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WARNANTIAN

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(4 figures)

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ABSTRACT. The Warnantian Substage is about 8 to 12 Ma long and was defined as corresponding to the Cf6 Foraminifer Zone by Conil *et al.*, 1977 (= MFZ13 to MFZ15 Zones of Devuyst & Hance (in Poty *et al.*, in press). Its base is taken at the base of the Bonne River Formation (Fm); its top is defined by the base of the Namurian stage, but its upper part is almost completely missing in the Namur-Dinant Basin. The substage is covered by the RC7 and RC8 Coral Zones. It comprises the Bonne River and the Anhée Fms, which are mainly composed of shallowing-upward parasequences which were deposited by aggradation on the shelf, as suggested by their lateral regularity. It corresponds to the HST of the third-order sequence 8 (Thon-Samson Member of the Bonne River Fm) and to the third-order sequences 9 and 10 (Hance *et al.*, 2001; Poty *et al.*, 2002). The lower (MFZ13-MFZ14, RC7) and the upper Warnantian (MFZ15, RC8) can be correlated respectively with the British Asbian and Brigantian Substages.

KEYWORDS: Warnantian, Viséan, Carboniferous, Belgium, lithostratigraphy, biostratigraphy, palaeogeography

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1. Name

Warnantian (English), Warnantiaan (Dutch), Warnantium (German), Warnantien (French).

2. Age

From 331 to 319 Ma (i.e. 12 Ma long) in a time scale with minimum ages and from 334.5 to 326.5 (i.e. 8 Ma long) in a time scale with maximum ages (Menning *et al.*, 2001)

3. Authors

The base of the substage is defined by 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) at the « base of the thick bed of dark bioclastic limestone overlying the beige algal limestones of the top of the Livian » (free translation from French), i.e. the base of the Thon-Samson Member (Mbr) of the Bonne River Formation (Fm). The substage corresponds to the *Neoarchaediscus* Zone (Cf6) of Conil *et al.* (1977). Its top is defined by the base of the Namurian Stage.

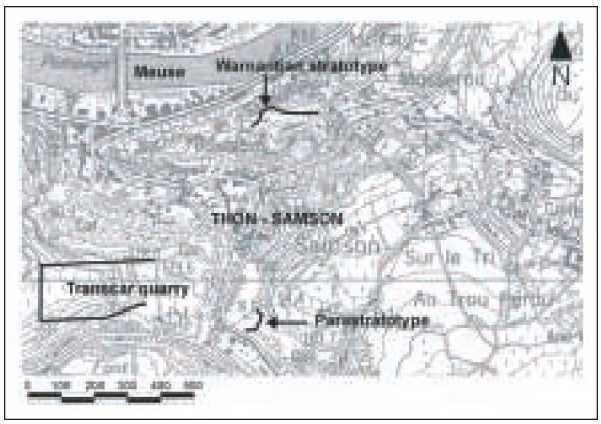

Figure 1. Location of the Warnantian stratotype.

4. Historical type area

The Warnantian Substage is named after Warnant, a locality in the Molignée valley, near Dinant (Dinant sedimentation area), where the substage is well exposed (De Jaiffe quarry and railway cutting at Warnant ; Demanet, 1938; Conil & Pirlet, 1970; Conil & Pirlet, 1974; Laloux *et al.*, 1988). However, the « Camp de César » old quarry, at Thon-Samson (Figs 1, 2; Pirlet, 1963; Pirlet, 1968; Conil & Pirlet, 1974) in the Namur sedimentation

area (NSA), was chosen as boundary stratotype by Conil *et al.* (1977). In the Samson valley, the Transcar quarry at Maizeret and the old quarry (Fig. 3) in front of the junction between the valley road and the road to Maizeret (Pirlet, 1963, 1968) are good boundary parastratotypes. Geological maps n° 145 (Andenne-Couthuin, 1893) and n° 155 (Gesves-Ohey, 1901), under revision by Delcambre & Pingot (in preparation).

5. Description

In the stratotype area, only the lowest part of the Warnantian, including the Thon-Samson Mbr and the lower part of the Poilvache Mbr, is exposed (Fig. 2, 4). This part corresponds to the Cf6α, β Subzones of Conil *et al.* (1991). The rest of the substage lacks and the Namurian siliciclastics directly top the Poilvache Mbr.

The Thon-Samson Mbr rests on the stromatolitic limestones of the Bay-Bonnet Mbr (top of the Livian Substage), and comprises at its base a shallowing-upward parasequence composed of 3 m of grey bioclastic limestone with cherts, capped by a 30 cm-thick bed of stromatolitic limestone. It is topped by 5 to 6 m of massive grey crinoidal limestone.

The Poilvache Mbr is composed of 6,5 m of thin-bedded stromatolitic limestone interbedded with some argillaceous layers (« plates escailles ») overlain by 14 m of thick-bedded pale stromatolitic to bioclastic limestones.

The most complete sections of the substage are in the Condroz (CSA) and in the Dinant (DSA) sedimentation areas. But the upper Warnantian (corresponding to the Cf6δ Foraminiferal Subzone of Conil *et al.*, 1991, ~ Zone MFZ15 – *Janischewskina typica* Interval Zone of Devuyst & Hance (in Poty *et al.*, in press) and to the RC8 Rugose Coral Zone of Poty, 1985), is always poorly developed and often almost totally absent.

Figure 2. Base of the Warnantian Substage in its stratotype ("Camp de César" old quarry at Thon-Samson).

6. Historical background

The Viséan was formerly considered as a series and was divided into three stages by Conil *et al.* (1977), from base to top: Moliniacian (lower Viséan), Livian (middle Viséan) and Warnantian (upper Viséan). The Viséan was recently redefined as a stage by the IUGS Subcommission on Carboniferous Stratigraphy (Heckel, 2004) and, as a consequence, the Warnantian is now a substage. The British Asbian and Brigantian Substages correspond respectively to the lower and the upper Warnantian.

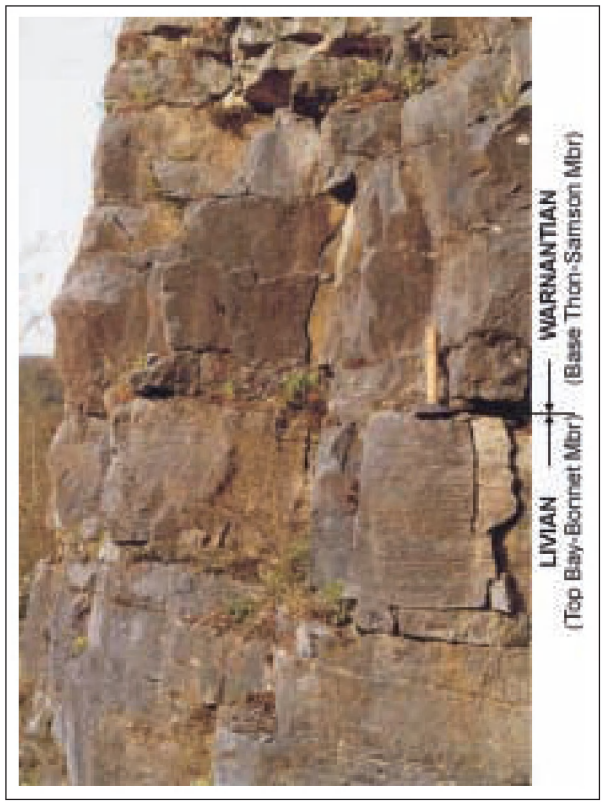

Figure 3. Base of the Warnantian in the old quarry in front of the junction between the valley road and the road to Maizeret at Thon-Samson (parastratotype).

7. Lithology

The lithology and the lithostratigraphy (Fig. 4) of the substage are relatively constant in the Namur-Dinant basin, but deposits are locally missing: the gap includes the uppermost Warnantian in the DSA and progressively extends stratigraphically downwards up to the uppermost Livian in the NSA. A deep palaeokarst filled with Namurian siliciclastic deposits is sometimes developed at the top of the substage.

In the CSA and DSA, where the substage is best developed, it is about 120 m-thick and comprises two formations: the Bonne River Fm and the Anhée Fm.

The Bonne River Fm comprises the Thon-Samson and the Poilvache Mbrs. The Thon-Samson Mbr (sensu Poty *et al.*, 2002, is 8 m-thick and composed of massive well-bedded, pale to dark limestone (grainstones-rudstones), usually crinoidal, sometimes with corals and brachiopods. The Poilvache Mbr (ibid.) is about 80 m-thick and comprises pale to dark limestones, sometimes cherty, organized in shallowing-upward parasequences dominated by lime mudstones and stromatolitic limestones. It is poor in fossils.

The Anhée Fm (ibid.) is composed of two members: (1) the Lower Mbr is about 25 m-thick and comprises parasequences of dark limestones dominated by wackestones and packstones, locally very fossiliferous (Chabôfosse Facies); (2) the Upper Mbr, a few metres to 8 m-thick, comprises argillaceous limestones, shales and siliceous shales. The upper part of the Lower Mbr and the Upper Mbr were previously attributed respectively to the lower and to the upper parts of the Warnant Fm (Paproth *et al.*,1983).

The Bonne River Fm and most of the Lower Mbr of the Anhée Fm correspond to the lower Warnantian. The top of the Lower Mbr and the Upper Mbr of the Anhée Fm correspond to the upper Warnantian that is very poorly developed and often missing.

Note that collapse brecciation triggered by the solution of the underlying Livian evaporites (Grands-Malades Fm) can affect the Warnantian limestones ("Grande Brèche Viséenne").

In the Visé-Maastricht sedimentation area (VSA), the Substage corresponds to the upper part of the Visé Limestone Fm (Pirlet, 1967; Poty *et al.*, 2002), which is the historical type unit of the Viséan Stage, and to the upper part of the Berneau Fm (Poty *et al.*, 2002).

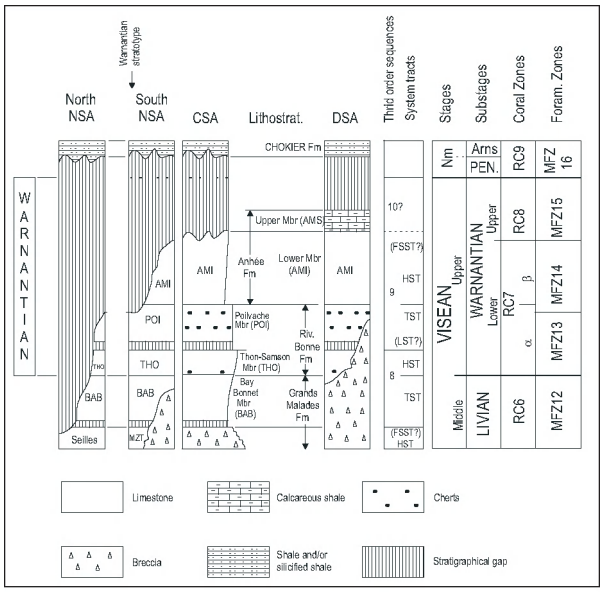

Figure 4. Stratigraphical pattern of the Warnantian in southern Belgium.

The Visé Limestone comprises pale to grey sedimentary limestone breccias, turbidites and massive algal and bioclastic boundstones forming buildups very rich in fossils.

The Berneau Fm is mainly composed of dark limestone turbidites and breccias. Most of the upper part of the Substage is also missing in the area. The thickness of the Substage varies from 0 m in the Souvré tectonic block to some hundreds metres in the Maastricht block system (Poty, 1991).

In the Avesnois (Mansy *et al.*, 1989), the substage corresponds to the Saint-Hilaire and Saint-Rémy-Chaussée Limestones (lower Warnantian) and to the Queue Noir-Jean shales and silicified shales (upper Warnantian). In the Boulonnais, it comprises the Joinville and the Réty Fm; its uppermost part is also missing (Poty, 1994).

8. Sedimentology and palaeogeography

The Thon-Samson Mbr corresponds to the HST of the third-order sequence 8 of Hance *et al.* (2001), while the Poilvache Mbr and the Anhée Fm correspond respectively to the TST (and LST?) and to the HST (and FSST?) of sequence 9. The sequence 10 is not developed in the basin.

During the Warnantian, the Visé-Maastricht sedimentation area belonged to the Campine Basin which was separated from the Namur-Dinant Basin by the emergent Brabant Massif. Therefore, the Warnantian deposits in the Campine Basin are not similar to those known in the Namur-Dinant Basin (see above). The Warnantian is better developed in Great-Britain and Ireland where it is locally more than 1000 m-thick (George *et al.*, 1976).

9. Palaeontology

9.1. Foraminifers

The Warnantian is covered by the MFZ13 to MFZ15 foraminifer zones of Devuyst & Hance (in Poty *et al.*, in press). It is equivalent to the Cf6 Zone of Conil *et al.* (1977, 1991), which is well documented by Laloux (1988) and Laloux *et al.* (1988).

The MFZ13 Zone starts with the entry of *Neoarchaediscus* and *Planospirodiscus* in the lowermost part of the Thon-Samson Mbr in its type area (NSA), in sequence 1 of Pirlet (1968; see also Laloux, 1988). *Vissariotaxis* sp., *Palaeotextularia* with a bilaminar wall and typical *Endothyra spira* enter at this level. *Chomatomediocris* sp., *Neoarchaediscus incertus*, *Vissariotaxis compressa* and primitive *Howchinia* are other typical elements. *Pseudoendothyra* sp. appears higher in the zone.

The MFZ14 Zone, equivalent to the Cf6γ Subzone and the lower part of the Cf6δ Subzone of Conil *et al.* (1977, 1991), covers the uppermost part of the Poilvache Mbr and most of the Lower Member of the Anhée Fm (sensu Poty *et al.* 2002). *Howchinia bradyana* and *Bradyina rotula*

enter in the uppermost part of the Poilvache Mbr (DSA), together with cribrate *Palaeotextulariidae* (*Cribrostomum* and *Koskinobigenerina*). The successive incomings of *Cribrospira panderi*, *Bibradya* sp., *Asteroarchaediscus* sp., *Globispiroplectammina* sp. and *Plectostaffella* sp. complete the association. *Archaediscus* ex gr. *karreri*, *Endothyranopsis crassa*, large *Omphalotis* and *Eostaffella* aff. *mosquensis* are also present. Archaediscids at the '*tenuis* stage' appear in the uppermost part of the Zone. *Loeblichia paraammonoides* enters in the upper part of the lower member of the Anhée Fm in the DSA and CSA, at the same level or at a short distance above the entry of *Warnantella* (Laloux, 1988; Laloux, in Poty *et al.* 1988). The base of the MFZ15 Zone is defined at the entry of *Janischewskina typica* a few metres above *L. paraammonoides*. It correlates with the upper part of the Cf6δ Subzone and with the lower part of the Cf7 Zone that does not yield significant new taxa. Most of the key taxa typical of Zone MFZ14 are still present. *Asteroarchardiscus* and archaediscids at the '*tenuis* stage' are abundant. The first *Monotaxinoides* are reported by Conil *et al.* (1991) in the upper part of the zone.

9.2. Corals

The Warnantian is covered by the rugose coral Zones RC7 and RC8 (Poty, 1985; Conil *et al.*, 1991; Poty *et al.*, in press).

In the type area, the first coral assemblage of the Zone RC7 is recorded in the massive crinoidal limestone of the upper part of the Thon-Samson Mbr. The new characteristic taxa are *Siphonodendron scaleberense*, *S. pauciradiale*, *Siphonophyllia samsonensis* (= *S. benburbensis*) and *Dibunophyllum* sp. The genus *Diphyphyllum* (*D. furcatum*) appears in the overlying Poilvache Mbr (sequence "i" of Pirlet, 1968).

The Anhée Fm is characterized by the appearance of *Lithostrotion maccoyanum*, *Siphonodendron junceum*, *Diphyphyllum lateseptatum*, *D. fasciculatum*, and later the genus *Aulophyllum* (*A. fungites*). Other common taxa appearing in the RC7 Zone are: *Lithostrotion decipiens*, *Siphonodendron intermedium*, *Clisiophyllum keyserlingi*, *Dibunophyllum bipartitum* and *Pseudozaphrentoides juddi*.

The genera *Lonsdaleia sensu lato* (including fasciculate, subcerioid and cerioid species) and *Palastraea* appear in the upper part of the Lower Member of the Anhée Fm and mark the base of the RC8 Zone.

RC7 and RC8 zones are easily correlatable everywhere in Europe.

9.3. Other fossils

Brachiopods are common, but they need to be revised to be used for the stratigraphy of the substage. The occurrence of gigantoproductids in the substage is worth mentioning. The Warnantian corresponds to the top of the *Gnathodus homopunctatus – Taphrognathus transatlanticus* and to the *Gnathodus bilineatus* Conodont Zones (Paproth *et al.*, 1983), and to the goniatite faunas GF10 to GF16 of Ramsbottom (in Paproth *et al.*, 1983). However conodonts and goniatites are very uncommon and without practical biostratigraphical value in Belgium.

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).

11. Geochronology

No radiometric dates are available for the Warnantian 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

Warnantian deposits are part of the Variscan orogenic cycle. Those of the Namur-Dinant Basin were deposited by aggradation on the shelf as suggested by their lateral regularity, while those of the Campine Basin were affected by tectonic block faulting. In southern Belgium, Warnantian deposits are distributed on both sides of the Midi-Eifel fault zone and occur in two main structural units: the Brabant Parautochton and the Ardenne Allochton. These structural units were part of the Namur-Dinant Basin during the time of deposition. Warnantian deposits are largely folded except for those situated in the northern part of the Brabant Parautochton. The Warnantian stratotype is located on the southern flank of the Namur Synclinorium, at the front of the Variscan folding and the beds are gently folded. In the Campine Basin, Warnantian deposits are faulted but not folded, excepted for those situated in the Visé area which suffered Variscan folding.

13. Reference sections in Belgium

In the DSA, three sections are important reference sections: The old "De Jaiffe" quarry and the railway cutting at Warnant (Demanet, 1938; Pirlet, 1968 ; Conil & Pirlet, 1970; Conil & Pirlet, 1974; Laloux *et al.*, 1988), a section situated in front of the Yvoir bridge at Anhée and the disused Watrisse quarry (Pirlet, 1968; Conil & Pirlet, 1970) south of Anhée. In the CSA, at Royseux (Hoyoux valley), sections along the road (Pirlet, 1964) and on the slopes of both sides of the valley (Poty et al, 1988; Aretz, 2001) expose very fossiliferous limestones of the Anhée Fm ("Chabôfosse Facies") overlying the Bonne River Fm.

The latter formation is well exposed on the east bank of the river Bonne at Modave (Pirlet, 1968). In the NSA, the lower part of the substage is well exposed in the Samson valley, in the Transcar quarry at Maizeret (fig. 1) and in an old quarry in front of the junction between the valley road and the road to Maizeret (righ side of the valley, fig. 1, 3; Pirlet, 1963, 1968). The Warnantian part of the Visé Limestone (historical Visean stratotype) is exposed in old quarries situated south of Visé (Pirlet, 1967), but access is now very difficult.

14. Main contributions

Conil, Groessens & Pirlet (1977); Conil & Pirlet (1970); Devuyst, Hance & Poty, 2005; Hance, Poty & Devuyst (2001, 2002); Laloux *et al.* (1988); Paproth *et al.* (1983); Pirlet (1963, 1964, 1967, 1968); Poty *et al.* (2002).

15. Remarks

The base of the Warnantian Substage is placed at the bioclastic limestone bed which marks the base of the Bonne River Fm (Thon-Samson Mbr). The underlying Bay-Bonnet Mbr is composed of stromatolitic limestones and is almost totally devoid of fossils. Therefore, the appearance of the characteristic taxa of the substage is due to ecological factors allowing their presence, and a lectostratotype has to be searched in a succession developed in open marine facies.

16. Acknowledgements

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