Ministry of Economic Affairs, Adm. of Mines, Belgian Geological Survey
*Annales de la Société géologique de Belgique,* T. 109 - 1986, pp. 175-186

Special volume "Aachen 1986"
Avril 1986

# FAMENNIAN PALEOGEOGRAPHY AND EVENT STRATIGRAPHY OF NORTHWESTERN EUROPE

by

**Eva PAPROTH [1], Roland DREESEN [2] & Jacques THOREZ [3]**

(8 figures)

**ABSTRACT.** - The distribution of red beds, evaporites, pedogenic carbonates in the late Devonian of northwestern Europe, and the type of floral assemblages as well as the high feldspar content and the common occurrence of tempestites in the Upper Famennian arkosic sands of the "Psammites du Condroz", are symptomatic of the then prevailing semi-arid climatological conditions of a tropical trade wind belt. A possible source area is here proposed for the latter arkosic sands. The paleogeographical evolution of the Ardenno-Rhenish Massif during the Upper Famennian, is largely the result of an interaction between a strong, southern equatorial current (the deflected Western Boundary Current) and the episodic reactivation of blockfaults (Ardenne) and/or inversion structures (Rheinisches Schiefergebirge). Some regional tectono-sedimentary events as well as some probable worldwide paleoclimatological events are briefly discussed.

**RESUME.** - La distribution de couches rouges, d'évaporites et de carbonates pédogénétiques à la fin du Dévonien du N-W de l'Europe et le type de flore, la présence commune de tempestites et la haute teneur en feldspaths des sables arkosiques des "Psammites du Condroz" au Famennien supérieur, témoignent de conditions climatiques semi-arides prédominantes dans une ceinture tropicale à régime d'alizés. Une source est proposée pour ces sables arkosiques. L'évolution paléogéographique du Massif ardenno-rhénan pendant le Famennien supérieur est, en majeure partie, le résultat d'une interaction entre un fort courant sud-équatorial (le "Western Boundary Current" dévié) et la réactivation épisodique d'un système de blocs faillés (Ardenne) et/ou d'inversion de structures (Rheinisches Schiefergebirge). Quelques phénomènes tectono-sédimentaires régionaux ainsi que des événements paléoclimatologiques probablement d'ampleur mondiale, sont discutés brièvement.

## 1. - LATE DEVONIAN CLIMATE

During the late Devonian, the Ardenno-Rhenish-Polish sedimentary realms were occupied by shallow epicontinental seas bordering the southern parts of the Old Red Continent. This Continent was intersected by the Caledonian mountain belt.

The frequent occurrence of redbeds, evaporites and pedogenic carbonates (caliche, calcretes) on and around the Old Red Continent is symptomatic of prevailing semi-arid climatic conditions of the tropical wind belt (between $10^{o}$ and $30^{o}$S paleolatitude; fig. 1). Similar climatic conditions might explain the abundance of fresh feldspars in the Upper Famennian Condroz arkosic sands in the Belgian Ardenne (Thorez *et al.*, 1986, Thorez & Dreesen, 1986).

The large amount of continental clastics (in the Old Red Sandstone facies) and marine clastics (in the Condroz Sandstone facies) along the European side of the Caledonian mountain belt resulted from the rising and cooling of westward trade winds (T.W.) over these mountains, carrying moist air from the Paleotethys and from the shelf seas to the East of the Old Red Continent. This cooled moist air produced abundant rainfall and subsequent shedding of siliciclastics to the East. The large amount of clastics associated with evaporites (predominantly anhydrite and gypsum) in Europe is in sharp contrast with North American carbonate-associated evaporites because the trade winds carried practically no moist air over the Caledonides,

*1 Geologisches Landesamt Nordrhein Westfalen, De Greiff Str. D 4150 Krefeld, F.R.G.*

*2 INIEB, rue du Chéra, 4000 Liège, Belgium.*

*3 Université de Liège, Minéralogie, Sart Tilman par 4000 Liège, Belgium.*

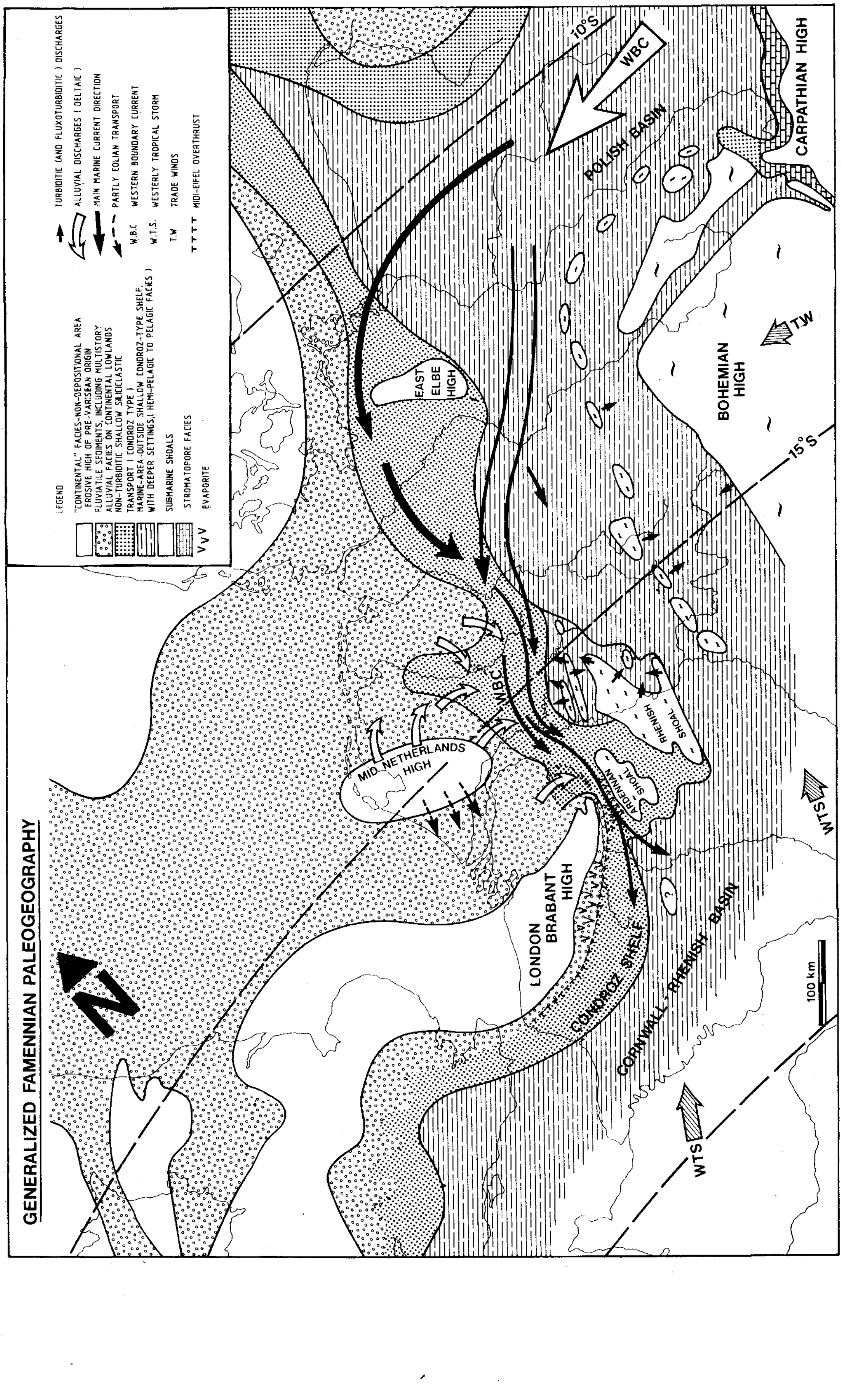
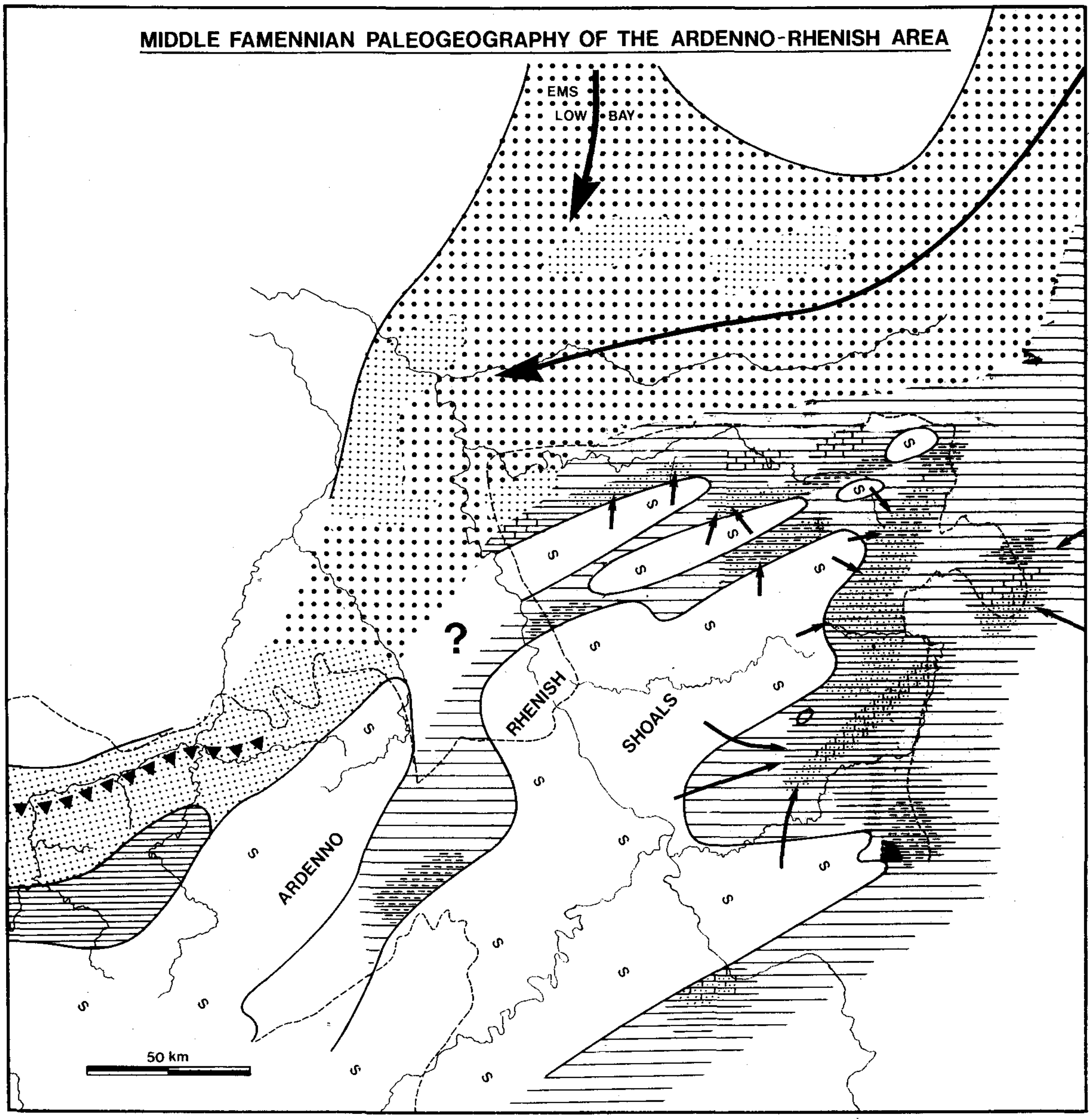

GENERALIZED FAMENNIAN PALEOGEOGRAPHY
N
LEGEND
"CONTINENTAL" FACIES-NON-DEPOSITIONAL AREA
EROSIVE HIGH OF PRE-VARISEAN ORIGIN
FLUVIATILE SEDIMENTS, INCLUDING MULTISTORY
ALLUVIAL FACIES ON CONTINENTAL LOWLANDS
NON-TURBIDITIC SHALLOW SILICICLASTIC
TRANSPORT ( CONDROZ TYPE )
MARINE-AREA-OUTSIDE SHALLOW CONDROZ-TYPE SHELF,
WITH DEEPER SETTINGS,( HEMI-PELAGIC TO PELAGIC FACIES )
SUBMARINE SHOALS
STROMATOPORE FACIES
EVAPORITE
TURBIDITIC (AND FLUXOTURBIDITIC ) DISCHARGES
ALLUVIAL DISCHARGES ( DELTAIC )
MAIN MARINE CURRENT DIRECTION
PARTLY EOLIAN TRANSPORT
W.B.C WESTERN BOUNDARY CURRENT
W.T.S. WESTERLY TROPICAL STORM
T.W TRADE WINDS
MIDI-EIFEL OVERTHRUST
EAST ELBE HIGH
MID NETHERLANDS HIGH
LONDON BRABANT HIGH
CONDROZ SHELF
CORNWALL-RHENISH BASIN
ARDENNIAN SHOAL
RHENISH SHOAL
POLISH BASIN
BOHEMIAN HIGH
CARPATHIAN HIGH
WBC
WTS
TW
10°S
15°S
100 km

Figure 1




LEGEND

- CONTINENTAL LOWLAND
- SUPPOSED WELL-AERATED WATER AREA
- SUPPOSED SHELF-TYPE "CONDROZ SANDSTONE FACIES"
- SUPPOSED QUIET WATER AREA
- SUPPOSED "HERCYNIAN FACIES"
- BARRIER SYSTEM
- S S S S SHOALS ( SUBMARINE AND SUBAERIAL )
- SANDSTONE-SILTSTONE
- MUDSTONE-SILTSTONE
- NODULAR LIMESTONE
- TURBIDITY CURRENT DIRECTION
- SEA CURRENT DIRECTIONS,NON-TURBIDITIC TRANSPORT

Figure 2

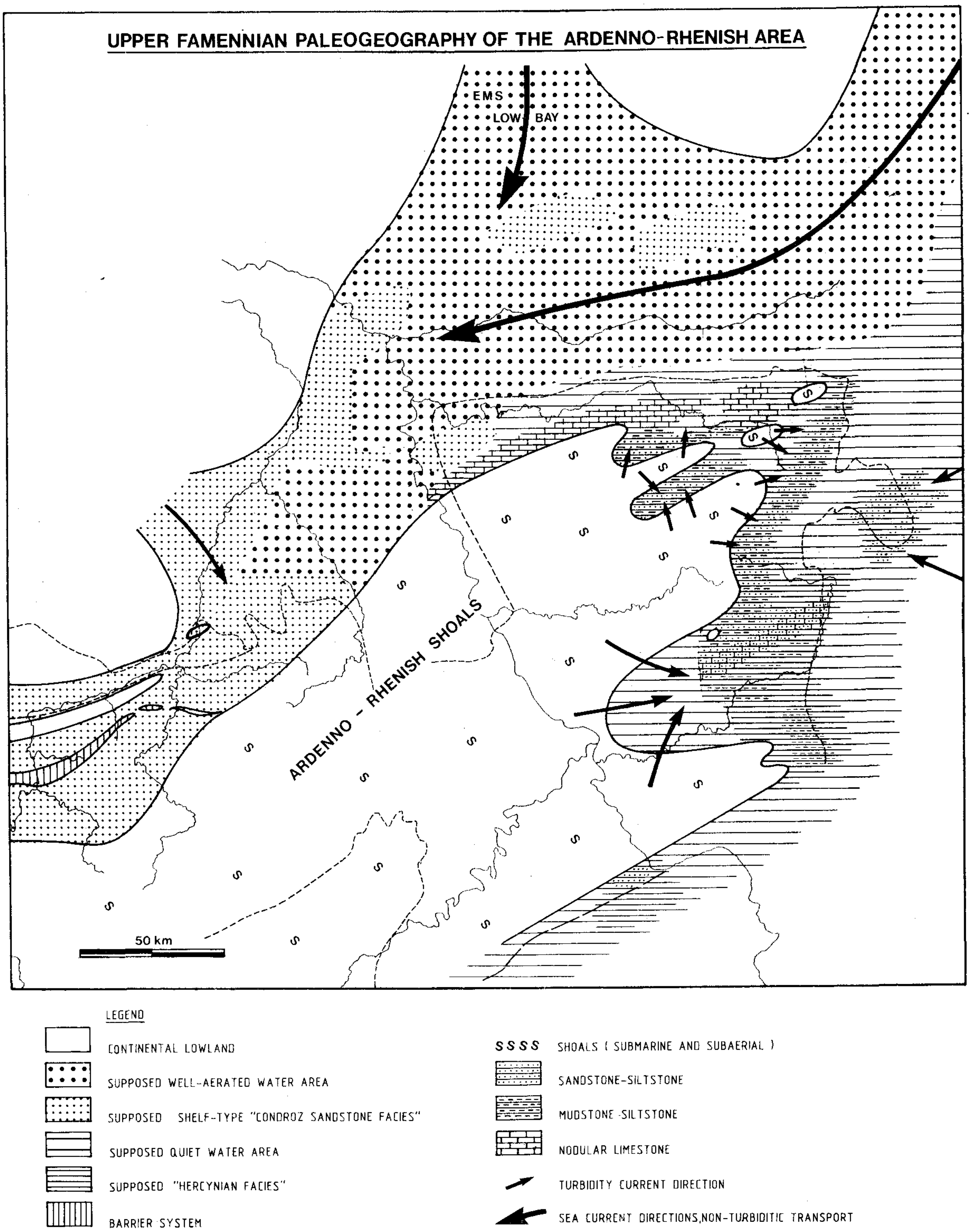

UPPER FAMENNIAN PALEOGEOGRAPHY OF THE ARDENNO-RHENISH AREA
EMS
LOW BAY
ARDENNO - RHENISH SHOALS
50 km
LEGEND
CONTINENTAL LOWLAND
SUPPOSED WELL-AERATED WATER AREA
SUPPOSED SHELF-TYPE "CONDROZ SANDSTONE FACIES"
SUPPOSED QUIET WATER AREA
SUPPOSED "HERCYNIAN FACIES"
BARRIER SYSTEM
SSSS SHOALS ( SUBMARINE AND SUBAERIAL )
SANDSTONE-SILTSTONE
MUDSTONE-SILTSTONE
NODULAR LIMESTONE
TURBIDITY CURRENT DIRECTION
SEA CURRENT DIRECTIONS,NON-TURBIDITIC TRANSPORT

Figure 3

and became so highly dessicating that rock salt and potash salt were formed (Heckel & Witzke, 1979).

The occurrence of thick coal-bearing clastics in the Upper Devonian of the Canadian Arctic Islands seems to be related to the doldrum rainfall in the near-equatorial tropical rain belt (Heckel & Witzke, 1979), whereas the abundant floral remains in the Famennian swamps of the Appalachians (Banks *et al.,* 1985) are consistent with the temperate humid belt (30$^o$ to 40$^o$S paleolatitude) on the windward, rainy side of the Acadian mountains. The Famennian humid belt floral assemblage contained conspicuous near-swamp lycopod tree communities (Scheckler, 1986a) which is in contrast with the coeval North European trade wind belt flora : here levees and floodplains were colonized by *Archaeopteris* whereas *Rhacophyton* dominated the coastal marshes and alluvio-lagoonal ponds (Fairon-Demaret, pers. communic.).

There is also a fundamental difference in fluvial regime between both areas : in the late Devonian Catskill Delta, sediments of numerous meandering streams in lowland interfluves and floodplains have been observed (Scheckler, 1986b) whereas the streams tended to be rather "flashy" in the NW European lowlands. The frequency of tempestites and that of hummocky stratification within the late Devonian Condroz Sandstones ("Psammites du Condroz") in the Belgian Ardenne, is consistent with the distribution of Paleozoic hurricane deposits which may be expected from latitudes of about 10$^o$ to 45$^o$S, with a maximum between 10$^o$ and 20$^o$S (Duke, 1985).

In the then southern hemisphere, the easterly trade winds were accompanied by a warm equatorial westward sea current between the equator and about 20$^o$S (Heckel & Witzke, 1979). This southern equatorial current flowed through the Paleotethys towards central Europe, split at the southeastern side of the Russian Platform, with one branch moving southwestward through the intricately subdivided basinal area of Central Europe as a western boundary current (W.B.C.) (fig. 1.).

A branch of the western boundary current may have been deflected by numerous shoals and islands formed by the *in situ nascendi* Variscan tectogen. There is no evidence for strong sea currents in the Polish, Czechoslovakian or German outcrops. Very remarkably is the survival of stromatoporoid facies in the Famennian in Moravia and neighbouring areas near the Pre-Carpathian Platform (Dvořák, 1986).

A more northerly branch of the same current passed through the Polish Basin and was then deflected by the Old Red Continent, where it passed through (rather) narrow seaways in between the emerging Ardenno-Rhenish Shoals (cf. the "Vesdre Corridor", fig. 6), redistributing the alluvial discharges of prograding deltas which came from the Old Red Continent in the Netherlands and North German Lowlands. Thus the classical Upper Famennian "Psammites du Condroz" originated through a current-induced destruction of delta lobes and a subsequent westward redistribution of the pro-delta sands. Although "flashy" fluvial regimes with episodic, high discharge periods are more likely to supply coarse sediments to a delta (e.g. the Old Red Sandstones of the British Isles), the Condroz Sandstones are fine-grained. This results most probably from the reworking of an originally eolian-alluvial sediment which derived from a nearby, supposedly Pre-Cambrian gneissic source rock area, the Mid-Netherlands High.

Evidence exists in South America (North Brazil), and possibly also in Central Africa, for an early to late Famennian glaciation (Caputo, 1985; Streel, 1986). It might have caused a global narrowing of the warm climatic belts, sharp regressions and increased siliciclastic sedimentation. Together, with the reciprocal effects at the end of the glaciation this should have resulted in important facies changes in the world geological record.

## 2. - STRUCTURAL FRAMEWORK

The southwestern boundary between the East European or Russian Platform and the Variscan tectogen dominates the structural development of Central Europe (Fig. 4). West of the Tornquist Line, the rim of the Platform seems to be broken into a chessboard-like structure. In Central Europe, a main line crossing the Platform and in parts forming the boundary between Platform and tectogen is marked by the Hamburg-Cracow Lineament (Dvořák, 1968). Further to the West, the Platform seems to be even more fragmented in northern Germany, the Netherlands and northern Belgium. In the Netherlands and northern Germany, the long-lasting effects of both NNW/SSE and N/S trending structures are supposed to be inherited from Pre-Variscan and Pre-Cambrian basement (Pratsch, 1979; Bless *et al.,* 1980).

One of the main NNW/SSE trending elements seems to be the Mid-Netherlands-(Zandvoort-Maasbommel)-Krefeld High. Our knowledge of it is scarce; the oldest direct hint to its existence are pebbles of epizonal metamorphic rocks in the Givetian Schwarzbachtal-Konglomerat North of Düsseldorf (Makrutzi, 1982; Neumann-Mahlkau, 1982). The influence of this structure can be traced from the Givetian into at least the Cretaceous (Van Staalduinen *et al.,* 1979). Inversions of this "High" are well known (Klostermann, 1983). In the Famennian, it may have been a main source of siliciclastic detritus that was deposited in the Condroz Sandstones facies. In the long Post-Famennian history of this "High", lateral movements and rotations have certainly changed the topography particularly of the southern portion (Plein *et al.,* 1982; Klostermann, 1983). Any reconstructions based on modern topography are hampered by these difficulties.

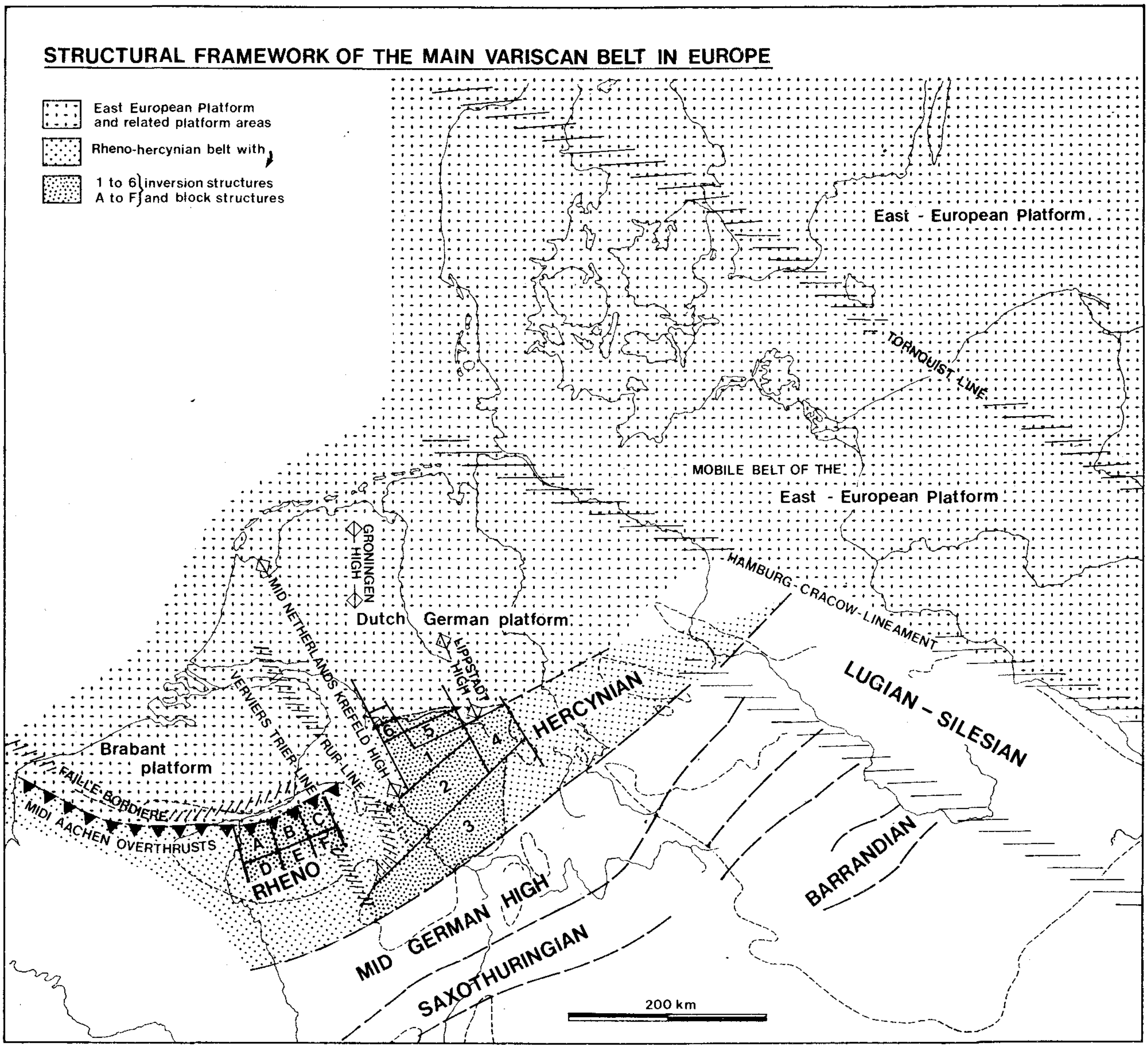



Figure 4

The Mid-Netherlands-Krefeld High and a line continuing it in a southern direction seem to bound two different areas :

- on the West : the area of the Brabant platform is marked by a shallower level of the basement, that gradually rises northwards until it reaches its highest level North of the Faille du Midi or near the Faille Bordière (Legrand, 19 ).
- in the East : the area of the Dutch-German Platform is marked by a deeper position of the basement; it finally drops steeply beneath the Variscan tectogen.

## 3. - FAMENNIAN PALEOGEOGRAPHY AND EVENTS

### 3.1. - GENERALITIES

In the early Famennian, the beginning of a Famennian glaciation may have caused a cooling of the ocean waters. The worldwide refrigeration would explain the increase in clastic sedimentation (i.e. the "Psammites du Condroz") in areas where tropical biochemical sedimentation (e.g. the extensive Givetian and Frasnian carbonate shelves with reef belts) pre-

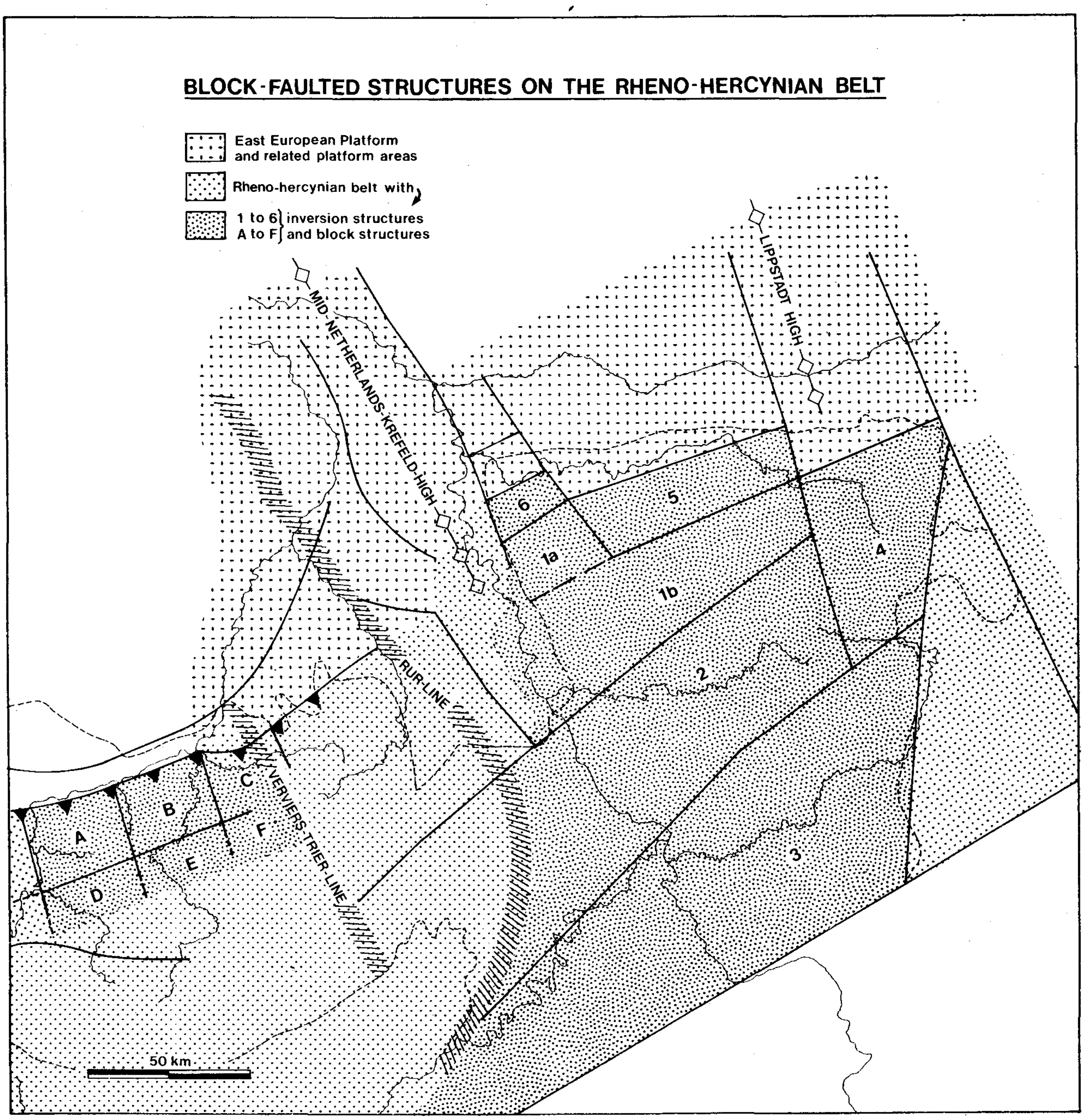



Figure 5

viously predominated. Moreover, the first appearance of plant seeds in the late Famennian (VCo spore zone) coincides with this "event". Would this indicate an evolutionary adaptation of plant life to an increasingly dry environment (Gillespie *et al.*, 1981; Fairon-Demaret, 1986)?

Near the Devonian-Carboniferous boundary, a general climatic change - the end of the Famennian glaciation ? - may have affected the southeastern borders of the Old Red Continent. The effects of a "worldwide" post-glacial warming of the ocean waters may have been intensified by the simultaneous northward shift of the Old Red Continent crossing the equator. This post-glacial warming of the ocean waters in the latest Famennian and a small northern shift of the Old Red Continent ($5^{o}$ at the most) towards the equator might well explain the reappearance of stromatoporoids and calcareous ooids (Etroeungt and Hastière Limestones in Belgium) in the area here described.

Famennian stromatoporoid reef facies seems to be restricted in Central Europe to the shelf regions without siliciclastic sedimentation such as those bordering or near the Pre-Carpathian Platform. Crinoidal debris "reefs" and cryptalgal sponge-bearing carbonate buildups could exceptionally develop within the northern siliciclastic shelf settings in NW Europe, on pre-destinated highs during a temporary waning of the siliciclastic supply (Dreesen *et al.*, 1985). Carbonate buildups such

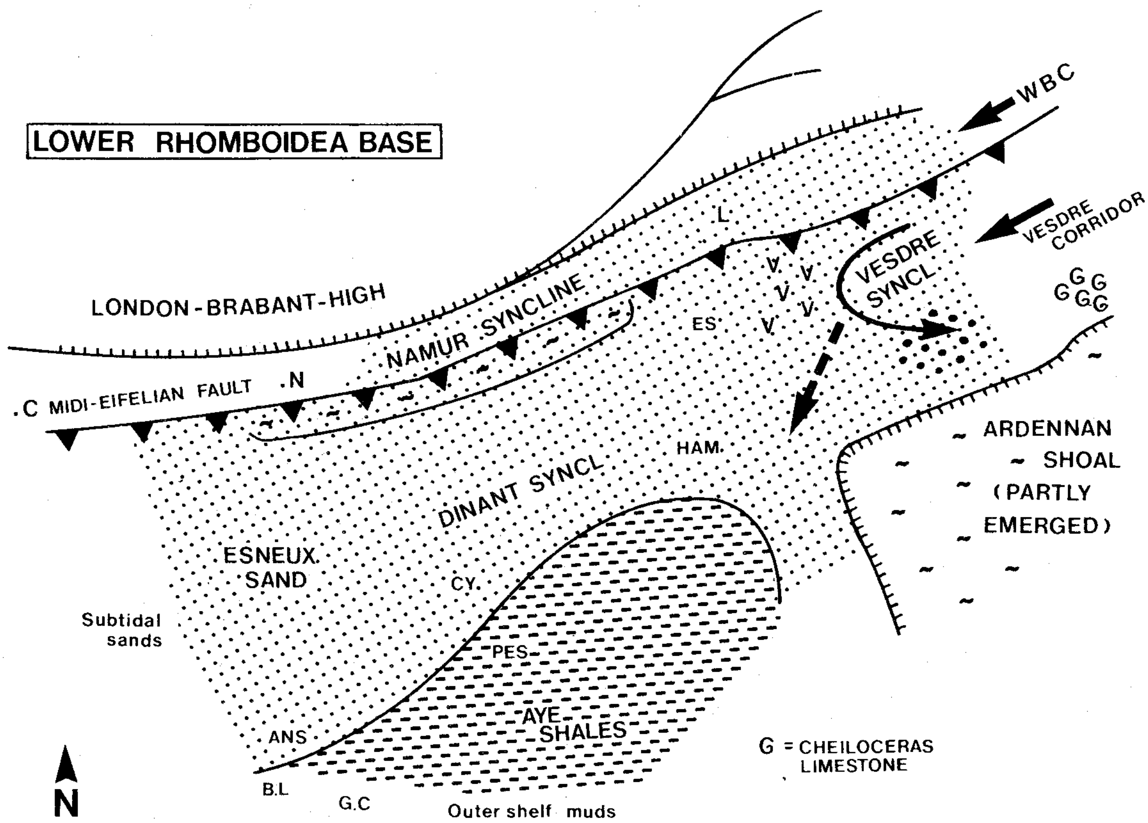



Figure 6

as the "Baelen reefs", represent a Famennian "reef" episode that coincides with a short transgressive pulse resulting in the temporary appearance of protected shelf carbonates and in the immigration of primitive pluri-locular Foraminifera (Conil *et al.,* 1986). This short-term transgressive event in the northern Ardenne shelf area possibly matches a coeval deepening event on the platform settings of the western United States (Johnson *et al.,* 1985).

Other interregional or worldwide transgressive pulses so far observed in the Famennian are few, and the interpretation that these were caused by transgressions seem to be traditional rather than based on facts. Effects of the extensive "*Annulata* Black Shale" event in Germany have been recognised in North America (event Q of House, 1983), and might also be recognizable in Belgium. Indeed, conspicuous black shales (up to 15 m thick) interrupt the younger sandstone units of the "Psammites du Condroz" at a level approximatively corresponding to the base of the *P. postera* conodont Zone (top of the German *Platyclymenia* Stufe). Another supposed deepening event is observed in the *Wocklumeria* Stufe in Germany, producing few centimeters of alum shales with *Cymaclymenia evoluta.*

However, the most striking event observed within the Upper Famennian shallow shelf area is a regional regression which is characterized by the progradation of alluvio-lagoonal coastal barrier and tidal flat complexes, South and Southeast of the London-Brabant High (Thorez, 1969; Thorez *et al.,* 1977; Thorez & Dreesen, 1986). This offlap is rhythmic and is apparently associated with episodic reactivation of small tectonic blocks producing differential subsidence and the persistence of non-depositional areas (Thorez & Dreesen, 1986).

At about the same time, inversion structures became reactivated in the Rheinisches Schiefergebirge (Rhenish Shoals) - the increase of these morphological structures as potential source for the siliciclastics may have been caused by the regression - producing and triggering turbidites towards depocenters in the immediate surroundings (Nehdenian and Dasbergian Sandstones in Germany). An incipient mountain chain, the Mid German Shoals, gradually rised in the southern geosynclinal areas, announcing the forthcoming flysch stages (greywackes).

The tectonic blocks in the Ardenne (Thorez & Dreesen, 1986) and the inversion structures in the Rhenish Massif are bordered by NNW/SSE and WSW/ENE directed block faults which are supposed to have been inherited from the basement.

### 3.2. - THE WESTERN AREAS

The influence of synsedimentary tectonic movements is demonstrated by the paleogeographic evolution of the "Psammites du Condroz" case study in the

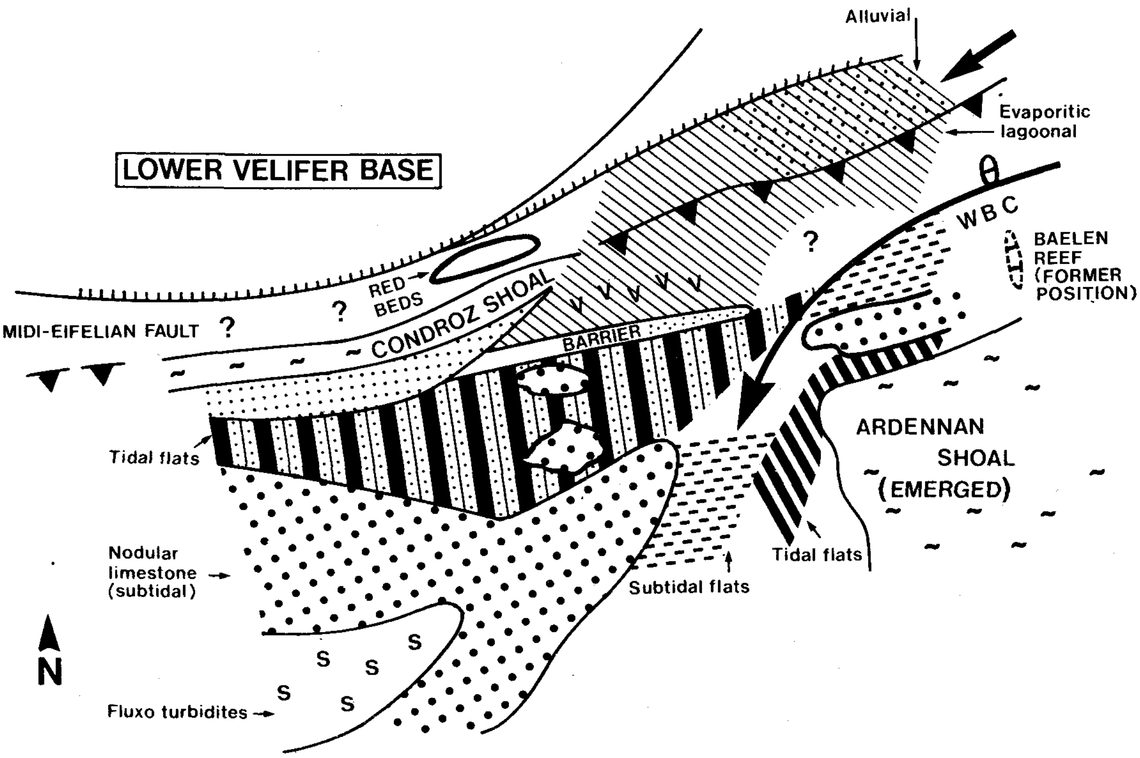



Figure 7

eastern part of the Dinant Synclinorium (Thorez & Dreesen, 1986). The reconstruction has been completed on the basis of a slice-by-slice framework that includes eleven superposed sedimentary phases, matched by the "rhythmostratigraphy", the interpretation of the depositional environmental conditions (at different scales of the sedimentation) within the eastern part of the Dinant Synclinorium, and by micropaleontological arguments (the mgm or "micropaleontologic guide marks" proposed during the 1974 Namur Symposium, Bouckaert & Streel, Eds.; Thorez *et al.,* 1977). Three of these partial reconstructions are here reproduced (Fig. 6, 7, 8). They concern the Upper *P. crepida*-Lower *P. rhomboidea,* the Lower *S. velifer,* and the VCo biostratigraphical invervals. However, these three paleogeographic reconstructions are not based on a palinspastic development as presented in Thorez & Dreesen (1986). As emphasized by Thorez & Dreesen (1986) the progradational evolution of the "Psammites du Condroz" in their type-area was controlled by the interplay of paleomorphology, paleohydrodynamics, paleotectonics (block-tilting) and paleoclimatology.

For the first time, also, sedimentary and stratigraphic relationships between the Upper Famennian of Germany and Belgium are here forwarded. This circumstance has favoured a broad picture of the entire depositional framework during this crucial period in the Old Red Continent evolution. The reconstructed depositional system of the "Psammites du Condroz" in Belgium sheds some light on similar but still not detailed patterns in the neighbouring area, particularly in the Federal Republic of Germany. Even if no comparable analysis has been completed for the latter area, it is possible to gather some arguments helping to trace the pathways of the siliciclastics accumulated on the Condroz Platform in Belgium (Thorez & Dreesen, 1986). The three selected paleogeographic reconstructions for the Upper *P. crepida*-Lower *P. rhomboidea,* Lower *S. velifer* and VCo biozones, point to a certain similarity in facies, tectonic influence and paleogeography West and East of the Ardenno-Rhenish Shoals (Figures 6, 7, 8). The influence of the Western Boundary Current is the most conspicuous fact on the Condroz Platform after its passage through the "Vesdre Corridor" separating the London-Brabant High and the Ardenno-Rhenish Shoals.

Evaporites and oolitic ironstones seem to have been closely associated in time and space during the late Devonian. The oolitic ironstones were formed during a temporary emersion of protected shelf areas, mostly along coastal embayments. They became then winnowed and redistributed over large parts of the shelf areas by tropical storms, whereas longshore currents subsequently dispersed them into the more offshore shelf settings.

The offshore, pelagic to hemi-pelagic settings of the Cornwall-Rhenish Basin are characterized by shales, entomozoan ostracode shales and nodular shales, with locally condensed cephalopod limestones on submarine shoals (submerged former reefs, volcanic mounds or inversion blocks). The offshore settings of the Dinant Synclinorium show a less "pelagic" character because

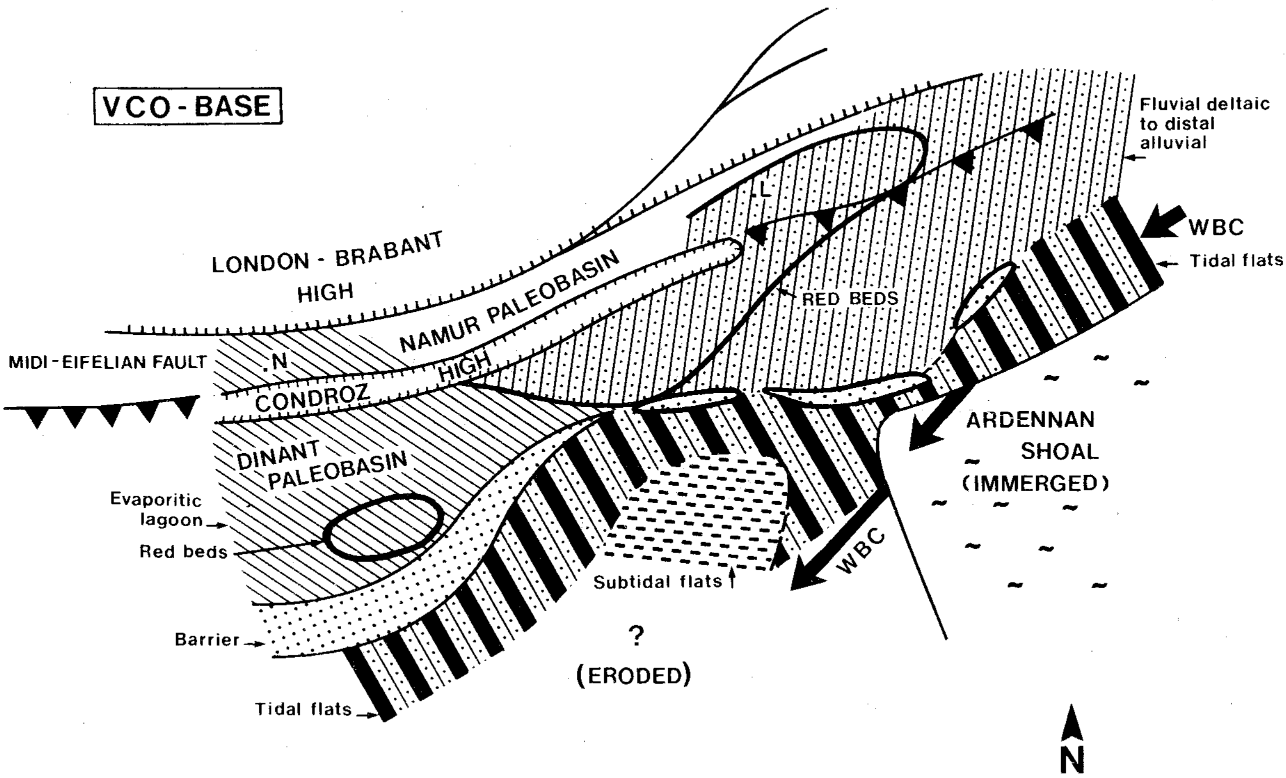



Figure 8

of the persistent contamination by fine siliciclastics (pelites, silts) brought in from the Northeast by the longshore currents (Western Boundary Current).

The episodic reddening of muds and carbonate sediments in the more basinal areas matches the episodic occurrence of oolitic ironstones on the Condroz shelf with synsedimentary volcanic activity in the Lahn-Dill area (Dreesen, 1981, 1982). Although Dvořák (1985) related the red colour of pelites and associated coarser siliciclastics in the Rheinisches Schiefergebirge (during Nehdenian times) to periodical detrital influx from inversion structures, a volcano-sedimentary origin (halmyrolysis of volcanic ash-falls) cannot be excluded (Dreesen & Thorez, 1980). Moreover, regularly interbedded shabkha-related redbeds have been observed in the Dinant Synclinorium. These form excellent local marker beds within the youngest strata of the "Psammites du Condroz", especially along the southeastern border of the London-Brabant High (Thorez *et al.*, 1986).

The shallow Condroz shelf area and its lateral equivalents formed the recipient of predominantly coarser siliciclastics, the Condroz sandstones. Thorez (1969) has demonstrated that those sandstones are, in fact, very fine-grained micaceous arkoses. For a long time, geologists have been puzzled by their exact origin and source area. The concept of a remote, northern Caledonian or Scandinavian source area should now be rejected in the light of the more recent knowledge on Famennian climatic and paleogeographic conditions : the presence of a high fresh feldspar content would have been practically impossible to meet under the humid tropical conditions which presumably influenced the Scandinavian area. Instead, a progressive physical weathering under dry, semi-arid conditions is suggested here, of a nearby (supposedly Precambrian gneissic (and granitic ?) source rock : the core of the Mid Netherlands High, figure 1, 4, 5). This would explain both the high mica (muscovite plus biotite) and fresh feldspar content. Furthermore, the fineness and good sorting of those sands would best be explained by a trade wind-induced eolian transport of the siliciclastics from the above source area to the adjacent lowlands. A subsequent episodic alluvial transport by "flashy" rivers would have transported the reworked eolian sands to a high-destructive wave-influenced delta lobe where (Fig. 1, Thorez *et al.*, 1986) strong longshore currents (W.B.C.) picked up the prodelta sands, reworking them towards the western shallow shelf areas; there the coarser material (sands) was resedimented as longshore coastal sand bars, and the finer clastics (silts and muds), as offshore silty shales. The gradual increase of the feldspar/quartz ratio and the gradual decrease of the mica content towards the younger formations of the "Psammites du Condroz" are possibly explained by a gradual change of the source rock composition : a progressive denudation, or "peeling", of a metamorphic basement rock (the Mid-Netherlands-Krefeld High) would have produced successively phyllitic, micaschist and, then gneissic detrital material. Furthermore, the sudden drop of the feldspar content (from about 50 °/o in the youngest Evieux Formation, to 5 °/o in the Strunian) could be related to a final leveling of the suggested source area and/or by a climatic change (a temporary increase of the number and length of the wet periods ?).

### 3.3. - THE EASTERN AREAS

In the Rhenish Massif, East of the Rhine river, incompletely studied sediments of the Condroz Sandstone facies crop out in the Velbert Anticline. During the Famennian, the actual Velbert Anticline was a rapidly subsiding trough (the youngest of the inversion structures, nr 6, fig. 5) where presumably some 1000 m thick fine-grained shallow-water siliciclastics accumulated. The boundary between the "Condroz Sandstone" facies Velbert Formation, and the typical quiet water ("basinal") facies to the East is sharp and crops out at Wuppertal. The very sharp facies boundary indicates no great differences in water depth, the main difference between the facies belts was possibly the relative water energy (Schmidt, 1935).

On top of the Mid-Netherlands-Krefeld High and East of it, in the southerly parts of the Dutch-German platform, only few boreholes have penetrated sufficiently deep into Famennian rocks for a tentative interpretation. The differences in thickness and grainsize of Famennian Condroz Sandstone facies siliciclastics suggest a decreasing energy of marine currents for the Münsterland-1 borehole area. This may have been caused by an increased width of the sea way thus suggesting the existence of a bay matching the Ems Low trend.

In the "basinal" areas of the Variscan tectogen, greywacke sands were transported by turbidity currents into rapidly descending basins in proximal parts of the geosyncline (Andelska Hora Formation in Moravia, Urfer Grauwacke and equivalents in West Germany). The erosion of the Mid German shoals and islands started during this period.

Another source of siliciclastic detritus was the rising Rhenish Massif where the inversion structures 1 to 5 (Figs. 4, 5) were locally eroded, producing small amounts of detritus. Eastern (and northern in the Nehdenian) fringes of the Rhenish shoals area were more eroded than inner and western parts of the region (Kayser *et al.,* 1978). A particular feature is the Hörre-Kellerwald-belt, where longitudinal transport of siliciclastics started in the narrow basin persisted intermittently into the Visean (Homrighausen, 1979).

Sedimentary areas that were not easily reached by the siliciclastics mentioned above were covered - so far as known - by nodular limestone material with varying contents of argillaceous and silty material, depending on whether they were in distal reach or not of the source areas.

Water energy and consequently aeration of the sea waters and the sea bottom were weak. Benthonic fossils may locally occur but are not common.

## REFERENCES


BANKS, H.P., GRIERSON, J.D. & BONAMO, P.M., 1985. The flora of the Catskill clastic wedge. Geol. Soc. Amer. Spec. Pap. 201 : 125-141.

BLESS, M.J.M., BOUCKAERT, J. & PAPROTH, E., 1980. Environmental aspects of some Pre-Permian deposits in NW Europe. Meded. Rijks Geol. Dienst, 32 (1) : 3-13.

CAPUTO, M.V. 1985. Late Devonian glaciation in South America. Paleogeogr., Paleoclimatol., Paleoecol., 51 : 291-317.

CONIL, R., DREESEN, R., LENTZ, M.-A., LYS, M. & PLODOWSKI, G., 1986. The Devono-Carboniferous transition in the Franco-Belgian basin with reference to Foraminifera and Brachiopods. *In* Late Devonian events around the Old Red Continent, M.J.M. Bless & M. Streel (eds), Ann. Soc. géol. Belg., 109 : 19-26.

DREESEN, R., 1981. Importance paléogéographique des niveaux d'oolithes ferrugineuses dans le Famennien (Dévonien supérieur) du Massif de la Vesdre (Belgique orientale). C.R. Acad. Sc., Paris, 292 (II) : 615-617.

DREESEN, R., 1982. Storm generated oólitic ironstones of the Famennian (Fa1b - Fa2c) in the Vesdre and Dinant synclinoria (Upper Devonian, Belgium). Ann. Soc. géol. Belg., 105 : 105-129.

DREESEN, R., KASIG, W., PAPROTH, E. & WILDER, H., 1985. Recent Investigations within the Devonian and Carboniferous North and South of the Stavelot-Venn Massif. N.Jb. Geol. Paläontol. Abh., 171 : 237-265.

DREESEN, R. & THOREZ J., 1980. Sedimentary environments, conodont biofacies and paleoecology of the Belgian Famennian (Upper Devonian). An approach. Ann. Soc. géol. Belg., 103 : 97-110.

DUKE, W.L', 1985. Hummocky stratification, tropical hurricanes and intense winter storms. Sedimentology, 32 : 167-194.

DVOŘÁK, J., 1968. The Tectogenesis of the Central European Variscides. Internat. Geol. Congr. Reports, 23rd Sess. Czechoslovakia, 1968, Abst., Sect. 3, 8.

DVOŘÁK, J., 1985. The red shales of the Upper Devonian in the Rhenish Slate Mountains. N. Jb. Geol. Paläontol. Abh., 1985 : 329-339.

DVOŘÁK, J., 1986. The Famennian of Moravia (ČSSR) : the relation between tectonics and sedimentary facies. *In* Late Devonian events around the Old Red Continent, M.J.M. Bless & M. Streel (eds), Ann. Soc. géol. Belg., 109 : 131-136.

FAIRON-DEMARET, M., 1986. Some Uppermost Devonian megafloras : a stratigraphical review. *In* Late Devonian events around the Old Red Continent, M.J.M. Bless & M. Streel (eds), Ann. Soc. géol. Belg., 109 : 43-48.

GILLESPIE, W.H., ROTHWELL, G.W. & SCHECKLER, S.E., 1981. The earliest seeds. Nature, 293, 5832 : 462-464.

HECKEL, P.H. & WITZKE, B.J., 1979. Devonian world paleogeography determined from distribution of carbonates and related lithic paleoclimatic indicators. *In* : "The Devonian System" (M.R. House, C.T. Scrutton & M.C. Bassett, Eds.), Spec. Pap. in Palaeont., 23 : 99-124.

HOMRIGHAUSEN, R., 1979. Petrographische Untersuchungen an sandigen Gesteinen der Hörre-Zone (Rheinisches Schiefergebirge, Oberdevon-Unterkarbon). Geol. Abh. Hessen, 79 : 84 p.

HOUSE, M.R., 1983. Devonian eustatic events. Proc. Ussher Soc., 5 : 396-405.

JOHNSON, J.G., KLAPPER, G. & SANDBERG, C.A., 1985. Devonian eustatic fluctuations in Euramerica. Geol. Soc. Amer. Bull., 96 : 567-587.

KAISER, H., PAPROTH, E. & STADLER, G., 1978. Neue Beobachtungen zur Entstehung des Rheinischen Schiefergebirges. Z. dt. geol. Ges., 129 : 181-199.

KLOSTERMANN, J., 1983. Die Geologie der Venloer Scholle (Niederrhein). Geol. Jb. A 66 : 115 p.

MAKRUTZKI, I., 1982. Die Gesteinsbruchstücke der Devon-Sandsteine in der Bohrung Schwarzbachtal 1. Senckenbergiana lethaea, 63 : 97-110.

NEUMANN-MAHLKAU, P., 1982. Die Gerölle in den Schwarzbachtal-Konglomeraten bei Ratingen und ihre paläogeographische Aussage. Senckenbergiana lethaea, 63 : 79-95.

PLEIN, E., DÖRHOLT, W. & GREINER, G., 1982. Das Krefelder Gewölbe in der Niederrheinischen Bucht - Teil einer grossen Horizontalverschiebungszone ? Fortschr. Geol. Rheinld. Westfalen, 30 : 15-29.

PRATSCH, J.-C., 1979. Regional structural elements in northwest Germany. J. Petrol. Geol., 2 (2) : 159-180.

SCHECKLER, S.E., 1986a. Geology, floristics and paleoecology of Late Devonian coal swamps from Appalachian Laurentia (USA). *In* Late Devonian events around the Old Red Continent, M.J.M. Bless & M. Streel (eds), Ann. Soc. géol. Belg., 109 : 209-222.

SCHECKLER, S.E., 1986b. Old Red Continent facies in the Late Devonian and Early Carboniferous of Appalachian North America. *In* Late Devonian events around the Old Red Continent, M.J.M. Bless & M. Streel (eds), Ann. Soc. géol. Belg., 109 : 223-236.

SCHMIDT, H., 1935. Die bionomische Einteilung der fossilen Meeresböden. Fortschr. Geol. u. Paläontol., 12 (H. 38).

STREEL, M., 1986. Miospores contribution to the Upper Famennian-Strunian event stratigraphy. *In* Late Devonian events around the Old Red Continent, M.J.M. Bless & M. Streel (eds), Ann. Soc. géol. Belg., 109 : 75-92.

THOREZ, J., 1969. Sedimentologie du Famennien supérieur dans le Synclinorium de Dinant. Doctoral thesis, Liège Univ., 225 p. (unpublished).

THOREZ, J., STREEL, M., BOUCKAERT, J. & BLESS, M.J.M. 1977. Stratigraphie et paléogéographie de la partie orientale du Synclinorium de Dinant (Belgique) au Famennien supérieur : un modèle de bassin sédimentaire reconstitué par analyse pluridisciplinaire sédimentologique et micropaléontologique. Meded. Rijks Geol. Dienst (The Netherlands), N.S., 28 : 17-32.

THOREZ, J., DREESEN, R. & GOEMAERE, E., 1986. The "Psammites du Condroz" A progradational deltaic lagoonal sand bar and tidal flats complex in the late Upper Devonian of Belgium. Sedimentology (in press).

THOREZ, J. & DREESEN, 1986. A model of a regressive depositional system around the Old Red Continent as exemplified by a fieldtrip in the Upper Famennian "Psammites du Condroz" in Belgium. *In* Late Devonian events around the Old Red Continent, M.J.M. Bless & M. Streel (eds), Ann. Soc. géol. Belg., 109 : 285-323.

VAN STAALDUINEN, C.J., VAN ADRICHEM BOOGAERT, H.A., BLESS, M.J.M., DOPPERT, J.W.Chr., HARSVELT, H.M., VAN MONTFRANS, H.M., OELE, E., WERMUT, R.A. & ZAGWIJN, W.H., 1979. The geology of The Netherlands. Meded. Rijks Geol. Dienst, 31 (2) : 9-49.