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JOTNIAN SANDSTONES IN MORAINE DEPOSITS OF SOUTH-EASTERN LITHUANIA

Iryna Poberezhska, *Candidate of Geological and Mineralogical Sciences, Associate Professor, Head of the Department of Mineralogy, Petrography and Geochemistry named after Professor Orest Matkovskyi*
iryna.poberezhska@lnu.edu.ua
https://orcid.org/0000-0001-5020-8326

Dmytrii Biruk, *Postgraduate Student of the Faculty of Geology*
Dmytrii.Biruk@lnu.edu.ua
https://orcid.org/0009-0005-7129-2244

Sviatoslav Kozhushyna, *3rd year Student of the Faculty of Geology*
Sviatoslav.Kozhushyna@lnu.edu.ua
https://orcid.org/0009-0004-0770-6046

Pavlo Kempa, *3rd year Student of the Faculty of Geology*
Pavlo.Kempa@lnu.edu.ua
https://orcid.org/0009-0008-4867-6268

Ivan Franko National University of Lviv,
4, Hrushevskoho St., Lviv, Ukraine, 79005

The article presents the results of a comprehensive lithological and paleogeographical study of erratic fragments discovered in the Skersabaliai quarry (Vilnius district, Lithuania). The relevance of the study lies in the necessity of detailing the reconstructions of glacial stream dynamics during the last Weichselian (Nemunas) glaciation, specifically its maximum Grūda stage. The primary focus is on red Jotnian quartzite sandstones, which serve as key indicator boulders.

Mineralogical and petrographic analysis identified these rocks as medium-grained quartz arenites, which are derivatives of the Mesoproterozoic Jotnian deposits from the Satakunta formation (Finland) and the Bothnian Sea basin. Diagnostic features include a regenerative structure, the presence of chloritized siliceous fragments, and specific turbidization of quartz cores. It is demonstrated that the high textural maturity of these rocks is associated with their formation within the extensive paleoriver systems of the Fennoscandian Shield.

A crucial scientific confirmation of the Bothnian-Åland transport vector is the established paragenetic association of rocks in the Skersabaliai quarry. Alongside the sandstones, a complex of igneous (red granites, rhyolite porphyries) and metamorphic rocks (gneisses, amphibolites, migmatites of the Svecofennian belt) was identified. The presence of epidotized granites with garnet indicates deep glacial erosion of the Fennoscandian crystalline basement. Simultaneously, findings of Palaeozoic sedimentary rocks (Ordovician and Silurian limestones) and an intact coral testify to the incorporation of material from the Baltic region's sedimentary cover during the glacier's transit through Estonia.

The totality of the described findings proves that the eastern branch of the Bothnian ice stream passed through eastern Lithuania. The authors reconstructed the full transport trajectory: from formation in the Scandinavian Mountains and the entrapment of Jotnian rocks in the Gulf of Bothnia to the accumulation of material in south-eastern Lithuania after transit through the Baltic basin. The results obtained are of significant importance for refining the stratigraphy of Quaternary deposits and the dynamics of Pleistocene glaciations in the Baltic region.

Key words: erratic clasts, Jotnian quartzite sandstone, southeastern Lithuania, Vistula glaciation, Fennoscandian Shield, quartz, zircon, regeneration cement.

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Problem Statement. The glaciations of the last ice age have different names according to the historical tradition of these regions: Fraser (in the Pacific Cordillera in North America), Wisconsin (in central North America), Devensian (in the British Isles), Midland (in Ireland), Würm (in the Alps), Meridian (in Venezuela), Vistula (in northern Central Europe and Northern Europe), Valdai (in Eastern Europe), Zyryan (in Siberia), Yankiue (in Chile), Otiran (in New Zealand) [10; 11; 21]. The Vistula glaciation, known in Lithuania as the Nemunas, is the last major ice age, which ended about 11–12 thousand years ago. It lasted from about 115,000 to 11,700 years ago. The most severe phase (maximum glaciation) occurred between 20,000 and 18,000 years ago. A huge ice sheet extended from the Scandinavian Mountains [4] to the eastern coast of Schleswig-Holstein, Central Germany and Northwestern Russia; it covered Scandinavia, Northern Germany, Poland and part of Great Britain. In Northern Europe, it is the last of the glaciers of the Pleistocene ice age.

The Scandinavian shield was the centre of glaciation. Erosion processes took place, the glacier worked as an abrasive, mechanically cleaning the surface layers of rocks. The ice sheet, up to 3 km thick, literally «scraped out» loose rocks and weathered granites under its own weight. «Ram foreheads» were formed: masses of ice smoothed the rocks, turning them into characteristic sloping hills with smooth tops. Ice flows deepened tectonic faults, creating deep valleys, which after the glacier melted were filled with the sea (fjords of Norway and the Baltic Sea basin). After the ice melted, isostatic processes occurred – the Fennoscandian Shield began to «float» due to the removal of colossal pressure. This uplift continues today (in places up to 1 cm per year), due to which the area of Sweden and Finland is gradually increasing [17; 19].

The south-eastern part of Lithuania is unique as it marks the maximum limit of the last glaciation, locally referred to as the Grūda Stage (correlated with the Branderburg Phase inj the regional stratigraphic scheme [2; 7; 16].

The extreme border of the Vistula (Niamun) glacier ran along the foot of the Medininka Upland. The territories to the southeast of it (for example, near Vilnius) were not covered by ice during this period, but were in the permafrost zone. The relief here is dominated by moraine ridges, sand plains formed by meltwater flows that washed sand from under the edge of the glacier, eskers and kami. The typical hilly-lake landscape of Lithuania is the result of the melting of ice remnants that were buried under a layer of soil. Of particular interest from the point of view of geology are the fragments of rocks that were brought by the glacier and deposited after its melting. This is of scientific interest for determining the primary sources of material supply, the conditions of its transfer, the directions of glacier movement, the area of glaciation, etc. [9]. In geological and glaciological literature, such fragments are called erratic (erraticus in Latin means «wandering») [23].

Research analysis. The primary material for the research was rock samples of erratic fragments, which were found in the Skėrsabalyai quarry in the Vilnius district of Lithuania. This is a technological area operating in an open-pit mining method. The facility specializes in the extraction of sand-gravel mixture (SGM) and other sedimentary non-metallic rocks, which are used as aggregates in construction. During the processing of the extracted mixture, large fragments of various rocks, once brought by the glacier, are separated. Among them, red quartzite sandstones were found.

The rocks identified as erratic clasts in the south-eastern part of Lithuania belong to different genetic types and have different age dating. By origin, they are igneous (acidic plutonic and volcanic), metamorphic and sedimentary rocks. Among the acidic rocks, the most common are heterogeneous granites of predominantly red color: biotite granite, muscovite granite, epidotized granite with garnet, pegmatite granite. Volcanic rocks of acidic composition – rhyolite quartz porphyries – were also recorded at the sampling site. Among the erratic clasts of metamorphic origin, epidote-amphibolite schist, amphibolite gneiss, migmatite, quartzite, marble was identified. Sedimentary rocks are represented by various types. Among them, carbonate (hemogenic ferruginous limestone, heterogeneous ferruginous dolomite, coral of the genus Heliolites), siliceous (spongolite) and clastic formations (quartzite sandstones) have been identified [15]. Such a variety of rocks in one place is a classic sign of moraine material, where the glacier «mixed» rocks from different parts of Fennoscandia.

Further studies have made it possible to determine that the found red quartzite sandstones belong to the Jotnian deposits. Jotnian sandstone is the oldest known sedimentary rock in the Baltic region that has not undergone metamorphism. These are the oldest cover rocks, common in the southern, southwestern and eastern parts of the Fennoscandian Shield, where they are preserved in grabens (Western Onega, Satakunta, Muhos, etc.) and are represented by quartzite sandstones with subordinate clay shales (Western Onega, Satakunta, Dalarna, Gävle, Trysil in Norway, Nordingra, Tersky coast, etc.), less often by quartzites (Almasakra), siltstones and clay shales (Muhos), which are composed of strata 500–1000 m thick. They are adjacent to somewhat earlier Subiotnian and Hoglandian acidic effusive rocks with subordinate tuffs and sedimentary formations (Dalarna, Hogland Island) and corresponding granites [18]. They occur as relics of unmetamorphosed sedimentary cover rocks on the washed-out folded structures of metamorphosed Precambrian geosynclinal formations.

In the modern International Chronostratigraphic Scale, the term «Jotnian» is officially absent; it is a regional name for the deposits of the Fennoscandian Shield, which belong to the Mesoproterozoic eon. The stratigraphic position of these deposits is the Late Mesoproterozoic, which corresponds to the international period of Stenian (Stenian) MP3 or S; age is 1200–1100 million years ago.

The aim of our work was to study the erratic fragments of quartzite sandstone found in the Skėrsabalyai quarry in the Vilnius region of Lithuania and to determine its original sources.

Terminological aspects. The most accurate term for a strong sandstone with quartz cement is quartzite sandstone – the more commonly used term in Ukrainian geology. In such sandstone, the spaces between the quartz grains are filled with secondary regeneration quartz cement, with indentation cementation. This is not yet fully metamorphic quartzite, but it is already stronger than ordinary sandstone. Metasandstone is a genetic term that directly indicates that the rock was sandstone, but underwent changes under the influence of pressure or temperature. Quartz arenite – (Quartz-rich sandstone) – in English-language literature and modern lithology, this term denotes a clastic rock of psammite dimension with a high content of quartz grains (over 90–95 %) and a small amount of matrix («cement») between them.

Description of the main material. Macroscopic description. The studied quartz sandstones have a rich red-brown colour, which is due to the presence of iron oxides in the rock composition, most likely hematite, which border the quartz grains with a thin film and fill the space between them. The structure of the rocks is psammite (sandy), fine-medium-grained, the rock is well sorted, quartz grains fit tightly to each other. The texture is massive, homogeneous. Rock fragments have an uneven fracture. Visually, quartz dominates the rock (over 90 %); The luster on the fracture is barely noticeable, matte, in some places the glass luster characteristic of quartz is observed (Fig. 1).

Fig. 1. Erratic fragment of red-brown quartzite sandstone

Microscopic description. The rock is composed of quartz (Q), its content in the framework is 95–97 %, according to the refractive index – IV group (according to V. Lodochnikov); the grains are colourless, their contours are outlined by a thin brownish-brown border of hematite. Under cross polarized light (XPL), grey, light grey to white colours of interference of the first order are observed ($n_g – n_p$ = 0.007–0.009) [22]. A wavy attenuation characteristic of quartz grains is noted: the colour of the grain is heterogeneous, it seems to «flow». This is a sign of internal stresses in the crystal lattice of quartz, obtained in the parent rock or during tectonic processes.

Grain size. The bulk of the clastic material has a size of 0.2–0.8 mm, the medium-grained fraction (0.25–0.50 mm) prevails. The average value is ~ 0.43 mm.

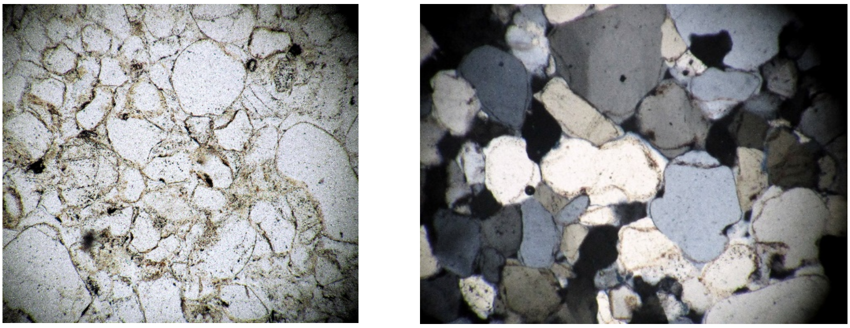
Character of cementation. A thin dark border of iron oxides is clearly visible in many quartz crystals, which forms «phantom» contours and fixes the primary shape of the grains before the beginning of the cementation process. Most grains have a high degree of rolling, which indicates long-term transport in the aquatic environment (Fig. 2). Behind this border, secondary quartz grows, which has the same optical orientation as the main grain; the size of the regeneration borders is 0.02–0.04 mm. Thus, regeneration cement was formed, which completely eliminated porosity, turning the rock into a dense drain quartzite sandstone. After the cement growth, the quartz grains seemed to grow together with the formation of a mosaic, practically non-porous structure. This explains the high strength of the studied rock. Toothed and depressed contacts are clearly visible. The grains are so tightly fitted to each other that the boundaries between the regeneration borders of neighbouring grains merge into a single mosaic.

Iron oxides (hematite, hydrogoethite) precipitated from solutions simultaneously with the growth of quartz cement or immediately before it (see Fig. 2, *b*). A thin ferruginous «shirt» covers the primary grain, and pure regeneration quartz grows on top of it, which makes the rock visually red-brown.

Degree of sorting. To assess the sorting, we used the sorting coefficient S_o (according to the Trask method). The grain size ranges from 0.2 to 0.8 mm, the average size is 0.43 mm, which corresponds to medium-grained sandstone; standard deviation σ ≈ 0.21; coefficient of variation V = 48.8 %. For the calculation according to the Trask method ($S_o = \sqrt{Q_3 / Q_1}$) we defined the quartiles:

Q_1 (25 % samples) ≈ 0.25 mm; Q_3 (75 % samples) ≈ 0.65 mm.

$$S_o = \sqrt{0.65 / 0.25} = \sqrt{2.6} \approx 1.61.$$



a *b*

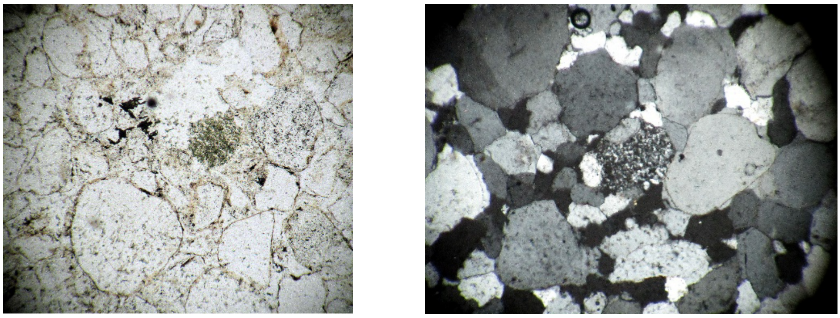
Fig. 2. Quartzite sandstone with regeneration cement: *a* – PPL; *b* – XPL; ×75

If S_o < 2.5, the rock is considered well sorted, i.e. an index of 1.61 indicates a fairly high degree of sorting, which is typical for mature quartz sandstones [24]. For Jotnian deposits, such a high purity of quartz indicates that before burial the sediment underwent multiple washings, which «cleaned» all unstable minerals, except for rare orthoclase grains.

Most quartz grains look dusty or speckled, since, as it turned out, they contain thousands of microscopic vacuoles with a gas-liquid phase. Such turbidization (clouding) of quartz by small gas-liquid inclusions is characteristic of Scandinavian Jotnian rocks. Linear structures are traced inside the grains – these are secondary chains of inclusions that «healed» microcracks in quartz even before it became part of the sandstone. This is a typical feature of quartz from ancient granite massifs.

In quartzite sandstones, tabular grains of pelitic alkali feldspar (group II in terms of refractive index) [22] are present, the size of which is on average 0.2 mm. The yellowish cloudy colour of the grains in plane polarized light (PPL) is a manifestation of the processes of pelitization, during which the smallest particles of clay minerals replace alkali feldspar, making it opaque and «dirty» compared to pure transparent quartz. The size of feldspar grains of 0.2 mm with an average quartz grain size of 0.4–0.8 mm corresponds to hydraulic equivalence: alkali feldspar is less stable and more easily subject to mechanical wear; therefore, its grains are usually smaller than quartz in the described rock. Since there is no microcline lattice, and the grains are pelitizated and have a yellowish tint, this is most likely orthoclase (it is less stable than microcline and undergoes pelitization more quickly).

The composition of the studied quartzite sandstones contains lithoids – fragments of siliceous rocks – quartzites or flints [24], 0.2–0.5 mm in size, which have a rounded shape, which confirms the good sorting of the rocks and indicates intensive processing of the material (for example, in coastal marine conditions or during long-term river transportation), when less stable minerals were destroyed, and quartz and siliceous fragments acquired a rounded shape. The fraction 0.2–0.5 mm fits well into the general granulometric spectrum of rocks, which makes these fragments part of the grain framework. Some fragments of siliceous rocks have a greenish tint in plane polarised light (Fig. 3) – this is a very characteristic detail for the Jotnian sandstones, which were formed due to the erosion of older Archean-Proterozoic strata, for example, series of the greenstone belts type. This colour is most likely due to the presence of small chlorite flakes, which give the rocks a uniform grey-green colour. In the context of Jotnian age, such green flints are often the product of redeposition of the products of destruction of older volcanic or metasedimentary rocks.



a *b*

Fig. 3. Fragment of greenish siliceous rock in quartzite sandstone: *a* – PPL; *b* – XPL; ×75

Among the accessory minerals in the studied rocks, zircon was found – a mineral of group VII, under cross polarised light with high interference colours of the II and III orders of the spectra according to the Michel-Lévy colour nomogram [22], the extinction is straight. This is a stable accessory mineral, very characteristic of sandstones formed as a result of the destruction of the Rapakivi granites, the main foundation for the Jotunheimen in Finland. Both independent zircon grains and its inclusions in quartz are present. The grains have an elongated-rounded shape, size – from 0.08 to 0.10 mm, clearly of terrigenous origin (released during the destruction of parent rocks) (see Fig. 2, *a*). Since zircon is heavier than quartz (its density is 4.6 g/cm^3 versus 2.6 g/cm^3 in quartz), it precipitates together with quartz grains, which are two to three times larger than zircon, which perfectly corresponds to the law of hydraulic equivalence. Zircon inclusions in quartz are 0.02–0.04 mm in size. This is primary zircon that crystallized together with quartz in the parent rocks, granites or gneisses of the basement. The grains have a subisometric and slightly elongated shape with rounded edges (Fig. 4). Rolled zircon grains with an elongation factor of 2 to 3 (length to width ratio of about 2:1 or 3:1) are a characteristic feature of grains from ancient metamorphic or igneous complexes that have undergone prolonged transportation. Zircon is one of the hardest minerals (7.5 on the Mohs scale); to give it a perfectly rounded shape, a huge amount of work is required by the aquatic environment, probably multiple redepositions in the coastal zone.

The studied rocks contain idiomorphic crystals of ore minerals of a clear geometric shape. There are square grains ranging in size from 0.04 to 0.10 mm and triangular grains ranging in size from 0.10 to 0.12 mm. Presumably, they are of authigenic origin (they could have grown directly in the sandstone during diagenesis), since their edges are perfectly sharp. A brown shell is formed around some ore minerals – «limonite halo» – a halo of secondary iron oxides and hydroxides, which suggests the presence of iron in the minerals (pyrite, magnetite?). Such shells are formed under the influence of oxygen and groundwater: iron in the mineral is oxidized with the formation of goethite or limonite. This is a common phenomenon for ancient sandstones that have undergone weathering. The formation of a brown halo around pyrite grains indicates its gradual replacement by limonite; if the ore mineral is magnetite, it is transformed into hematite or hydrogoethite. It is precisely such microscopic iron oxide inclusions, which diverge from the ore grains or are contained in the cement, that give the Jotnian quartzite sandstones their characteristic pink-red or brick colour. The presence of such idiomorphic grains with decay products around them is a classic sign of mineralogically mature Proterozoic sediments.

Alternating areas with quartz grains of different sizes were found in the sections of the studied rocks; such microlayering is an important indicator of the dynamics of the sedimentary environment. The energy of the flow changed: larger grains (0.6–0.8 mm) were deposited during

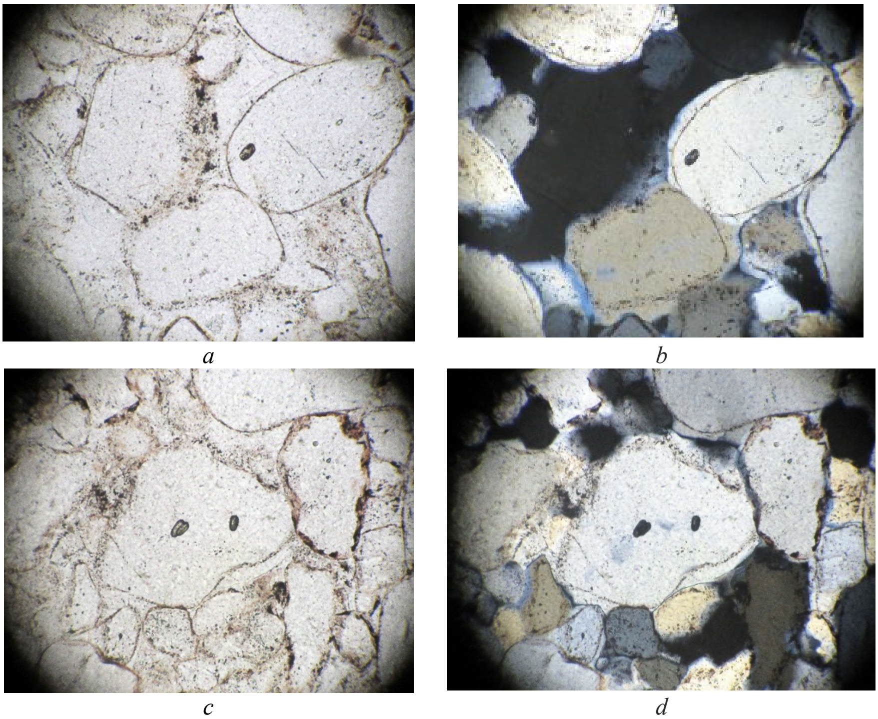


Fig. 4. Zircon inclusions in quartz in quartzite sandstone: *a*, *c* – PPL; *b*, *d* – XPL; ×100

the peak of the activity of the aquatic environment, while smaller ones (0.2–0.4 mm) were deposited during the lull. The constant change in the speed of the water flow led to the sorting of the material by mass and size. In areas with large grains, the pores were larger, so they often recorded wider regeneration borders (up to 0.04 mm), while in fine-grained areas, cementation occurred faster through free space.

Thus, the results of microscopic analysis show that quartzite sandstones, selected in the Skērsabalyai quarry of Vilnius district of Lithuania, are medium-grained quartz arenites (quartzite sandstones) with a regeneration structure. The structure of the rocks is heterogeneous with a predominance of the medium-grained fraction, the grain size ranges from 0.2 to 0.8 mm (average – 0.43 mm). The texture is massive, in places micro-layered: micro-layers of grains with sizes of 0.2–0.4 and 0.6–0.8 mm alternate. The clastic part of the rock is mainly quartz, and the quartz grains are from semi-rolled to well-rolled; There are single grains of pelitic plagioclase (size – 0.2 mm), rolled fragments of siliceous rocks (0.2–0.5 mm), rolled grains of accessory zircon (0.1 mm) and idiomorphic ore (iron-bearing) minerals with limonite borders (0.04–0.12 mm). Inclusions of relict zircon grains 0.02–0.04 mm in size occur in quartz. The rock cement is regenerative quartz (the thickness of the shells is 0.02–0.04 mm), ferruginous (brown pigment), with indentation cementation.

The discovery of erratic fragments of the Jotnian sandstone in the north-eastern part of Lithuania indicates the transfer of material from the north-west, approximately from the Baltic Sea or the adjacent territories of Finland and Sweden.

The main places of primary occurrence of the bedrock from which the erratic fragments of quartzite sandstones were brought could be the following [1; 3; 5; 6; 8; 12–14; 20]:

1) the Satakunta basin – a coastal province in south-western Finland –is the most famous terrestrial source of this type of rocks. The Satakunta sandstones form a thick layer in a graben that extends from the coast to the bottom of the Gulf of Bothnia. Glacial flows transported this material southeast through Estonia and Latvia to the northern part of Lithuania;

2) the Gulf of Bothnia – huge massifs of Jotnian sediments are hidden under water between Finland and Sweden, they constitute a significant part of the moraine that the glacier carried to the Baltic;

3) the Ladoga-Pash Graben – this source is located further east, but it also contains identical red sandstones (Priozerskaya and Salminskaya suites), which could have entered the region with other branches of the glacier;

4) separate underwater massifs in the Baltic Sea, for example, the Landsort Basin near the Stockholm archipelago, where deposits of red Jotnian sandstones have also been recorded (Fig. 5).

Fig. 5. Probable sources of erosion of the Jotnian quartzite sandstones [8]: *1* – Satakunta Basin; *2* – Gulf of Bothnia water area; *3* – Ladoga-Pasha Graben; *4* – Landsort Basin; *5* – sampling site (Skersabalyai quarry)

Regarding the formational affiliation of the studied rocks, the following main formations can be assumed to have been the primary source of the erratic quartzite sandstone boulders in Lithuania:

1) Satakunta Formation – the main source; its rocks occur in the region of the same name in southwestern Finland and continue under the floor of the Bothnian Sea. The formation is composed mainly of red and red-brown sandstones, often with oblique bedding, which indicates their fluvial or deltaic origin. These rocks are most often identified as «indicator boulders» in Lithuania and neighbouring countries [14];

2) Muhos Formation – located much further north, has sandstones in its composition, but also contains a significant proportion of siltstones and clays. Although it belongs to the Jotnian complex, its contribution to the Lithuanian moraines is much smaller compared to Satakunta due to the remoteness and direction of the glacier movement [20];

3) formations located in Sweden, which are lithologically identical: these are the Gävle/Hälsingland sandstones, which lie on the western shore of the Bothnian Sea; the Mälar sandstone formation – a separate outcrop in central Sweden near Lake Mälaren; the Dala/Dalarna sandstone formation – the largest area of outcrops in Sweden, but usually these boulders spread more to the territory of Poland and Germany [5; 6].

The following general mineralogical and petrological features of the mentioned Jotnian sandstones are given. In composition, these are quartz-rich sandstones (quartz arenites), but arkose sandstones (with a feldspar content of over 25 %), siltstones, shales and conglomerates are also found. They are characterized by a red or reddish-brown colour due to deposition in subaerial (terrestrial) conditions, which led to the oxidation of iron (hematite pigmentation). Cross-bedding, ripple marks and drying cracks are often found, which indicates a fluvial (river) or deltaic origin.

Conclusions and prospects for further research. Considering the location of the erratic fragments of the Jotnian sandstones in north-eastern Lithuania and the mineralogical and petrological features of the studied rocks, it can be concluded that the most likely primary source is the Satakunta Formation. Geographically, the main centres of the original occurrence of the Jotnian sandstones were the continental Satakunta basin (southwestern Finland) and its submarine extension in the Bothnian Sea (southern part of the Gulf of Bothnia) [3].

The Satakunta Basin (Finland) is the main «supplier» of red erratic boulders for the Baltics. These quartzite sandstones are often called «red grinding steel» because of their hardness, which is caused by the regeneration of quartz grains. The Bothnian Sea is home to vast underwater fields of Jotnian sandstone. The glacier, moving southeast, «excavated» this material and carried it across the territory of Estonia, Latvia, and Lithuania. From a geological perspective, this is the same Satakunta Graben, which is partially submerged by the sea. However, to describe the paths of glacial transport, it is advisable to separate them, since the glacier «collected» material from both the seabed and the land. The submarine part (in the Bothnian Sea) is territorially much larger than the mainland part. Most erratic boulders in the Baltic region originate from the seabed. Glacial streams moving towards Lithuania first crossed mainland Finland (Satakunta) and then «scooped» material from the Bothnian Sea floor, moving further to the southeast.

Mineralogical and petrological features of the erratic fragment of red quartzite sandstone from north-eastern Lithuania allow us to identify it as a derivative of the Mesoproterozoic Jotnian deposits of the Satakunta Formation (Finland) and the Bothnian Sea basin. Diagnostic features of this origin are the feldspar-quartz composition of the rocks, the saturation with iron oxides, which determine their characteristic colour, and the presence of rounded fragments of chloritized siliceous rocks. Accessory mineralization is represented by idiomorphic crystals of ore minerals and well-preserved zircon grains, which occur as individual grains and inclusions in quartz. The genetic relationship is confirmed by the specific microtextural organization of the quartz aggregate: pronounced turbidization of primary grain nuclei against the background of optically clear regeneration borders with conformal and compressed contact types. The high degree of textural maturity of the rock is emphasized by the good rolling of grains and their high level of sorting, which indicates the formation within the powerful paleoflug systems of the Fennoscandian Shield. The fragment was delivered to its present location by a Pleistocene glacial flow moving from the Bothnian region in a south-east direction in transit through the Baltic Basin to the territory of Lithuania.

This thesis is confirmed by the fact that in the Skėrsabalyai quarry of Vilnius district, a complex of rocks of various composition and genesis was found in a parasteric association with the studied quartzite sandstone. These are igneous rocks, among which red granites and rhyolite porphyries prevail, on which Jotnian sandstones lie directly in the grabens of the Fennoscandian Shield.

The presence of such rocks fully confirms the Bothnian-Åland vector of material removal by the glacier. The presence of garnet in granites and their epidotization indicate zones of metamorphic changes around large granite intrusions of the Fennoscandian Shield. The metamorphic complex – gneisses, amphibolites, migmatites – is the foundation of Fennoscandia – the Svekofenn belt (Southern Finland and Eastern Sweden). The fact that they are found nearby indicates deep erosion of the shield by the glacier, which «scraped» both the young sedimentary cover (quartzite sandstones) and the ancient crystalline base. The finding of sedimentary rocks indicates that this material, which the glacier picked up closer to the place of unloading the material, comes from the Ordovician and Silurian sediments of the Baltic region (Estonia or the bottom of the Baltic Sea). The discovery of a whole coral indicates that the glacier did not carry it too far, or it was preserved in a large block of limestone – this is a clear indicator of the presence of Palaeozoic cover rocks.

The totality of the described finds is evidence that the Bothnian Ice Stream (its eastern branch) passed through Skersabalyai. The beginning – formation in the area of the Scandinavian Mountains, movement through the Gulf of Bothnia (capture of Jotnian rocks and porphyries); transit – movement to the southeast through the territory of modern Estonia (island part and mainland), where sedimentary formations got into the moraine; finish – deposition of material in the northeast of Lithuania during the last (Valdai/Vistula) glaciation.

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ЙОТНІЙСЬКІ ПІСКОВИКИ В МОРЕННИХ ВІДКЛАДАХ ПІВДЕННО-СХІДНОЇ ЛИТВИ

Ірина Побережська, Дмитрій Бірук, Святослав Кожушина, Павло Кемпа
iryna.poberezhska@lnu.edu.ua

Львівський національний університет імені Івана Франка,
вул. М. Грушевського, 4, Львів, Україна, 79005

У статті представлено результати комплексного літологічного та палеогеографічного дослідження ератичних уламків, виявлених у кар’єрі Скерсабаляй (Вільнюський район, Литва). Актуальність роботи зумовлена необхідністю деталізації реконструкцій руху льодовикових потоків під час останнього Віслинського (Нямунського) зледеніння, зокрема його максимальної стадії Груда. Основним об’єктом дослідження є червоноколірні йотнійські кварцитопісковики, які є індикаторними валунами.

Мінералого-петрографічний аналіз дав змогу ідентифікувати ці породи як середньозернисті кварцові арініти, що є дериватами мезопротерозойських відкладів формації Сатакунта (Фінляндія) та басейну Ботнічного моря. Діагностичними ознаками є регенераційна структура, наявність хлоритизованих кременистих уламків і специфічна турбідизація ядер кварцу. Доведено, що висока текстурна зрілість цих порід пов'язана з їхнім формуванням у потужних палеорічкових системах Фенноскандинавського щита.

Важливим науковим підтвердженням Ботнічно-Аландського вектору знесення матеріалу є виявлена парагенетична асоціація гірських порід у кар’єрі Скерсабаляй. Поруч з пісковиками наявний комплекс магматичних (червоні граніти, ріолітові порфіри) і метаморфічних порід (гнейси, амфіболіти, мігматити Свекофеннського поясу). Знахідки епідотизованих гранітів з гранатом свідчать про глибоку ерозію льодовиком кристалічного фундаменту Фенноскандії. Водночас знахідки палеозойських осадових порід (ордовицьких і силурійських вапняків) та цілого корала є доказом захоплення матеріалу з чохла Балтійського регіону під час транзиту льодовика через територію Естонії.

Сукупність описаних знахідок засвідчує, що через територію Східної Литви проходила східна гілка Ботнічного льодовикового потоку. Реконструйовано повну траєкторію транспортування від формування в районі Скандинавських гір і захоплення йотнійських порід у Ботнічній затоці до акумуляції матеріалу на південному сході Литви після транзиту через Балтійську улоговину. Отримані результати мають суттєве значення для уточнення стратиграфії четвертинних відкладів і динаміки плейстоценових зледенінь Прибалтики.

Ключові слова: ератичні уламки, йотнійський кварцитопісковик, південно-східна Литва, Віслянське зледеніння, Фенноскандинавський щит, кварц, циркон, регенераційний цемент.

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