lower part of the Awirs Mbr (about 20 m thick). See 7 for lithological description. The Livian type area was part of the Namur sedimentation area (NSA; Hance *et al.*, 2001).



Figure 2. Overview of the Livian stratotype.

6. Historical background

The Viséan was previously considered as a series divided into three stages (Conil *et al.*, 1977). From base to top : Moliniacian (lower Viséan), Livian (middle Viséan) and Warnantian (upper Viséan). It has recently been redefined as a stage by the IUGS Subcommittee on Carboniferous Stratigraphy (Heckel, 2004), and Livian consequently became a substage.

7. Lithology

The substage is about 136 m thick and includes the Lives Fm and the Grands Malades Fm.

The Lives Fm is composed of well-bedded, pale grey to dark limestones, often rich in rugose corals and productids, organized in shallowing upward parasequences. Its base corresponds to a 10-30 cm thick argillaceous bed of volcanosedimentary origin (« Banc d'or de Bachant »;

bentonite L1 of Delcambre, 1989), locally pedogenized. It comprises three members, from its base to the top:

The Haut-le-Wastia Mbr (« V2b α » of Conil *et al.*, 1967), composed of 30 m of thick-bedded, pale grey to grey limestones in parasequences in which stromatolites and lime mudstones are dominant, and brecciated in places due to the dissolution of evaporitic layers.

The Corphalies Mbr (« V2b β », *ibid.*), composed of thick-bedded, dark, bioclastic limestones overlain by thin-bedded, dark, lime mudstones, and forming a single, 18 m-thick, parasequence (« sequence number 0 »). Some

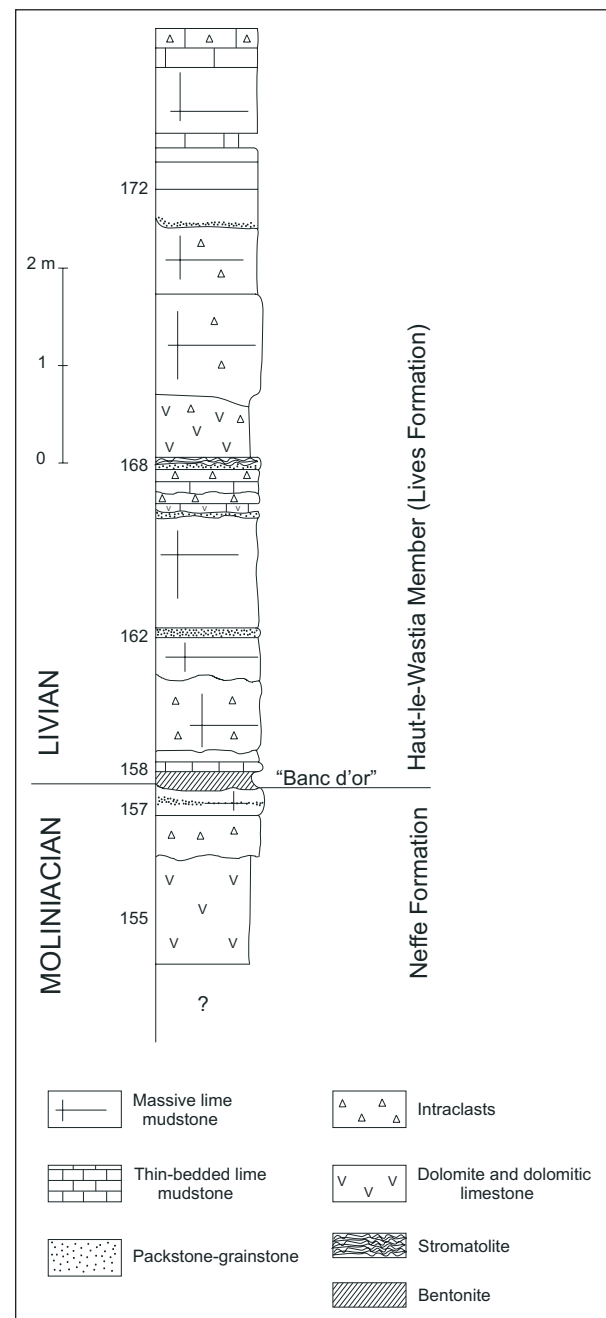


Figure 3. Log of the base of the Livian in the stratotype (from Hance, 1979)

metric to decametric microbe-bryozoan reefs are locally present (Lauwers, 1992; Chevalier & Aretz, 2005). A bentonite of volcanic origin (bentonite L3 of Delcambre, 1989), 5–30 cm thick, is present in the upper part of the parasequence and is recorded everywhere in the basin.

The Awirs Mbr (« V2by–ε », *ibid.*), 35 m thick, mainly composed of dark grey limestones in which bioclastic packstones are dominant, and locally rich in cherts.

The Grands Malades Fm comprises the Seilles Mbr (eastern part of the NSA) that passes laterally to the Maizeret Mbr, and the overlying Bay-Bonnet Mbr.

The Seilles Mbr is 35 to 40 m thick and is composed of thick-bedded, pale limestones, organized in shallowing upward parasequences, dominated by bioclastic limestones in which brachiopods and rugose corals are common, and capped by algal boundstones and mudstones.

The Maizeret Mbr is 35 m thick and is composed of thick-bedded, pale limestones (mainly algal boundstones and mudstones-wackestones), dolomites, breccias, and thick beds of coarse or prismatic calcite (pseudomorphs of evaporites); breccias can dominate.

The Bay-Bonnet Mbr is composed of 8 m of thick-bedded, pale, laminated stromatolitic limestones (boundstones), with numerous serpulids.

The top of the substage corresponds to the top of the Bay-Bonnet Mbr, the base of the overlying Thon-Samson Mbr (Bonne River Fm), i.e. a bed of crinoidal limestone, corresponds to the base of the Warnantian Substage.

In the Boulonnais (Poty, 1994), the substage comprises the upper part of the Haut-Banc Limestone (corresponding to the Haut-le-Wastia Mbr and to part of the Corphalie Mbr up to the bentonite L3; the lower part of the Haut-Banc Limestone corresponding to the Terwagne and Neffe Fm), the *Siphonodendron martini* Dolomite (from the bentonite L3 of the Corphalie Mbr to the top of the Awirs Mbr), the Lunel Limestone (= Seilles Mbr) and the Napoleon Limestone (= Bay-Bonnet Mbr).

In the Campine Basin (north of the Brabant Massif), Livian deposits seem to be generally missing. The base of the substage can be correlated with the base of the Clifton Down Limestone of the Avon section (Bristol) in Southwest England (Hance *et al.*, 2002), and with the base of the Holkerian British Substage in North Wales (Great Britain).

8. Sedimentology and palaeogeography

The Lives Fm corresponds to the LST (Haut-le-Wastia Mbr) and to the TST (Corphalies and Awirs Mbrs), and the Seilles – Maizeret Mbrs to the HST (and to the FSST?), *sensu* Plint & Nummedal (2000) of the third-order sequence 7 of Hance *et al.* (2001). The Bay-Bonnet Mbr corresponds to the TST of sequence 8. The Livian is composed of shallowing-upward parasequences (about 33.1 to 18 m-thick, can be recognized in sequence 7), comprising typically from the upper part of the Haut-

le-Wastia Mbr: bioclastic pack-grainstones rich in corals, brachiopods, foraminifers and calcareous algae in their lower part and mudstones and stromatolitic boundstones in their upper part.

The lithology and the lithostratigraphy of the substage is relatively constant, suggesting deposition by aggradation on the shelf areas that were covering the whole Namur-Dinant Basin, from eastern Belgium to northern France (Boulonnais and Avesnois).

During the Livian however, more open marine facies developed progressively to the north, while restricted facies and evaporites developed in the southern part of the basin. It is mainly the case in the Haut-le-Wastia Mbr and Maizeret Mbr, giving rise respectively to the “Petite Brèche Viséenne” and to the “Grande Brèche Viséenne” by solution collapse. This inversion in the shape of the basin could be related to an early phase of Variscan shortening.

9. Palaeontology

9.1. Foraminifers

The Livian Substage is covered by the MFZ12 Zone of Devuyst & Hance (in Poty *et al.*, in press) which marks a drastic change in the composition of foraminifer associations (= Cf5 Zone of Conil *et al.*, 1977, 1991). The guide *Pojarkovella nibelis* enters at very short distance above the base of the Lives Fm in the southernmost part of the DSA. In the other sedimentation areas of the Namur-Dinant Basin, the base of the Lives Fm is almost devoid of plurilocular foraminifers and *P. nibelis* enters high in the Haut-le-Wastia Mbr (Poty *et al.*, 2002). In the Livian stratotype, the first occurrence data of *P. nibelis* is 14.3 m above the base of the substage. In addition to this index taxon, *Koskinotextularia* is a useful auxiliary guide entering at a similar level, low in the zone. Other typical elements include *Palaeotextularia* gr. *consobrina*, *Lituo-tubella* sp., *Rhodesinella* sp., *Omphalotis minima*, abundant *Eostaffella* spp. and *Endothyra* spp., *Nodosarchaediscus* spp. and *Archaediscus* spp. Associations are more diversified in the upper part of the zone (Grands Malades Fm), where large forms are common.

9.2. Rugose corals

The Livian is covered by the RC5 γ Subzone and the RC6 Zone (Poty, 1985; Conil *et al.*, 1991). The RC5 γ Subzone is characterized by *Axophyllum vaughani*, *Siphonodendron irregulare*, *Caninophyllum archiaci* and *Clisiophyllum garwoodi* with the appearance in the first open-marine bioclastic limestones in the Haut-le-Wastia Mbr, close to the base of the Substage.

The base of the Corphalie Mbr is characterized by a horizon which contains the first *Lithostrotion araneum*, the oldest representative of the genus *Lithostrotion*. It

marks the base of the RC6 Zone (*Lithostrotion araneum* interval Zone, Poty, 1985). This horizon can be traced as far as the Avon Gorge section (Bristol, England), where it occurs at the base of the Lower Clifton Down Limestone (« *Lithostrotion basaltiforme* band » of Vaughan, 1906). *Lithostrotion vorticale*, *Siphonodendron sociale* and *Siphonophyllia siblyi* appear in the Livian (Zone RC6). Note that the most common coral species in the Livian are the long-ranging *Siphonodendron martini* and *S. irregulare*. The top of the RC6 Zone corresponds to the top of the Substage (Poty *et al.*, in press).

9.3. Other fossils

Brachiopods (mainly productids and Composita) are common, but a revision is needed for a better evaluation of their biostratigraphic potential. Goniatites are very uncommon and without stratigraphic value to define the substage. Facies are unsuitable for conodonts and most common taxa belong to the genera *Cavusgnathus* and *Taphrognathus* (Webster & Groessens, 1991).

10. Chronostratigraphy

Fig. 4 gives the Foraminiferal and Coral Zonations used in Western Europe. More details about the chronostratigraphy and the stratigraphical correlations outside Western Europe are given in Poty *et al.* (in press).

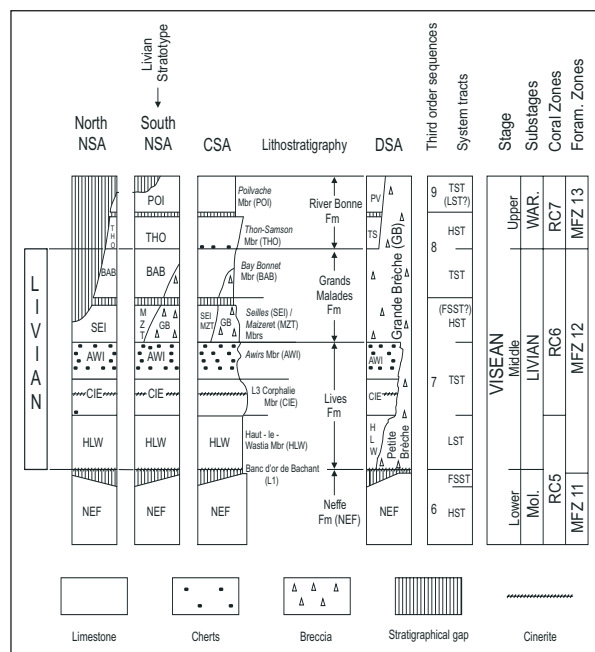


Figure 4. Litho-, bio- and sequence stratigraphy of the Livian Substage in the Namur (NSA), Condroz (CSA) and Dinant (DSA) sedimentation areas

11. Geochronology

No radiometric dates are available for the Livian in Belgium. The time scale used is based on datations obtained from other Carboniferous basins in Europe and in Australia (Menning *et al.*, 2001).

12. Structural setting

Livian deposits of the Namur-Dinant Basin are part of the Variscan orogenic cyclus. They are distributed on both sides of the Midi-Eifel fault. Deposits in the Ardenne Allochthon and in the southern part of the Brabant Parautochthon are largely folded. Those situated in the northern part of the Namur Synclinorium are gently dipping to the south.

13. Reference sections in Belgium

Numerous outcrops and quarries expose the base of the substage along the Meuse valley between Namur and Liège. Good reference sections for large parts of the substage including its base are the Awirs and the Engihoul quarries at Flémalle (NSA), the Lefte quarry at Dinant and the Haut-le-Wastia quarry at Anhée (DSA).

14. Main contributions

Gerards & Michot (1963); Pirlet (1963); Conil, Groessens & Pirlet (1977); Devuyt, Hance & Poty (2005); Hance (1979); Paproth *et al.* (1983); Conil *et al.* (1991); Lauwers (1992); Hance, Poty & Devuyt (2001, 2002); Poty *et al.* (2002); Chevalier & Aretz (2005).

15. Remarks

The base of the Livian Substage, defined at the base of a lithological marker bed (« Banc d'Or de Bachant ») and not coinciding with the entry of the palaeontological guides in the stratotype is not satisfactory. It limits the use of the Livian Substage in its original definition to the areas which were covered by the « Banc d'Or » bentonite, i.e., the Namur-Dinant Basin. That bentonite suffered pedogenesis in many places and in the stratotype, and indicates a stratigraphical gap (erosion and/or break in sedimentation) between the third-order sequences 6 and 7 of Hance *et al.* (2001). The search for a lectostratotype using the stratigraphical incoming of a palaeontological guide as boundary criterion is in progress. The problem is difficult as generally the Moliniacian-Livian boundary interval displays very shallow-water facies with an

impoverished fossil association. It is not certain yet that the guide *Pojarkovella nibelis* is not entering in the late Moliniacian, in more open marine settings or that the Moliniacian guides persist into the early Livian. That coexistence between *P. nibelis* and Moliniacian guides has been found in South China (Devuyt *et al.*, 2003), in the Mendips (SW England, Austin *et al.*, 1973) and in the Visé sedimentation area in Belgium (Conil, in Kimpe *et al.*, 1978, p. 58).

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