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WAULSORTIAN

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(2 figures)

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ABSTRACT. The term "Waulsortian" was introduced in 1863 for a particular assemblage of limestones in the Lower Carboniferous of Belgium. In 1883 it was given the status of a stage, ranking equally with Tournaisian and Visean. Within five years, this was shown to be invalid because the Waulsortian limestones demonstrably passed laterally into rocks of upper Tournaisian and lower Visean age. Thereafter, "Waulsortian" has been used as a facies term, extending internationally as limestones of closely similar age and character have been discovered outside Belgium.

In Belgium, the massive Waulsortian limestones were originally interpreted as reefs, rich in stromatoporoids and bryozoans. However, by the early 20th century the so-called stromatoporoids were shown to be sparry precipitates, and the "reefs" were acknowledged to be unlike modern organic reefs in several important respects. Since that time, the interpretation has evolved so that Waulsortian limestones are now regarded as carbonate mud-mounds characterised by microbially mediated muds. The mounds were colonised by a range of organisms indicating growth in marine environments extending from depths of several hundred metres to relatively shallow, photic waters.

KEYWORDS: Carboniferous, Mississippian, Waulsortian, Belgium, stratigraphy, facies, limestones, mud-mounds.

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1. Introduction

Names: Waulsortian (English), Waulsortiaan (Dutch), Waulsortium (German), Waulsortien (French).
The term "Waulsortian" has not been validly applied to a stage, in Belgium or elsewhere, since 1888. Instead, it has acquired international status as a facies term applied to a range of carbonate buildups which were particularly well-developed during late Tournaisian times.

2. Origin of "Waulsortian" as a stratigraphic term

The "Assise de Waulsort" was introduced by Edouard Dupont (1863) as one of six stratigraphic units comprising the Carboniferous Limestone of Belgium. It took its name from the village of Waulsort, which is situated along the River Meuse about 7.5 km SW of Dinant. Generally massive in outcrop, the rocks were distinguished lithologically as "... *un calcaire grenu, à teinte ordinairement pâle. Son caractère pétrographique principal est de contenir des noyaux de spath radié, entourés d'un bord bleu foncé*". Dupont explained the discontinuous distribution of the Assise by the presence of «lacunes».

3. The Waulsortian as a stage

The existence of such lacunes was soon contested by other geologists who showed that the Waulsortian rocks could be traced laterally into stratified rocks of different aspect. Accordingly, when describing the geological map of the Dinant area, Dupont (1883a) modified his scheme and divided the Carboniferous Limestone into three stages: in stratigraphic order, Tournaisian, Waulsortian and Viséan. Thus defined, the "Etage waulsortien" included the (massive) Waulsortian rocks of his original description together with stratified lateral equivalents. No specific type locality was defined, but the type area has been generally considered to be the Pauquys crags, on the left bank of the River Meuse north of Waulsort, extending for about 1 km from the old railway station of Waulsort north-eastwards through the Roche al'Rue (Fig. 1). Unfortunately, neither the base nor the top of the complete Waulsortian succession is exposed there.
Because of the characteristic "noyaux de spath radié, entourés d'un bord bleu foncé", which he interpreted as stromatoporoids, and their association with abundant fenestellid bryozoans (Fig. 2A), Dupont (1883b) interpreted the massive Waulsortian rocks as reefs.

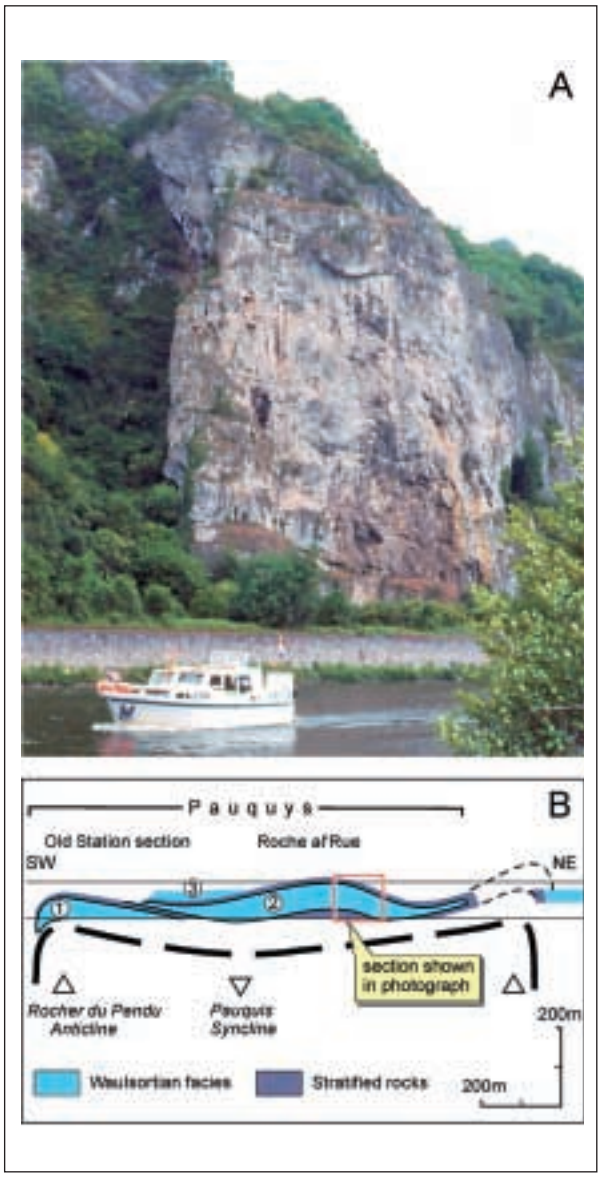

Figure 1. A. The Pauquys site: one of the cliffs in the north-eastern part of the Roche al'Rue exposing a section through one of the "reefs" (section F of Dehantschutter & Lees, 1996). The enveloping stratified rocks (mainly cherty dolomites) can be seen at the top and bottom of the cliff.
B. Cross section of the Pauquys area showing that it comprises parts of 3 superposed "reefs" (first recorded by H. Dupont, 1969, fig. 9). The position of the exposure illustrated in A is outlined.

4. The Waulsortian Stage discredited

During an excursion to the Dinant area in 1888, de la Vallée Poussin (1890a, 1890b) showed that the Waulsortian rocks passed laterally into the upper part of the Tournaisian and the lower part of the Viséan (as then defined). Clearly, therefore, the Waulsortian could not be a stage.

5. Why is the term "Waulsortian" still used?

In 1895 (p.231 *et seq*), H. de Dorlodot, who contributed much to the understanding of these rocks in Belgium, referred to the "Faciès de Waulsort" and thus initiated use of the term "Waulsortian" with no chronostratigraphic implications. He regarded as Waulsortian both the massive "reef" limestones and the laterally equivalent stratified limestones and dolomites if they differed from the normal regional facies at the stratigraphic level concerned.
More widespread use of this terminology was soon encouraged by the discovery, outside Belgium, of several examples of limestones with similar lithological character, macrofauna and stratigraphic position. Excluding that part of France immediately adjacent to the Belgian type area, the first reference appears to be that of Douglas (1909) who described some Lower Carboniferous limestones from County Clare, Ireland, and compared them closely with the Belgian Waulsortian. Then Vaughan (1915) noted that the lowest "knoll-reefs" of the Clitheroe-Bolland region of northern England had the same fauna as the Waulsortian "reefs" he had visited in Belgium. In the 'Discussion' to Vaughan's paper, Dixon went further and stated that the "Waulsortian limestones exposed in the Meuse Valley near Hastière agreed exactly with the Clitheroe knoll-limestones, not only in their fauna and in their more obvious lithological features.... but also in the peculiarities of their minute structure, peculiarities which were not met with in ordinary limestones". Dixon later (1921) recorded a bryozoan knoll-reef of Waulsortian facies from Pembrokeshire in South Wales.
Since that time, limestones of Waulsortian character have been encountered in many parts of the world, mainly concentrated in the late Tournaisian (see Lees & Miller, 1995, for localities and stratigraphic range). Some of those accumulations are very large, notably in Ireland where they range up to 1000 m in thickness and originally extended over an area of about 30,000 km^2. The term "Waulsortian" has thus become firmly entrenched in the scientific literature as a major sedimentary facies package. Admittedly, it is not ideal : its continued use has been criticised because it does not "immediately convey a particular form, composition or genesis" (Bridges *et al.*, 1995, p.173) and because it has sometimes been misapplied (details in Lees, 1988). However, the terminology is acknowledged internationally (e.g. Bolton *et al.*, 1982) and no adequate substitute has yet been proposed, so there is no reason to discontinue its use provided it is carefully applied (for a working definition, see Lees & Miller, 1995, p.259).
When thick and laterally extensive, Waulsortian buildups require recognition as lithostratigraphic mapping units. They are given formation status both in Ireland (e.g. as "Waulsortian Limestones"; Sleeman & Pracht, 1999) and in Belgium (see below).

6. Developments in Belgium

Early in the 20th century, de Dorlodot recognised that the massive Waulsortian rocks included lithologies other than the classic "calcaire pâle, à veines bleues" with numerous fenestrate bryozoans. He distinguished, in addition, limestones that were "subgrenu ou subcompact", and dolomites (see de Dorlodot, 1909, for full field descriptions). These distinctions were later maintained and extended by Lees *et al.* (1977) who recognised 3 massive limestone facies: "veines bleues", biomicrite, and crinoidal. Since de Dorlodot's time, the Waulsortian terminology has become mainly restricted to the massive rocks, the stratified lateral equivalents (e.g. the Bayard Formation) being regarded as "peri-Waulsortian".

Waulsortian limestones and dolomites are now classified as the Waulsort Formation, a brief description of which is given by Poty *et al.* (2001, p.80). The "Formation de Waulsort" mapped on the "Carte géologique de Wallonie: Hastière – Dinant" (Delcambre & Pingot, 1993) is an example of its application. Hance *et al.* (2001) position the formation in the framework of Dinantian sequence stratigraphy.

As regards recent sedimentological studies, the Waulsortian rocks of the "type area" near Waulsort were reassessed by Dehantschutter & Lees (1996), while Lees (1997) analysed the relationships between the Waulsortian buildups and the surrounding sediments of the Dinant area during the major environmental changes that occurred through late Tournaisian times.

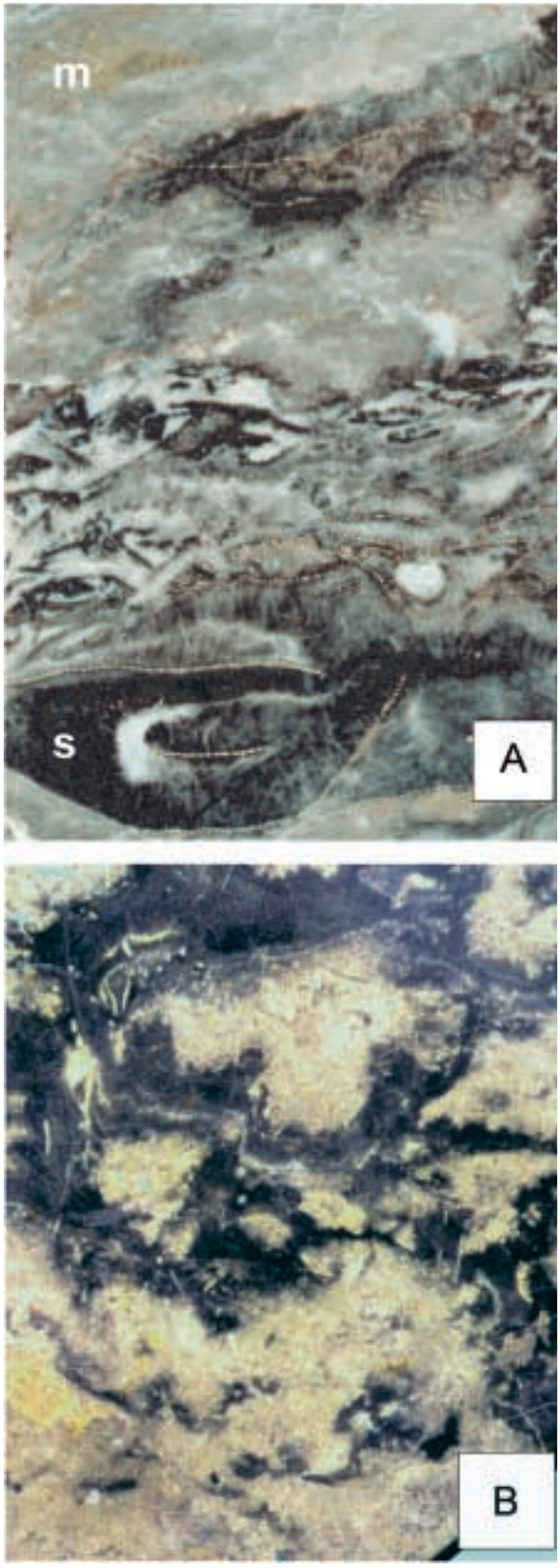

Figure 2. A. Polished surface of "classic" Waulsortian limestone showing the fine-grained component rich in carbonate mud (m) and sparry masses of fibrous calcite cement (mainly black and white) that grew from the surfaces of fenestrate bryozoan fronds (here seen in cross-section as rows of dots). The large sparry mass 's' recalls the "noyaux de spath radié" of Dupont's original description. Sample from Gendron-Celles. White square is 1 cm x 1 cm.
B. Polished surface of a selectively dolomitised sample from the Dinant area showing the respective proportions of fine-grained sediment (originally wackestone, now dolomite and yellowish in colour) and sparry calcite (mainly blue-black, cavity-filling cement). White square is 1 cm x 1 cm.

7. Evolution of genetic interpretation

Edouard Dupont's "reef" interpretation has been progressively modified over the years. Already in 1911, de Dorlodot argued that Dupont's "stromatoporoids" were not fossils, and that the Belgian Waulsortian "reefs" were unlike modern coral/algal reefs in structure, composition and depositional environment. However, it was not until the 1950s that sedimentological work in Ireland showed that Waulsortian limestones, although rich in skeletal debris, did not possess a rigid skeletal framework and were largely composed of carbonate mud associated with spar-filled cavity systems (Lees, 1961, 1964). The fine-grained nature of the limestones and the geometry of their major depositional structures prompted replacement of "reef" terminology by "carbonate mudbank" (a term essentially synonymous with "mud-mound", introduced later). Studies on the depositional fabrics have since shown that the Waulsortian muds, probably microbial in origin, were initially soft but had gel-like cohesion, allowing steep depositional slopes. Early diagenetic fabric changes were extensive, involving the formation and modification of complex cavity systems, redistribution of multi-generation carbonate muds, and rapid induration caused by increased coherence of the muds and precipitation of (fibrous) cements in cavities (details in Lees & Miller, 1995).

Because of severe, late diagenetic alteration (Fig. 2B) and tectonic deformation, Belgian outcrops contributed little to that type of sedimentological study. However, the particular character of the Belgian Waulsortian exposures (often "2-dimensional", on steep valley walls cross-cutting the regional strike) has encouraged systematic sampling through measured sections followed by detailed petrographic analysis. This revealed unexpected heterogeneity (Lees *et al.,* 1985), notably the presence of a range of skeletal grain-types divided, for convenience, into four assemblages. These provided evidence that the sediments formed over a considerable range of water depth, extending from perhaps 300 m upwards into the photic zone, but probably excluding very shallow, agitated waters. Later investigation (Lees & Miller, 1985) discovered similar features in mud-mounds of comparable type and age elsewhere in Europe and North America, so four depth-related Waulsortian Phases were distinguished (A, the deepest, to D, the shallowest) corresponding to the four grain-type assemblages.

The buildups developed in a ramp setting in Belgium (Lees, 1982; Hance *et al.,* 2001) as in many other areas (e.g. Ahr & Stanton, 1996; Jeffery & Stanton, 1996).

A more extended review of Waulsortian sedimentology was provided by Lees & Miller (1995).

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