

DEVONIAN CARBONATE FACIES PATTERNS IN THE DINANT SYNCLINORIUM, BELGIUM¹

T. J. A. REIJERS²

ABSTRACT

Reijers, T. J. A. 1984 Devonian carbonate facies patterns in the Dinant Synclinorium, Belgium – Geol. Mijnbouw 63: 019-029.

The Middle-Upper Devonian carbonate facies of the Dinant Synclinorium, Belgium are discussed. During the Middle Devonian the influence of the Old Red Continent is still appreciable and coarse to fine siliciclastics fringe the continent and the positive elements on the shelf. From Couvianian times onwards the shelves of the Cornwall-Rhenish basin are partially covered by carbonate masses.

During the Givetian and the Frasnian the influence of siliciclastic sediments on carbonate production is only noticeable in the northern lagoonal settings.

In the Frasnian a distinct separation into a northerly carbonate platform and a southerly basin is apparent. Carbonate bodies within the basin are 'stacked' in the south, whereas they 'float' in the north. The 'stacked' bioherms are perhaps related to rejuvenation of block faults, whereas the 'floating' mud mounds are characterised by their red colour, their age and the fact that they overstep the middle Frasnian carbonate platform from a southerly direction. Textural and structural differences are discussed, illustrated and interpreted. The carbonate platform is characterised by a porous dolomitised edge and a lagoonal interior with cyclic carbonate deposition.

INTRODUCTION

Within the overall structural setting of Western Europe during the Devonian, three major depositional areas have been recognised (ZIEGLER, 1982): the Cornwall-Rhenish, the Central Armorican-Saxothuringian, and the Cantabrian-Pyrenean basins. Of the first one, an area that is exposed in the Belgian Ardennes is described in some detail (Fig. 1) and an overview is presented of areal facies distribution (Fig. 2). This could serve as a framework within which more detailed studies and observations can be placed.

Silurian and older rocks in the northern part of the Belgian Ardennes and from there further to the north essentially reflect the deep-marine Caledonian basin in which pelagic siliciclastics accumulated. During the Silurian and Early Devonian compressional tectonic activity welded the Laurentian-Greenland and the Fenno-Scandian plates together and this produced local uplift and structural deformation in the

area of interest. In the north these Caledonian movements only caused gentle folding, but towards the south, evidence is found of somewhat stronger folding that was connected with some erosion which affected Cambrian and Lower Ordovician strata. Because of its stable nature, its relative positive elevation and its somewhat rigid behaviour during subsequent structural phases, the northern area is known as the 'Brabant Massif'. It continues into England and Wales.

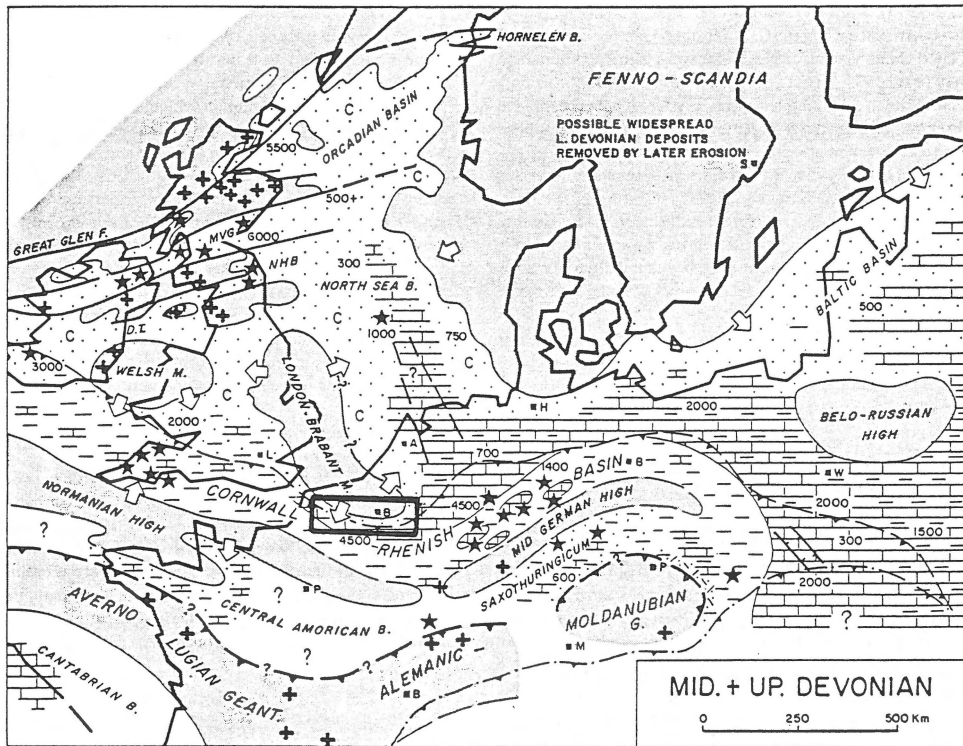
From the Early Devonian onwards this positive element became incorporated in the continental 'Old-Red' facies that formed north of the deeper-marine facies of the Cornwall-Rhenish basin. Throughout the Devonian the depocentre shifted northwards in a characteristic way.

The Devonian sediments are covered by shallow to deeper-marine carbonates (Dinantian) which in turn are overlain by limnic and paralic Namurian sediments. Hercynian movements during the Carboniferous produced a number of topographic highs and lows. Consequently, the following elements can now be recognised from south to north (Fig. 3): 1. the synclinorium (basin) of Neufchâteau-Eifel, 2. the anticlinal (positive) zone of the Ardennes with a Cambrian or Cadomian core, 3. the synclinorium (basin) of Dinant, 4. the

¹ Manuscript received: 1982-12-16.

Revised manuscript accepted: 1983-03-03.

² Shell Internationale Petroleum Maatschappij B.V. The Hague, The Netherlands.



LEGEND TO PALEOGEOGRAPHIC MAP

DOMINANT LITHOLOGIES

	Sandstones, conglomerates		Shales		Carbonates
	Sandstones		Organic shales		Anhydrite
	Flysch, deep water sands		Deep marine shales		Halites

OTHER SYMBOLS

	Positive areas	500	Thickness in m.		Variscan deformation front
	Volcanics		Salt		Alpine deformation front
	Intrusives		Coal		Active deformation fronts
	Sea mounts	c	Continental		Faults (schematic)
	Continental slope		Direction of clastic supply		Area studied.

Fig. 1.
Middle and Upper Devonian palaeogeography (after Ziegler, 1982).

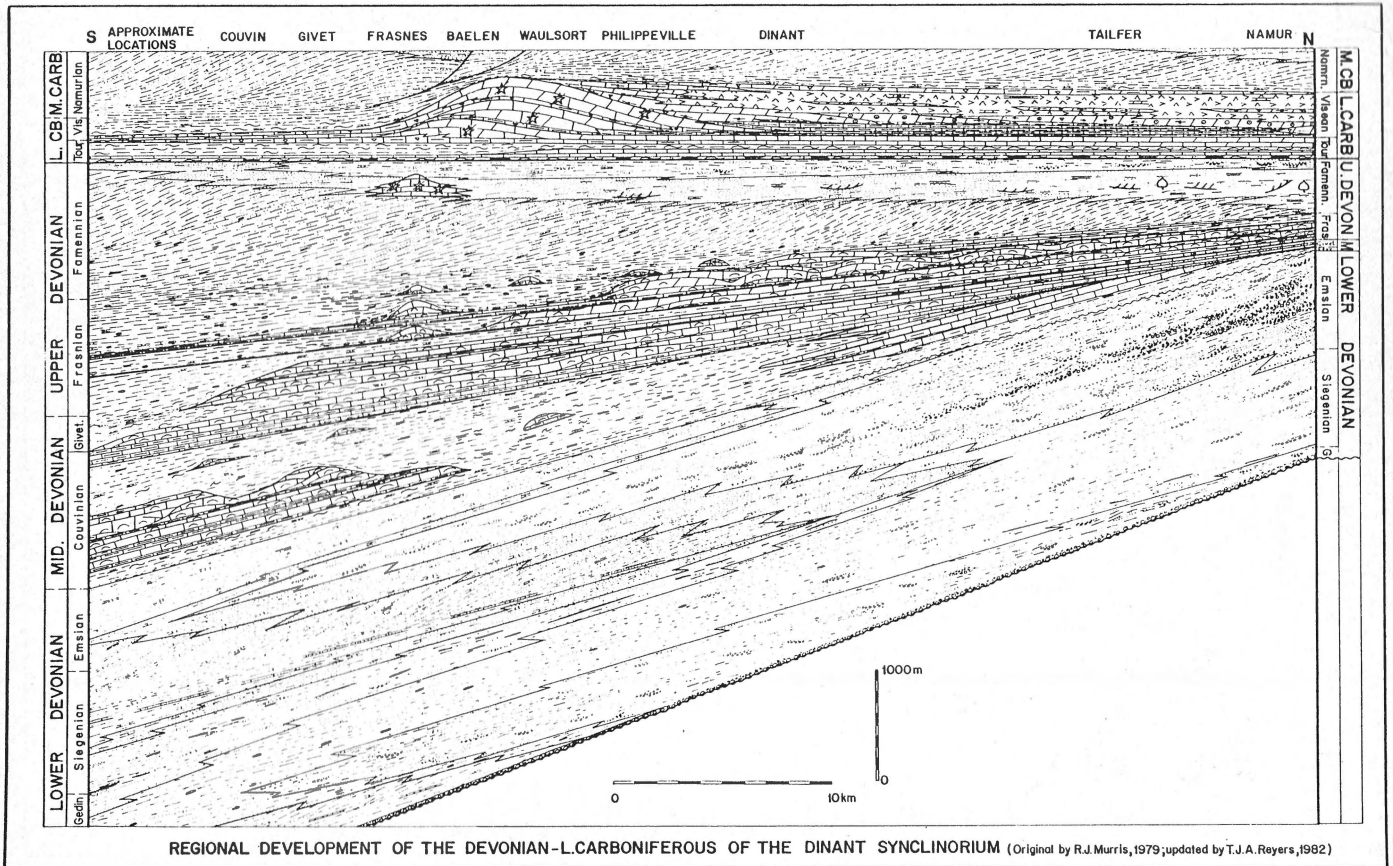
anticlinal zone (swell) of Condroz with a Silurian core, 5. the synclorium (basin) of Namur, 6. the anticlinal (positive) zone of Brabant with a Silurian core, 7. the Old Red Continent, and finally 8. the Campine graben, which occurs within the Old Red continent.

THE EARLY DEVONIAN

During the Early Devonian the depocentre in the Cornwall-Rhenish basin was situated over the present-day Neufchâteau-Eifel synclorium; only from the Early Couvinian onwards deposition reached the Namur synclorium. Com-

parison of facies types in the south and in the north shows little variation during the Early Devonian (ASSELBERGH, 1954; LECOMTE, 1963). All are siliciclastic and reflect a shallow-marine (neritic) to continental (occasionally lagoonal) environment of deposition.

The Early Devonian is characterised by a transgression over peneplained Cambro-Silurian rocks deformed by the Caledonian orogeny. The sea encroached on the land from south to north, giving rise to conglomeratic and arkosic sand formations. It brought neritic elements onto the former land. The whole siliciclastic Lower Devonian complex is referred to as the 'Old Red Continental facies' which, however, is frequently marine, rather than continental. No attempt is



REGIONAL DEVELOPMENT OF THE DEVONIAN-L. CARBONIFEROUS OF THE DINANT SYNCLINORIUM (Original by R.J. Murris, 1979; updated by T.J.A. Reyers, 1982)

Fig. 2

made here to distinguish individual facies within the Old Red complex.

During the Emsian, sea bottom movements of an epeirogenic nature (ASSELBERGH, 1954) caused uplift of certain areas and overall regression. Coarse siliciclastics can often be related to local areas of emergence. At this time, differentiation into a southern basinal-marine and a northern coastal marine facies becomes discernible within the area of interest. The basinal facies is fine siliciclastic but in the coastal area there are carbonates in those places where siliciclastic influx from the Old Red Continent was only modest.

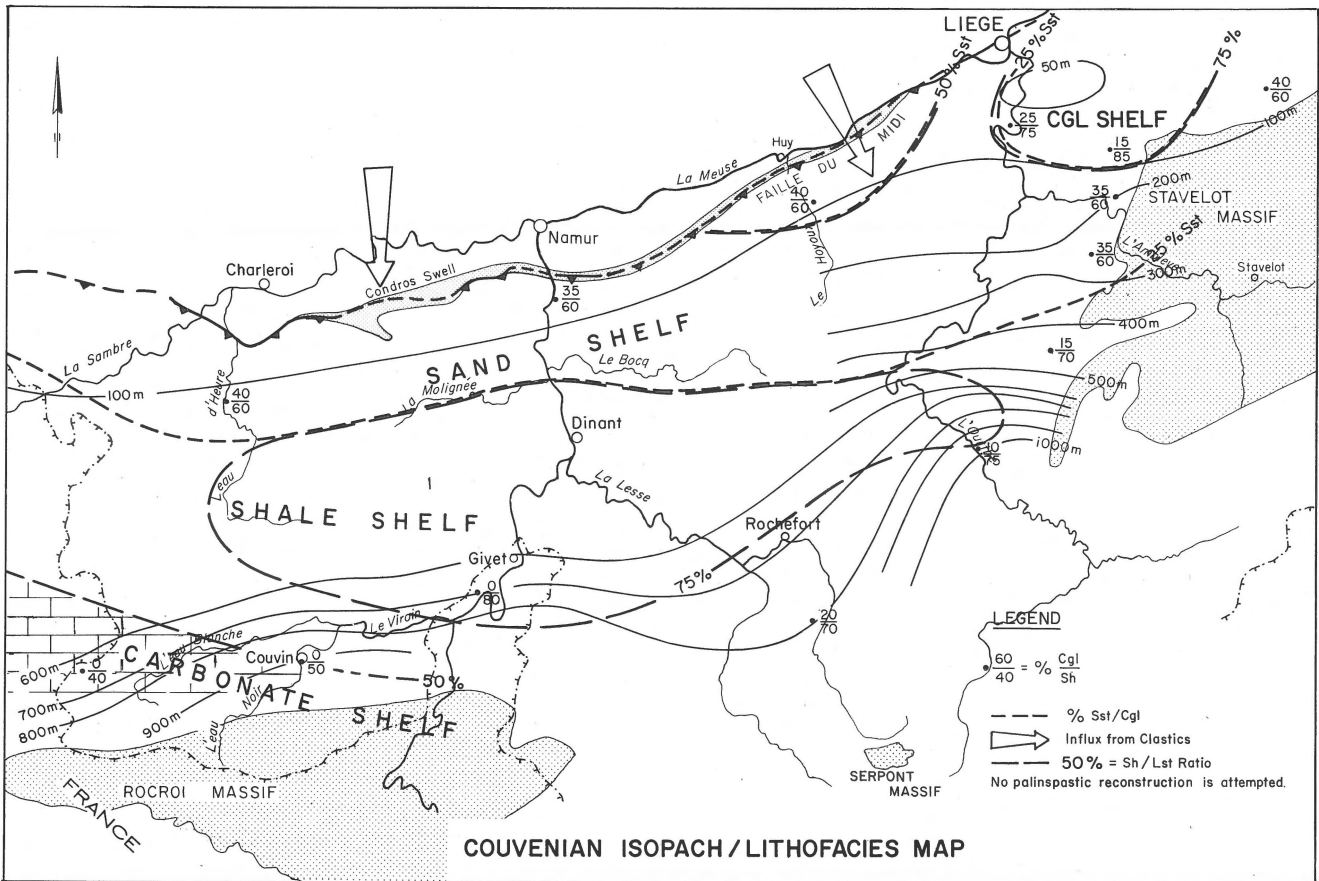
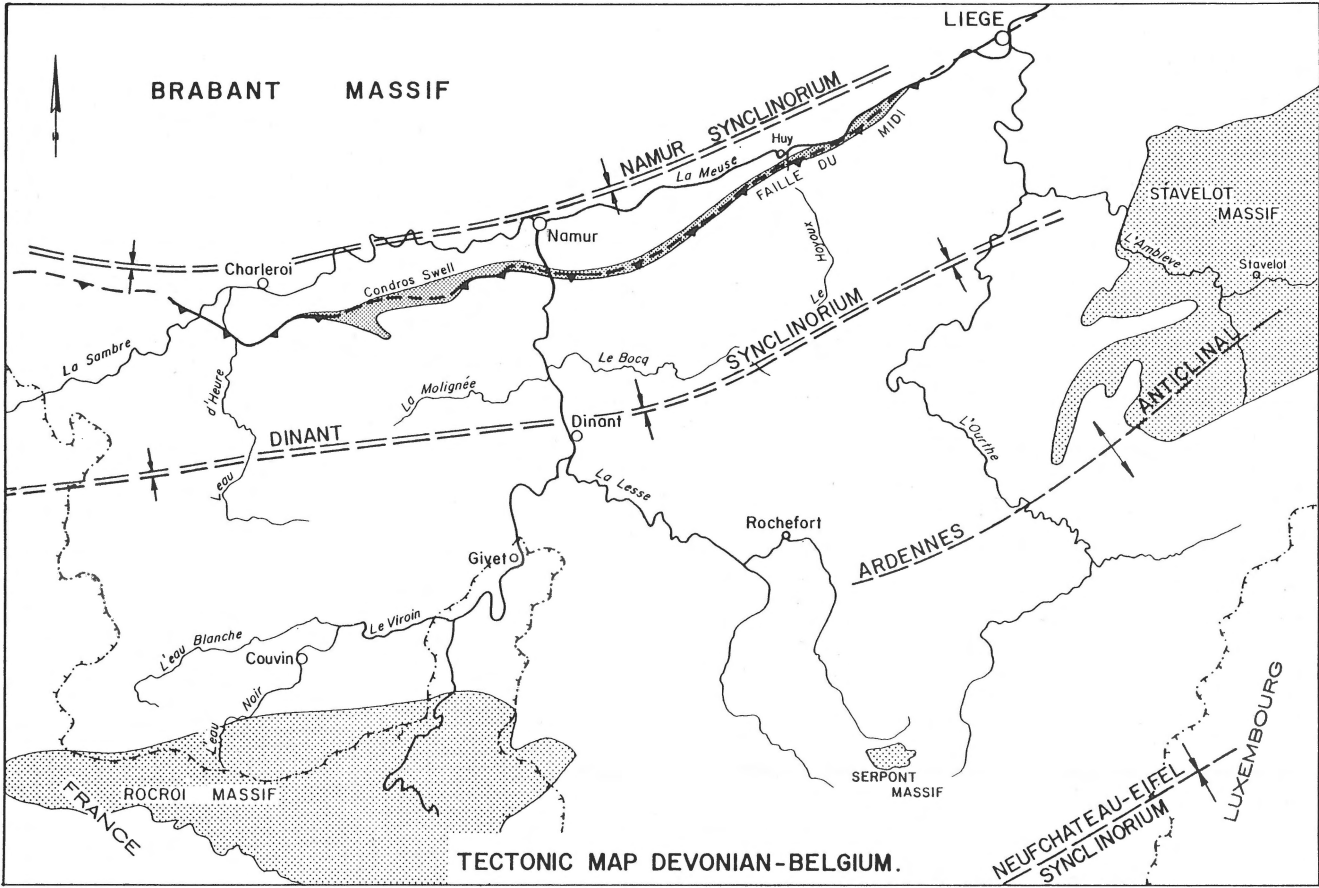
THE MIDDLE AND LATE DEVONIAN

From the Couvinian onwards the differentiation between carbonates and siliciclastic sediments on the shelf was very pronounced (Fig. 4). Local highs, perhaps erosion remnants on an otherwise peneplained surface, are surrounded by the breakdown products of a transgressing sea. These products range from coarse conglomerates to fine sands. Further away from such high areas and at some distance from the Old Red Continent, carbonate sediments take over on the shallow marine platform. They become dominant towards the edge of

the shelf (which is situated south of the area depicted in Fig. 4) and change in facies with the basinal fine siliciclastics.

During the Couvinian the sea transgressed from the Dinant basin over the positive zone of Condroz into the Namur basin; this transgression continued throughout the Givetian (Fig. 5) and the Frasnian (Fig. 8) and proceeded in a northerly direction. The positive character of the Condroz area is reflected in the presence of siliciclastics to the south of it during the Couvinian, and the reduced thickness of carbonate accumulation during the Givetian and the Frasnian. Via a graben the transgression reached deep into the Old Red Continent, as is shown by recently encountered open-marine Devonian carbonates with a Frasnian flora and Middle to Upper Devonian ostracods in the central part of the North Sea (ZIEGLER, 1982; and personal observations). Anhydrites are intercalated with these open-marine carbonates.

During the Givetian and the Frasnian the entire northern part of the Cornwall-Rhenish basin was a huge, shallow-marine carbonate platform and the carbonate accumulation of Givetian age reached up to 400 m (Figs 5 and 6). Owing to siliciclastic influxes from the positive Condroz swell in the north (Fig. 6) and restriction in the interior part of the platform, carbonate production was less prolific away from the platform edge. Near Givet and Couvin, close to the edge



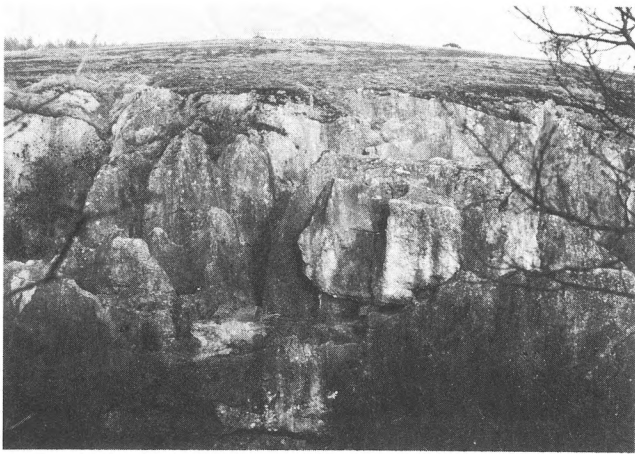


Fig. 7a
Fondry des Chiens. East of Couvin, Belgium. Karst exposes Givetian limestones that have been deposited close to the edge of the Givetian carbonate platform. (Top sequence to the left.)

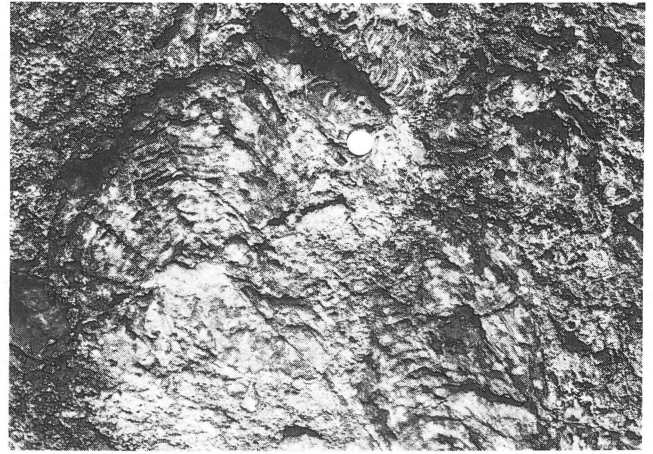


Fig. 7b
The top part of the Givetian carbonate sequence is almost entirely made up of big bulbous stromatoporoids. Most of them are in life position. Fondry des Chiens, Belgium.

of the carbonate platform, impressive stromatoporoid bioaccumulations occur which are frequently built over bioclastic calcarenites. A good example is the bioherm exposed as a result of karstification at 'Fondry des Chiens' southeast of Couvin (Fig. 7a). Here bioclastic grainstone bars are covered with poorly bedded stromatoporoid bioclastic packstones and

locally with bindstones; the succession is topped by massive stromatoporoid bindstones (Fig. 7b).

From the Middle Frasnian onwards there was a distinct separation between a northerly shallow-marine carbonate platform and a southerly deeper-marine offbank environment. These environments and their carbonate facies will be investigated more closely.

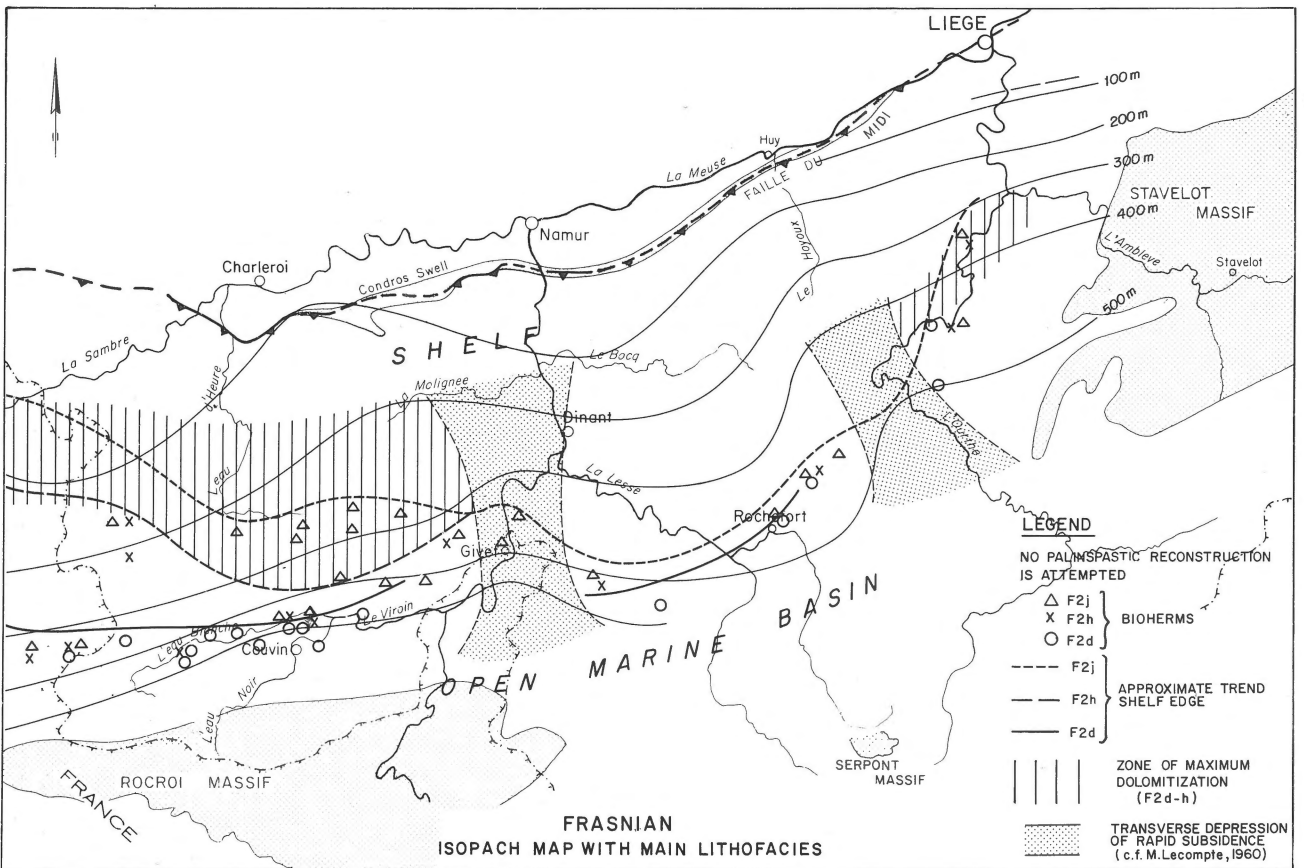


Fig. 8

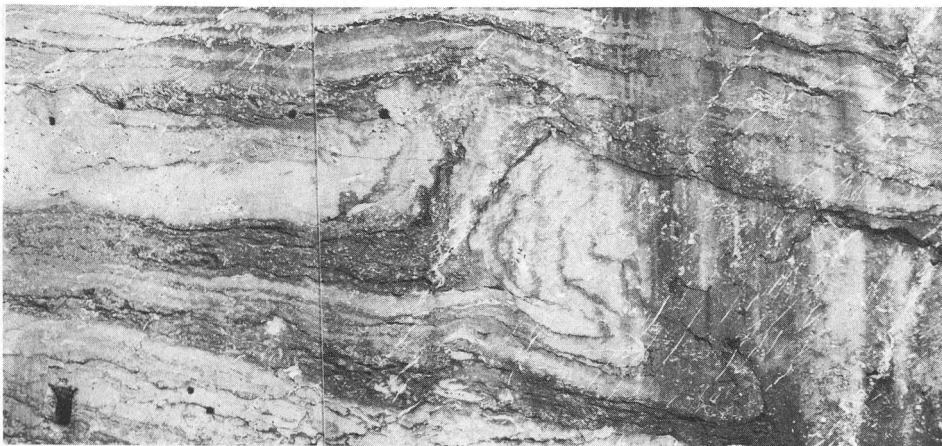


Fig. 9
Carrière du Beauchâteau, Frasnian, Belgium. Red mud mound with slump and flow structures. Note the apparent 'squeezing' of certain layers. Note also the en-echelon arranged tension cracks that are the result of the Hercynian deformation.

THE FRASNIAN FACIES ZONES

The position of the dividing line between the southerly deeper marine offbank facies and the northern continuous carbonate platform changed with time. It runs in an E-W direction from Beaumont, via Neuville and Philippeville, to just west of the Meuse near Givet, and possibly continues to the Ourthe-Ambleve area. It tended to shift in a northerly direction throughout the Frasnian (Fig. 8). The position of this line is characterised in the field by extensive dolomitisation (e.g. Carrière de Merlemont at Vodocée). The dolomitised zone, however, is in places confined by transverse N-S depressions of rapid subsidence as described by LECOMPTE (1961) and depicted in Fig. 8. The shallow-marine bank to the north of the dolomitised zone was subject to influx of terrestrial material from the Old Red Continent. This adversely

influenced carbonate production. The offbank, deeper-marine setting is characterised by the prolific development of individual carbonate build-up structures in certain places. A number of noteworthy facies gradients are apparent within the Frasnian.

The various carbonate mud mounds – quite a number of which have been studied in great detail by LECOMPTE (1961, 1963) and TSIEN (1971, 1974, 1979, 1980) – tend to become younger in a northerly direction. This, of course, reflects the ongoing transgression during the Frasnian. Moreover, there is a distinct zone, just north of Couvin, near the village of Frasnes, where bioherms and mud mounds are 'stacked' on top of each other. One such example is the well-known sequence of the lower Frasnian Arche quarry bioherm followed by the middle Frasnian Lion quarry bioherm that underlies the upper Frasnian bioherm at Bossu-en-Fagne.

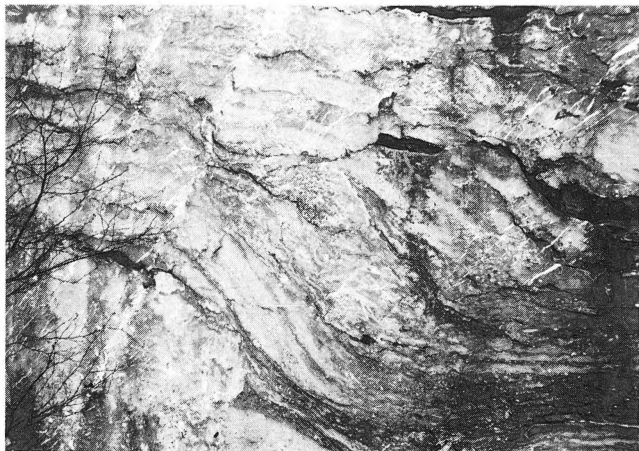


Fig. 10a
Carrière du Beauchâteau, Frasnian, Belgium. Detail of interior red mud mound with an abundance of *Disphyllum* colonies. These give the rock a bafflestone texture. There is also a great abundance of *Hexacorallia* colonies, branching tabulates, brachiopods and crinoids. Algae frequently bind the mud-matrix.



Fig. 10b
Carrière du Beauchâteau, Frasnian, Belgium. Note the stromatactes with geopetal sediment fill and platy tabulates, brachiopods and *Hexacorallia*. Bafflestone-bindstone.

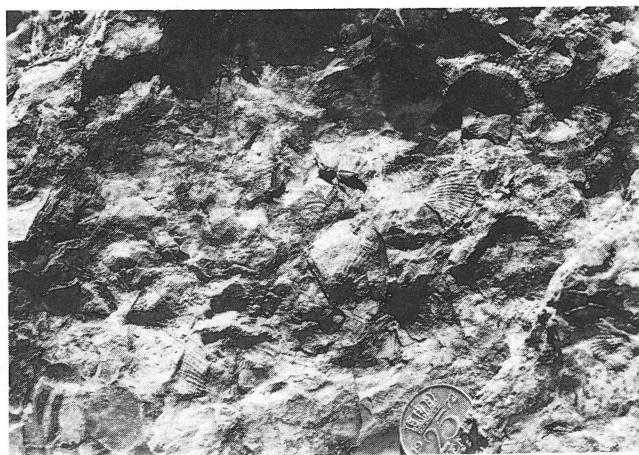


Fig. 11a, b
Carrière du Cimetière, Bossu-en-Fagne, Belgium. Frasnian. The facies surrounding and overlying the mud mounds locally contain great abundances of *Thamnopora*, *Alveolites*, crinoids and brachiopods. Thus, a bafflestone to rudstone texture is formed, as in the case of these two examples.

Such stacking of bioherms characterises the southernmost belt of carbonate bodies. This belt will be referred to as the 'facies belt of stacked bioherms'.

Further to the north this facies belt is followed by a zone in which reddish mud mounds of late Frasnian age occur. Such carbonate bodies (e.g. Carrière 'des Croisettes' at Vodocée) also overstep the middle Frasnian carbonate platform but do not form part of it. They are usually entirely encased in shale. Their presence also reflects the ongoing transgression of the sea which has flooded the dolomitised, porous, southern zone of the carbonate platform (Fig. 8). Internally, these mud mounds are characterised by slump and flow structures, Neptunian dykes and a considerable amount of differential compaction (e.g. Carrière de Beauchâteau, Senzeille – Fig. 9). Texturally they are usually bafflestones to floatstones in which *Favositidae*; *Phillipsastridae*, *Alveolites* and *Renalcis* are dominant elements (Fig. 10a, b). The surrounding shales contain variable amounts of barren carbonate nodules. Alternatively, great abundances of *Thamnopora* could occur together with spiriferids and crinoids (e.g. Carrière du Cimetière at Bossu-en-Fagne – Fig. 11a, b). Thus the surrounding shales and their variable fauna content also reflect variations in depositional environment.

The reddish colour of the late Frasnian mudmounds is a remarkable feature. Such a colour is not found in the 'stacked bioherms' further to the south. Another striking aspect is their 'floating' habitat; i.e. they are not 'stacked' on top of each other but are isolated in the upper Frasnian shales. Both colour and 'floating' aspect, as well as the extreme high content of lime-mud in the mounds and certain petrographic features (see MOUNTJOY & TSIEN; in press) distinguish them from those further south; it therefore seems justifiable to refer to two distinct reefoid facies belts. The southern one is situated in front of the carbonate platform in the somewhat deeper part of the basin, the northern one partly oversteps the dolomitised edge of the carbonate platform. Figure 12 is a

generalised lithofacies map of the Frasnian. Here both facies-belts have been included in the 'reef tract', north of which a lagoon is situated. In this lagoon carbonates alternate with siliciclastics that probably reflect occasional terrestrial influxes. The characteristic lagoonal facies sequence is splendidly exposed in the Carrière de Tailfer, where a marked cyclicity in the extremely shallow carbonates is evident. It is characterised by an alternation of fetid limestones in which small bulbous stromatoporoids occur (Fig. 13a, b), overlain by rudstones with big bulbous stromatoporoids, followed in turn by bindstones with small platy and subsequently big platy stromatoporoids and *Hexacorallia* colonies. The cycle is completed in an upward direction either by an increase in siliciclastic material (a terrigenous 'pulse') or by a restriction and ensuing fetid conditions. In both cases the faunal elements reduce in size and quantity and occasionally also in dominant morphology. This reflects a deterioration of environmental conditions, preventing prolific carbonate production. A diastem may follow (Fig. 13a). Towards the top of the section in Tailfer, there are dolomites with vague stromatolitic structures which, suggest occasional intratidal to supratidal depositional conditions. Although these occur in the northernmost position of the facies studied here, closest to the palaeo-coastline, it is still surprising to find them there, as will be discussed next.

DISCUSSION

Both, the pronounced north-south and the subdued east-west facies differences in the Couvinian, Givetian and Frasnian (Fig. 8) are to a large extent controlled by synsedimentary structural movements. The change in depositional regime from siliciclastics to carbonates at the turn Lower to Middle Devonian reflects an advanced peneplanation of the Old Red Continent. It coincides with the epeirogenetic formation of longitudinal positive zones, and genetically related negative

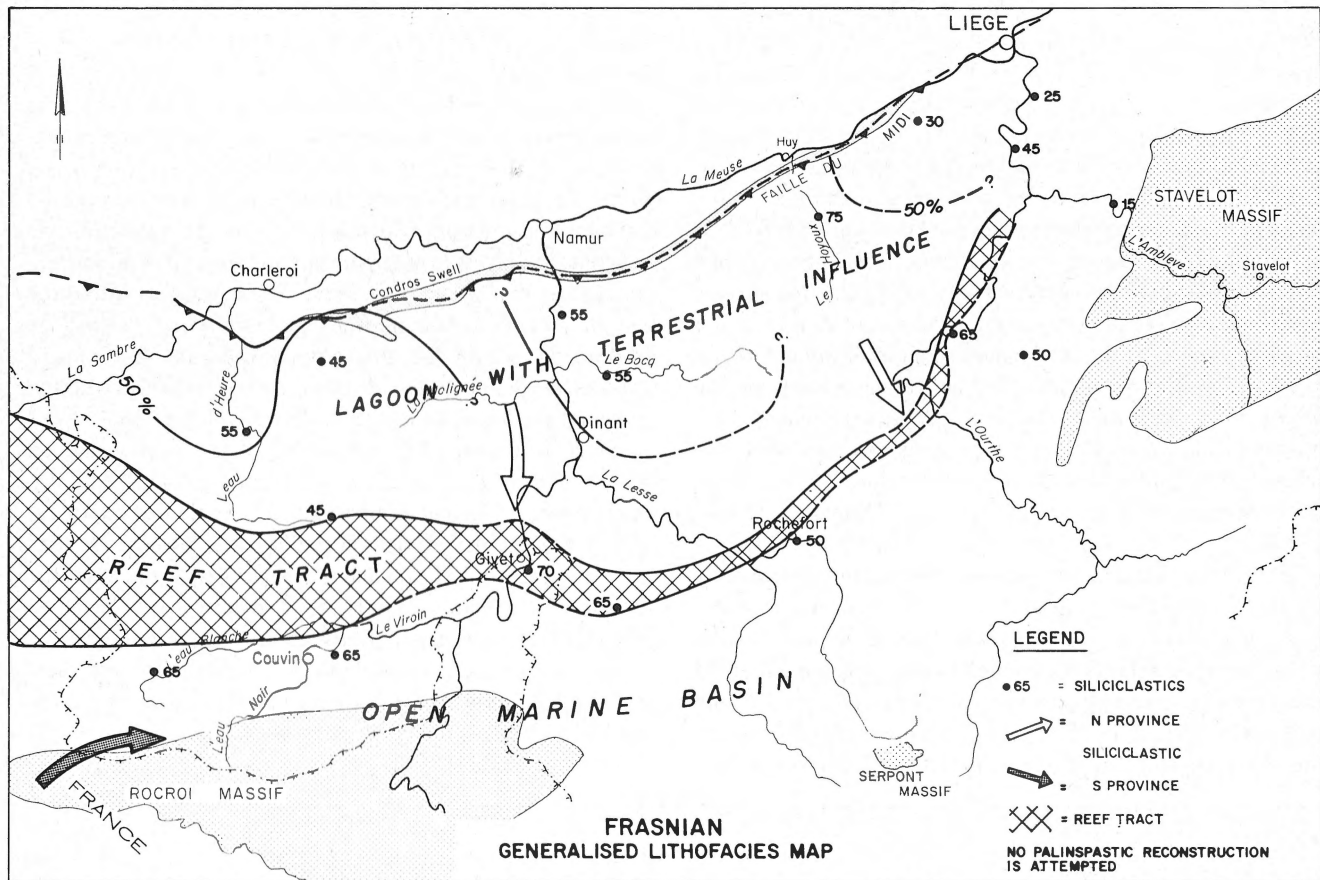


Fig. 12

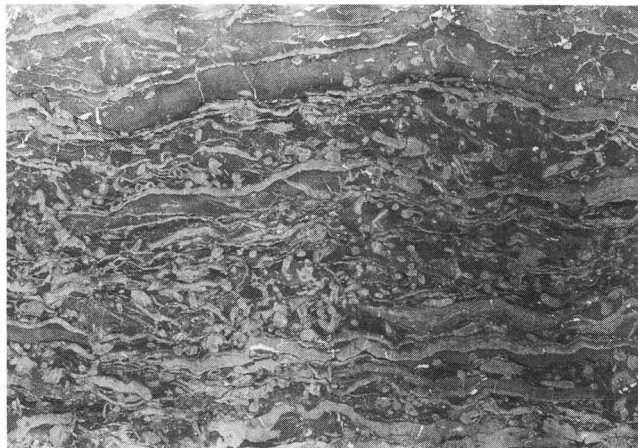
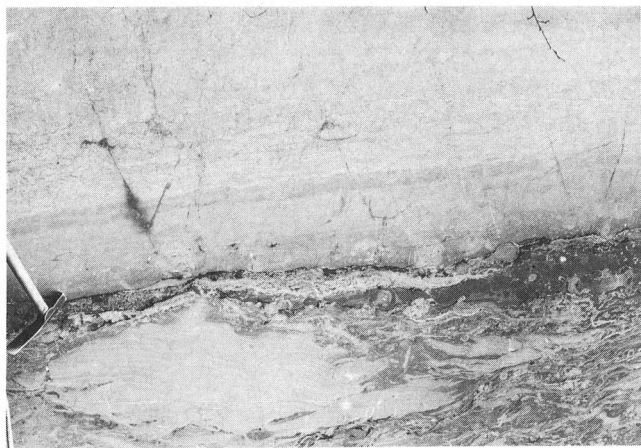


Fig. 13a, b

Carrière de Tailfer, Tailfer, Belgium. Frasnian. Note the diastem in the middle of Fig. 13a, on top of which small bulbous stromatoporoids established in a lime-mudstone surrounding. This is followed by a light-grey sequence of intra-supratidal wackestones-packstones in which desiccation cracks, sheet cracks and bird's-eye-like structures occur next to bioclastic hash and small platy stromatoporoids.

This sequence is usually followed by bigger platy stromatoporoids and tabulate corals. The stromatoporoids are frequently digitated at the top and may be in (micro-) stylolitic contact with each other at the bottom. The digitated upper part indicates the presence of a fair admixture of siliciclastics that makes the water dirty. This is also suggested by the dark colour of the limestone.

A sequence frequently ends, as is visible at the bottom half of Fig. 13a. Certain faunal elements dominate and increase in size. Others decrease quickly in size and abundance, and a diastem, either indicating a brief period of exposure or a considerable pulse of siliclastic influx, ends the cycle.

ones (e.g. Dinant basin, Condros high, Namur basin). The formation of these epirogenetically controlled zones is reflected in the isopach patterns. Perhaps these elements are precursors of the Hercynian deformations.

The Hercynian deformation is also responsible for the considerable amount of folding and for the thrusting of the Dinant Synclinorium over the Namur Synclinorium. As a result of this displacement the observed facies gradients of the units in the Dinant basin, now the Dinant Synclinorium, only reflect some general aspects of the overall palaeogeography that prevailed before thrusting. Palinspastic restoration would allow a more detailed palaeogeographic interpretation but such restoration is hampered by the uncertainty on the nature and magnitude of the displacement. It remains true, however, that the section at Tailfer is the northernmost one (closest to the palaeo-coast), although it reflects environmental conditions that prevailed tens of kilometres to the south.

The facies differentiations throughout the Devonian mainly reflect the northward transgression of the sea, progressively covering parts of the land. This land could have been characterised by a soil relatively enriched in iron minerals. Many of these minerals are resistant to weathering and leaching and they could account for iron ooids that are found at the base of the Frasnian (e.g. at Tailfer) and throughout the Upper

Devonian siliciclastics. Towards the end of the Frasnian the iron affected the carbonate sedimentation pattern, as will be discussed below.

The focus of mud-mound formation – as is often the case with carbonate build-up structures – may have been predetermined by topographic irregularities on the sea bottom. If this is the case, such relief differences are accentuated by carbonate production, which is prolific in the euphotic zone and considerably reduced in the aphotic zone. If iron, washed into the sea during the transgression, was trapped within the belt in which carbonate mud mounds form, it can be postulated that only the iron trapped within the mud-mound stood a chance of being oxidised because it remained with the ‘growing’ mud-mound in the shallowest part of the depositional environment. The remainder of the iron had been deposited between mounds in an overall reducing environment, where it became green (e.g. Carrière de Beauchâteau) or where it formed pyrite, if sulphur was present. In this model the presence of iron and the ensuing reddish discolouration in mud-mounds is understood in terms of distance to palaeo-coast line, ongoing transgression and growth potential of carbonates within the euphotic zone. The factor ‘distance’ explains the diminished occurrence of red material within the ‘stacked bioherms’ further to the south.

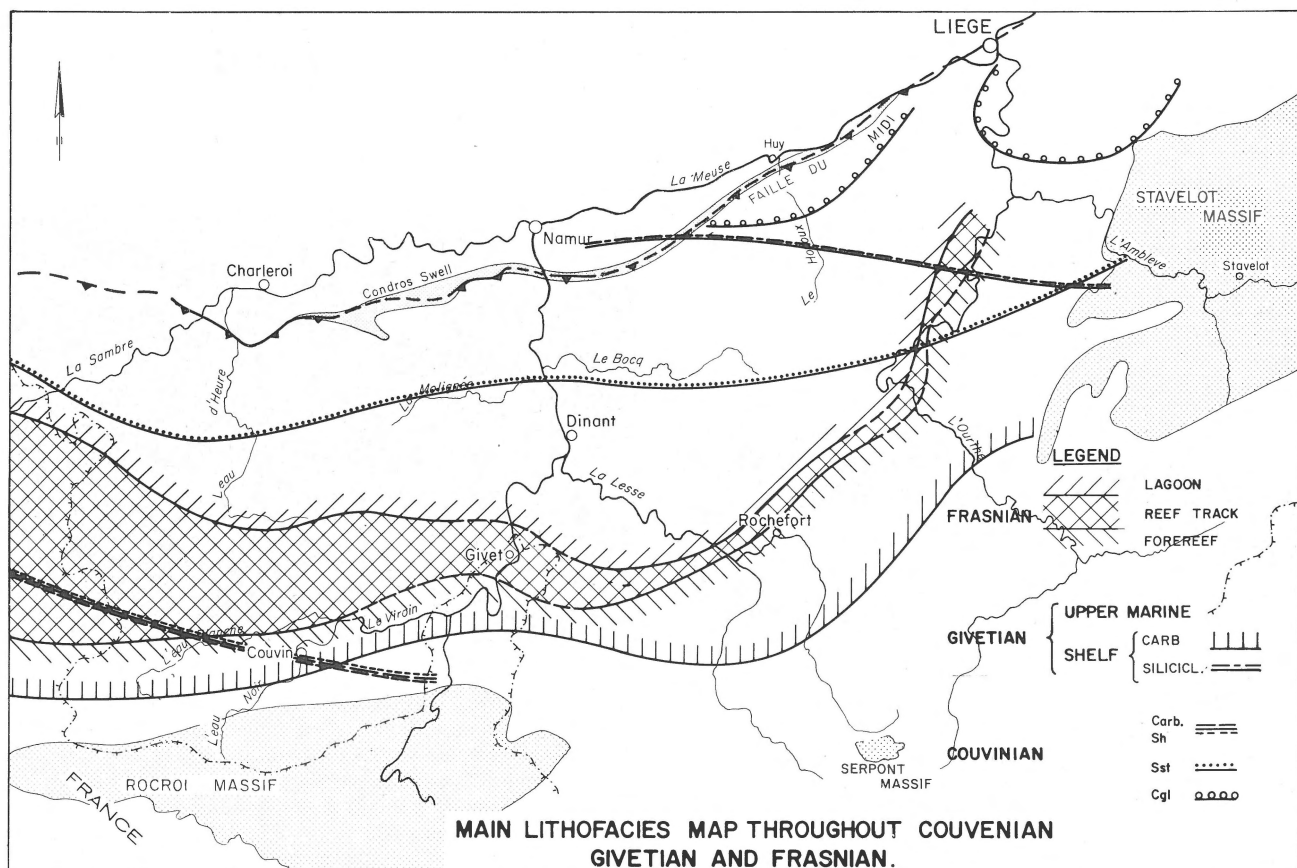


Fig. 14

Sea bottom irregularities, perhaps related to rejuvenated fault blocks, could locally and temporarily have brought parts of the sea bottom within the euphotic zone. Here then carbonate reefs could form, but carbonate production slowed down and even came to a standstill following increased input of terrigenous material or acceleration of the transgression. Repeated rejuvenation or perhaps differential compaction of the shale drape over the previously formed carbonate body could again create a sea bottom irregularity at the same location, and this explains the 'stacking' of build-ups in the southern reef belt.

ZIEGLER'S (1982) megatectonic reconstruction clarifies the tensional structural regime that must be held responsible for the formation of longitudinal basins and swells from the middle Devonian onwards. The facies gradients described in this paper are in accordance with such a regime. The tensional regime changed into an extensional one during the late Devonian, and this could have given rise to the formation of structural lineaments such as those referred to above, along which bioherms were stacked. The carbonate masses – mud-mounds and carbonate platform together – are the result of a balance of carbonate production and overall basin subsidence. They followed the transgression to the north (Fig. 14), as a result of which the overall sedimentary mechanism (REIJERS, 1980) is that of building-up and building-in.

The middle Frasnian carbonates are succeeded by the fine, dark, source rock-like siliciclastics of the upper Frasnian Matagne shales, which represent the acme of Upper Devonian transgression. During this transgression, true basinal facies overstepped basin-edge facies. These sediments will be the topic of a future discussion.

ACKNOWLEDGEMENTS

The preparation of this paper was possible as a result of information which I acquired while guiding excursions for Shell International Petroleum Maatschappij's trainees in the

area described. I have drawn freely on the work of a number of my Shell colleagues, as is reflected in the maps and diagrams in this publication. The know-how and expertise of these colleagues are gratefully acknowledged. I also benefited from discussions with Dr. M. J. J. Bless (Natuurhistorisch Museum, Maastricht) and from discussions and correspondence with Dr. H. H. Tsien (University of Louvain). Data thus acquired were supplemented with my own work, carried out during 1981 and 1982. All facies interpretations and field photographs are mine. The conclusions arrived at in this publication do not necessarily reflect the views of the Shell Group of Companies and are my responsibility.

I am indebted to Shell Internationale Petroleum Maatschappij B.V. for giving me the opportunity to work on this topic and for granting permission to release this work.

REFERENCES

- Asselbergh, E. 1954 L'Eodévonien de l'Ardenne. In: P. Fourmarier (ed.): *Prodrome d'une description géologique de la Belgique* – Soc. Géol. Belg.: 826 pp.
- Lecompte, M. 1961 Facies Marins et stratigraphie dans le Devonian de l'Ardenne – *Ann. Soc. Géol. Belg.* 85: 17-57.
- Lecompte, M. 1963 Note préliminaire et introductive. Excursion C-D. *Vie Congrès International de Sédimentologie Hollande-Belgique*. 1963 – I.A.S.: 48 pp.
- Mountjoy, E. W. & H. H. Tsien (in press) Late Frasnian red mud mounds (Belgium and northern France) – *Sedimentology*.
- Reijers, T. J. A. 1980 Sedimentary mechanisms in Spanish Devonian carbonates – *Geol. Mijnbouw* 59: 87-96.
- Tsien, H. H. 1971 The Middle and Upper Devonian reef complexes in Belgium. *Petroleum Geology of Taiwan* 8: 119-173.
- Tsien, H. H. 1974 Palaeoecology of Middle Devonian and Frasnian in Belgium. *Int. Symposium Namur*. 1974 12: 53 pp.
- 1979 Palaeoecology of algal-bearing facies in the Devonian (Couvenian to Frasnian) reef complexes of Belgium. *Palaeogeogr., Palaeoclimatol., Palaeoecol.* 27: 103-127.
- 1980 Les régimes récifaux Devoniens en Ardenne. *Soc. Belge de Geol. Bull.* 89: 71-102.
- Ziegler, P. A. 1982 *Geological Atlas of Western and Central Europe* – Elsevier (Amsterdam), 130 pp, 40 encl.