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SEDIMENTOLOGICAL AND PALEOGEOGRAPHIC ASPECTS OF THE VENDIAN—CAMBRIAN TRANSITION ON THE EAST EUROPEAN PLATFORM

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Abstract. The greatest sedimentological-paleogeographic change on the East European Craton took place on the traditional Vendian—Cambrian boundary, on the level of the Valdai and Baltic series transition. The lower, Vendian part of the section is dominated by glacial sediments, volcanic, often red-coloured rocks, as deposits of freshened aquifers, whilst the typically marine sediments are still scarce. Beginning with the Baltic Series and upwards, through the whole Lower Cambrian, the situation changes abruptly. Here normal marine clastic sediments reduced to grey by diagenesis and showing permanent glauconitic-phosphatic mineralization, traces of sulphate reduction, and typically marine associations of clay minerals predominate. This change is obviously caused by the significant alterations in the connection with the oceans during both periods studied. This crucial event should surely be reflected on the maps of the IGCP Project 319 "Global Paleogeography of Late Precambrian and Early Paleozoic".

Key words: Vendian, Cambrian, paleogeography, stratigraphy, East-European Platform.

Differently from the other regions of the world, on the East European Craton the whole Vendian and most of the Cambrian sequence are represented by a non-carbonate complex of clastic sediments. This can be explained by the location of the area in the cool climatic belt, possibly on high latitudes close to the South Pole. Such an explanation is supported by constantly increasing paleomagnetic and palinspastical information.

In spite of its external similarity, the terrigenous sequence studied is not uniform in origin, but falls into several characteristic complexes, commonly treated as Valdai, Baltic, Liivi, and Aisčiai series on the East European Craton. The most distinct change occurred on the transition from the Valdai to the Baltic series, usually considered as the Vendian—Cambrian boundary level. The nature of this crucial change has been established by continuous lithological investigations carried out during the last decades (Mens & Pirrus, 1986). Particularly significant has been investigation of the main features of authigenic mineralization in the sedimentary basins of that time, to which a substantial contribution has also been made by Estonian geologists.

Before giving a brief review of the sedimentological-paleogeographic aspects of these changes, the Vendian—Cambrian boundary problem on the East European Craton should be discussed. Despite the fact that the region is also the stratotype of the Vendian complex, this problem is still open to debate and, judging by recent stratigraphical decisions, has become even more obscure.

The complex of Vendian (Valdai) sedimentary rocks, distinguished on the East European Craton in 1952 (Соколов, 1952, 1953), constitutes an association of unmetamorphized normal sediments lying horizontally on the folded basement of the platform. On the basis of more recent biostratigraphical investigations (acritarchs, algae, ichnofossils, traces of soft-bodied organisms) this association was subdivided into three rather unanimously accepted stages.

The Lower Vendian, belonging to the Drevliany Stage, is represented by sedimentary rocks containing tillites in their lower part and showing traces of volcanic processes in the upper part. The upper Vendian, which is characterized by more sorted basin sediments, comprises two stages—Redkino (lower) and Kotlin (upper) stages. As sedimentary complexes, the Lower Vendian is known also as the Vilchany and Volyn' series, the Upper Vendian as the Valdai Series (Maknach et al., 1986).

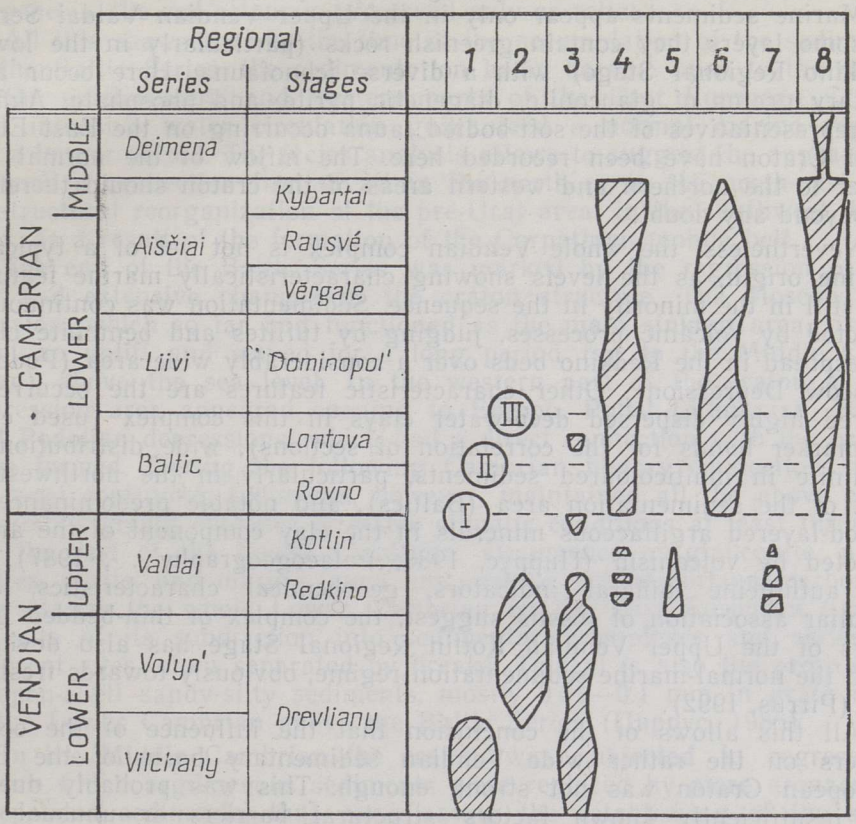
The above-mentioned classical Vendian is overlain by an up to 200 m thick sedimentary complex of the Baltic Series, which has a distinctly cyclic structure and contains fragments of primitive skeleton-forming organisms (*Sabellidites*, *Platysolenites*, *Aldanella*, the earliest brachiopods(?), unidentified chitinous sclerites). At the lower boundary of the series also the ichnofauna undergoes essential innovation becoming considerably more diverse (Федонкин, 1987). Biostratigraphically the Baltic Series is divided into two parts: the lower Rovno and the upper Lontova regional stages. In spite of its very characteristic biostratigraphy and occurrence of the famous so-called Cambrian blue clay in it, the position of the whole Baltic Series in the Vendian—Cambrian transition is uncertain. Attempts have been made to join its lower part with the Vendian, and to correlate the upper part with the earliest Cambrian—Tommotian Stage (Решение . . . , 1986). The Estonian geologists (as well as many researchers of the western areas of the East European Craton) find both ungrounded. Data contradicting the correlation of the Tommotian Stage with the Lontova Regional Stage and showing the younger age of the former are becoming more and more abundant (Moczydlowska & Vidal, 1988; Кирьянов et al., 1991). Connecting the lower Rovno Regional Stage with the underlying Vendian complex and thus increasing the initial extent of the latter in the stratotype area is not a very correct procedure either. Even worse—this would introduce into the Vendian a clearly Cambrian biotic element represented by a new type of the ichnofauna and remains of skeleton-forming organisms (*Sabellidites*, in higher layers also *Platysolenites*). The most serious drawback is that according to this concept the Vendian—Cambrian boundary is reliably definable on acritarchs as the only criterion for the distinction of the boundary between the Rovno and Lontova regional stages. In this way the Vendian—Cambrian boundary can be determined on the basis of phytopaleontological data, which, however, is not correct in case of Phanerozoic units. Yet, as is already seen from a monograph presenting this argumentation (Вендская система, 1985), this standpoint is in great contradiction with the basic data and is rejected even by several authors of this publication (M. Fedonkin, Ye. Aksyonov).

The Baltic Series seems to be a distinct independent phase at the Vendian—Cambrian transition, obviously having analogues also in

other regions of the world. Biostratigraphically it belongs to the Paleozoic (also to the Cambrian) rather than to the Proterozoic (also to the Vendian), constituting the initial stage in the appearance of the skeleton-forming fauna and preceding the classical Cambrian based on trilobite evolution.

Regardless of the stratigraphical solutions of this problem on the East European Craton, the Baltic Series is more closely related to the overlying Lower Cambrian strata than to the Vendian as the sedimentational data suggest. The remaining part of the Lower Cambrian, subdivided into the Dominopol', Vērgale, and Rausvé regional stages, has not caused serious problems as it contains already scarce undoubtedly Cambrian trilobite fauna.

Now let us give a review of the characteristics of the Vendian and Cambrian sedimentation on the East European Craton.



Stratigraphical subdivision of the Vendian and Cambrian on the East European Craton and the most essential changes in the sedimentary conditions.

1 — glacial deposits, *2* — volcanic-sedimentary rocks, *3* — red-coloured sediments, *4* — normal marine reduced grey rocks with glauconitic-phosphatic-pyritic mineralization, *5* — Precambrian type of trace fossils, *6* — Cambrian type of trace fossils, *7* — soft-bodied Metazoa, *8* — skeleton-building organisms.

Assumed positions of the lower Cambrian boundary: I — traditional, supported by the author; II — proposed in the conference on the stratigraphy of the East European Craton, 1983; III — the lower boundary of the Tommotian Stage on the basis of new paleontological data.

The main problem seems to be the absence of typically marine sediments in the Vendian (Vilchany, Volyn', and Valdai series) in spite of its distinct structural differentiation from the rest of the Proterozoic. On the contrary, most of the early Vendian, spreading near the filled Upper Proterozoic aulacogenes (in Belarus and the Pachelma Depression), shows evidence of extensive continental glaciation: rocks with tillites or of the laminated glacioaqueous complex (Чумаков, 1978). These are succeeded by the complex of volcanogenic or terrigenous sediments, the latter containing the volcanic admixture transported by the air or simply redeposited. The rocks are predominantly reddish being not reduced by diagenesis and belong rather to volcanic-depositional formations. Their occurrence is restricted coinciding with or being close to the distribution of the deposits of the glacial area. This relation may be possible not only due to generally limited preservation of Lower Vendian strata, but might also have genetical reasons—volcanism may be the expression of the isostasy of glaciation processes.

Marine sediments appear only in the Upper Vendian Valdai Series. In some layers they contain greenish rocks (particularly in the lower, Redkino Regional Stage) with a diverse ichnofauna. Here occur also solitary grains of glauconite, diagenetic pyrite, and phosphate. Almost all representatives of the soft-bodied fauna occurring on the East European Craton have been recorded here. The inflow of the normal sea water to the northern and western areas of the craton should therefore be beyond any doubt.

Nevertheless, the whole Vendian complex is not yet of a typically marine origin, as the levels showing characteristically marine features are still in the minority in the sequence. Sedimentation was continuously affected by volcanic processes, judging by tuffites and bentonite clays widespread in the Redkino beds over a considerably wide area (Podolia, Moscow Depression). Other characteristic features are the occurrence of red highly dispersed deep-water clays in this complex (used even as marker bands for the correlation of sections), wide distribution of kaolinite in multicoloured sediments, particularly in the northwestern part of the sedimentation area (Baltics), and notable predominance of mixed-layered argillaceous minerals in the clay component of the areas affected by volcanism (Пиррус, 1980; Palaeogeography..., 1987). As the authigenic mineral indicators, geochemical characteristics, and peculiar association of fossils suggest, the complex of thin-bedded grey clays of the Upper Vendian Kotlin Regional Stage has also deviated from the normal-marine sedimentation regime, obviously towards freshening (Pirrus, 1992).

All this allows of the conclusion that the influence of the ocean waters on the rather wide Vendian sedimentary basin of the East European Craton was not strong enough. This was probably due to yet insufficiently known factors—structural barriers or unusual climatic conditions preventing the unification of the water salinity and sedimentation temperature in the basin studied. The present-day distribution of sediments and the paleogeographic picture drawn on its basis show the Vendian sedimentation area to be of elongated shape. More exactly, it is squeezed between two extensive continental shields, the Ukrainian-Sarmatian and Fennoscandian, where it functioned as a strait-like basin (Palaeogeography..., 1987). As yet there is not sufficient data about the processes taking place on these shields and in the adjacent mobile areas, neither has the facies analysis of the sediments offered enough information in this respect. Still, namely the elongated shape of the basin squeezed between the two potential uplift areas could be the answer to this problem as it indicates isolation from

the world ocean and the resulting characteristic sedimentation. Anyway, this peculiarity is worthy of stressing on the paleogeographic maps to be compiled within the framework of the IGCP Project 319.

The situation on the platform changed completely beginning with the Baltic Series assigned here to the Cambrian. Though the configuration of the sedimentation area and the main direction of the transgression remain unchanged, the rock composition refers to a distinct rearrangement in the hydrochemical regime of the basin: the influence of volcanism stops, red-coloured sediments disappear, kaolinite falls out of the clay component. The base of these beds shows the appearance of glauconite in the sediment, regular phosphatic mineralization, fixation of pyrite in argillaceous sediments indicating sulphate reduction (Пиррус, 1981). A principally new type of rich ichnofauna appears, the first primitive exoskeleton builders (*Sabellidites*) are found, the composition of clay minerals is of typically marine character (illite, chlorite). The sediments take on a greenish colouring reduced by total diagenesis, the red colour is preserved only as relict.

All this shows that by the time of the accumulation of the sediments of the Baltic Series the sedimentation basin became open to the ocean in the northwestern and western parts of the East European Craton and intensive water circulation guaranteed a normal marine regime for a longer period. The facies analysis allows to suggest the appearance of such a connection first of all in the north or in the north-east due to structural reorganization of the pre-Ural area; in the southwest, however, as a result of the formation of the Carpathian mobile belt.

The end of the Baltic Series was marked by the regression of the sea and extensive changes in the craton structure. The Moscow Depression, which so far had functioned as the main sinking area, underwent an uplift and stayed for a long period (up to the Middle Cambrian) above the sea level. In the western part of the craton a new depression area appeared opening to Europe. Polish-Lithuanian, Brest, and Podolian depressions, which had a direct connection with the ocean, were formed. During the following Cambrian history connections with the west continued; sediments, however, maintained all the above characteristics giving evidence of stable climatic conditions at least throughout the rest of the Lower Cambrian. Occurrence of glauconite, phosphates, pyrite, and marine fauna and lack of sedimentational carbonate characterize the whole Lower Cambrian on the East European Craton in spite of its subdivision into sedimentary complexes and series of different ages, often separated by breaks. Typical is also the prevalence of open-shelf sandy-silty sediments, mostly 0.01—0.1 mm in grain size, in the Lower Cambrian above the Baltic Series (Пиррус, 1986).

In the Middle Cambrian the craton was subjected to regression, during which argillaceous sediments were replaced by more arenaceous redeposited sediments, thus complicating the establishing of the sedimentation areas and their interrelations. In the Upper Cambrian the appearance of a new type of sediments, dark, organic-rich argillites, is recorded. Carbonate interbeds appear and the amount of glauconite decreases. Phosphatic brachiopod fauna, whose skeletal debris serves as a new rock-forming component, becomes highly significant. The Lower Cambrian sedimentation area distributed in the western part of the craton and related to the Polish-Baltic Depression disappears, sedimentation is renewed in the Moscow region. Paleogeographically this event is very important and noticeable.

Nevertheless, the most essential fact is that the Vendian East European Craton has not yet typically marine characteristics. On the global paleogeographical maps this should be marked by a corresponding

conventional sign. In the overlying Lower Cambrian (beginning with the Baltic Series), however, the craton constitutes an area of distinctly non-carbonate marine sedimentation, mostly characterized by permanent glauconitic-phosphatic mineralization. This feature, particularly the lack of sedimentational carbonate in the section, should be pointed out on the paleogeographical maps.

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IDA-EUROOPA VENDIST KAMBRIUMI ÜLEMINEKU SEDIMENTOLOOGILIS-PALEOGEOGRAAFILISED ASPEKTID

Enn PIRRUS

Erinevalt maailma teistest regioonidest on vendi ja kambriumi läbilõige Ida-Euroopa platvormil esindatud karbonaatidevaba terrigeensete setete kompleksiga, mis seletub settimispiirkonna paiknemisega sel perioodil jahedas kliimavöös kõrgetel laiustel lõunapooluse lähikonnas. Hoolimata niisugusest ühendavast joonest pole terrigeenne läbilõige siiski ühtne, vaid jaotub kaheks tekkelooliselt erinevaks osaks. Alumises, vendi kompleksi kuuluvas osas on tüüpmerelised setted veel tagaplaanil. Suure osa kivimeist moodustavad siin jäätumisperioodi setendid, vulkaanilis-settelised, sageli punast värvi kivimid ja magestunud veekogude moodustised. Alates kambriumi alumisest, Balti seeriast olukord muutub ja püsivaks saavad normaalmerelised, diageneesil halliks redutseeritud settekivimid, iseloomuliku glaukoniit-fosfaatse mineralisatsiooni, sulfaatreduktsioonijälgede ja savimineraalide tüüpmerelise kooslusega. See muutus avaldub peaaegu üheaegselt kogu platvormi piires ning on põhjustatud paremast avatusest maailmamerre. Nimetatud murrangulist sündmust tuleb tingimata kajastada IGCP projekti nr. 319 raames koostatavatel paleogeograafilistel kaartidel, sõltumata kambriumi alumise piiri lahendamisviisist, mille üle praegu veel elavalt diskuteeritakse.

СЕДИМЕНТОЛОГО-ПАЛЕОГЕОГРАФИЧЕСКИЕ АСПЕКТЫ ПЕРЕХОДА ВЕНДА В КЕМБРИЙ НА ВОСТОЧНО-ЕВРОПЕЙСКОЙ ПЛАТФОРМЕ

Энн ПИРРУС

В отличие от других регионов мира венд и нижний кембрий Восточно-Европейской платформы представлены исключительно бескарбонатными терригенными породами, что объясняется расположением области седиментации в это время в прохладной климатической зоне в высоких широтах недалеко от южного полюса. Хотя условия были сходными для всего терригенного разреза, по характеру осадконакопления он четко подразделяется на две части. В нижней части, соответствующей стратотипическому объему венда, преобладают не типичные морские отложения, а ледниковые и вулканогенно-осадочные образования, часто красноцветные, а также отложения опресненных водоемов. Начиная же с балтийской серии преобладающими становятся редуцированные диагенезом нормально-морские отложения с глауконит-фосфатной минерализацией, признаками сульфатредукции и типичными нормально-морскими ассоциациями глинистых минералов.

Это изменение происходит почти одновременно по всей платформе, что явно указывает на установление прямой связи зоны осадконакопления с Мировым океаном. Это переломное событие должно быть отражено и на глобальных палеогеографических картах, составляемых по проекту МПГК № 319, независимо от того, как будет разрешен дискутируемый сейчас вопрос о нижней границе кембрийской системы.