TOURNAISIAN

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(6 figures)

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ABSTRACT. The main elements that prompted the international community to use the Tournaisian as a name for the oldest stage of the Mississippian Subsystem are the same as those for the Viséan, i. e., the quality of exposures in southern Belgium, the diversity of facies, the pioneering palaeontological work that started in the mid 19th century and development of foraminiferal, conodont and rugose corals zonations in the last decades. The numerous Tournaisian sections in southern Belgium document a progressive change in environmental setting, from a ramp during the early Tournaisian to a shelf during the late Tournaisian. The spectacular late Tournaisian Waulsortian buildups that occurred within 2 third-order sequences had a strong impact on subsequent Viséan sedimentation. Recent advances in understanding the sequence stratigraphy has led to new insights on correlation between the central Dinant Sedimentation Area and more proximal areas.

KEYWORDS: Tournaisian, Belgium, Lithostratigraphy, Biostratigraphy, Palaeogeography.

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1. Name

Tournaisian (English), Tournaisiaan (Dutch), Tournaisium (German), Tournaisien (French).

2. Age

The Tournaisian is included in the early Mississipian Epoch (359.2 – 318.1 Ma) of the Carboniferous Period. It has a duration of about 12 Ma (353.7 ± 4.2 to 342 ± 3.2) from Menning *et al.* (2001) and 15.3 Ma (359.2 ±2.5 to 345.3 ± 2.1) from the Geological Time Scale in Gradstein *et al.* (2004).

3. Authors

Dumont (1832) was the first to divide the Lower Carboniferous into two stages that were later named the calcaire de Tournai (or Tournaisian) and calcaire de Visé (or Viséan). The first mention of the "calcaire carbonifère de Tournai" was given by de Koninck (1842-1844). The latter stratigraphic unit successively became the étage du calcaire de Tournai (Gosselet, 1860), Assise de Tournai (Dupont, 1861) and "Etage de Tournai" in the legend of 6 sheets of the geological map of Belgium at the scale of 1:20 000 (Dupont, 1882-1883).

4. Historical type area

Geological map Antoing-Leuze (37/7-8; Hennebert & Doremus, 1997a) and Hertain-Tournai (37/5-6; Hennebert & Doremus, 1997b).

The "Calcaire de Tournai" refers to the town of Tournai in western Belgium, close to the border with France (Fig. 1), where numerous quarries were opened for building material during the 19th Century (Fig. 2). Demanet (1958) gave an exhaustive review of the old literature about the Tournai type area.

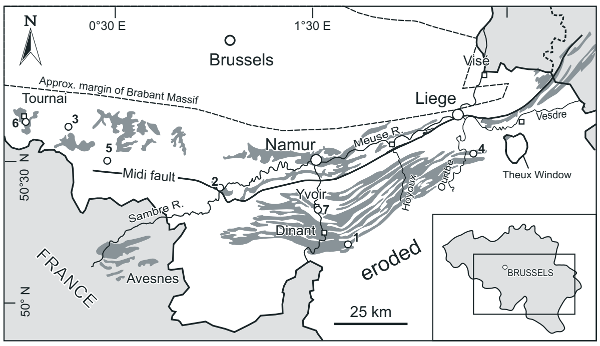

Figure 1. Location of Tournaisian sections mentioned in the text. 1. Gendron-Celles; 2. Landelies; 3. Leuze drillhole; 4. Rivage; 5. Saint-Ghislain drillhole ; 6. Tournai, Asile d'Aliénés drillhole; 7 Yvoir. The shaded areas represent Lower Carboniferous outcrops.

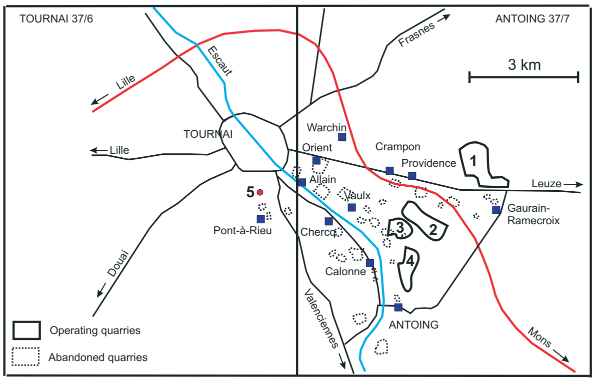

Figure 2. The Tournai area. Location of main quarries, operating and abandoned (from Delepine, 1911), opened in the "Calcaire de Tournai" and most important localities. 1. C.C.B. quarry at Gaurain-Ramecroix; 2. Milieu quarry (Obourg Granulats S.A.), at Gaurain-Ramecroix; 3. Lemay S.A. quarry at Vaulx; 4. Antoing S.A. quarry at Antoing. 5. Location of the Tournai drill hole.

5. Description

The "Calcaire de Tournai" of the old literature does not cover the whole Tournaisian succession, but only its early and middle Ivorian part (*carina* conodont Zone), including the Tournai and Antoing Fms (Hennebert & Doremus, 1997a-b; Poty *et al.*, 2001; Larangé *et al.*, 1998). The famous "Tournai fauna" comes from the Allain, Providence, Pont-à-Rieu and Vaulx Mbrs of the Tournai Fm and from the lower part of the Calonne Mbr of the Antoing Fm (Conil *et al.*, 1971).
The thickness of the "Calcaire de Tournai" is about 310 m in its type area.

6. Historical background

For a discussion of the old literature, see Delepine (1911), Demanet (1958), Mortelmans (1976), Groessens (1975) and Hance *et al.* (The Viséan Stage, this volume b).
The "Calcaire de Tournai" comprises the limestone formations cropping out in the Mélantois-Tournaisis Anticline (Hennebert & Doremus, 1997a-b), which have been quarried since the Roman conquest. Its relationship with the succession of the Dinant area was only understood following study of the Asile d'Aliénés borehole at Tournai and the Vieux-Leuze borehole at Leuze (Legrand *et al.*, 1966). These boreholes exhibited a rather typical middle Tournaisian succession below the "Calcaire de Tournai" that was easy to correlate with the succession of the Dinant area. The conodont data collected by Groessens (1975; 1978) and Larangé *et al.* (1998) revealed that the "Calcaire de Tournai" and the equivalent succession in the Ecaussinnes area correlates with the *carina* conodont Zone, and hence does not include the Upper Tournaisian (Fig. 3).

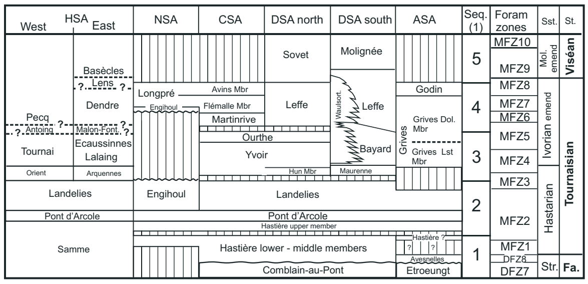

Figure 3. Lithostratigraphic framework for the Tournaisian of Belgium and Northern France (modified from Hance *et al.*, in press). Units correspond to formations except otherwise noted. Seq. : third order sequences from Hance *et al.*, 2001; Sst. Substages; St. Stages.

The base of the Carboniferous and hence of the Tournaisian (Lower Carboniferous), was first formally defined during the 1935 Heerlen Congress at the entry of the cephalopod *Gattendorfia subinvoluta* above the Strunian. That definition was not followed by Belgian specialists who considered the Strunian fauna to have Carboniferous affinities. The palynological data of Streel (1969) confirmed, however, the correlation of the Strunian with the uppermost Famennian of Germany and forced Conil *et al.* (1977) to introduce a Strunian Stage preceding the Hastarian Stage marking the base of the Dinantian - former Lower Subsystem of the Carboniferous, including the Tournaisian and Viséan Series (see Groessens, The Dinantian, this volume). Hence, the Tn1a interval of the old literature was transferred to the Devonian.
In 1976, the IUGS officially organized a working Group on the Devonian-Carboniferous boundary. In 1980, the D-C Working Group made the recommendation that the base of the Carboniferous be defined at the entry of the conodont *Siphonodella sulcata* within the evolutionary lineage from *S. praesulcata* to *sulcata*. This definition was accepted because it was close to the definition of the D-C boundary at the base of the *Gattendorfia* Zone as recommended at the 1935 Heerlen Congress (Paproth & Streel, 1984). The corresponding boundary GSSP at the base of bed 89 in a section at La Serre (France) was finally ratified in 1991.
In the recently ratified global Carboniferous stratigraphic scheme (Heckel, 2004), the Tournaisian Stage is the only stage included in the Lower Mississippian Series.

7. Lithology

In the Condroz Sedimentation Area (S.A.) and in the northern part of the Dinant S.A., the Tournaisian consists dominantly of crinoidal limestones (mainly packstones) of the Hastière, Landelies, Yvoir, Ourthe and Martinrive Fms and crinoidal dolostones of the Flémalle Mbr (Longpré Fm). Shaly interbeds, thicker shaly units (Pont d'Arcole Fm, Maurenne Fm) and poorly developed oolitic to peloidal grainstones forms minor lithologies (Figs 3-5). In the

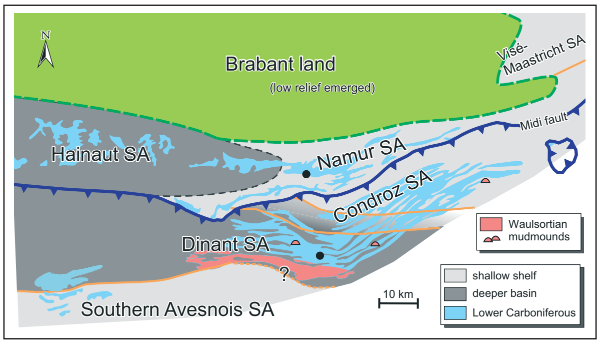

Figure 4. Palaeogeography of the Namur-Dinant Basin at the time of the Tournaisian-Viséan transition (modified from Hance *et al.*, 2001).

southernmost part of the Dinant S.A., the Waulsortian buildups started growing at a level close to the base of the Ivorian. The dominantly violet-grey wackestones to packstones of the Leffe Fm form their lateral equivalent.

In the Hainaut S.A., the Carboniferous starts with the Samme Fm, characterized by sandstones, shales, dolomitic sandstones and dolomitic limestones. The overlying Pont d'Arcole and Landelies Fm keep the characters they have in southern Belgium (Poty *et al.*, 2002). In the western part of the Hainaut S.A. (Tournai-Leuze area), the Orient Fm rests on the Landelies Fm. It consists of calcareous shales with crinoidal and other fossiliferous beds. Dominant lithologies of the overlying "Calcaire de Tournai" are thin- to medium-bedded, dark crinoidal limestones, locally argillaceous, including marlstone layers, cherty layers and shelly beds. An argillaceous bed, the "Gras Délit", is the marker for dividing the "Calcaire de Tournai" into two formations, the Tournai and Antoing. The Pecq Fm overlying the "Calcaire de Tournai" consists of massive crinoidal limestones and dolomites. The succession in the eastern part of the Hainaut S.A. is slightly different but displays similar facies. The famous building stone "Petit Granit" is a crinoidal limestone which corresponds to the Soignies Mbr of the Ecaussinnes Fm. It includes in its upper part a marker bed, the "Délit à la terre bleue" which correlates with the "Gras Délit" of the Tournai area.

8. Sedimentology and palaeogeography

After the late Devonian regression, the depositional setting was a carbonate platform which evolved from a south fac-

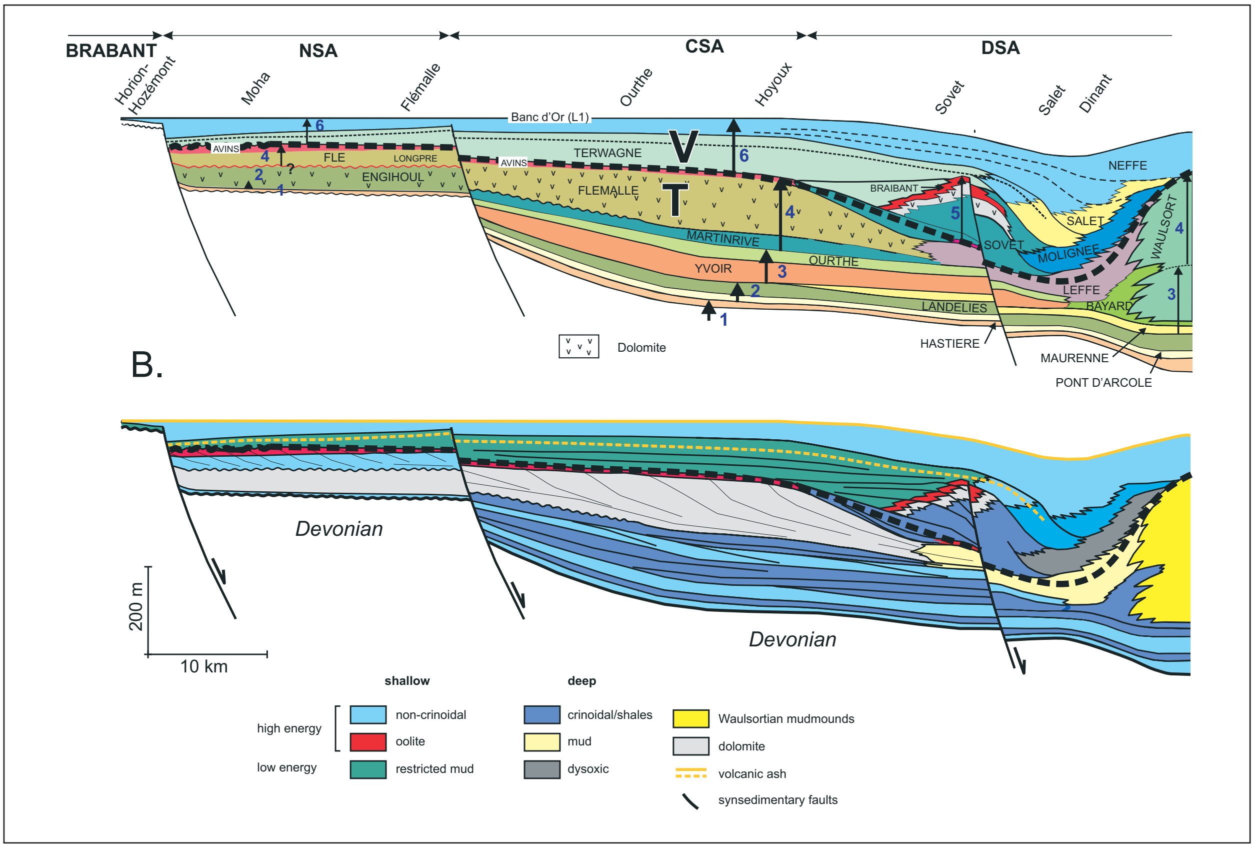

Figure 5. A. Organization of Tournaisian (T) and Lower Viséan (V) sedimentation across the Namur-Dinant Basin. Numbered black arrows indicate third-order sequences. Note 1) the evolution from a homoclinal ramp at the time of the Devonian-Carboniferous boundary to a shelf in the latest Tournaisian, 2) the position of the T-V boundary which coincides with a gap in the inner shelf areas and whose transition can only be documented in the deeper-water facies of the Dinant S.A. NSA= Namur Sedimentation Area; CSA= Condroz Sedimentation Area; DSA= Dinant Sedimentation Area.
B. Facies distribution

ing ramp at the D/C boundary to a rimmed shelf during the late Tournaisian (Fig. 5; Hance *et al.*, 2001). The Hastarian (Lower Tournaisian) succession displays rather similar facies throughout the Namur-Dinant Basin, reflecting a very gentle slope ramp setting. Lithostratigraphic correlations are well documented. Towards the north, formations become thinner and stratigraphic gaps increase. During the Ivorian (Upper Tournaisian), the ramp evolved progressively to a rimmed-shelf and a discontinuous barrier of Waulsortian buildups developed in the southwestern part of the Dinant Sedimentation Area (Lees, 1997).
Four third-order sequences are identified in the Tournaisian of southern Belgium (Fig. 5; Hance *et al.*, 2001, 2002; Poty *et al.*, 2002). A similar trend is observed in northern France (Hance *et al.*, 2001), southwestern Britain (Hance *et al.*, 2002) and Poland (Poty *et al.*, in press).

9. Palaeontology

9.1. Foraminifers

Poty *et al.* (in press) recognize 8 foraminiferal zones, MFZ1 to MFZ8 in the Tournaisian (Fig. 6). The fossil group is more diversified, mainly in the Upper Tournaisian, than indicated previously by Conil *et al.* (1991). Several levels are useful for long distance correlation : the entry of *Palaeospiroplectammina tchernyshinensis* in the upper part of the Landelies Fm (MFZ 3), the entry of spinose endothyrids in the lower part of the Yvoir Fm (MFZ4), the *Paraendothyra nalivkini* fauna in the upper part of the Yvoir Fm (MFZ5 = Cf2 of Conil *et al.*, 1991) coexisting with abundant *Granuliferella* and *Tournayellina* and, the entry of *Lugtonia monilis* in the Flémalle Fm (MFZ7) and that of *Eoparastaffella* Morphotype 1 (Poty *et al.*, in press) in the Avins Mbr (Longpré Fm), the lowermost part of the Sovet Fm and uppermost part of the Leffe Fm (MFZ8).

9.2. Rugose corals

The zonation of Poty (1985; in Conil *et al.*, 1991) has been outlined in Poty *et al.* (in press) and correlated with the foraminifer and conodont occurrences (Fig. 6).
The Tournaisian is covered by four Rugose Coral Zones: RC1 to RC4 Zones. The base of the Stage is within the RC1α Subzone (the base of RC1 is situated just above the Hangenberg event, at the base of the upper *praesulcata* conodont Zone) and the top corresponds approximately to the top of the RC4β1 Subzone
Some Tournaisian coral zones defined in northwestern Europe can be recognized across Eurasia and in some cases as far as North America and Australia and, therefore, are useful for long-distance correlation. These are:
(1) the base of the RC1 Zone characterized by the spread of survivors of the Hangenberg event (Eurasia, North America) ;
(2) the base of the RC1γ Subzone (corresponding to the base of the Pont d'Arcole Fm in Belgium) which is characterized by the appearance and dispersal of *Uralinia* (Eurasia) ;
(3) the RC3α Subzone (lower part of the Yvoir Fm) characterized notably by the appearance and dispersal of *Uralinia* of the *U. gigantea* group, *Cyathoclisia* and *Keyserlingophyllum* (Eurasia) ;
(4) the RC4β1 Subzone (Avins Mbr) which comprises taxa (*Amygdalophyllum* and *Merlewoodia*) which are found in Eurasia, including Japan, and Australia.

9.3. Conodonts

The conodont pattern for the Tournaisian is detailed and offers a powerful correlation tool. It is mainly the result of work by Groessens (1975), Belka & Groessens (1986), Conil *et al.* (1991) and Webster & Groessens (1991). Unfortunately, the facies in the lower part of the Hastière Fm are unsuitable and the evolutionary lineage from *Siphonodella praesulcata* to *S. sulcata* cannot be found in Belgium. The entry of *Polygnathus communis carina,* just after the disappearance of the siphonodellid fauna, marks the base of the Ivorian (see Hance & Poty, The Ivorian Substage, this volume a). The successive incomings of *Dollymae bouckaerti*, *Protognathodus cordiformis*, *Scaliognathus europensis*, and *Doliognathus latus* are among the most significant levels for correlation.

9.4. Other groups

Abundant illustrations of Tournaisian macrofauna (brachiopods, gastropods, bivalves, crinoids, cephalopods) can be found in the pioneering works of de Koninck (1842-

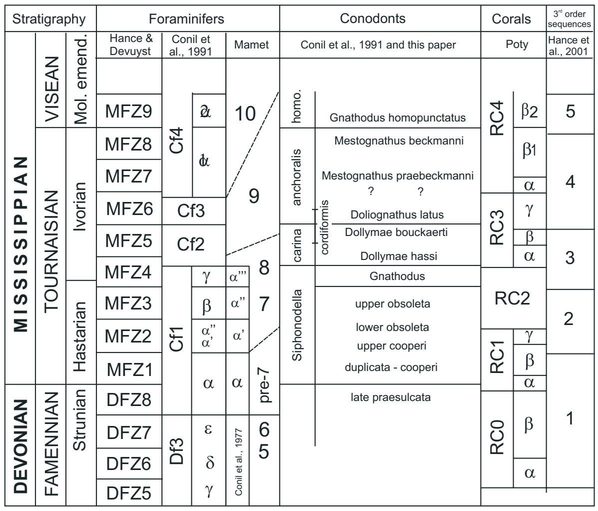

Figure 6. Biostratigraphic pattern for the Tournaisian of Belgium (modified from Hance *et al*., in press). The correlation of the Hainaut S.A. succession with that of southern Belgium is tentative. The position of the Dendre Fm and Lens Fm is based on the foraminifers. The conodont fauna from the Pont de Lens Mbr (Dendre Fm) and from the Lens Fm, documented by Groessens *et al*. (1982), correlates with Zone MFZ7 of Hance *et al*. (in press).

1844), relying mainly on the fauna from the Tournai area. Subsequent papers are numerous and the reader is referred to Demanet (1958).

10. Chronostratigraphy

The base of the Tournaisian coincides with that of the Carboniferous. The latter is defined by the entry of the conodont *Siphonodella sulcata* in the lineage from *S. praesulcata* to *S. sulcata* in a section at La Serre, France (Paproth *et al.*, 1991). This entry follows the Hangenberg event, a drastic sea-level drop responsible for the demise of Devonian fauna (Paproth, 1986 ; Dreesen *et al.*, 1988). In southern Belgium, this event is recorded by a metre-thick bed of rudstones and grainstones with lithoclasts, ooids, crinoids and a reworked Devonian fauna. The D/C boundary has traditionally been placed at its top, although diagnostic conodonts are lacking at this level (Paproth *et al.*, 1983 ; Conil *et al.*, 1986).

11. Geochronology

No radiometric data have yet been obtained within the Belgian Tournaisian.

12. Structural setting

The Dinant Sedimentation Area and the Condroz S. A. are included in the Dinant Synclinorium, which was part of the Ardennes Allochton. The Lower Carboniferous formations and the Famennian siliciclastics form respectively the core of synclines and anticlines. Palaeogeographic reconstructions have enabled the Ardennes Allochton to be restored to its original position, 15 to 30 km southwards of its present position .

The Hainaut S.A. and the northern part of the Namur S.A. correspond to the Brabant Parautochton (northern flank of the Namur "Synclinorium"). The southern part of the NSA is exposed in the thrust sheets distributed along the Midi fault (southern flank of the Namur "Synclinorium").

The Visé S.A. has a complex tectonic history and sedimentation is governed by block faulting (Poty, 1997)

13. Reference sections in Belgium

Hainaut Sedimentation Area

- Lemay quarry, SE of Tournai (Hennebert & Doremus, 1997b).
- Asile d'Aliénés (Legrand *et al.*, 1966 ; Coen *et al.*, 1981) ; Vieux-Leuze (Legrand *et al.*, 1966 ; Groessens, 1975 ; Coen *et al.*, 1981) and Saint-Ghislain boreholes (Groessens *et al.*, 1982).

Dinant Sedimentation Area

- Railway cut at Gendron-Celles station (Conil, 1968; Groessens, 1975; Lees *et al.,* 1985; Conil *et al.*, 1988 ; Van Steenwinkel, 1993).
- Abandoned quarries at Yvoir railway station (Conil, 1960 ; Groessens, 1973, 1975).
- Rivage section (Conil, coll. Lys & Paproth, 1964; Groessens, 1975 ; Conil *et al.*, 1986).

Namur Sedimentation Area

- andelies, Sambre River section (Mamet *et al.*, 1970 ; Groessens *et al.*, 1976 ; Groessens, 1985 ; Delcambre & Pingot, 2000)

14. Main contributions

In addition to the works already mentioned :
De Dorlodot (1895) ; Camerman (1944) ; Conil (1968); Mortelmans (1969, 1976).

15. Remarks

The Tournaisian is currently the only stage of the Lower Series of the Mississippian Subsystem (Heckel, 2004); its elevation to the rank of series is possible but requires also the elevation of selected local substages to the stage level. This would require for each the definition of a biostratigraphic criterion useful for long distance correlation and an appropriate GSSP.

16. Acknowledgements

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