Paleotectonic pre-quaternary deposit formation conditions on the territory of Novgorod region

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Abstract. The following article characterizes the paleotectonic conditions timed to the main Earth development periods. The author has demonstrated the meaning of every tectonic phase during the pre-quaternary deposit formation, which is the basis for Novgorod region massive sedimentary strata layer.

1. Introduction
The geological history of Earth is full of many different events, phenomena and processes that are essentially the paleogeographic conditions that influenced the formation of the sedimentary strata.

The Novgorod region is geologically and geomorphologically part of the Eastern European Craton. It occupies an area in the central part of the platform and is located on the wing of the Moscow Syncline. The platform is based on a complex of magmatic and metamorphic rocks formed during the geosynclinal period of development and is its crystalline basement. The platform has passed the aulacogen and plate development stages. At the first stage, aulacogen was filled with terrigenous sediments of continental origin, and then the territory of the platform was subjected to sinking, flooding by the sea and the formation of a sedimentary cover on it, covering most of the platform. Such areas of the platform overlain by sedimentary strata are called plates (Russian plate), while there are areas, having a tendency to rise – these are shields (Baltic, Ukrainian), on which the cover is almost not formed. Within the Russian plate, anteclines and synclines are distinguished, characterized in the first case by the elevation of the basement, slow deflection of the territory, and reduced sedimentary cover capacity (Belarusian, Voronezh). Synclines, as a rule, are located above aulacogen and represent the most bent areas of the platform with a powerful thickness of sedimentary cover (Baltic, Moscow, Mezen). On these largest tectonic structures, a number of smaller positive structural elements (arches, shafts, elevations) and negative structural elements (depressions, deflections) [2].

2. Objects and methods of research
The object of the study was the paleotectonic conditions for the formation of the pre-quaternary sedimentary strata of the Novgorod region.

The analysis of paleotectonic conditions was carried out on the basis of identification and comparison of tectonic activity processes of certain time periods leading to the formation of a pre-quaternary thickness in the sedimentary strata of the Novgorod region.
3. Results and discussion
In the history of the sedimentary strata area platform formation, occupied by the Novgorod region, there are several stages associated with the main time periods – eras.

The period of time until the middle of the Archaean is characterized by magmatism and the emergence of the first sedimentary basins, which led to the appearance of the cores of future stable geostructural elements of the Earth at the end of the Archaean. Such a core can be considered, among other things, the Novgorod median mass, which plays a consolidating role in the solidification of the crystal basement.

In the Proterozoic, the formation of the primary granite-gneiss layer of the Earth crust continued, which was subjected to folding, which led, among other things, to tectonic breaks, erosion and destruction of rocks, and the accumulation of terrigenous sediments in depressions. Increased tectonic activity at the end of the Proterozoic led to the formation of the Moscow Syncline, within which there was a vast continental shallow sea basin with slightly increased salinity, in places with a stagnant process and a lush flowering of algae, which completely covered the territory of the Novgorod region. The basin accumulated mainly terrigenous sediments enriched with organic matter, as well as a relatively thick layer of clays. The middle and late Riphean of the Proterozoic is also characterized by the formation of the Krestetsky graben [1].

The Paleozoic era is a time of ancient life, characterized by the dominance of invertebrates (various clams, crustaceans, worms), the appearance of the first vertebrates (fish and ancient amphibians), as well as plants on land.

The first period of the Paleozoic era (Cambrian) lasted 65 million years, during which the territory of Europe was flooded by the sea, over which the Baltic shield rose as a hill. The coastline of the sea changed periodically due to slow vertical movements of the Earth crust. At the beginning of the Cambrian, there were several South-Eastern transgressions of a shallow warm sea with a fairly abundant bottom fauna (arthropods, sea worms, etc.) and normal salinity, in a basin where sand-clay and clay deposits accumulated. The hot climate contributed to physical and chemical weathering, resulting in the formation of clay and sand-clay crust on land weathering kaolinite, ferruginous and hydromicaeous composition. By the middle of the early Cambrian, the territory is subjected to the rise and erosion of previously formed eluvial-deluvial deposits, as well as to the formation of a vast Baltic depression (syncline), along which the sea, unlike the previous stages, came from the West and completely flooded the territory now occupied by the Novgorod region. The second half of the Cambrian is characterized by a new restructuring of the geological structure, as a result of which the sea again floods the Moscow synclise, reaches the North-Western territory to Estonia and the Leningrad region. The inhabitants of the shallow, relatively calm basin were trilobites, worms, jellyfish, sponges, brachiopods, algae, and other representatives of fauna and flora. Sand and clay sediments accumulated on the bottom [3].

Most of the Moscow synclise at the beginning of the Ordovician was land and was part of the Eastern European continent. The sea came from the West, from the Scandinavian-Baltic basin. Since marine organisms have increased the ability to form solid shells, so the deposits of this period are rich in fossils. Thus, in the coastal parts of the basin, non-sorted sands were formed with the inclusion of remnants of marine organisms’ shells, and in the lagoons, finer clay material was deposited. In the area where the Kresttsy is now located, Pestovo, layers of clay were formed with a thickness of up to 100 m [1].

Gradually, there is an expansion of the transgression and an increase in the depth of the basin. So in the middle Ordovician, the territory occupied by the Novgorod region was completely covered by a deep sea basin, in which clay-carbonate and carbonate sediments accumulated. For example, in the area of Chudovo, organogenic clay material was deposited, which then transformed into combustible shales (kukckersites).

The territory of the Novgorod region in the late Ordovician was completely submerged by a shallow sea, fluctuations in the level of which led to the appearance of silt-clay material in the sediments. The fauna and flora of the seas were somewhat richer in comparison with the Cambrian. Trilobites,
brachiopods, graptolites, clams, mosses, tabulatas, etc. were widely represented. On the land that stretched to the South, the first psilophytic plants appeared in the Ordovician [1].

The Silurian period, which lasted 30 million years, was marked by the Caledonian folding, which in the geosyncline areas led to the rise of the Russian platform and the retreat of the sea far to the West. The shallow bay of this sea reached only the South-Western part of the Pskov region. Land in arid climate became an arena of exogenous processes, where psilophytic plants grew and the first attempts to adapt marine animals to continental conditions were made [4].

The Devonian period, lasting 48 million years, was characterized by relative tectonic quiescence. So in the early Devonian, the territory of the Novgorod region was mostly the raised land, which was exposed to exogenous processes, the most significant of which is the formation of a dense network of rivers, ravines and gullies.

In the middle Devonian, sections of the Moscow and Baltic syneclise began to sink again intensively, and the sea gradually began to penetrate into the territory of the Novgorod region and completely flooded it. The sea was shallow, and clay-carbonate sediments accumulated on the bottom. At the end of this time, in a hot and humid climate, new uplifts of the territory occur, leading to the formation of a leveled alluvial-lake plain, subject to chemical weathering processes with the formation of kaolinite weathering crust.

At the beginning of the late Devonian, the territory of the Novgorod region is completely submerged in the process of a new sinking of the Central areas of the Eastern European platform. At the bottom of a shallow desalinated sea, red-colored terrigenous material deposited from the Eastern edge of the Baltic shield. Stable lowering of the North-Western wing of the Moscow syneclise, on which the Novgorod region is located, led to the change of the shallow sea to a deeper one, in which terrigenous-carbonate and carbonate, mainly dolomite, sediments began to be deposited. The inhabitants of the Devonian sea were brachiopods, echinoderms, brush-finned fish, and the first bony fish [1].

The end of the Devonian is characterized by a marked strengthening recovery of the territory and the retreat of the sea towards the Moscow syneclise, and the vacant land gradually flattens out, turning into a lacustrine-alluvial coastal plain, and subjected to active activities such exogenous agents as river erosion.

The Carboniferous period of the Paleozoic era, lasting 74 million years, inherits the main trends of the Devonian stage, but still differs markedly from it in that most of the area develops under continental conditions.

The climate of the early Carboniferous changed from arid to humid subtropical. The Carboniferous sea, even at its maximum stage, did not move further West than the rivers Lovat and Volkov. In coastal-continental conditions, the products of rock washing, carried down from the neighboring hills, accumulated in the lowered areas. Denudation led to the gradual reclamation of such territories, except for those that continued to be subjected to sea transgression, which led to the swamping of coastal plains and the creation of freshwater lakes, lagoons, small bays and estuaries within them. Coastal zones were characterized by vegetation associations such as mangroves, which caused the formation of carbon-sand-clay deposits [1].

Short-term invasion of the sea led to the formation of low-power layers of clay limestones and marls with the fauna of foraminifera, ostracods, brachiopods and nautilids in certain territories.

Bauxite accumulated on the slopes of hills and in erosional hollows, and kaolinite and montmorillonite clays, including fire–resistant clays, accumulated in depressions and at the foot of hills.

At the end of the early Carboniferous, marine transgression reached its maximum limits. The Eastern half of the region was occupied by the sea. The seashore ran along the Nebolchi-Okulovka-Valdai-Demyansk line [1].

In the middle of the Carboniferous, the Western part of the Moscow syneclise was again submerged, and thus a new transgression of the sea occurred. The entire Eastern part of the region was occupied by the water basin, where mainly red-colored terrigenous sediments with layers of Dolomites and limestones accumulated. This stage was characterized by the spread of fusulinids, choristids, sea urchins
and other previously unknown species. At the end of the middle Carboniferous, the area occupied by the sea began to shrink, and by the beginning of the late Carboniferous, the coastline of the sea was located South-East of the territory now occupied by the Novgorod region. Therefore, in the late Carboniferous, the territory of the region was a land covered with plowed forests [2].

The final stage of the Paleozoic era – the Permian period, lasting 38 million years, for the territory of the Novgorod region was marked by permanent uplifting of the territory, which was a platform area between the Baltic and Ukrainian shields. Only a small area in the late Permian in Pestovsky region briefly turned into a coastal plain. Within this territory, red-colored clay siltstones, calcareous deposits, with thin layers of Dolomites and dolomitized limestones accumulated in saline Gulf-like reservoirs.

The territory of the Novgorod region in the Mezoic era was an area of denudation, from which terrigenous sedimentary material was carried in the southern and South-Eastern direction to the Moscow syncline. Hot and dry climate is gradually replaced by hot and humid, which leads to the flowering of forests (coniferous, ginkt, cicadas) and the formation of weathering crust in the Triassic mainly sandy-wooden composition, in the Cretaceous period – the crust of chemical weathering [1].

4. Conclusion
The paleotectonic conditions, discussed in the research, led to the formation of a pre-quaternary sedimentary strata layer of various composition and thickness, reaching approximately 600–900 meters on the territory of the Novgorod region.

References
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