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INFLUENCE OF ACID VOLCANISM AND CO_2 PRODUCTION ON SEDIMENTATION AND DISTRIBUTION OF ORGANIC MATER (VARISCAN CENTRAL EUROPE)

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(2 figures)

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ABSTRACT. From Silurian to Permian times we can document the existence of a single supercontinent - Pangea. The mobile zones within Variscan Europe, which developed on unstable continental crust, were flooded by epicontinental seas. Northward continental drift of the Pangea was documented. There is a considerable contrast between Middle Devonian time of reef-limestone sedimentation (fixation of CO_2 from the water and atmosphere in limestones) and the later Carboniferous sedimentation and contemporaneous acid volcanism with a high rate of production of CO_2 and probably short-lived greenhouse effects.

KEY WORDS: Europe, Variscan mountains, Devonian, Carboniferous, sedimentation, volcanism, climatic conditions.

RESUME. Influence du volcanisme acide et de la production de CO_2 sur la sédimentation et la distribution de matière organique (Europe centrale varisque). Du Silurien au Permien on peut se référer à un seul supercontinent, la Pangée. Les zones mobiles à l'intérieur de l'Europe varisque, qui se développerent sur une croûte continentale instable, furent immergées par des mers épicontinentales. Une dérive vers le Nord de la Pangée est attestée. Il y a un contraste considérable entre la sédimentation de calcaires récifaux au Dévonien Moyen (fixation du CO_2 de l'eau et l'atmosphère dans les calcaires) et la sédimentation de la fin du Carbonifère, contemporaine d'un volcanisme acide avec un degré de production élevé de CO_2 et probablement d'effets serres de courtes durées.

MOTS-CLES: Europe, montagnes varisques, Dévonien, Carbonifère, conditions climatiques, sédimentation, volcanisme.

1. INTRODUCTION

Numerous indications, particularly facies and fossil distribution contradict a separation of continents at the time of the Variscan orogeny. From Silurian to Permian times we can document the existence of a single supercontinent - Pangea (Boucot & Gray, 1983). The mobile zones within Variscan Europe, which developed on unstable continental crust, were flooded only by epicontinental seas. Northward continental drift of the whole Pangea supercontinent was documented not only on the basis of paleomagnetism, but mainly from the shift of climatic zones.

2. DISCUSSION

During the Middle Devonian and Frasnian (Upper Devonian), an extensive reef-limestone complex developed not only in Central Europe but over the whole world from Canada to China (Hladil, 1986). The conditions under which the pure reef-limestone complex was deposited can be summed up as follows: a) warm climate; b) continuous subsidence of the basement (locally more than 1000 m, as documented by the thickness of reef-limestones); c) transgression of the sea over a peneplaned continent, and a minimum inflow of fresh water into the basin. This led to a typical vertical circulation of

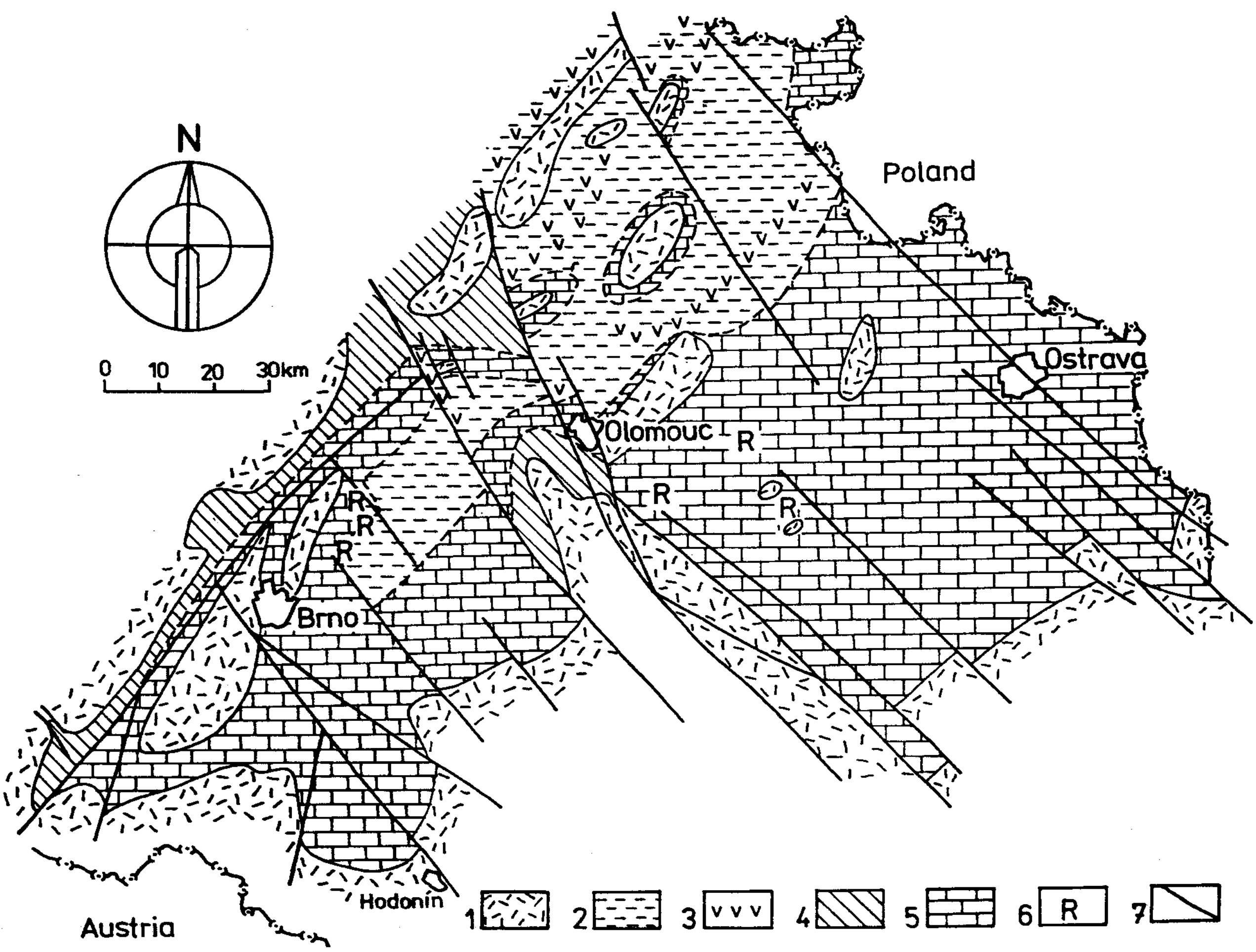

Figure 1. Simplified paleofacies map of Moravia and Silesia in the time of the Lower Frasnian. 1 - dry land (deeply weathered proterozoic crystalline rocks); 2 - dark coloured shally facies; 3 - contemporaneous basic (locally acid) volcanism; 4 - facies of thin laminated limestones with some traces of evaporites and limestone lenses with stromatoporoid and coral fauna; 5 - reef limestones (reef-core and back-reef undifferentiated); 6 - documented reef-cores; 7 - synsedimentary acting dislocations

water: considerable evaporation resulted in an increase of salt content in surface waters causing the dense waters to sink to the bottom while the light waters rose upwards (Heckel & Witzke, 1979). Therefore even the bottom waters were rich in oxygen and the residual organic matter was totally destroyed; d) an open sea with a good circulation owing to sea currents; e) basic submarine volcanism in mobile zones reached a maximum during the Givetian (calcium was released from feldspars and passed into sea water during spilitisation); f) huge quantities of pure limestones fixed CO_2 not only from sea water, but also from the atmosphere; g) the faunal-reef ecosystem thus produced over 15 Ma was very sensitive to external chanching factors.

The onset of flysch deposition in the late Frasnian reflected a fundamental change. Flysch sedimentation occurred within a narrow zone of maximum subsidence, while sedimentary processes were of different nature in the major part of the basin. Reef development came to an end between the Middle Frasnian and Lower Famennian, indicating that subsidence ceased almost completely during this timespan (Dvorák, 1980, 1986). However, this gradual change from a transgressive trend to a regressive one was not isochronous throughout the basins. Until the early Famennian, light grey pure limestone had still been accumulated locally in the vicinity of the continental platforms. Stromatoporoid and coral assemblages disappeared very slowly and were replaced by foraminifer assemblages.

Many fault blocks were tilted towards the basin center. Thin sequences of nodular micritic limestones were deposited on the edges of these blocks. Purple lateritic clay material (Al_2O_3/Na_2O ratio: 80 to 130; Fe_2O_3/FeO ratio: 50) was washed down from the slowly rising ridges of weathered crystalline rocks into the basin and deposited in a shallow toxic environment (Dvorák, 1986).

The rise of a mountain range in the morphological sense led to an increase of rainfall and thus to an accelerated erosion and to the introduction of clastic material into the subsiding flysch basin. Fresh, chemically unaltered clastic material was deposited under reducing conditions (Kukal, 1980). Apparently,

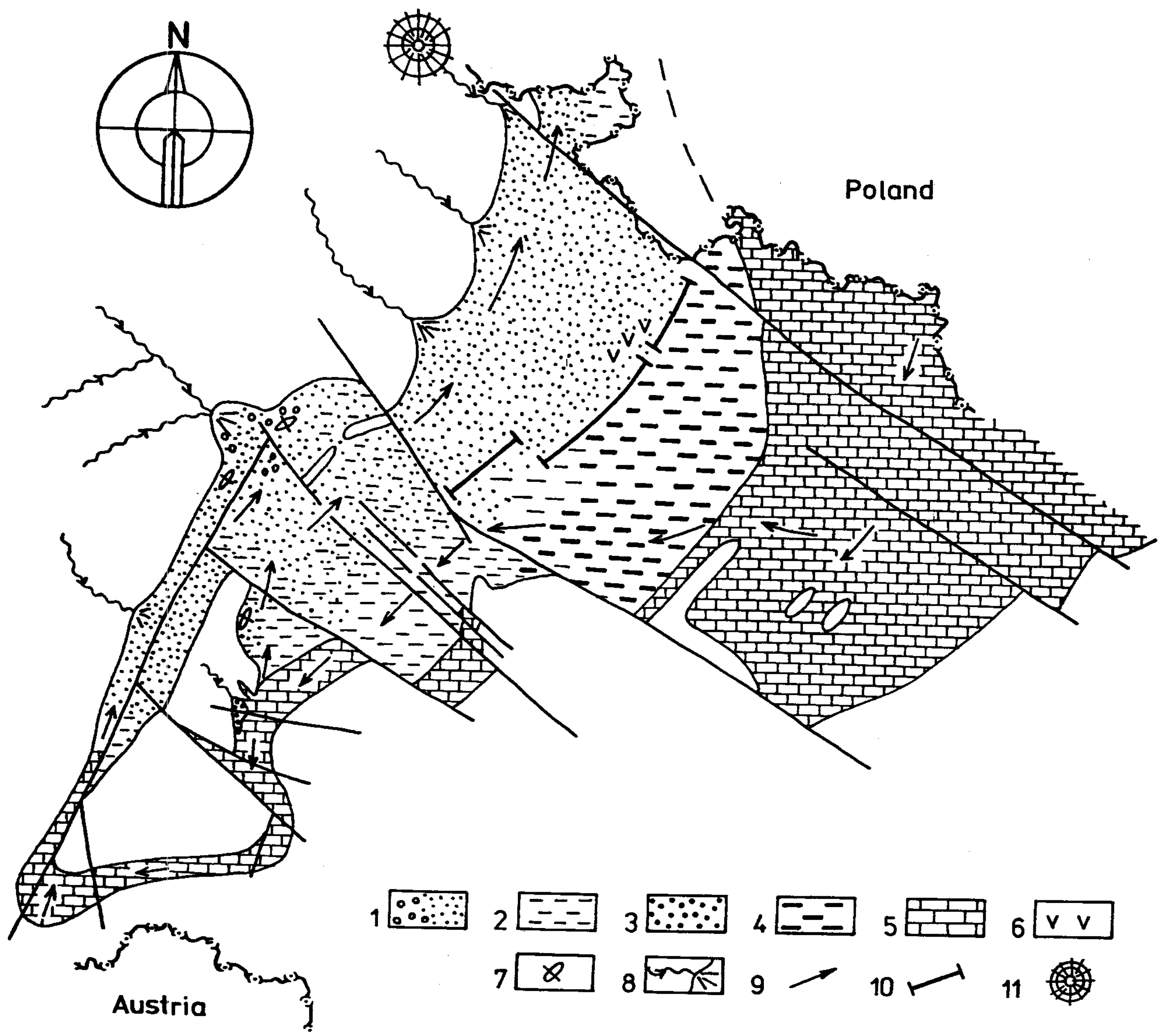

Figure 2. Simplified paleofacies map of Moravia and Silesia in the Lower and Middle Viséan. Palinspastic restored. 1 - polymict conglomerates and greywackes; 2 - shales and siltstones; 3 - quartz-sandstones; 4 - siliceous shales; 5 - dark grey biodetrital limestones; 6 - contemporaneous basic volcanism; 7 - limestone lenses in the greywackes and shales near the western coast; 8 - rivers and clastic wedges in the basin; 10 - trends of elevations below the sea level; 11 - terrestrial acid volcanoes on the top of the mountain belts

the introduction of fresh water into the basin changed the circulation pattern - the uppermost layers comprising less saline waters, the lowermost ones having a highest salt content. There was little vertical intermixing. This hydrological regime is reminiscent of the aqueous stratification as observed in the Baltic or Black Sea (Byers, 1977; the present author notes); however, that the bathymetry of today Black Sea cannot be directly applied to Palaeozoic basins! Thus, the complex equilibrium existing in reef ecosystem was disturbed: nutrients for reef-forming fauna were no longer available.

Red-coloured, redeposited products of lateritic weathering are known to occur in the Lower and Middle Viséan and are contemporaneous with thick flysch sediments elsewhere. This fact indicates that with exception of the source area of the flysch, a warm climate prevailed, with an early phase locally even semiarid (evaporite trend), later predominantly humid (Dvorák, 1990). The change to a cooler climate, which only affected the mountain tops (transport of chemically unaltered clastic material - Al_2O_3/Na_2O ratio: 8 to12). The height of the mountain range is difficult to assess, but the vertical climatic stratification was probably different from the present one.

The rapid rise of many blocks of the Variscan mountain range was related to ascending granitoid magmas. The foreland blocks were underthrusted below the mobile belt and the Variscan median mass. Because of steep geothermal paleogradient (70 to 200° C/km) the underthrusted crystalline granitic layer was melted, migrating below the rising mountain range and intruding it as granitoid plutons (Dvorák & Paproth, 1988). Acid volcanoes topped the mountain belts. We can compare such conditions with Yellowstone National Park volcanoes (Eaton *et al.,* 1975, Christiansen & Blank, 1972).

Ashes from these volcanoes were blown into the basin. The proportion of rhyolite pebbles and volcanic material in the flysch and molasse deposits increased during Carboniferous. The first tuffites containing volcanic quartz, apatite, zircon and biotite occured in the uppermost Frasnian. They are rare in the Famennian and Tournaisian. Volcanic activity appears to have been very violent in the Lower Viséan with a maximum in the early part of Namurian A.

Favourable conditions for expansion of terrestrial flora existed in a warm climate at the mouths of rivers which emptied into the basin; one additional factor might have been the exhalations of carbon dioxide related to the steadily increasing terrestrial acid volcanism (Brunn, 1983). The basin had been supplied not only with clastic material transported by rivers, but their waters also carried a quantity of finely dispersed organic matter, mainly of vegetable origin; this explains the dark colour of flysch sediments and the slightly higher content of organic C in very thick shales. Bioturbation, locally very abundant and diverse, excluded the possibility of accumulation of sediments within the euxinic deep-sea environment. The content of organic C increased in the course of Devonian and Carboniferous deposition in Central Europe (Schulz-Dobrick & Wedepohl, 1983). The Lower Carboniferous shales contain up to 9.5 ppm Corg and 2.1% S. Welte & Kalkreuth (1975) observed a continuous rise of CARSPECIAUX 100 \f "Symbol" \s 1213C in the kerogene fraction of marine shales in the Devonian and Carboniferous, with maximum values in the Carboniferous. In their opinion this is the consequence of a photosynthetic activity. Tracing the content of C org in the Lower Carboniferous sediments from NW to SE of Rhenohercynicum, it may be observed that the values increase towards the source area of the clastic material, i. e. towards the Variscan mountain range. The high rainfall in the mountain range was the main cause of high organic production.

Zimmerle (1985) pointed out the rather common association between black shales and pyroclastic admixtures and tuffs. This interrelation is complex in nature: volcanic ashes and glass ejected during violent eruptions had a harmful effect on the life of organisms in marine basins. Thus, the equilibrium and complex relationships existing in an ecosystem were disturbed. The synsedimentary alteration of pyroclastic debris and volcanic glass into smectite of a high absorbtion capacity considerably affected the depositional environment on the sea-floor by changing chemical conditions; the resulting black sediments preserved organic matter (oil source rocks).

Acid tuffs and pyroclastic sediments commonly have a large areal extent; they mark isochronous events in sediments (the thin black "Kellwasser Limestone" of the Upper Frasnian and Annulata Shales of the Middle Famennian - Dvorák *et al.*, 1988). This facies model is closely comparable with the geological setting of black Devonian shales in the Appalachians (Conkin & Conkin, 1979; Roen, 1984 - Tioga, Belpre-Centre Hill ash beds).

Strong volcanic eruptions may have ultimately resulted in the extinction of specialized faunas inhabiting a shallow water environment, thus enriching the sediments in organic matter. Keith (1982) put forward evidence that CO_2 produced by intense volcanic activity had a considerable effect on the climate (with a warming due to the greenhouse effect).

3. CONCLUSION

There is a considerable contrast between Middle Devonian time of reef-limestone sedimentation (fixation of CO_2 from the water and atmosphere in limestones) and the later Carboniferous sedimentation with a contemporaneous acid volcanism producing a high rate of CO_2 and inducing probably short-lived greenhouse effects.

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