International Union of Geological Sciences
Commission on Stratigraphy

Subcommission on Carboniferous Stratigraphy (SCCS)

FAMENNIAN REEFAL BEDS IN THE VESDRE SYNCLINE (EASTERN ARDENNE, BELGIUM)

GUIDEBOOK

by

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Battice
THIMISTER-CLERMONT
HERVE
Melen
Cerexhe-Heuseux
Evegnée-Tignée
Queu-du-Bois
Retinne
Micheroux
Ayeneux
SOUMAGNE
Chaineux
Andrimont
DISON
Petit-Rechain
Grand-Rechain
Xhendelesse
Soiron
Lambermont
VERVIERS
Stembert
LIMBOURG
Goé
Dolhain
BAELEN
Bilstain
Renoupré
OLNE
Forêt
TROOZ
Nessonvaux
Fraipont
Cornesse
Wegnez
Ensival
PEPINSTER
Heusy
La Boverie
Jehanster
JALHAY
Andoumont
Banneux-Notre-Dame
Les Forges
Juslenville
THEUX
Polleur
Oneux
Louveigne
Hotchamps
La Reid
Sougné-Remouchamps
AYWAILLE
Nonceveux
Quareux
Vert-Buisson
Desnié
SPA
Creppe
Niveze
Sart
FRANCORCHAMPS
Francorchamps
Malchamps
Tiège
Arbespine
Balmoral
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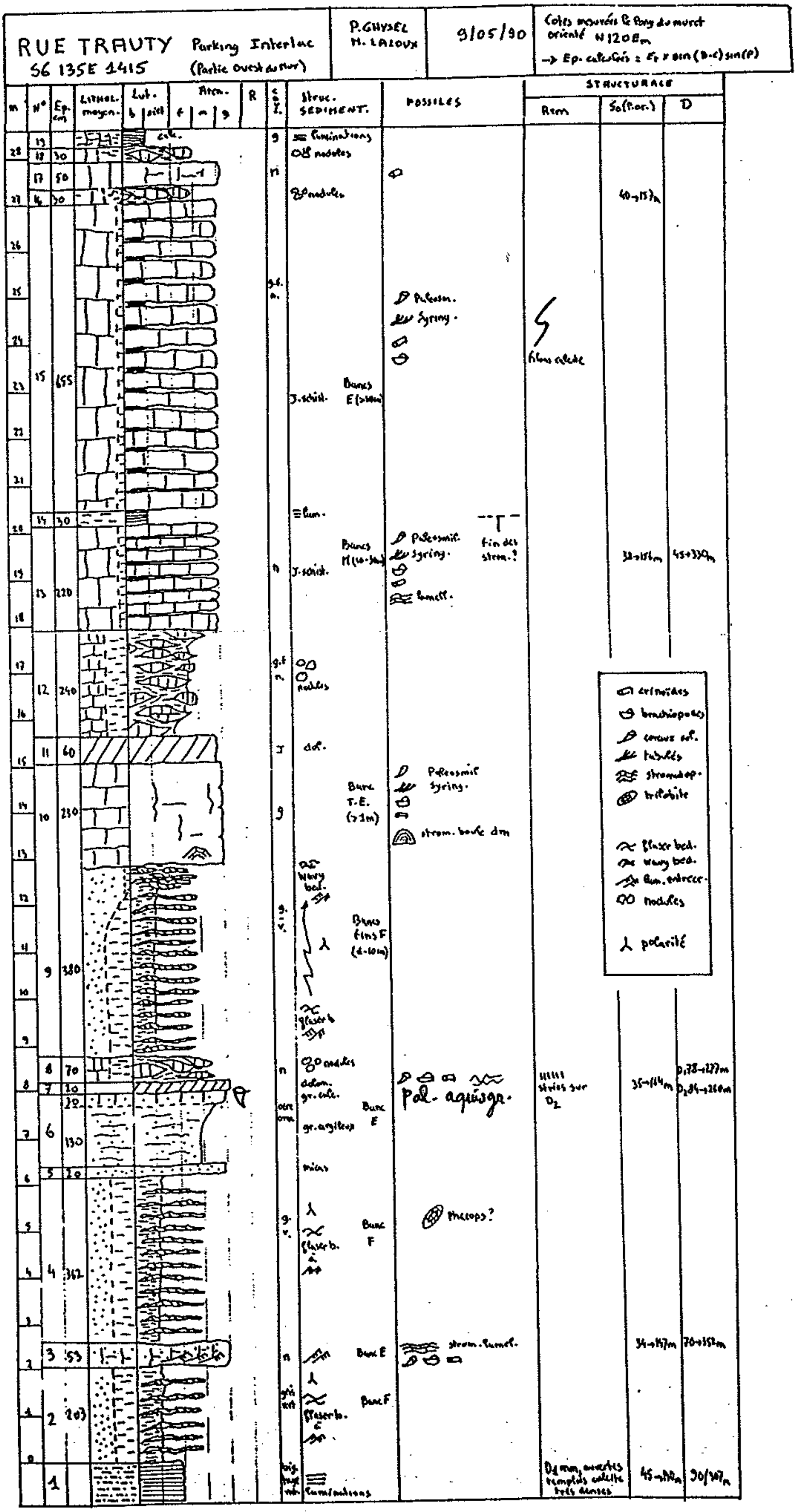
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H. LALOUX
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LITHOL. moyen.
Lut.
Aren.
R
Struc. SEDIMENT.
FOSSILES
STRUCTURALE
Rem
D
crinoïdes
brachiopodes
tabulés
trilobite
flaser bed.
wavy bed.
nodules
polarité

Fig. 0

The "Strunian" biostromes of the Vesdre area

leader : E. Poty

Stop 1 Trauty street section at Dison.

This section displays the "biostromes" defined by CONIL (1968) in the Strunian of the Vesdre area. The two lower "biostromes" are interbedded in sandstones and correspond to sandy limestones with corals and stromatoporoids. The third ("main biostrome") is composed of 15 m of boundstones with stromatoporoids and corals (mainly *Palaeosmilia aquisgranensis*). All the coral are typical of the RC0 zone. The D/C boundary is not visible here but is probably situated at some meters above the last bed of the section.

Miospores in the lowermost shaly beds

P. Steemans & M. Streel

The lowermost shaly beds visible in this section contain *Retispora lepidophyta.* The biometric analysis of the population of this species reveals that specimens with a large size dominate in this shale .

It can be correlated, therefore, with the lowermost part of the Comblain-au-Pont Fm. in the reference section of Chanxhe in the Ourthe valley.

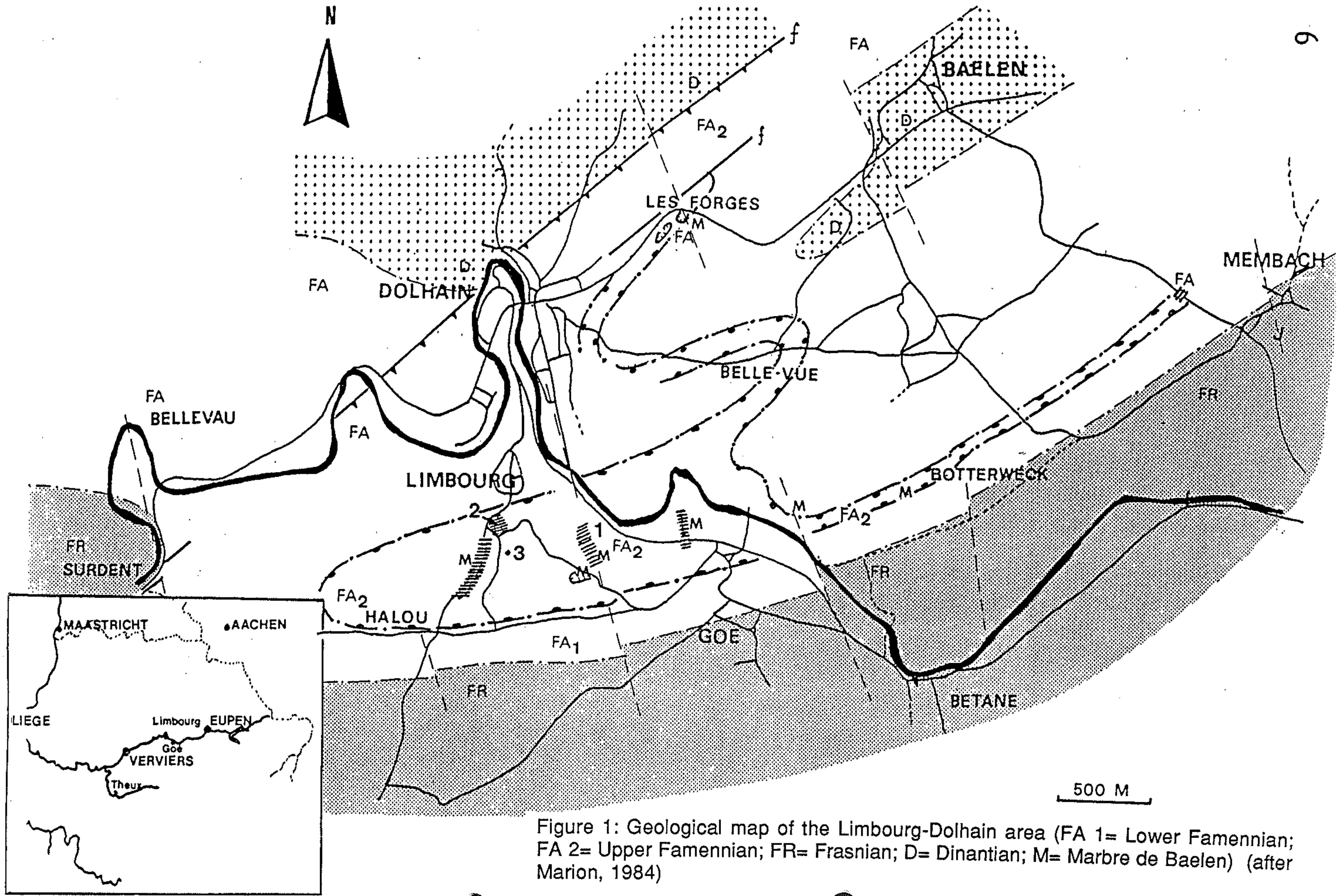


Figure 1: Geological map of the Limbourg-Dolhain area (FA 1= Lower Famennian; FA 2= Upper Famennian; FR= Frasnian; D= Dinantian; M= Marbre de Baelen) (after Marion, 1984)

STOP 2

Mid-Famennian cryptalgal-sponge crinoidal mud mounds and oolitic ironstones of the Limbourg-Dolhain area (Verviers Synclinorium, Eastern Belgium)

leaders: R.Dreesen and J.-M. Marion

1. The Baelen mud mound complex:

After the mass extinction of colonial reefs in the Ardennes at the Frasnian-Famennian boundary, (crypt)algal-sponge-crinoidal mud mounds suddenly appeared during mid-Famennian time (Early-Late *marginifera* zone) in the Verviers Synclinorium (eastern Belgium). These carbonate buildups represent the first reported occurrence of mud mounds in the latest Upper Devonian of Western Europe.

The mounding sites for the mud mounds (locally known as the "Marbre rouge à crinoïdes") are developed on a block-faulted basement (Marion, 1984; Dreesen *et al*, 1985; Thorez & Dreesen, 1986). Moreover, the location of the Baelen crinoidal mounds coincides with the northern extremity of a deep-seated fault, known as the Verviers-Trier dislocation (NNW-SSE directed transversal fault, Dvorak, 1973) (see figures 1 to 3)

The original thickness of this carbonate complex may have exceeded 150 m. A strong compaction and resulting pressure solution reduced its thickness to 90 m. The enveloping sediments are essentially micaceous siltstones and sandstones. Coeval formations include "back-mound" sandy nodular crinoidal-foraminiferal wackestones (the Souverain-Pré nodular limestones) and "fore-mound" micaceous sandstones with lenticular crinoidal pack/grainstones (inner sandy shelf setting ?) (see figure 4) (Dreesen, 1989).

It is suggested here that this "carbonate mud plug" within an essentially siliciclastic depositional setting (prodelta sands reworked by longshore currents) might be the result of *in situ* bacteria-triggered carbonate production. The abundance of those bacteria could have resulted from the availability of chemical nutrients through hydrothermal seafloor venting at the margins of the faulted blocks. The core of the mud mound complex is red-coloured due to the pervasive presence of hematite pigment. Analogous red-staining of Late Frasnian mud mounds in the Philippeville area (Dinant Synclinorium) has been related by some authors (e.g. Monty et al., 1982; Boulvain, 1989) to the effect of iron-depositing chemosynthetic bacteria (so-called "endostromatolites" or "ferro-oxydizing microstromatolites").

The "Baelen event" corresponds to a short-term eustatic sea level rise and a temporary waning of the siliciclastic supply interrupting the Famennian regressive megasequence on the Condroz shelf South of the London-Brabant Massif.
It correlates well with a minor onlap (expansion of the Pilot Basin) on the western U.S. platform (Johnson *et al*, 1985). Moreover, the "Baelen event" correlates with the first appearance of Clymeniina (post-Enkeberg event of House, 1985), and with an important migration of plurilocular foraminifera from eastern Europe (Bouckaert *et al*, 1976; Conil *et al*, 1986) (see fig. 5).
The Baelen limestone complex can be subdivided into several lithological units, the succession of which is cyclic (see figure 6):

"On peut signer un tableau
mais
jamais y mettre le mot fin."
Picasso

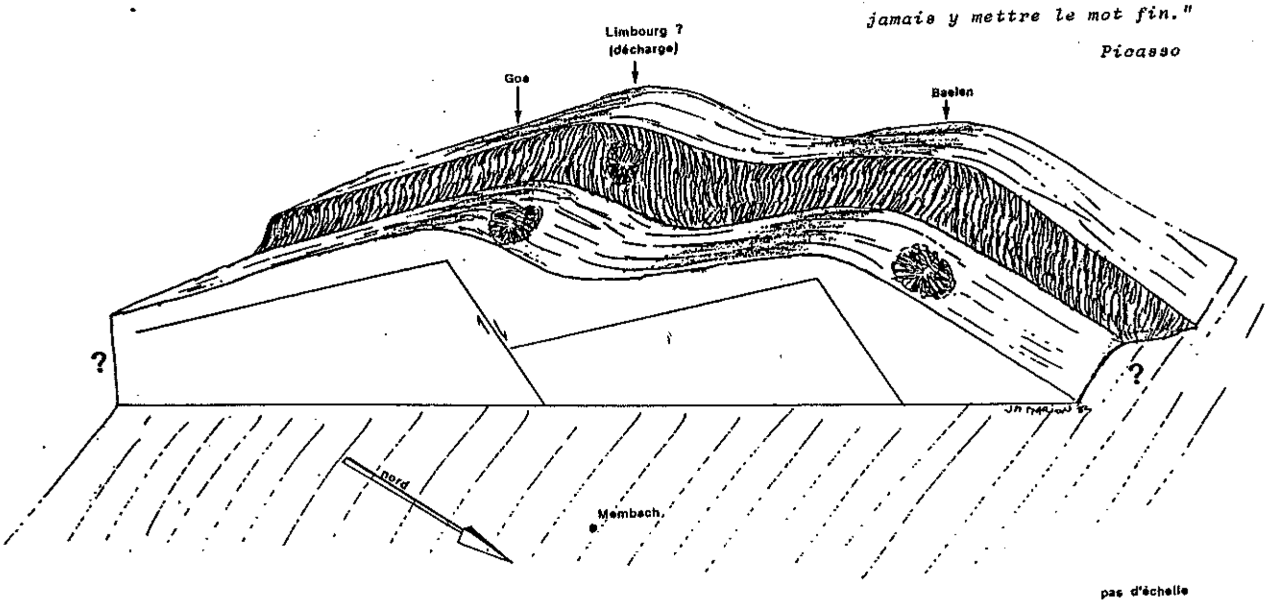


Figure 2: Mounding sites of the "Marbre de Baelen" related to block-faulted basement (Marion, 1984).

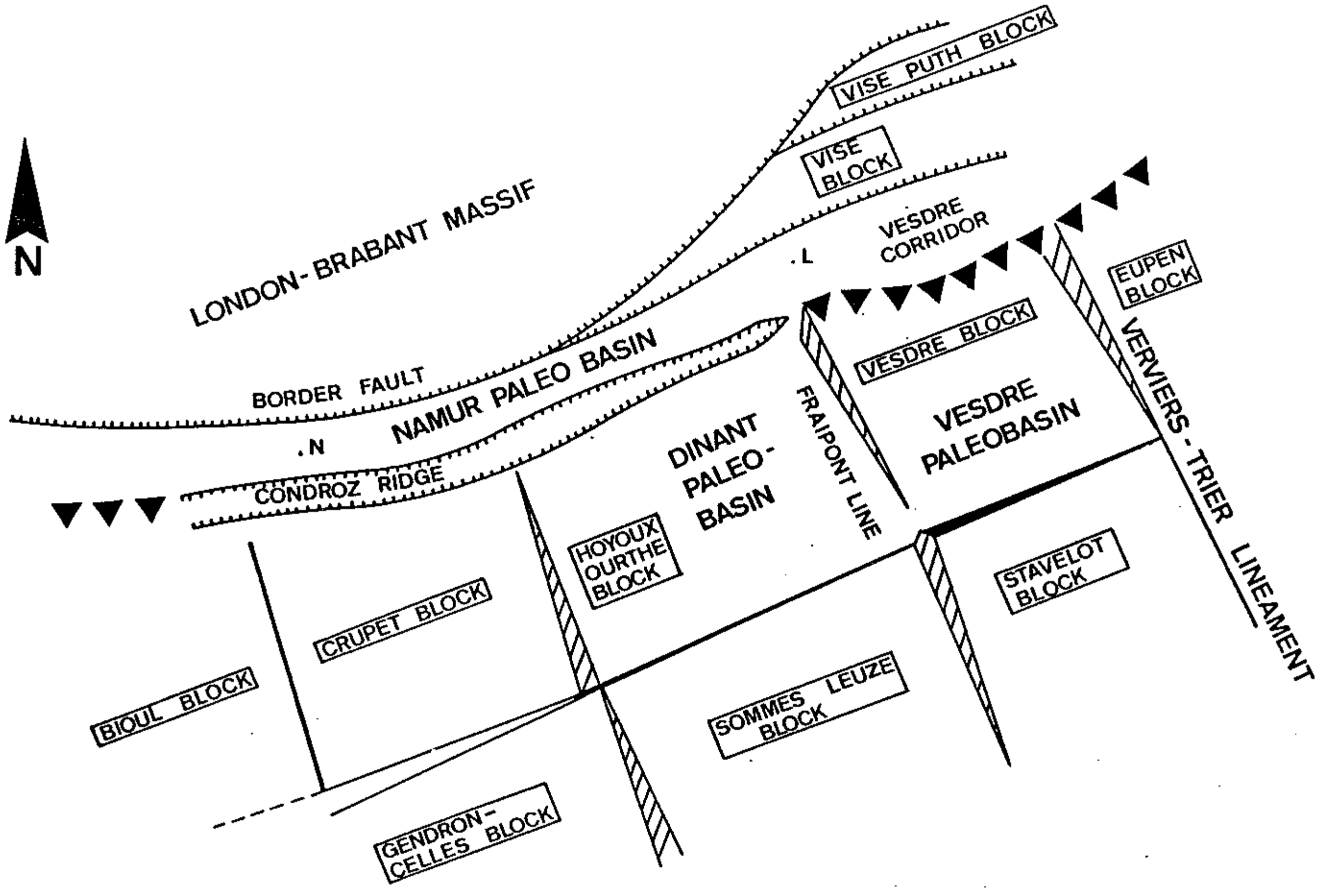


Figure 3: Intersecting fault pattern and fault blocks South of the London-Brabant Massif which are thought to have been intermittently reactivated during deposition of the Famennian strata (L=Liège; N=Namur; black triangles indicate future Midi Overthrust Thorez & Dreesen, 1986).

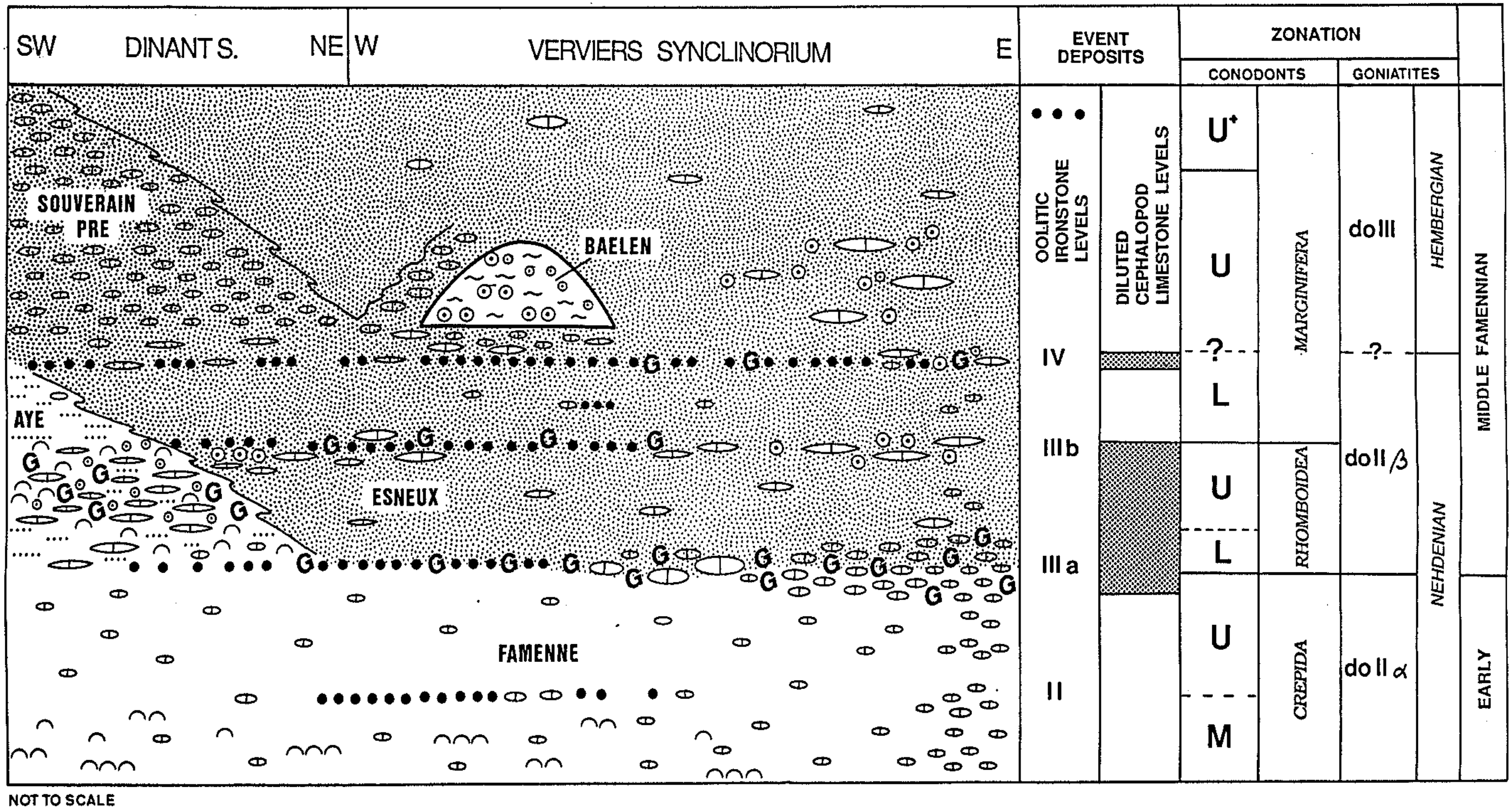
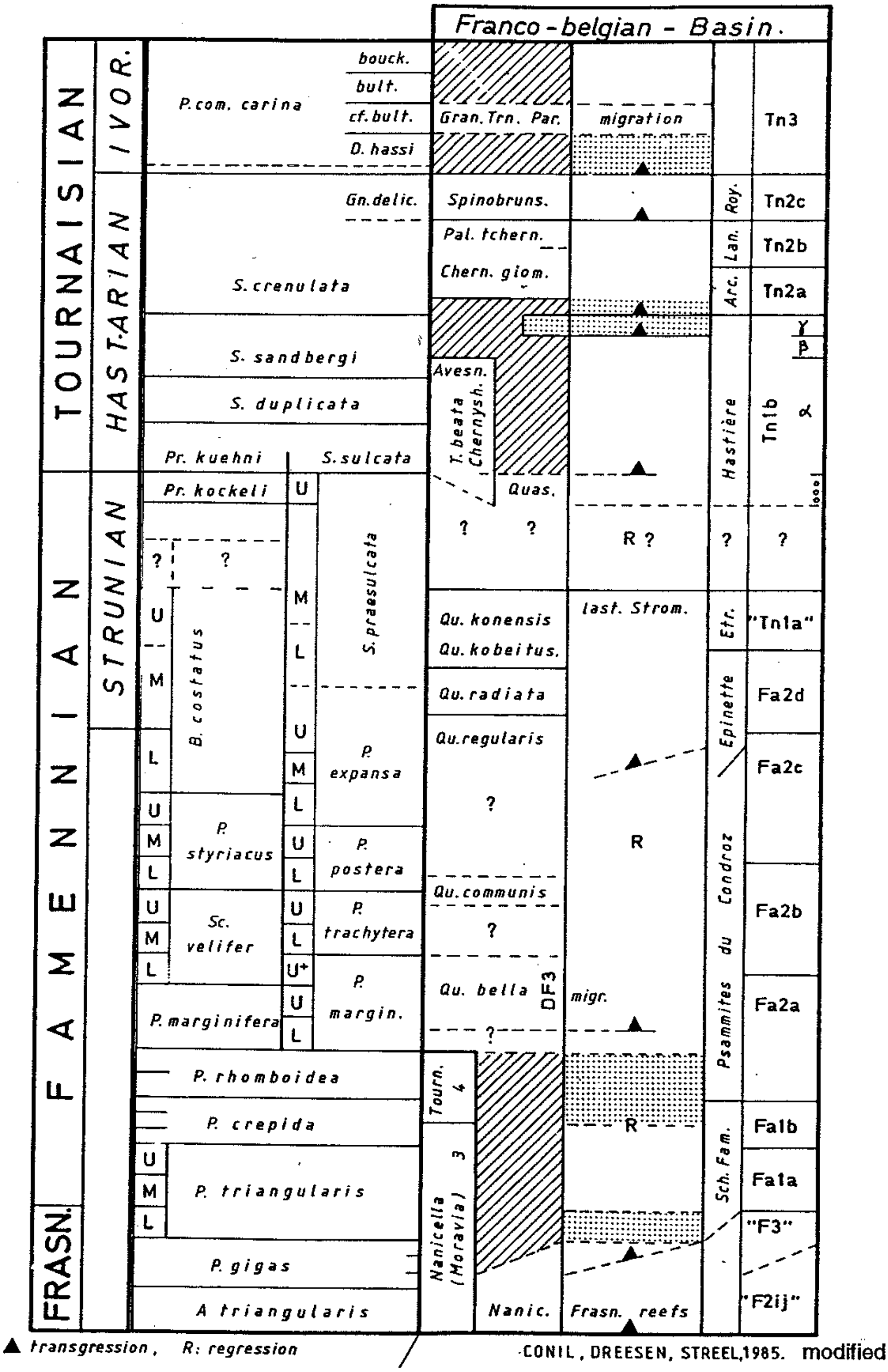


Figure 4: Schematic litho- and biostratigraphic correlation scheme of early to middle Famennian formations with special emphasis on event-stratigraphical marker beds (ironstones, cephalopod limestones) in eastern and southern Belgium (G = goniatites) (Dreesen, R., 1989 b).



Tentative correlation chart of . conodont and foraminifer Zones from the Franco-Belgian Basin : transgressions and extinctions are indicated by symbols (see legend below table), ecological events by stippled areas. The shaded areas represent intervals where foraminifera are absent or where only unilocular forms and *Earlandia* occur. Note : Gran-Trn. Par. : *Granuliferella, Tournayella, Paraendothyra.* (from Conil, Dreesen & Streel, 1985, unpublished).

Figure 5: Tentative correlation chart of conodont and foraminifer zonations in the Late Devonian-Early Carboniferous of the Franco-belgian Basin. Stippled areas correspond to ecological events; shaded areas represent intervals without plurilocular forams (Conil, Dreesen & Streel, 1985 in: Conil et al, 1986).

- the transition to the underlying micaceous silt-and sandstones of the Esneux Formation is gradual (nodular and lenticular sandy wacke/packstones scattered in micaceous arkosic silt- and sandstones). These limestones enclose a mineralized hardground, which correlates with oolitic ironstone level IV, located near or slightly below the base of the Souverain-Pré Formation.
- the lowermost lithological units A and B are composed of alternating nodular and lenticular algal mudstones, bioclastic wackestones and packstones, embedded in calcareous, micaceous arkosic sandstones. *Issinella* and *Baculella* (a colonial Dasyclad ?) are the dominant skeletal grains.
- the succeeding "argillaceous" heterogenous units C,E and F consist of several microfacies types which alternate and grade into each other:
a. cryptalgal bindstones grading into spiculitic wackestones, and *b.* crinoidal-algal wacke/ packstones grading into crinoidal-foraminiferal grainstones and rudstones.
A strong compaction and resulting pressure solution produced characteristic stylolaminitic textures as well as "secondary" microfacies. The latter often contain silicified crinoid ossicles. The presence of both large and small hexactines and of dermal spicules and root tuft elements, suggest that the sponges must had lived *in situ* in the Baelen mounds.
- unit D, the core of the carbonate complex and the only part which has been quarried for ornamental stone (at least since the 18th century) consists essentially of the same, but less sand-contaminated carbonate microfacies types, with a higher frequency of *stromatactis* - bearing spiculitic mudstones. Early-diagenetic bacterially induced (?) spar-cementing of the cavities consolidated the mound during growth.

The Baelen carbonate complex represents a low-diversity (crypt)algal-sponge-crinoidal mud mound, which grew on a predestinated mounding site, in a quiet, relatively deep, open marine shelf setting, just below wave base but still within the photic zone (abundance of algae). Crinoids, hexactinellid sponges and dasyclads might have formed a suitable trapping and baffling agent, so that the mud banks developed as a self-propagating system.
The mounds intermittently reached the wave base and/or were affected by storm wave activity (occurrence of lenticular poorly-sorted crinoidal-foraminiferal grainstones and rudstones, locally displaying grading, cross bedding, brecciation and erosional unconformities). The mound has also possibly been affected by seismic activity as evidenced by the presence of large slumps in its upper part.

The diagenetic history of the Baelen mounds comprises several sequential stages, characterizing succeeding diagenetic events in marine, mixed marine-meteoric, meteoric phreatic zones, and burial conditions (see figure 7). These reflect an early diagenetic cementation, a late-diagenetic uplift with possible emersion and an important final compaction with related dissolution of the carbonates.

2. Oolitic ironstones

Clinton-type oolitic ironstones occur at distinct stratigraphical levels within shelf siliciclastics, South and Southeast of the London-Brabant Massif. Seven distinct oolitic ironstone levels have been recorded so far in the Belgian Upper Devonian. With the exception of the lowermost level (ironstone O at the base of the Frasnian) and the uppermost level (level V within the Strunian), the oolitic ironstones are

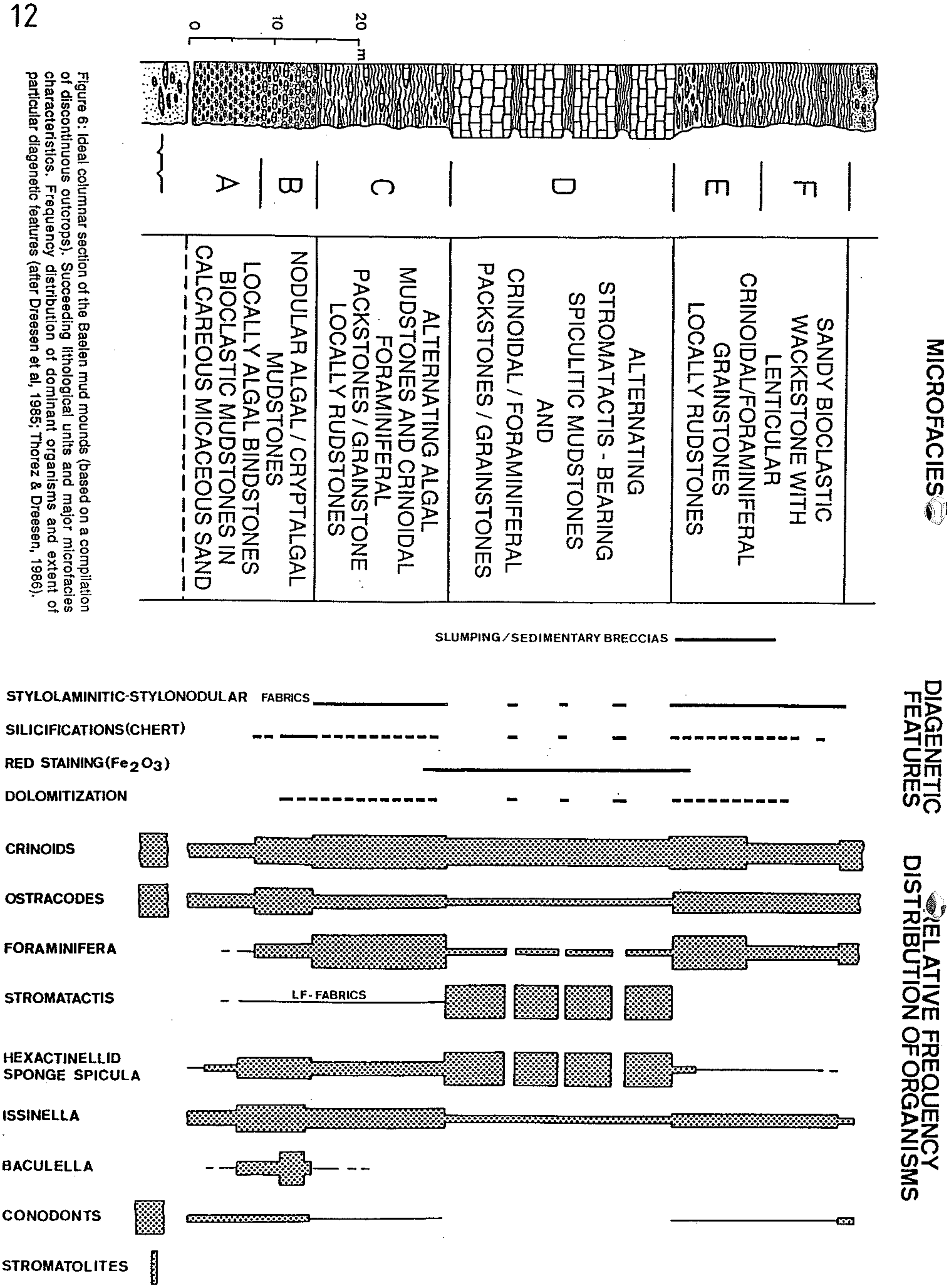


Figure 6: Ideal columnar section of the Baelen mud mounds (based on a compilation of discontinuous outcrops). Succeeding lithological units and major microfacies characteristics. Frequency distribution of dominant organisms and extent of particular diagenetic features (after Dreesen et al, 1985; Thorez & Dreesen, 1986).

concentrated within the lower half of the Famennian. It is striking that this interval, with the highest concentration of ironstones in Belgium, correlates with an interval in the hemipelagic to pelagic settings of the Rheinisches Sciefergebirge with red and green basinal shales enclosing numerous sandstone turbidites and metabentonites (volcanic tuffs) (Dreesen, 1982a, 1982 b) (Figure 8)

Although the ironstone beds are relatively thin (a few to a few tens of cm) they can easily be traced over tens of kilometers on the palaeoshelf. They represent excellent event-stratigraphical marker beds. They consist of thin ferruginous ooid-bearing limestones (bioclastic wacke/packstones and grainstones) which are embedded in either nodular shales (outer shelf settings) or micaceous silt- and sandstones (inner shelf).
Besides a precise dating of each oolitic ironstone level, conodonts have provided good evidence for condensation within the ironstone levels (at most half a conodont zone ?). This timespan marks a period of slow deposition or even an omission event, during which ferruginous coated grains were formed in nearshore environments, preceeding their subsequent rapid removal and transport onto the open shelf.

The Famennian oolitic ironstones display different "ore" facies: either flattened "flax seed"-type ferruginous ooids, highly fossiliferous "fossil ore" facies or less ferruginous "transgressive lag"- type deposits. "Flax seed" and "fossil ores" generally grade into each other and appear to be often mixed. However, the former type tends to represent a more proximal facies, whereas the latter is rather a distal shelf facies, with respect to the palaeocoastline. In the transgressive lag-type deposits, rounded bioclasts or skeletal grains are only slightly impregnated by ferric oxyde and Fe-rich chlorite.

Microfacies analysis of the ferruginized allochems points to the allochtonous character of the ironstone deposits (see figure 9): heterogenous ferruginized coated grains are mixed with calcitic bioclasts and fossils to form bioclastic wacke-, pack- and grain-ironstones. The hematitic or chloritic allochems comprise ooids, superficial ooids, multiple ooids, algal oncoids and pisoncoids, cortoids, slightly coated rounded bioclasts and algal-encrusted intraclasts. The more pseudo-oolitic ironstones ("fossil ore" and "transgressive lag" ironstone facies) are essentially composed of moderately to strongly iron-impregnated and only slightly iron-coated, bored bioclasts such as crinoid ossicles, bryozoans, brachiopod and ostracode shells. Locally hematite-infilled Charophycean oogonaia (*Sycidium, Umbellina*) have been observed as well.

Each ironstone level consists of at least one concentration of ferruginized allochems or of a ferruginized microstromatolitic hardground only, but it may also comprise several sublevels. The latter sublevels surmount basal erosional unconformities and are generally capped by or enclose ferruginized algal-encrusted hardgrounds.
This means that each ironstone level does not necessarily represent one single event, but that it may consist of different superimposed events, including erosional, condensation, non-deposition and transport events. The hardgrounds originated at the end of a shoaling upward sequence. The lithification itself occurred during reduced sedimentation, or non-deposition conditions.
The calcitic allochems of the host sediment often contain cephalopods (orthoceratids, goniatites) and locally even solitary rugose corals (*Campophyllum*).

The presence of a basal erosional unconformity, the allochtonous character of the ferruginized allochems and their density stratification, the lateral decrease of ironstone bed thickness and that of the total amount of hematitic allochems, have led

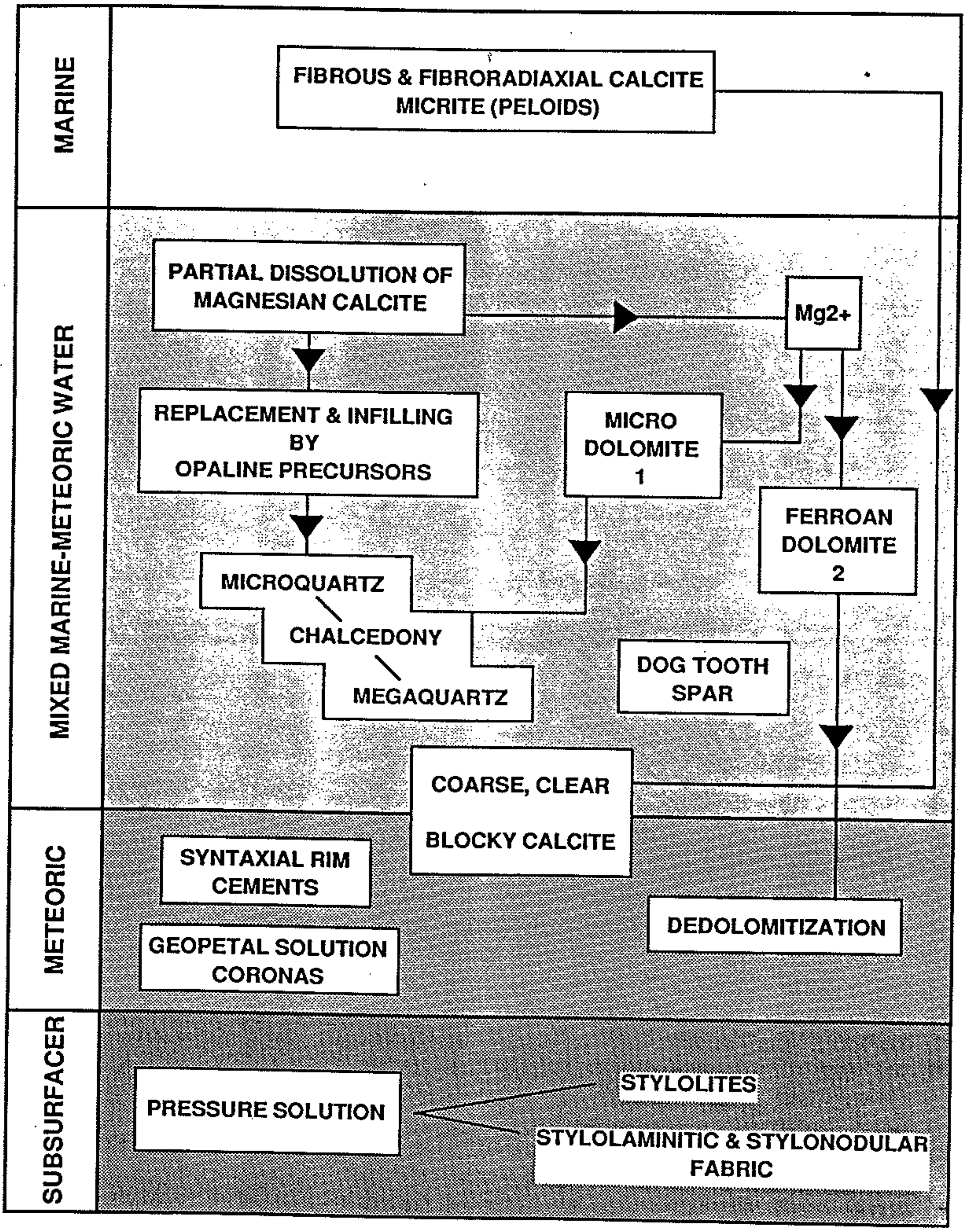


Figure 7: Successive diagenetic stages and diagenetic events observed within the Baelen limestone complex (after Dreesen et al, 1985).

us to the assumption that the Famennian oolitic ironstones represent storm deposits (Dreesen, 1982).

A working model has been proposed for the origin and distribution of the oolitic ironstones (Dreesen, 1989) (see figure 10): during a temporary decrease of the siliciclastic influx calcareous coated grains originated in the shallow, protected shelf and restricted marine environments of a near-coastal, broadly embayed area. Unusually strong storms may be evoked as a cause for the winnowing of the enveloping muds leading from mudstone to packstone concentration of the originally calcareous allochems. These coated grains became piled into shoals, probably proximal to lagoons, where they became periodically subaerially exposed. During the short emersion periods, vadose or phreatic weathering promoted the replacement of Mg by Fe in the original high-Mg calcite allochems (e.g. the crinoid ossicles, ooids and algal oncoids). Subsequently, the ferroan calcite was oxidized to form goethitic and later hematitic pseudomorphs. Alternatively, the more flattened, non-skeletal coated grains (the "flax seed" type ooids) could have originated as berthierine ooids in adjacent, low-energy muddy areas (lagoonal ponds) and were subsequently altered into hematite. Violent storm surges (tropical hurricanes ?) and even high-energy waves (tsunamis ?) could be evoked to explain the removal of the ferruginized coated grains and their dispersal onto the shelf. Finally, a strong longshore current may account for their redistribution over large shelf areas in the Ardenne.

The source of the iron is still a matter of speculation, but the classical concept of weathering of lateritic soils as for the Minette ore (Siehl & Thein, 1978) cannot be accepted here, because of the lack of good evidence for true humid tropical or subtropical conditions (see figure 11). The frequent occurrence of red beds, evaporites and pedogenic carbonates (calcretes, dolocretes) in the Belgian Famennian is more symptomatic of prevailing semi-arid climatic conditions of a tropical trade wind belt (Paproth, *et al*, 1986).
Instead, the iron required probably more than one source: the iron could have been derived from the surface waters of nearby-stratified evaporitic pans (Sonnenfeld et al, 1977); on the other hand, it is more likely that the iron-rich chlorites originated from the halmyrolysis and the diagenesis of volcanic ashes: indeed, chloritized angular bentonite relicts, vermicular chlorite extraclasts, weathered fragments of volcanic glass and idiomorphic zircon crystals have frequently been observed in the calcareous host sediment of the Upper Devonian oolitic ironstones (Dreesen, 1989).

The latter model is strongly supported by the recent analysis of Ordovician ironstones in Sweden (Sturesson, 1992): here iron-rich oolites are closely associated with volcanic ash beds. It is suggested that authigenic chamosite was formed from elements released into the sediment when the ash dissolved on the sea bottom. Chamosite precipitated on skeletal grains, and repeated reworking of the sediment oxidized the outer surface of the grains to goethite/hematite, thus creating the typical concentric ooid lamination.

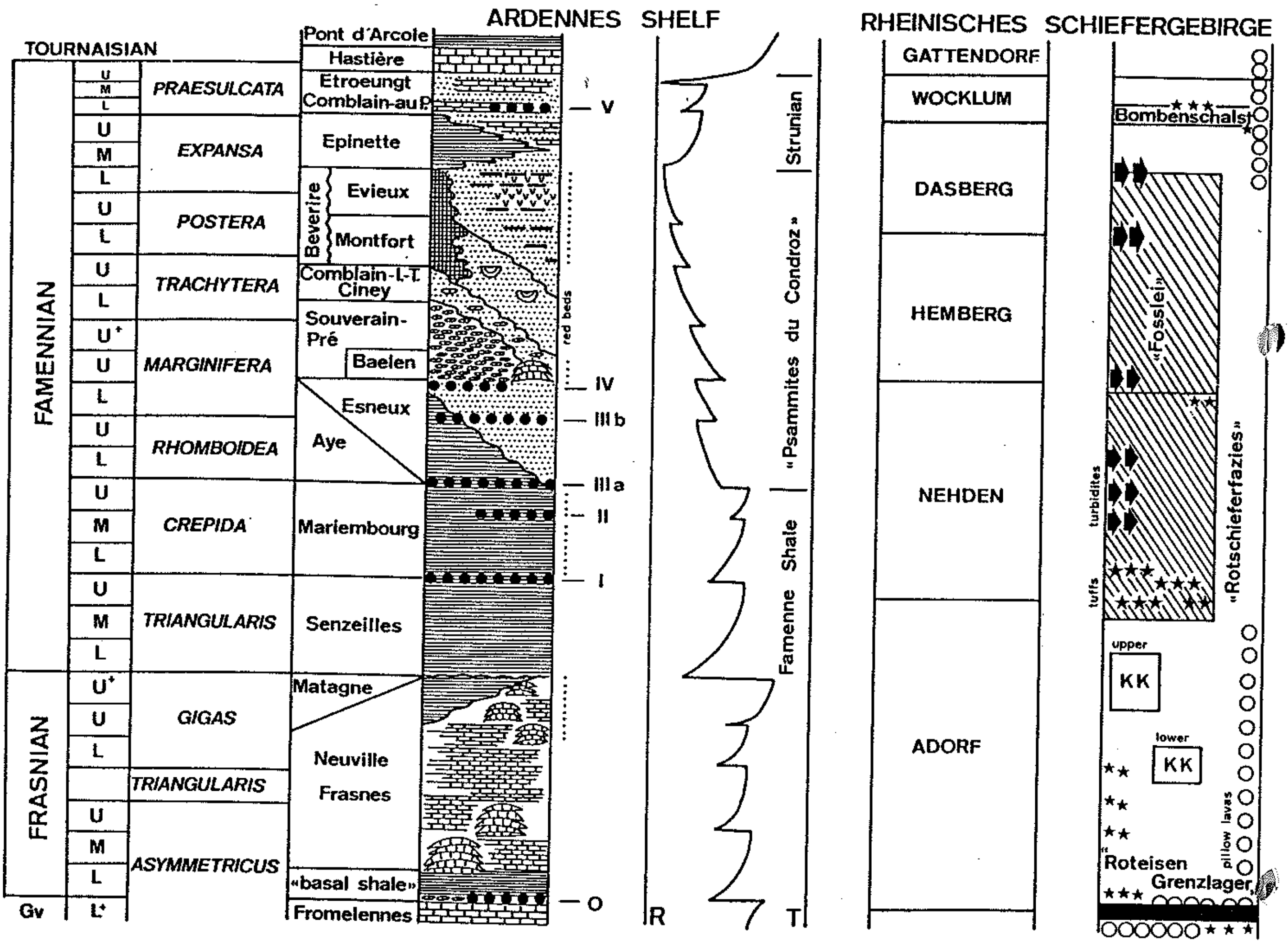


Figure 8: Stratigraphic correlation of Upper Devonian episodic events in the Ardenno-Rhenish Massif (Dreesen, 1989).

At the left: Belgian stages and standard conodont zonation; in the centre: lithologic columnar section for the Ardenne shelf, flanked on the left by informal and formal lithostratigraphical names and on the right by the designations for the seven ironstone levels. Just to the right is a suggested sea-level curve. On the extreme right is a graphic depiction of the event deposits of the Rheinisches Schiefergebirge in terms of six German Stufen. Pillow lavas are shown by circles, metabentonites by stars, turbidites by short black arrows, and basinal red shales by diagonal shading. KK refers to particular anoxic event deposits ('Kellwasserkalke').

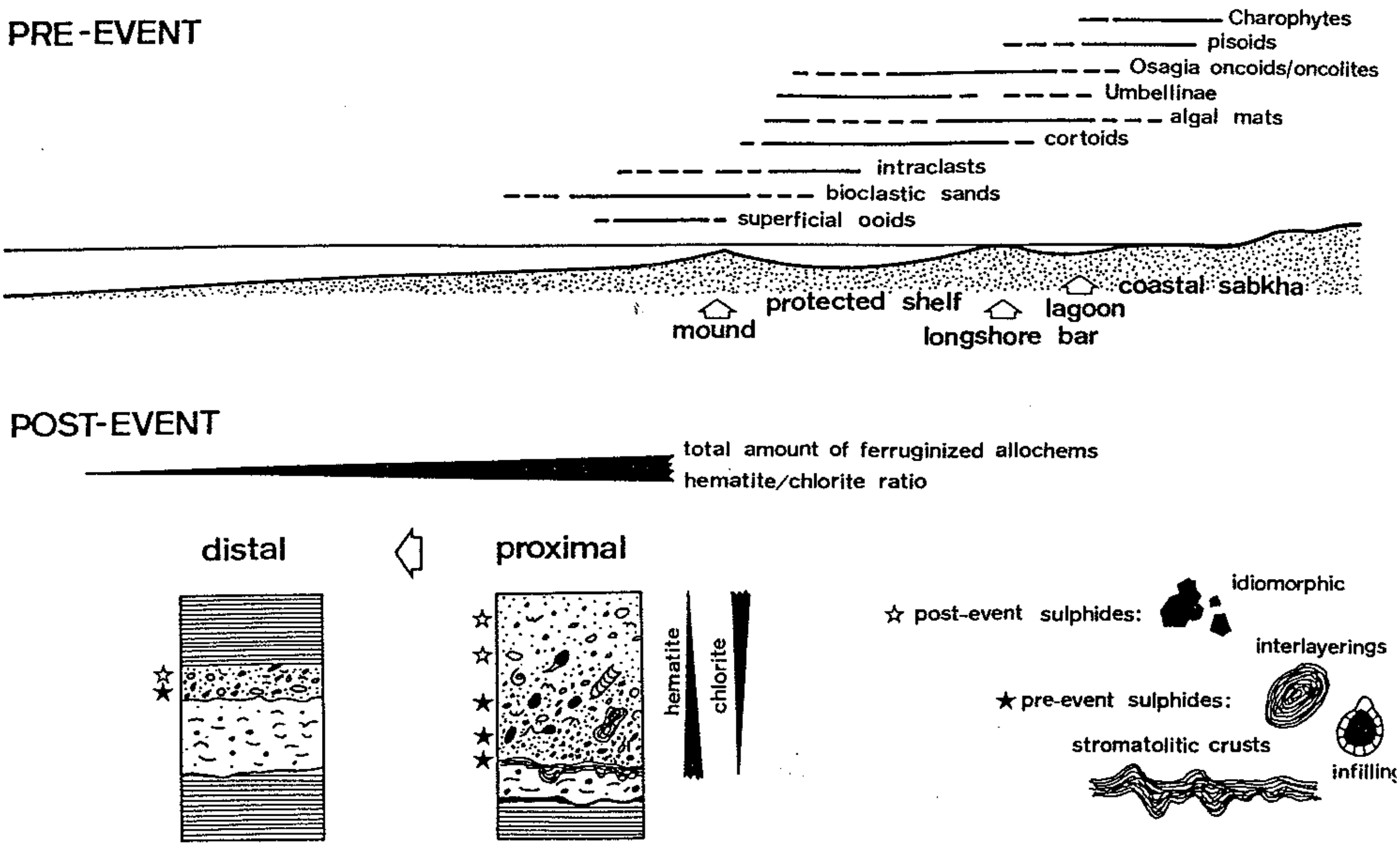
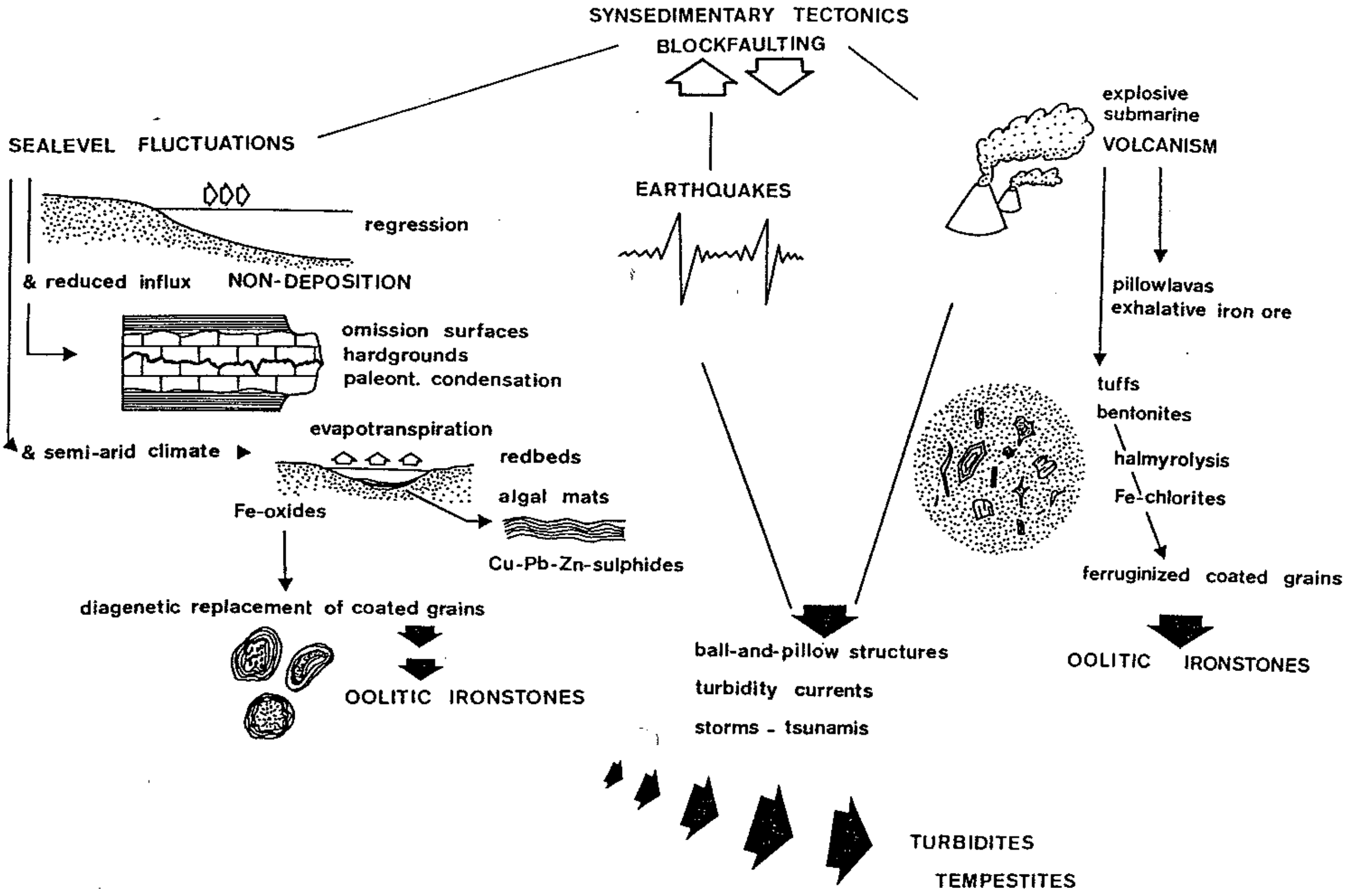
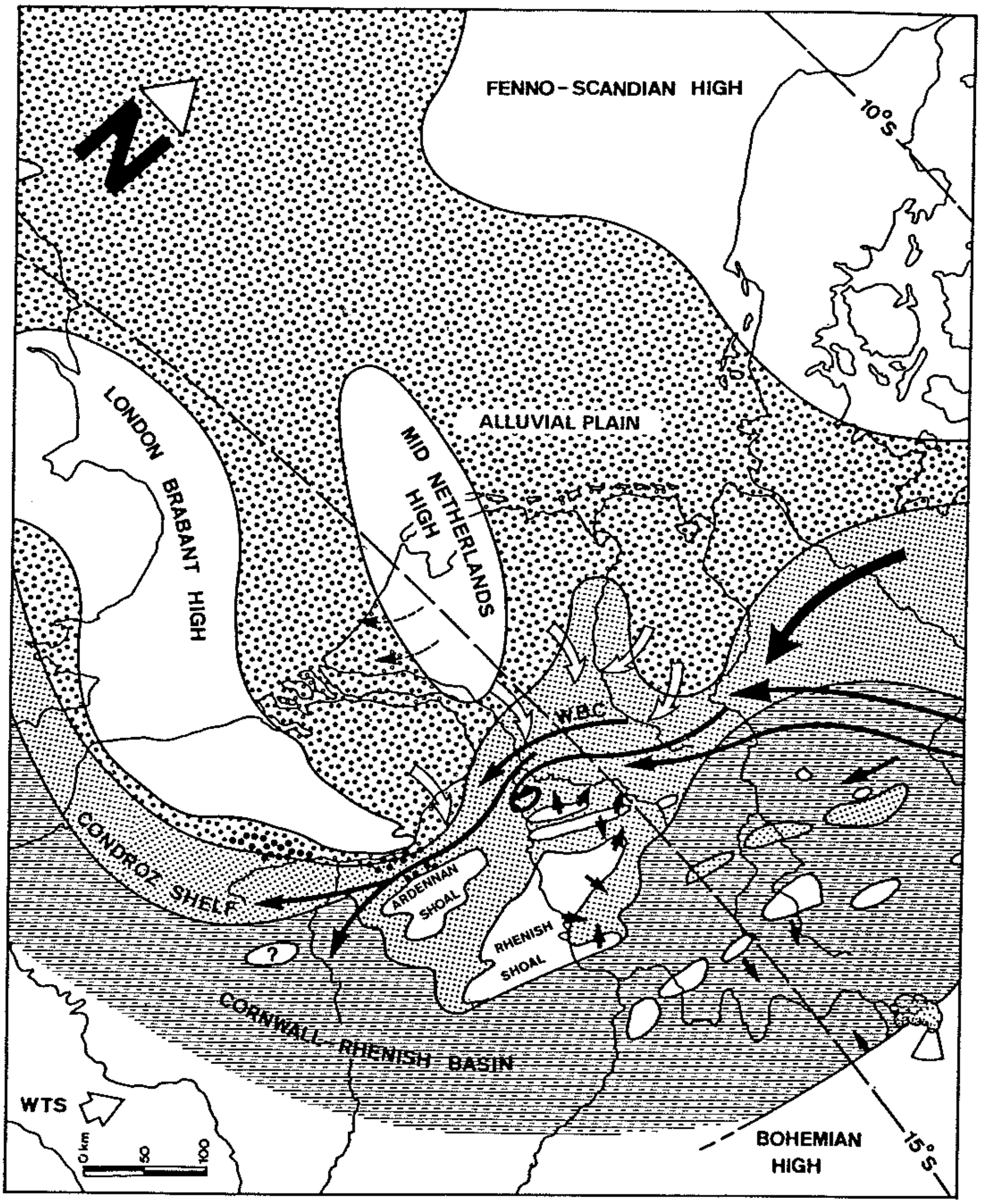


Figure 9: Diagram showing the idealized distribution of original carbonate coated grains prior to their ferruginization. Ideal proximal / distal differentiation within a Famennian oolitic ironstone, after removal and storm-induced transport of the ferruginized allochems (after Dreesen, 1989).



'Geophantasmogram' of strongly interdependent tectono-sedimentary processes which provided the mechanism for the formation and transport of ferruginized coated grains. The turbulent events that triggered the downslope transport were seismic shocks, which are evidenced by conspicuous ball-and-pillow levels that crosscut different depositonal environments (Thorez & Dreesen 1986). The seismic shocks, which probably fostered turbidity currents and possibly tsunamis, were produced by the episodic reactivation of block faults. The faults also may have provided feeders through which magmas fed submarine volcanic exhalations, which together with ashfalls from volcanoes, provided chemical enrichment for formation of the next cycle of ferruginization.

Figure 10: Working model for the origin and distribution of Late Devonian oolitic ironstones on the paleoshelf South of the London-Brabant Massif (Dreesen, 1989).



Reconstructed Famennian palaeogeography for part of NW Europe (modified after Paproth *et al.* 1986.) WTS = westerly tropical storms; WBC = western boundary current; long black arrows indicate current directions; short black arrows represent detrital shedding; white arrows represent deltaic discharges; dotted arrows indicate eolian sediment transport; heavy black dots represent the original setting and supposedly storm-generated accumulation of ferruginous ooids, before their removal and high-energy wave transport to the SW and to the E. Suggested presence of continental volcanic eruption centres on the Bohemian High. Submarine volcanic eruption centres not indicated but supposedly located N and E of the Rhenish shoals.

Figure 11: Reconstructed Famennian paleogeography for part of NW Europe (modified after Paproth et al, 1986, in: Dreesen, 1989).

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