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MIGRATION OF FACIES BELTS AS A RESPONSE TO CONTINENTAL DRIFT DURING THE LATE DEVONIAN AND CARBONIFEROUS

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and Eva PAPROTH (★★★)

ABSTRACT. - Continental drift in geological times is well documented by numerous paleomagnetic measurements all over the globe. Because of this continental wandering the relative position of the paleoequator shifted from Spitsbergen (Svalbard) in (compared to present-day geography) southeastern direction over Western Europe during the Late Devonian and Carboniferous. This southeastern migration of the relative position of the paleoequator can be traced by the shift of several mega-facies belts (notably evaporite and coal deposits) in the same direction.

RESUME. - Les nombreuses mesures paléomagnétiques ont démontré l'existence de la dérive des continenta durant les temps géologiques. A cause de cette dérive continentale, la position relative du paléoéquateur changea depuis le Spitsberg (Svalbard) vers (comparaison faite avec la position géographique actuelle) une direction sud-orientale en passant par-dessus l'Europe occidentale et cela pendant le Dévonien tardif et le Carbonifère. Ce changement peut être tracé par la mise en évidence de différents méga-faciès (notamment les évaporites et la formation des bassins houillers) qui se développèrent dans la même direction.

Today, major climatic belts are more or less subparallel to the equator. In an oversimplified cartoon (figure 1), four major climatic belts can be distinguished North and South of the equator, namely the doldrums belt, the arid to semiarid zone, the humid zone and the polar belt. Each of these is characterized by some very distinctive features.

The doldrums belt roughly extends between 5°S and 5°N latitude, and is characterized by luxuriant rain forest which flourish in a warm and wet tropical climate.

North, respectiveley South of this belt, the climate is frequently more dry (e.g. Sahara-Sahel, Sinai, Nefud, Rub-al-Chali, Large Salt Desert, Kyzylkum, Thar, Gobi, Mojave and Gila deserts to the North; Kalahari, Great Victoria and Atacama deserts and Patagonian Pampas to the South). There, extended evaporites can be found both on land (salt lakes, Dead Sea) and along shallow seas (e.g. Persian Gulf, Rhan of Kutch, Carabic). These semiarid to arid belts largely occur in between the horse latitudes (situated between 30°-35°N and between 30°-35°S latitudes). But they may extend well beyond these latitudes to the North (e.g. Kyzylkum and Gobi) and to the South (e.g. Patagonian Pampas).

More humid and mild climates predominate between the horse latitudes and the polar circles. However, precipitations rates may vary considerably (high rates along western margins of continents because of westerly sea-winds; low rates in the interior of the continents).

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Finally, the polar areas are characterized by widely extended perennial ice and permafrost. During so-called glacial periods, the ice sheets have been advanced across extensive areas in both the northern and southern hemispheres, en can be deduced from numerous old glacial deposits (e.g. moraines and other till deposits).

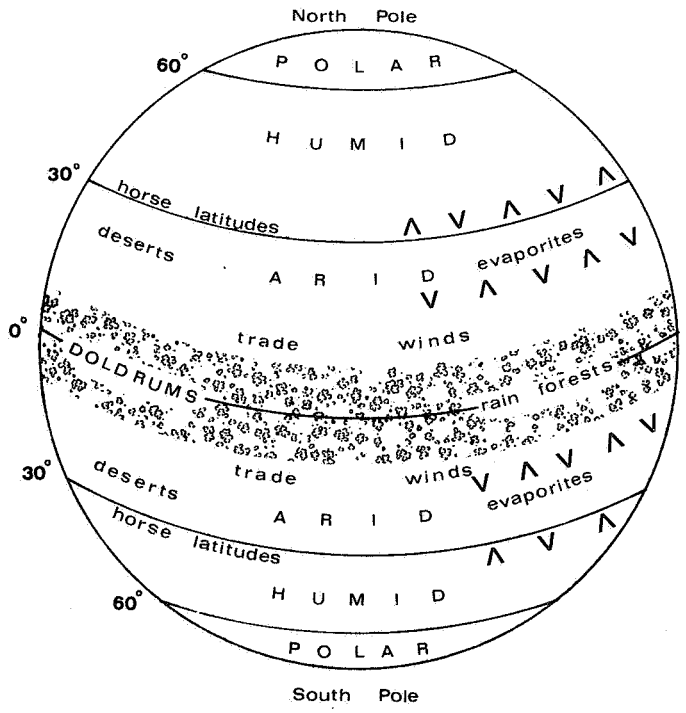

Fig. 1 - Cartoon showing distribution of principal climatic belts around the earth.

This very stylized, cartoon-like picture is supposed to have existed also in the geologic past. Accepting this concept, it must be possible to recognize these major climatic belts in the fossil deposits.

In the course of times, the position of the poles has changed in respect of the position of the continents, as shown by extensive paleomagnetic measurements. Therefore, also the climatic belts must have moved across these continents.

During the Late Devonian and Carboniferous, the relative position of the paleoequator is believed to have migrated across the so-called Old Red Continent. This Old Red Continent roughly stretched across large parts of Canada, Greenland and Scandinavia. It was surrounded by widely extended shelf seas (the "continental platform") with mixed marine and carbonate deposits.

The formation of this continent had been completed in Late Caledonian times, when the North American and Eurasian plates collided and the former Iapetus Ocean in between them was closed. The collision zone was marked by the rise of the Caledonides (a mountain range which can be traced in Eastern Greenland, Northwestern Great Britain and Western Scandinavia). This continent was separated from another continent to the South, Gondwana (formed by what is now Antartica, Australia, India, Iran, Africa and South America), by the so-called Paleotethys Ocean. A third important continent (Cathaysia; formed by what is now Central and Eastern Asia, except for Northeastern Asia - Kolyma - that is presumed to have formed part of the continental platform of the Old Red Continent) occurred somewhere to the South-East of the Old Red Continent.

Because of the north-northeastern drift of the continents during Late Devonian and Carboniferous times, the relative position of the paleoequator (and of the paleoclimatic zones related to the same) wandered to the South-East (with reference to the present geography) across the Old Red Continent. This can be deduced from the migration of several megafacies belts (notably evaporite occurrences and coal deposits) in the same direction (figures 2-3)

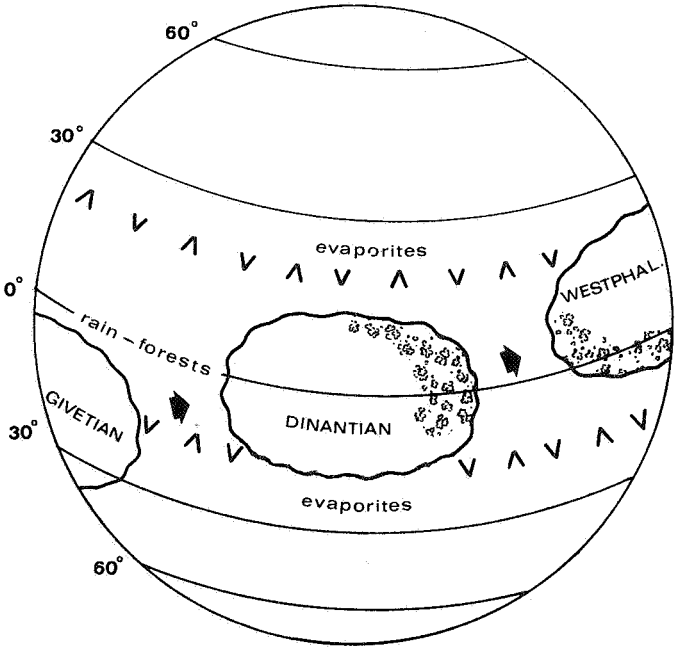

Fig. 2 - Cartoon showing suggested drift of Old Red Continent during Late Devonian and Carboniferous. The approximate position of the Old Red Continent in Middle Devonian (Givetian), Dinantian and (Late) Westphalian times is indicated, as well as the distribution of rain forests and evaporite belts. The relative position of Gondwana and Cathaysia is not considered on this figure.

In contrast to sometimes uttered suggestions, Carboniferous coal deposits are not evenly distributed across the globe or even across the Old Red Continent. Nor can the evolution of the "world's climate" in Devonian to Permian times be simplified in terms of an overall change from predominantly (semi-)arid for the Devonian (because of widespread Old Red Sandstone deposits in North America and Northwestern Europe) through predominantly warm-humid for the Carboniferous (because of the occurrence of coal deposits from Spitsbergen to Spain) into again (semi-)arid for the Permo-Triassic (because of the widespread occurrence of desert-type deposits in North America and Europe). First of all, this over-generalized picture is only true for

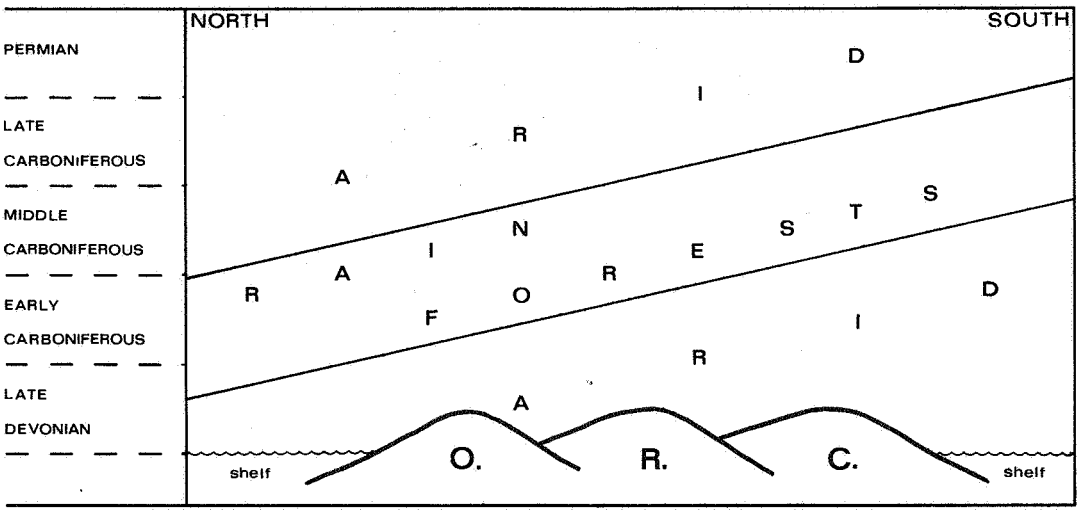

Fig. 3 - Cartoon showing gradual shift of climatic belts across the Old Red Continent since the Middle Devonian untill the Permian.

the Old Red Continent. And secondly, the distribution pattern of Devono-Carboniferous evaporites and coal deposits within and around the Old Red Continent suggests a close relationship between the occurrence of these mega-facies belts and the paleoclimatic girdles. This is illustrated by a concise description of paleogeographic maps for the Middle Devonian (Givetian), Dinantian, Namurian, (Late) Westphalian and Stephanian.

During the Middle Devonian (figure 4), the paleoequator must have been situated just North of the Old Red Continent. During this timespan, the

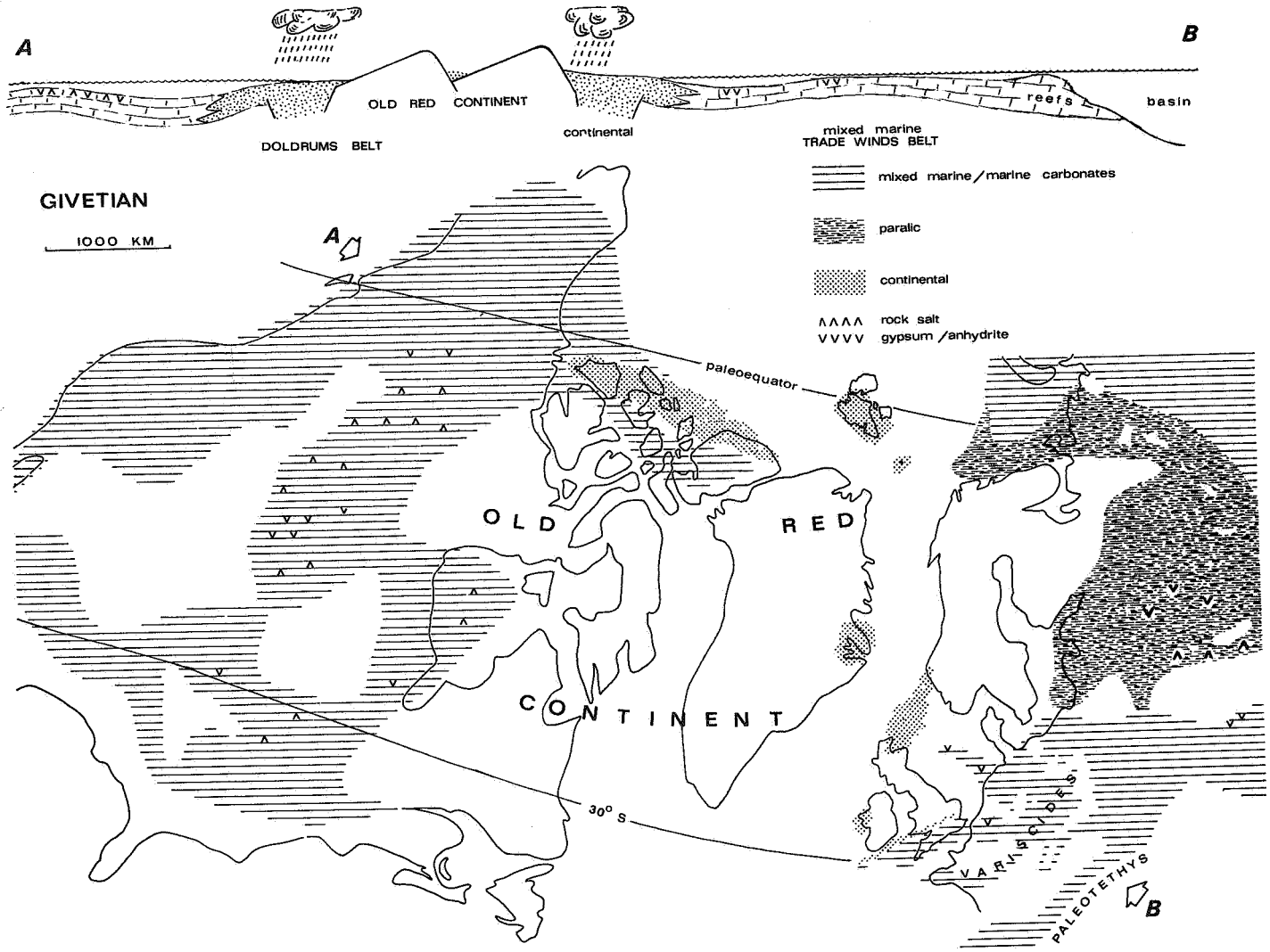

Fig. 4 - Paleogeography of the Old Red Continent during the Middle Devonian (Givetian) period. The cross-section A-B is not to scale ! Note the presence of thick siliciclastic deposits along the northern and eastern (windward) flanks of the continent, and the occurrence of thick rock salt accumulations to the West (a.o. Elk Point Basin) against predominantly anhydrite and gypsum occurrences to the East (a.o. North Sea, Belgium, Russian Platform).

vegetation had not yet been evoluated to such and extent, that widely distributed coal deposits might have been formed along the northern coastal plains of the continent. Therefore, the Givetian paleoequatorial zone is not marked by the presence of coal-bearing strata. Slightly to the South of the paleoequator, evaporites occur both in North America (a.o. Elk Point Basin), the Russian Platform (Baltic area, Pripyat) and Northwestern Europe (a.o. Argyll Borehole in Central North Sea, Annapes-1 Borehole in Northern France and Tournai Borehole in Southwestern Belgium).

During the Dinantian (figure 5), the paleoequator presumably was situated somewhere halfway Greenland, as can be deduced from the occurrence of several coal basins to the North (a.o. Sverdrup, Spitsbergen) and to the south (Southeastern Greenland, Moscow Basin). The evaporite belts appropriately occur farther to the North (Kolyma Omolon) and to the South (Southeastern Canada : Fundy Basin; Western U.S.; Northwestern Europe : Ireland, Great Britain, Northern France, Belgium, Southeastern Netherlands, Poland).

During the Late Westphalian (figure 7), the position of the paleoéquator must have been at the southern border of the Old Red Continent. This is easily shown by the position of coal deposits, which are mainly concentrated along the southern borders of this continent, and by the occurrence of evaporites along the western (a.o. Paradox and Eagle Basins in the United States) and northern borders (Sverdrup Basin).

The paleoclimatic change from humid to arid in an overall southeastern direction during the Late Westphalian and Stephanian (figures 7-8) can be traced in Western Europe by the gradual income of red beds and so-called "hinterland" floras and by the slightly later disappearance of coal beds in strata of the same age between Scotland and Central France.

The influence of the prevailing wind directions and of the relative relief of the Old Red Continent can be deduced from more suitable features, such as the main distribution of continental to paralic siliciclastics, the relative position

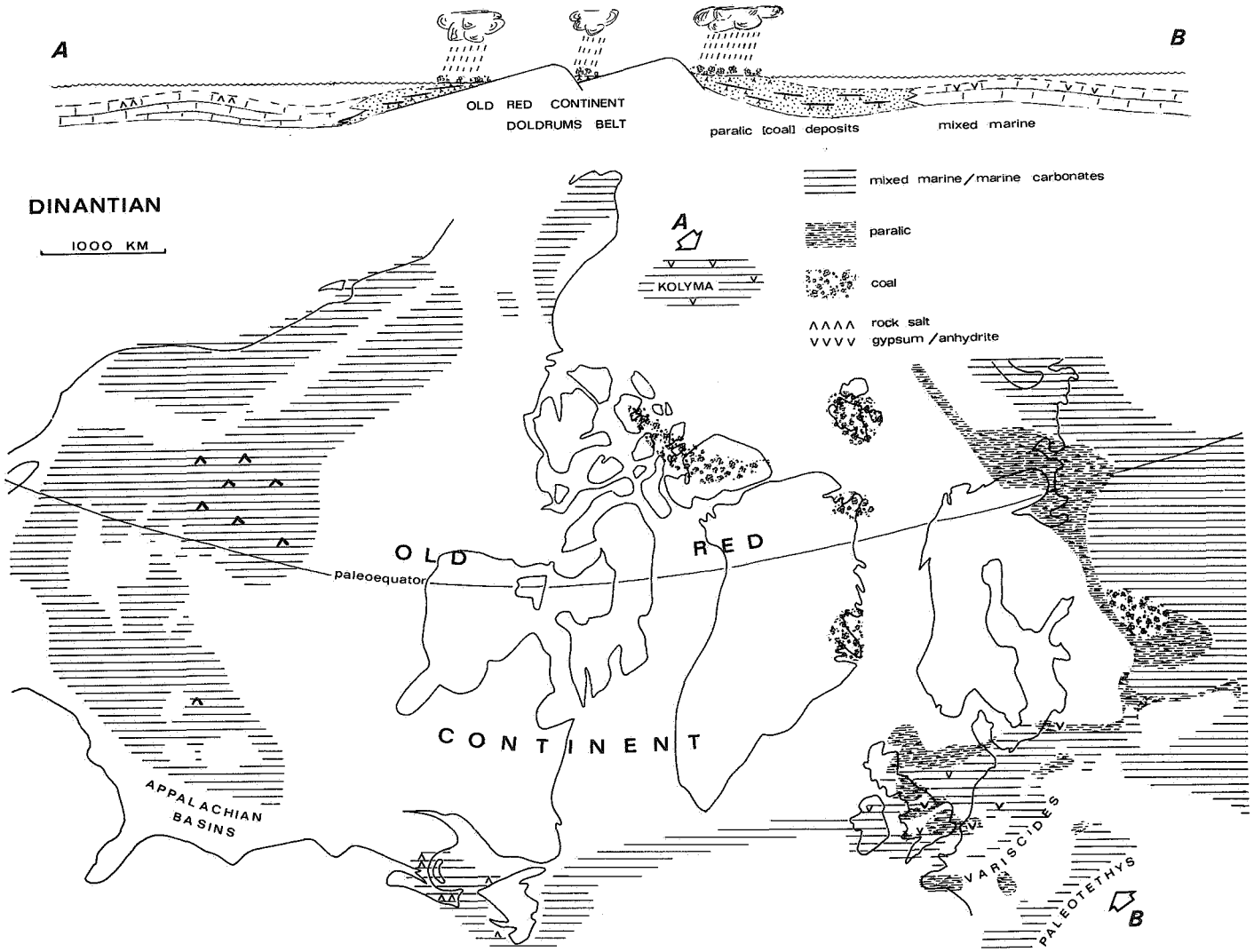

Fig. 5 - Paleogeography of the Old Red Continent during the Dinantian period. The cross-section A-B is not to scale ! Note presence of evaporites to the North (Kolyma/Omolon) and to the South (Fundy Basin of Southeastern Canada; Ireland, Great Britain, Northern France, Belgium, Southeastern Netherlands and Poland in Northwestern Europe) of the Old Red Continent, as well as the occurrence of coal deposits along the eastern flanks of the same (a.o. Sverdrup, Spitsbergen/Svalbard, Eastern Greenland, Russian Platform). Rock salt accumulation occurs in the Western U. S.

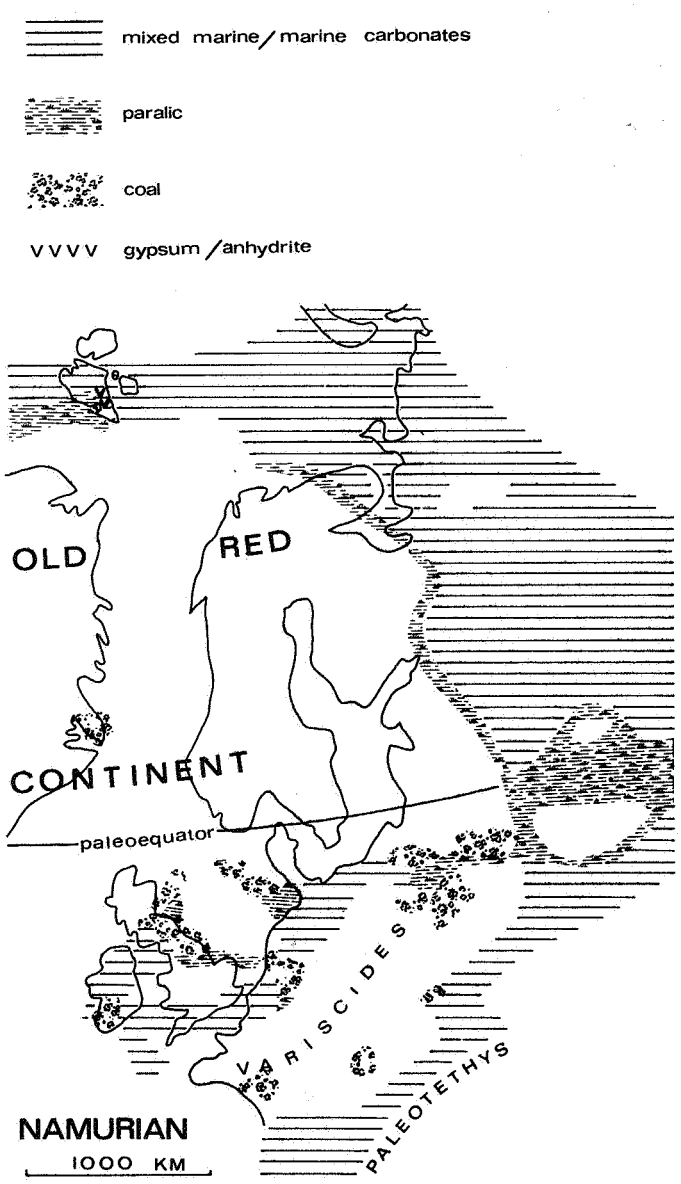

Fig. 6 - Paleogegraphy of the eastern half of the Old Red Continent during the Namurian period. Note presence of evaporites (anhydrite/gypsum) along the northern flank of the continent (Spitsbergen/Svalbard), and occurrence of coal deposits to the South (Southeastern Greenland, Great Britain, Belgium, Southeastern Netherlands, Federal Republic of Germany, Poland).

of the coal basins, and the distribution of rock salt deposits on the one hand of gypsum/anhydrite deposits on the other.

The overall Westward winds near the paleoequator (Doldrums Belt and Trade Winds zone) transported large amounts of moist air from the Paleotethys and shelf seas East of the Old Res Continent. Therefore, rainfall predominantly occurred along the northern, eastern and southern (windward) slopes of the continent. The western half of the same (a.o. protected by the Caledonides and by the Acadian Mountains in Southeastern Canada) was relatively dry throughout the Devonian and Carboniferous. This can be well observed in the paleogeographic maps on figures 4 to 8 :

1. the main accumulations of siliciclastics in paralic deposits occur along the eastern borders of the Old Red Continent during the Givetian, Dinantian, Namurian and Westphalian, whereas continental siliciclastics preferably accumulated in the eastern hal of the continent;

2. the coal deposits preferably occur in the northeastern and eastern half of the continent during the Dinantian, whereas these extend all along the southern flanks of the Old Red Continent during the Late Carboniferous, when the moist air could move freely along the southern borders of the continent, not hampered by the occurrence of intermediate mountain chains;

3. there is a remarkable difference between the occurrence of predominantly gypsum/anhydrite along the eastern flanks of the Old Red Continent and the occurrence of thick rock salt accumulations along the western borders of the same (e.g. Givetian rock salt deposits in Canadian Elk Point Basin; Dinantian rock salt deposits in Canadian Fundy Basin; Westphalian rock salt deposits in Paradox-Eagle Basin of Western United States).

The north-north-eastern drift of the Old Red and Gondwana Continents during the Devonian and Carboniferous periods may also be responsible for the peculiar phenomenon that rather "archaic" fossil assemblages are known from the Carboniferous deposits along the southern borders of the Paleotethys in Australia, Indian-Iran and North Africa. Apparently, quite a lot of organisms or their direct descendants could survive in those areas because of the relative migration of the paleoclimatic zones, when their relatives had disappeared already along the borders of the Old Red Continent because of the same paleoclimatic changes ? Maybe, the same migration of paleoclimatic belts across the Old Red Continent has been responsible for the fact that the stratigraphic range of certain floras in Late Carboniferous times seems to be different from place to place ?

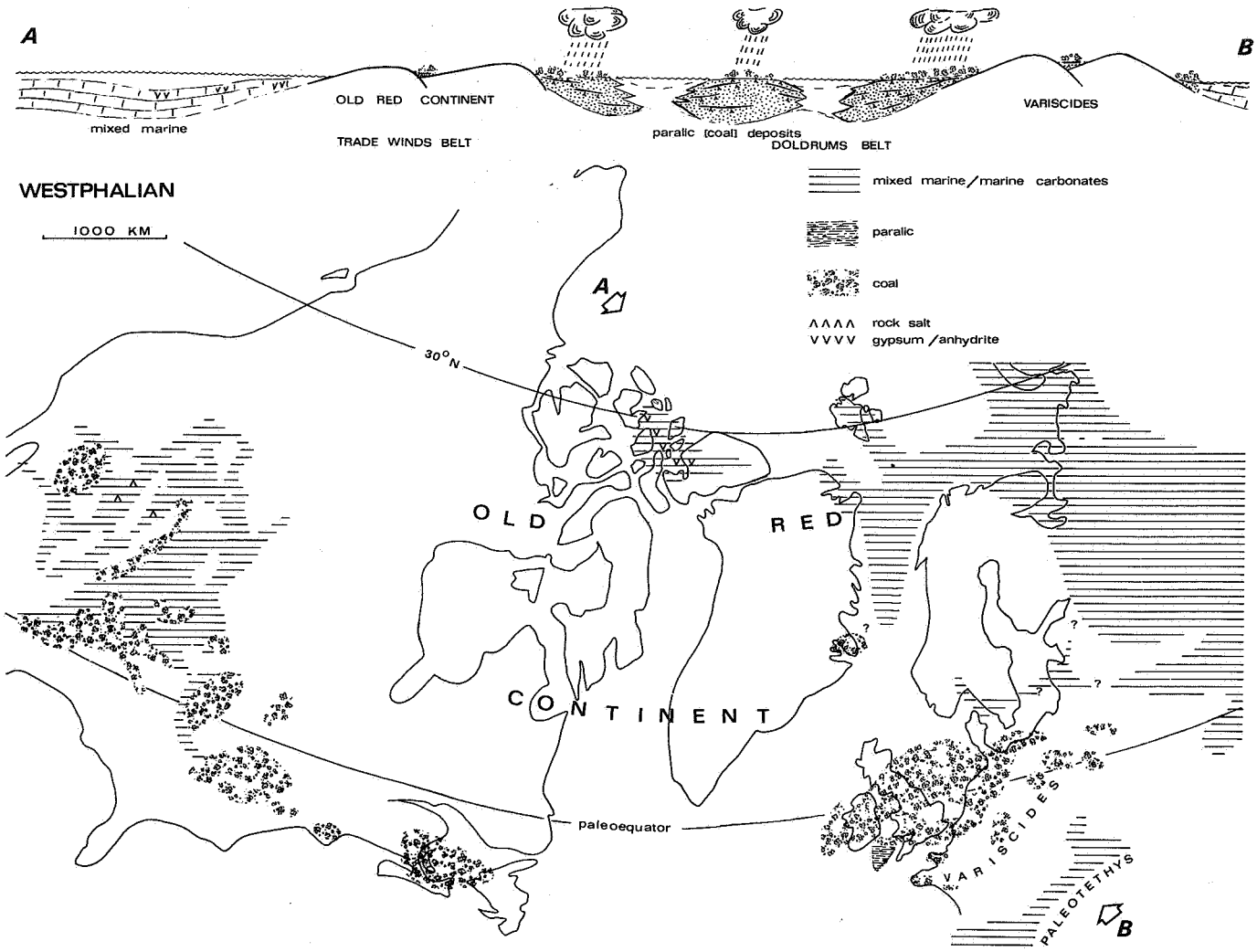

Fig. 7 - Paleogeography of the Old Red Continent during the (Late) Westphalian period. The cross-section A-B is not to scale ! Note the presence of evaporites in the North (Sverdrup Basin) and in the West (a.o. Paradox and Eagle Basins in United States), as well as the distribution of coal deposits along the southern flanks of the Old Red Continent.

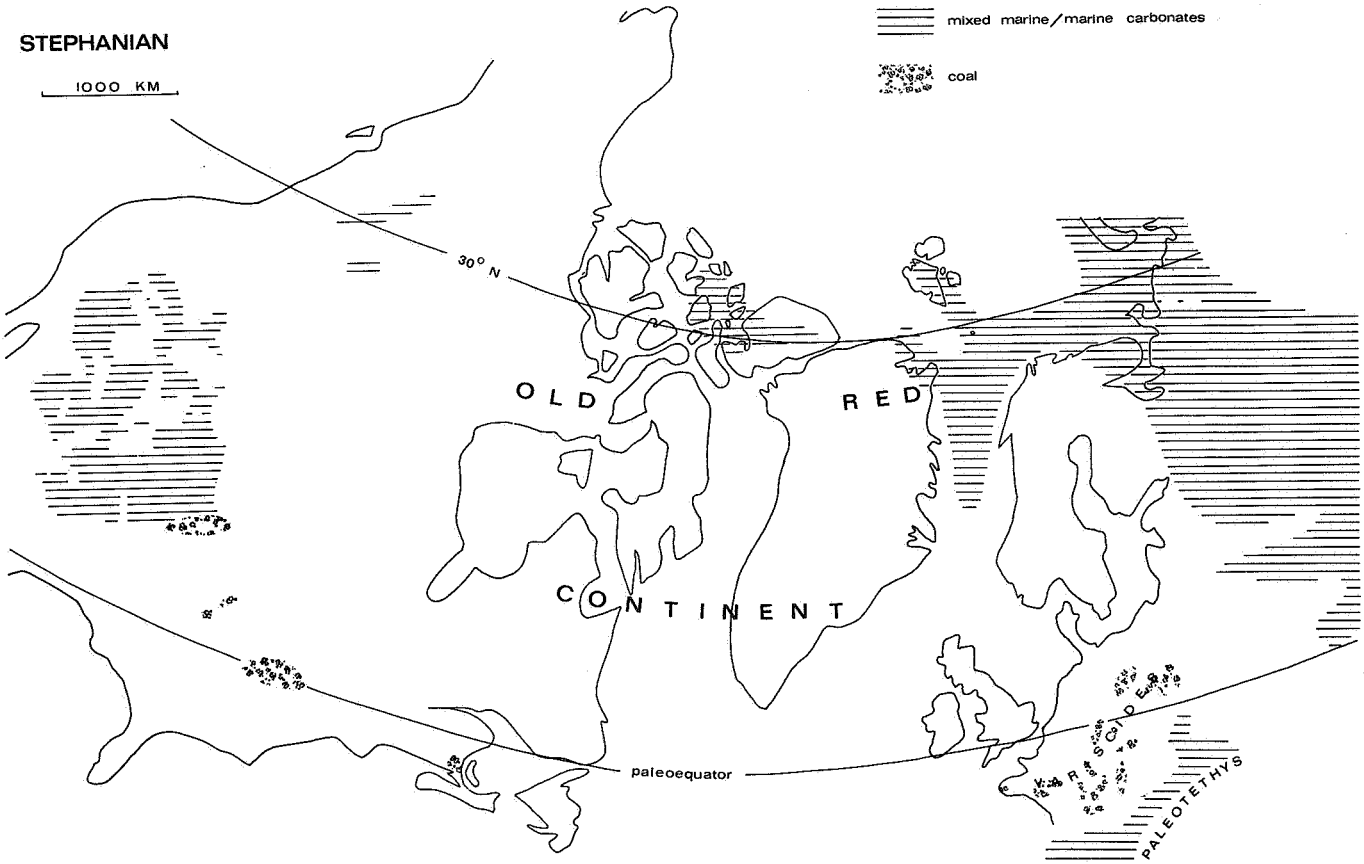

Fig. 8 - Paleogeography of the Old Red Continent during the Stephanian period. Note the occurrence of coal deposits restricted to the southernmost borders of the Old Red Continent (United States - Northern Appalachians, Illinois, Kentucky, Missouri, Kansas; Southeastern Canada; Variscan Mountain Range in Western Europe).

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BUITENGEWONE ZITTING

PALEOZOÏCUM VAN FERQUES (FRANKRIJK)

6, 7 en 8 october 1984.

Wij laten u weten dat de Buitengewone Zitting dit jaar ingericht wordt onder de leiding van Professor Denise BRICE (Faculté libre des Sciences, Lille).
Ziehier het programma :

Zaterdag, 6 october :

Voormiddag :

1. Terugblik op de Paleozoïsche structuur te Ferques. Studie van de breuken in het Paleozoicum langsheen de spoorwegen ontsluiting in de "Carrière de Basse Normandie".

2 Het Devoon in het Massief van Ferques.
. Studie van het Givetiaan in de groeves van Tinskal (Carrière du Griset, Carrière du Banc noir) en langsheen de nieuwe spoorweg Caffiers-Ferques.

Namiddag :

. Studie van het Bovendevoon.
Het Frasniaan zal bestudeerd worden in de nieuwe ontsluiting langsheen de spoorweg Caffiers-Ferques, in de "carrières de la Parisienne, du Bois et de la Briqueterie".
Naargelang de nog beschikbare tijd kan nog een bezoek worden gebracht aan de "Carrière Bouton".
Het Fameniaan is zichtbaar in de "Carrière de la Briqueterie".

Zondag 7 october :

3. Het Ondercarboon van Ferques.

Voormiddag :

. Studie van het Ondercarboon in het massief van Ferques (coupe Caffiers-Ferques).
. Terugkeer naar de "Carrière de Basse Normandie" om het Viseaan te bestuderen.

Namiddag :

. Het Carboon in de "carrière Napoléon " te Blecquenecques (Société des Marbres du Boulonnais).

Maandag 8 october : De deelnemingen zijn facultatief : ons te laten weten.

Excursie daarheen de post-paleozoïsche deklagen van de Boulonnais, onder de leiding van Professor F. ROBASZYNSKI (Faculté Polytechnique, Mons).

Overnachting is voorzien te Boulogne-sur-Mer

Het traject zal afgelegd worden in privaat wagens.

VERBLIJFSONKOSTEN : Deze zullen u later medegedeeld worden. Een voorschot van 2.000 F. zal gevraagd worden om de inschrijvingen in het hotel te dekken.
U deelname zal worden beschouwd als effectief met de ontvangst van deze som, die niet zal terugbetaald worden.
Ze kan gestort worden op onze rekening 088-0539160-29 (Belgische Vereniging, Brussel) met de vermelding "Buitengewone Zitting", het aantal en de namen der deelnemers.
Wij ontvangen de inschrijvingen tot 1 september.