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SHORT NOTE

A MAGNETIC SUSCEPTIBILITY CURVE FOR THE DEVONIAN LIMESTONE FROM BELGIUM

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(2 figures)

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ABSTRACT. This paper proposes a first magnetic susceptibility (MS) curve for the Devonian Limestone from Belgium. A comparison with a large scale depositional model shows the complex relations between MS and paleoenvironments. Other Devonian-scale MS curves from other parts of the world are necessary to constraint these relations.

KEYWORDS. Magnetic susceptibility, Devonian, limestone, Belgium.

1. Introduction

Magnetic susceptibility (MS) data are generally used to develop high-resolution, global correlation of marine sedimentary rocks (e.g. Crick et al., 1997). Without strong climatic or tectonic changes, MS in marine rocks is supposed to be related to sea level variations (Ellwood et al., 1999). A sea level fall increases the erosion of the exposed continental masses and leads to higher MS values in the sediment (Crick et al, 1997).

However, very few studies propose a link between MS and depositional environment (Borradaile et al., 1993; da Silva & Boulvain, 2006; da Silva, Mabille & Boulvain, 2009). In Palaeozoic rocks, this problem was investigated at relatively low scales (5th to 3rd order sequences - meter to tens of meters) through detailed study of Frasnian and Eifelian sections (da Silva & Boulvain, 2002, 2006; Hladil et al, 2005; da Silva et al., 2009; Mabille & Boulvain, 2007, 2008; Mabille et al., 2008). The aim of this short note is to question the link between MS and environmental parameters at a larger scale (2nd order –hundreds of meters) by providing a first MS curve for the Devonian Limestone from Belgium.

The present work integrates data from Uppermost Eifelian to Late Frasnian limestone along the southern border of the Dinant Synclinorium. The Eifelian-Givetian boundary is characterized by a mixed detrital-carbonate outer ramp, followed by a well-developed Givetian carbonate platform with environments ranging from external crinoidal facies to stromatoporoid-dominated biostromes and lagoonal facies. After the demise of the carbonate factory at the beginning of the Frasnian and the

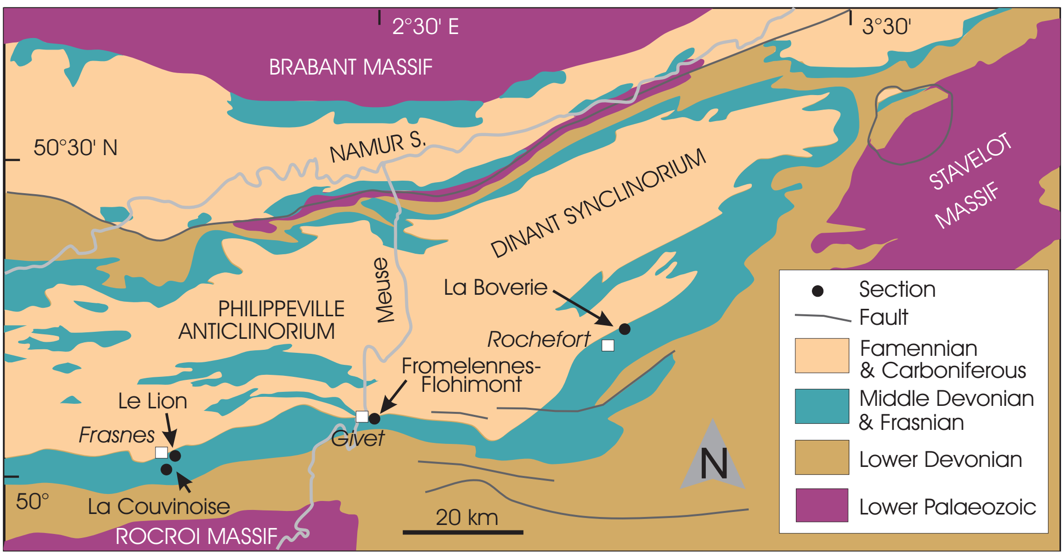

Figure 1. Geological context and location of sections.

generalization of argillaceous sedimentation, the Middle Frasnian is characterized by the succession of three carbonate mound levels, starting in quiet aphotic water and ending in shallow zone. All these outcrops (Fig. 1) and other time-equivalent sections have been the subject of detailed sedimentological studies (Boulvain, 2007; Boulvain et al., 2005, 2009; da Silva & Boulvain, 2004; da Silva et al., 2009; Mabille & Boulvain, 2007) which provide a good knowledge of facies (environmental interpretation and evolution) and sea level variations.

2. Methods

In this study, the microfacies analysis comes from the detailed bed-by-bed study of 4 outcrops (Fig. 1) and the petrographic observation of more than 1000 thin sections. For easy comparison of depositional environments through the entire composite section, all the microfacies were reported to 4 main facies belts: external ramp and platform (I); reef mound (II); reef (III) and internal platform (IV). For each sample, MS measurements were performed on our KLY-3 kappabridge device (cf. da Silva & Boulvain, 2006). Three measurements were made on each sawn samples (max 2.5-2.5cm) weighed with a precision of 0.01g and the data represent an average of the three measurements.

3. Results

The mixed carbonate ramp close to the Eifelian – Givetian boundary can be divided in different environments ranging from an outer ramp to an external platform (Mabille & Boulvain, 2007) (Fig. 2). It corresponds in the La Couvinoise quarry (0-90 m) to a succession of argillaceous mudstones, wackestones to packstones with crinoids and brachiopods (outer ramp, I), rudstones with debris of stromatoporoids, tabulate and rugose corals (mid ramp, I), followed by packstones and grainstones with peloids (external platform, fore-reef, III). The general evolution of the mean MS corresponds to a global decrease of values from the outer ($1x10^{-7}$ m^3/kg) to the mid ramp ($0.5x10^{-7}$ m^3/kg), followed by a slight increase for the external platform. A comparison of MS and facies evolution curves shows a relative opposition (Fig. 2).

The Fromelennes-Flohimont section exposes the largest part of the Givet Group (Boulvain et al., 2009). The Trois-Fontaines Formation starts with peloidal grainstones showing frequent hummocky cross stratifications (100-143 m), capped by five levels of paleosols. This prolongs the Hanonet Formation and shows very low MS values (0 10^{-7} m^3/kg), excepted for the paleosols. The upper part of the Trois-Fontaines Formation (143-170 m) is characterized by wackestones and mudstones with poorly diversified fauna and flora, attesting lagoonal conditions (IV). MS first shows very high values (3.5 10^{-7} m^3/kg), then decreases towards relatively low values (0.5 10^{-7} m^3/kg). MS and microfacies curves show comparable trends.

The lower part of the Terres d'Haurs Formation (170-208 m) is dominated by argillaceous wackestones with crinoids and brachiopods in an open ramp environment (I). MS signal rises and oscillates around moderately high values (1 10^{-7} m^3/kg). The upper half of the Terres d'Haurs Formation (208-237 m) shows an alternation of crinoidal wackestones and coral-stromatoporoid floatstones. A shallowing-upwards trend is obvious and is reflected by the lowering of MS values, oscillating from fairly high values (1.5 10^{-7} m^3/kg) to low values (0-0.5 10^{-7} m^3/kg) at the top of the lithostratigraphic unit.

The Mont d'Haurs Formation (237-415 m) shows a background of open-marine crinoidal wackestones interrupted by beds of coral-rich debris-flows coming from a near reef barrier (III). The upper part of the formation marks a change to more internal facies (III-IV), before a final deepening upwards trend. MS signal is very low (0 10^{-7} m^3/kg) but rises towards the top of the formation (0.5 10^{-7} m^3/kg). This is in opposition with the facies curve.

The lower part of the Fromelennes Formation (415-532 m) is characterized by dendroid stromatoporoid-rich carpets alternating with varied restricted facies like peloidal packstones, ooid grainstones and algal wackestones (IV). MS signal is low (0.2 10^{-7} m^3/kg) but oscillating. The upper part of the Fromelennes Formation (532-561 m) marks the return to more open-marine conditions (III), together with a rise in MS, reaching 1 10^{-7} m^3/kg. The opposition between the facies and the MS curves appears again clearly.

The La Boverie quarry shows a very complete section of the Frasnian starting from the base of the Moulin Liénaux Formation up to the Neuville Formation. The general context is of an external platform (I) with a succession of three mound levels (II) (Boulvain & Coen-Aubert, 2006).

The base of the Moulin Liénaux Formation (583-604 m) is characterized by floatstones with tabulate corals, crinoids and stromatactis. It is a classical mound facies, developed below the wave action zone. MS signal is very low, close to 0 10^{-7} m^3/kg. The upper part of the mound (604-652 m) shows shallow lagoonal facies with dendroid stromatoporoid rudstones and lithoclastic fenestral grainstones. MS signal rises slightly, close to 0.2 10^{-7} m^3/kg.

The second mound level (652-685 m) shows first argillaceous crinoidal wackestones, then lithoclastic grainstones and stromatoporoid rudstones. This short succession reflects a shallowing upwards sequence. MS signal first rises up to 0.5 10^{-7} m^3/kg, then decreases to low values, before rising again to 0.5 10^{-7} m^3/kg near the top of the mound.

The base of the Grands Breux Formation (685-701 m) consists of shale and argillaceous limestone, progressively enriched upwards in rugose corals. MS signal reaches 0.7 10^{-7} m^3/kg and decreases upwards.

Then the Grands Breux Formation includes the third Frasnian mound level. The lower part (mound facies, 702-728 m) is characterized by floatstones with stromatoporoids,

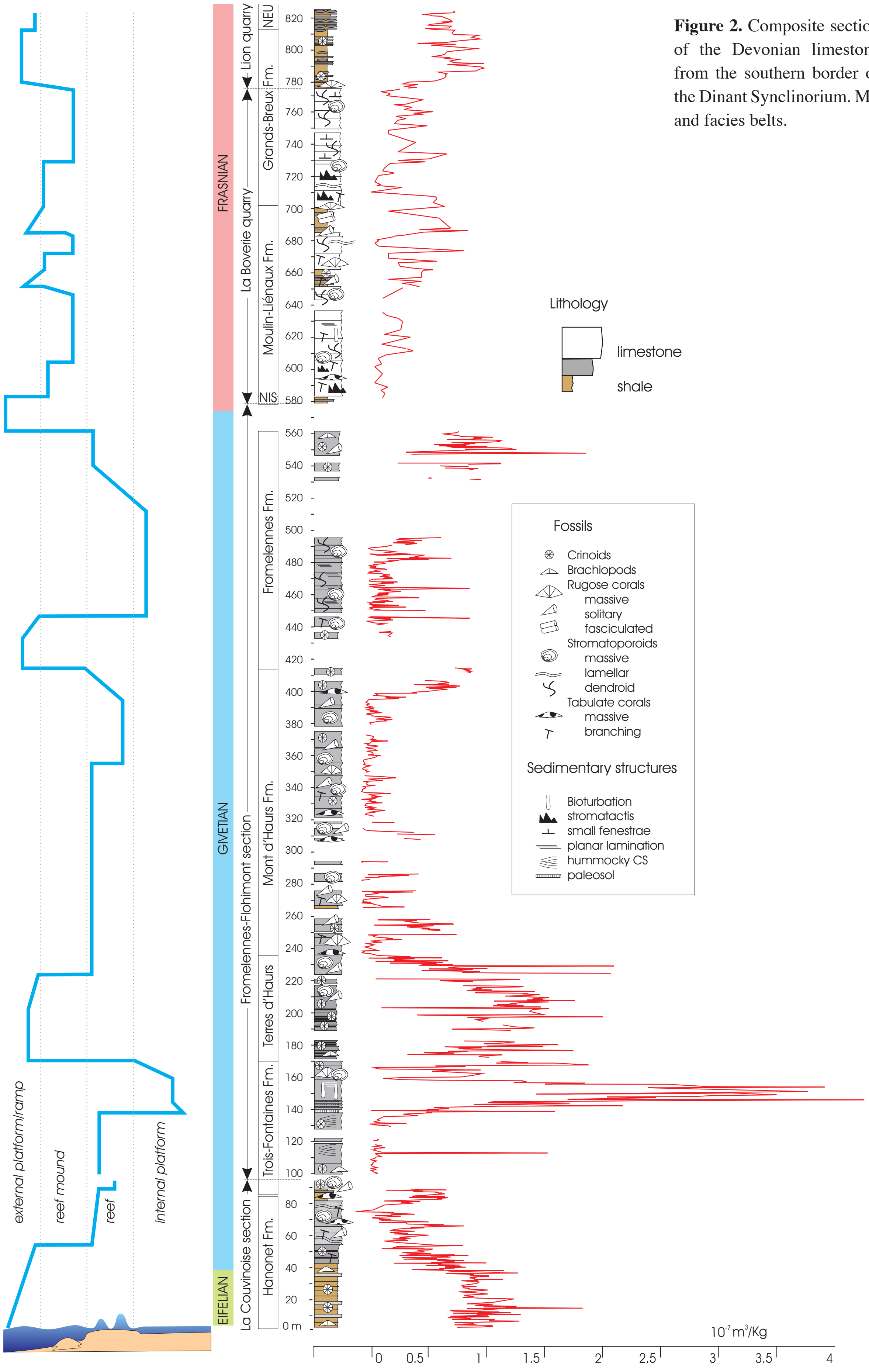

Figure 2. Composite section of the Devonian limestone from the southern border of the Dinant Synclinorium. MS and facies belts.

stromatactis and tabulate corals, whereas the upper part (728-775 m) shows stromatoporoid rudstones and fenestral limestone. MS signal oscillates around 0.5 10^{-7} m^3/kg, with again relatively higher values in the shallowest upper part of the mound.

The upper part of the Grands Breux Formation (775-811 m) and the Neuville Formation (811-825 m) were studied along the Lion southern access trench near Frasnes (Boulvain, 1993). Facies vary from shale to argillaceous wackestones, typical of an external platform setting (I). MS signal shows relatively high values, around 0.8 10^{-7} m^3/kg.

4. Discussion

This Devonian MS curve shows major trends: a decrease of the MS signal during the end of the Eifelian/beginning of the Givetian, A rapid increase of the MS signal during the lower Givetian, decreasing up to low values during the large part of the stage and rising up again before the Givetian/Frasnian boundary. The Frasnian MS signal is globally rising from base to top, with higher values for shale and argillaceous intervals. Buildup facies show higher values for the upper lagoonal unit than for the lower mound facies.

The MS signal in marine sedimentary rocks is carried mainly by detrital minerals (mostly ferromagnetic and paramagnetic minerals) whose concentration is related to the lithogenic fraction (continental contribution). This lithogenic input could be related to eustatic, climatic and tectonic variations (Crick et al., 1997). Theoretically, the MS curve increases during a sea level drop, shows high values during low level, decreases during a rising sea level and shows low values during high level. The present study, covering a large part of the Devonian Limestone, shows a relatively clear opposition of the MS and the distal-proximal curves, deduced from the microfacies record (Fig. 2). This opposition suggests that a deepening trend corresponds to a rising MS, in contradiction with the Crick model. A noticeable exception to the relative opposition between the two curves corresponds to the Lower Givetian paleosols that record very high MS values, in agreement with the model and with other observations (da Silva & Boulvain, 2002).

5. Conclusion

This first analyse of long-term trends in Devonian MS from Belgium suggests a correlation between relative bathymetry deduced from facies analyses and the MS signal. This relationship seams to be opposite to what could be expected from theoretical model (e.g. Crick et al., 1997). This was already observed for short-term variations in Eifelian-Givetian sediments from the Hanonet Formation (Mabille & Boulvain, 2007). To be interpreted, this result must now be compared with other long-term Devonian MS curves in different areas from the world.

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