HASTARIAN

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(6 figures)

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ABSTRACT. The Hastarian Substage is the lower subdivision of the Tournaisian. Its base coincides with that of the Carboniferous as defined by the first appearance of the conodont *Siphonodella sulcata*. Unfortunately, the oldest siphonodellids are absent across the Devonian-Carboniferous boundary in the lower part of the Hastière Formation. The top of the Hastarian is defined by the base of the succeeding Ivorian substage (as emended by Hance *et al.*, this volume) that is recognized by the first appearance of the conodont *Polygnathus communis carina*. The Hastarian correlates with foraminiferal Zones MFZ1 to MFZ4, rugose coral Zones RC1 and RC2 and the *Siphonodella* conodont Zone. Hastarian sedimentation occurred within a south-facing ramp setting. Thin-bedded crinoidal wacke- to packstones alternating with argillaceous limestones and thick-bedded crinoidal packtones form the dominant facies.

KEYWORDS: Hastarian, Lower Tournaisian, Carboniferous, Belgium

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1. Name

Hastarian (English), Hastariaan (Dutch), Hastarium (German), Hastarien (French).

2. Time

The Hastarian lasted for about 6 Ma, from 353.7 (+/- 4.2) Ma to 348 Ma, according to the compilation of Menning *et al.* (2001). Note that the base of Tournaisian (which corresponds to the base of the Hastarian) is dated at 359.2 (+/- 2.5) Ma in the 2004 International Stratigraphic Chart of the International Commission on Stratigraphy (Gradstein *et al.*, 2004).

3. Authors

Conil *et al.*, 1977, p. 368 and tab. 1. « Cet étage, reconnaissable mondialement par ses conodontes, comprend pratiquement le Tn1b et tout le Tn2 de la littérature antérieure. »

4. Historical type area

Geological map Hastière – Dinant (53/7-8; Delcambre & Pingot, 1993).

The substage is named after the "Sentier des Vignes" section located on the left bank of the Meuse River, northeast of the Hastière-Lavaux church (Conil *et al.*, 1974, excursion C, stop 2b) in the Dinant Sedimentation Area (S.A.) (Figs 1-2; Hance *et al.*, 2001). The holostratotype is now overgrown and exposures are discontinuous. We propose the railway cut at the Anseremme railway bridge as neostratoype (Figs 1-2). The latter section is much better exposed and has been studied in more detail (Van Steenwinkel, 1984, 1990, 1993; Casier *et al.*, 2004).
The sedimentation areas recognized by Hance *et al.* (2001) are used in this contribution.

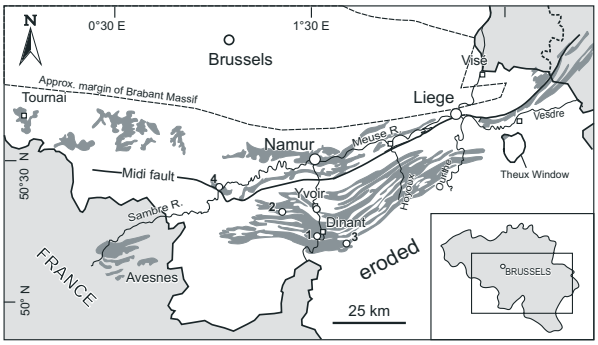

Figure 1. Location of Hastarian sections mentioned in the text. 1. Anseremme; 2. Denée drillhole; 3. Landelies; 4. Gendron-Celles. The shaded area represents Lower Carboniferous outcrops.

Figure 2. Detailed location of the neostratotype Anseremme railway bridge section.

5. Description

The lower boundary was originally defined in the "Sentier des Vignes" section at the base of the first shaly limestone (bed 311) above the basal bed of the Hastière Fm, a 1.5 m-thick rudstone to oolitic grainstone (Conil *et al.*, 1977; Paproth *et al.*, 1983). In the neostratotype, this latter bed contains the conodonts *Pelekysgnathus inclinatus*, *Pseudopolygnathus graulichi* and mainly *Protognathodus kockeli*, indicative for the Late *preasulcata* Zone (latest

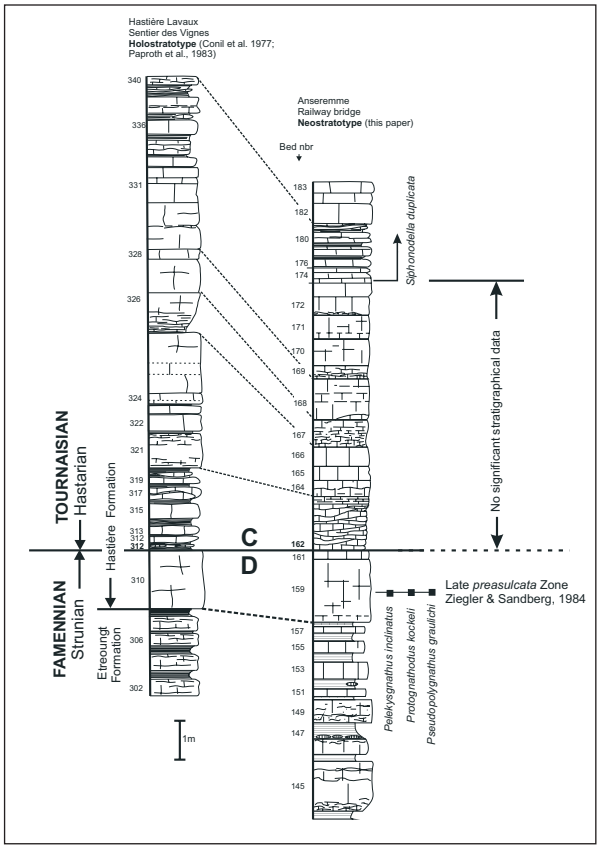

Figure 3. Lithology at the base of the Hastarian in the Hastière Fm at the Sentier des Vignes holostratotype and in the Anseremme neostratotype (modified, from Conil 1968).

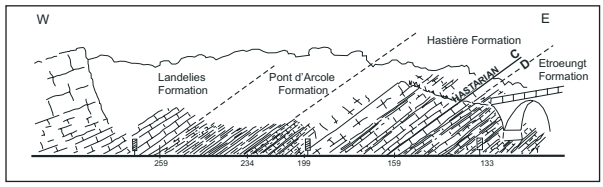

Figure 4. The Anseremme railway bridge section (after Conil *et al.*, 1974).

Devonian conodont zone; Van Steenwinkel, 1984; Conil *et al.,* 1986; Casier *et al.*, 2004), and, in its very basal part, quasiendothyrid representatives (Conil *et al.*, 1986). In the Royseux sections (Hoyoux valley), the basal bed of the Hastière Fm yields also brachiopods with Devonian affinities and the last *Phacops* trilobites (Conil *et al.*, 1986). Above that level with clear Devonian indicators, palaeontological criteria for defining the base of the Hastarian are lacking and the original definition of 1977 is purely lithological as discussed by Conil *et al.* (1986, p. 22): "In spite of detailed studies, micropaleontological evidences are either lacking or unsatisfactory near the lithological boundary between the Etroeungt and Hastière-Avesnelles Formations.… the Devonian-Carboniferous boundary has to be traced by using a negative criterium, namely by the disappearance of the Devonian fauna, rather than by a positive one which would be the beginning of the Carboniferous fauna."

This boundary is supposed to coincide with the base of the Carboniferous which is defined by the entry of the conodont *Siphonodella sulcata* in the lineage *S. praesulcata* to *S. sulcata* (Conil *et al.*, 1977). Unfortunately, this criterion is not applicable in the rather shallow carbonate platform facies of the Franco-Belgian Basin where these conodonts are never found. The oldest record of siphonodellid conodonts is from the Anseremme railway bridge section, in bed 174a, about 7 m above the basal bed of the Hastière Fm (Van Steenwinkel, 1984; Webster & Groessens 1991), where *S. duplicata* enters. In that section, the Hastarian starts with bed 162 (Figs 3-5).

The upper boundary is defined by the base of the overlying Ivorian Substage (emend. Hance & Poty, this volume).

6. Historical background

The Tournaisian was formerly considered as a series and was divided in two stages by Conil *et al.* (1977), from base to top: the Hastarian (lower Tournaisian) and the Ivorian (upper Tournaisian). The Tournaisian was recently redefined as a stage by the IUGS Subcommission on Carboniferous Stratigraphy (Heckel, 2004) and the Hastarian therefore now corresponds to a substage. The boundary between the Hastarian and Ivorian is now placed at the contact with the first cherty limestone bed marking the base of the Yvoir Fm. at Yvoir. This new boundary position is 2.5 m higher than the original placement by Conil *et*

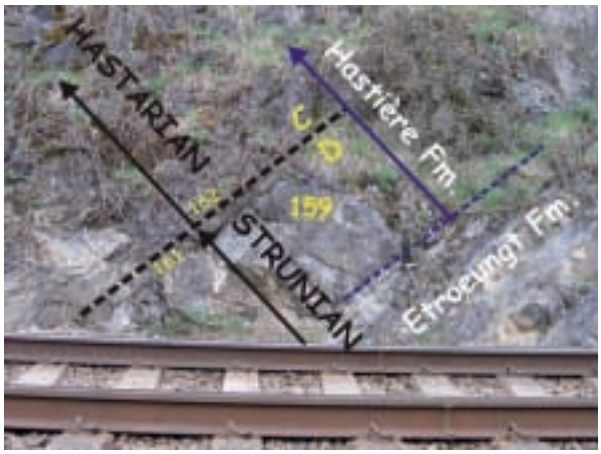

Figure 5. The base of the Hastarian Substage in the Anseremme neostratotype.

al. (1977) and coincides with the entry of the conodont *Polygnathus communis carina* as explained in Hance *et al.* (this volume). The 2.5 m section beneath the cherty limestone that previously was assigned to the Ivorian is now considered to be part of the Hastarian Maurenne Fm.

7. Lithology

In the Dinant S.A., the Hastarian is less than 100 m-thick. It encompasses all but the basal bed of the Hastière Fm (± 20-35 m), the Pont d'Arcole Fm (± 14 - 20 m), the Landelies Fm (± 35-40 m) and the Maurenne Fm (± 14 m).
At Yvoir along the northern margin of the Dinant S.A the sandy limestone of the Hun Mbr
(lateral equivalent of the Maurenne Fm) overlies the Landelies Fm. In the Condroz S.A., a similar succession is observed, except that the uppermost Hastarian corresponds to the lower Mbr of the Yvoir Fm resting directly on the Landelies Fm. In the eastern part of the Namur S.A., the succession is incomplete. It comprises the middle and upper members of the Hastière Fm resting directly on Famennian siliciclastics (Evieux Fm), the Pont d'Arcole Fm and the lower member of the Engihoul Fm which might correspond to the dolomitized lateral equivalent of the Landelies Fm (Poty *et al.*, 2002). In the Saint-Ghislain borehole (Hainaut S.A.), the base of the Hastarian is not precisely located. The Hastarian age of the Brugelette-Frézignies Limestone (4249.4-4254.75 m depth) and of the overlying Mévergnies-Attre Sandstone (4232.15- 4254.75 m) is inferred indirectly from palynological data (Streel, 1977) collected from the borehole. The rest of the Hastarian succession encompasses the Pont d'Arcole (45 m), Landelies (95 m) and Orient (85 m) Fms (Groessens *et al.*, 1982).
In the Avesnes S.A., the middle part of the Avesnelles Fm, formerly considered to be at the base of the Hastarian (Paproth *et al.*, 1983; Conil *et al.*, 1986; Mansy *et al.*, 1989), is now assigned to the upper *praesulcata* conodont Subzone (Hance *et al.*, in press) and therefore belongs to the Devonian. The Hastarian includes the upper part of the Avesnelles Fm, the Pont d'Arcole Fm and about 20 m of alternating beds of limestones and calcareous shales attributed to the Landelies Fm. The boundary with the Ivorian is unconformable (Mansy *et al.*, 1989). In the Visé-Maastricht S.A. the lithology is the same as in the Condroz S.A.
The dominant facies observed in the Hastarian are thin-bedded crinoidal packstones interbedded with shales (lower and upper members of the Hastière Fm), shales with minor crinoidal intercalations (Pont d'Arcole and Maurenne Fms), thick-bedded crinoidal packstones and locally oolitic grainstones (middle member of the Hastière and Landelies Fms) and crinoidal cherty dolomites and limestones, locally sandy and including fossiliferous shales intercalations (lower part of the Yvoir Fm in the Condroz S.A.).

8. Sedimentology and palaeogeography

The depositional setting during Hastarian time was a south facing homoclinal ramp. The proximal succession is incomplete, starting in many localities only with the middle member of the Hastière Fm.
In terms of sequence stratigraphy, the Hastarian Stage covers the upper part of sequence 1, sequence 2 and the lowermost part of sequence 3 of Hance *et al.* (2001, 2002). The lower and middle members of the Hastière Fm represent respectively the upper part of the transgressive systems tract (TST) and the highstand systems tract (HST) of sequence 1. The upper member of the Hastière Fm and the Pont d'Arcole Fm are interpreted as the TST of sequence 2, while the Landelies Fm forms its HST. The Maurenne Fm and its lateral equivalent correspond to the lower part of the TST of sequence 3.

9. Palaeontology

9.1. Foraminifers

The Hastarian correlates with Zones MFZ1 to MFZ4 of Hance & Devuyst (in Poty *et al.*, in press) (Fig. 6) and with Zone Cf1 of Conil *et al.* (1991). The two lower members of the Hastière Fm are almost devoid of plurilocular foraminifers. That interval corresponding to MFZ1 is dominated by unilocular forms. Plurilocular foraminifers are locally more abundant in the upper member of the Hastière Fm (MFZ2 Zone). A diversification is observed in the upper half of the Landelies Fm (MFZ3) and mainly in the lower part of the Yvoir Fm in the CSA where tuberculate endothyrids enter (MFZ4; Brenckle & Hance, 2005)

9.2. Conodonts

The basal bed of the Hastière Fm contains *Pelekysgnathus inclinatus*, *Protognathodus kockeli* and *Pseudopolygnathus graulichi*. This association is typical for the Upper *praesulcata* Zone and, therefore, latest Famennian (Ziegler & Sandberg, 1984; Casier *et al.*, 2004). The Hastarian is thought to coincide with the range of siphonodellid conodonts from the entry of *S. sulcata* upward (Fig. 5; CC1 Zone of Conil *et al.*, 1977). Unfortunately, the oldest siphonodellids are absent in the lower part of the Hastière Fm. The first record is *Siphonodella duplicata* which enters 7 m above the base of the Hastière Fm at Anseremme (Fig. 3; Van Steenwinkel 1980; Webster & Groessens 1991). This 7 m interval is also lacking other significant stratigraphical taxa.

9.3. Rugose corals

The Hastarian correlates with Rugose Coral Zones RC1 and RC2 of Poty (1985; Fig. 6). The base of the RC1 Zone (*Conilophyllum* interval Zone) coincides with the base of the Substage and is marked by the arrival of *Conilophyllum priscum* (= *Caninia tregaensis* Poty, 1982) and *Kizilia kremersi*, just above the basal bed of the Hastière Formation which yields reworked corals of the RC0 Zone. Note that in the deep-water facies of Germany, the earliest *C. priscum* are recorded just above the Hangenberg event, i.e. in the Upper *praesulcata* Conodont Zone (Weyer, 1994), and therefore, just below the Devonian-Carboniferous boundary.

9.4. Miospores

The Hastarian yields miospores assemblages assigned to four biozones of the miospore zonation established for the Tournaisian of southern Ireland (Higgs *et al.*, 1992). These are the VI (*Vallatisporites verrucosus - Retusotriletes incohatus*), HD (*Kraeuselisporites hibernicus - Umbonatisporites distinctus*), BP (*Spelaeotriletes balteatus – Rugospora polyptycha*) and PC (*Spelaeotriletes pretiosus – Raistrickia clavata*) zones. The base of the VI Zone is situated in the upper part of the Strunian Substage (latest Devonian).

9.5. Other fossils

Brachiopods are common in the Hastarian, but they need to be revised to be used for the stratigraphy of the substage. No goniatite was recorded in the Hastière Limestone.

10. Chronostratigraphy

Figure 6 gives the main chronostratigraphical elements for the Hastarian in southern Belgium. More details about the stratigraphical correlations outside Western Europe are given in Poty *et al.,* (in press).

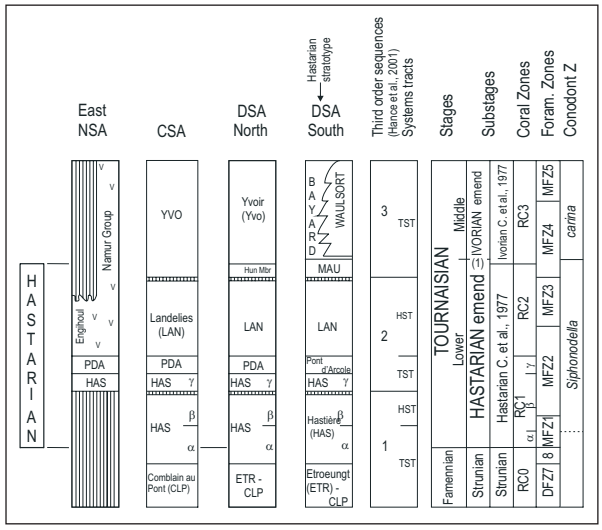

Figure 6. Stratigraphy of the Hastarian Substage in southern Belgium. (1) See comment in text. LST, lowstand systems tract; TST, trangressive systems tract; HST, highstand systems tract; FSST, falling stage systems tracts (sensu Plint & Nummedal, 2000).

11. Geochronology

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

12. Structural setting

The type area lies within the central and southern part of the Dinant Synclinorium, which is part of the Ardennes Allochton. The area is folded and faulted, but a complete succession can easily be reconstructed.

13. Reference sections in Belgium

The Hastarian is documented by numerous sections among which the following can serve as references:

- In the DSA: Gendron-Celles (Groessens & Noël, 1977), Anseremme (Conil, 1968; Van Steenwinkel, 1980, 1984, 1990, 1993; Casier *et al.*, 2004), Denée drillhole (Conil *et al.*, 1981).
- In the CSA: Hoyoux and Ourthe Valleys (Groessens, 1975)
- In the NSA: Landelies (Mamet *et al.*, 1970; Conil *et al.*, 1976 ; Groessens, 1975 ; Delcambre & Pingot, 2000).

14. Main contributions

Delépine, 1911; Demanet, 1958 ; Conil (coll. Lys & Paproth), 1964; Groessens, 1975; Conil *et al.*, 1977; Paproth *et al.*, 1983; Gilissen, 1988.

15. Acknowledgements

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