Late Pleistocene interglacial marine sequences in White Sea depression

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The presented analytical data specify the geological--stratigraphic position of interglacial sequences that serve as important geological and paleogeographic markers. Solution of this problem is of theoretical and paleogeographic significance in the correlation of Late Pleistocene events in different regions and prospecting for diamond and other mineral placers. The works were carried out in the western Terskii Coast of the White Sea (Fig. 1), where differently aged interglacial sediments are exposed along the steep slopes of river valleys.

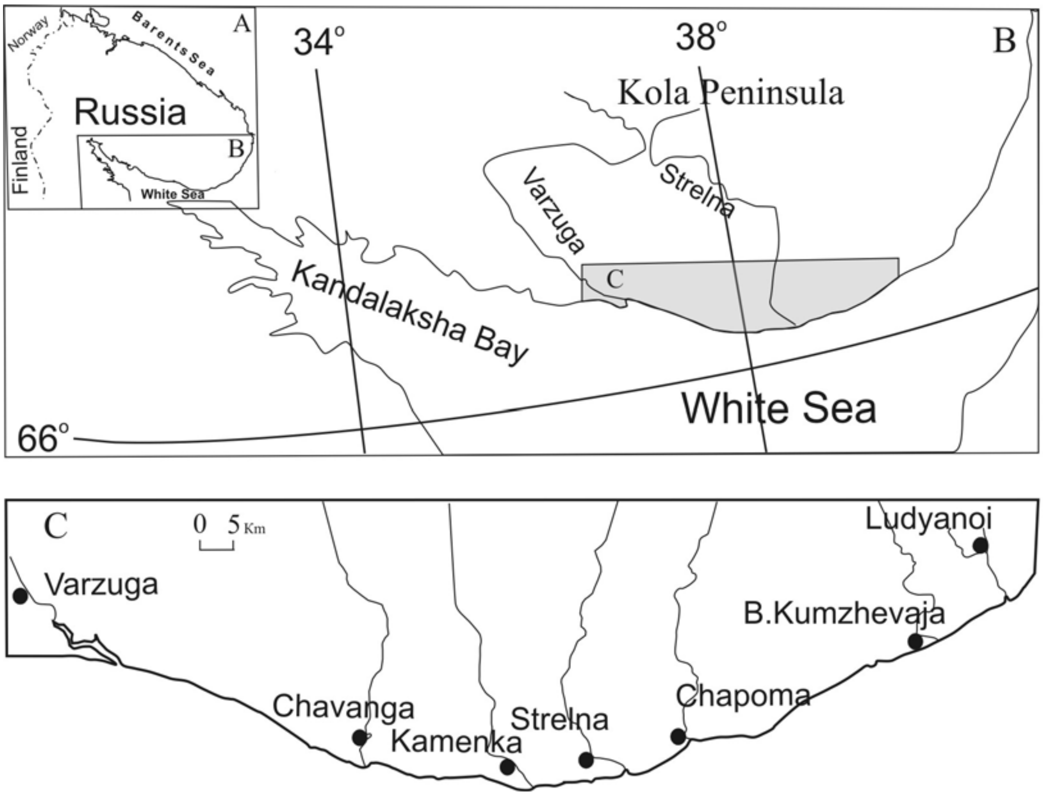

Fig. 1. Location of the study area (A, B) and examined exposures (C).

Collected samples were dated using the electron spin resonance (ESR) and optically stimulated luminescence (OSL) methods, which made it possible to specify the geological--stratigraphic position of interglacial marine sedimentary units.

In various examined sections, marine sediments constitute three differently aged sequences separated by stratigraphic unconformities that suggest three Late Pleistocene transgressions (Fig. 2). The number and age of these transgressions recorded in sedimentary sequences of the Kola region remain debatable issues. Three glacial units correlated with the Moscovian glaciation and two Valdaian glaciations are also established. The stratigraphically lower marine sequence, previously called the Ponoi Beds [1], is characterized by abundant macro- and microfaunal remains and diatoms.

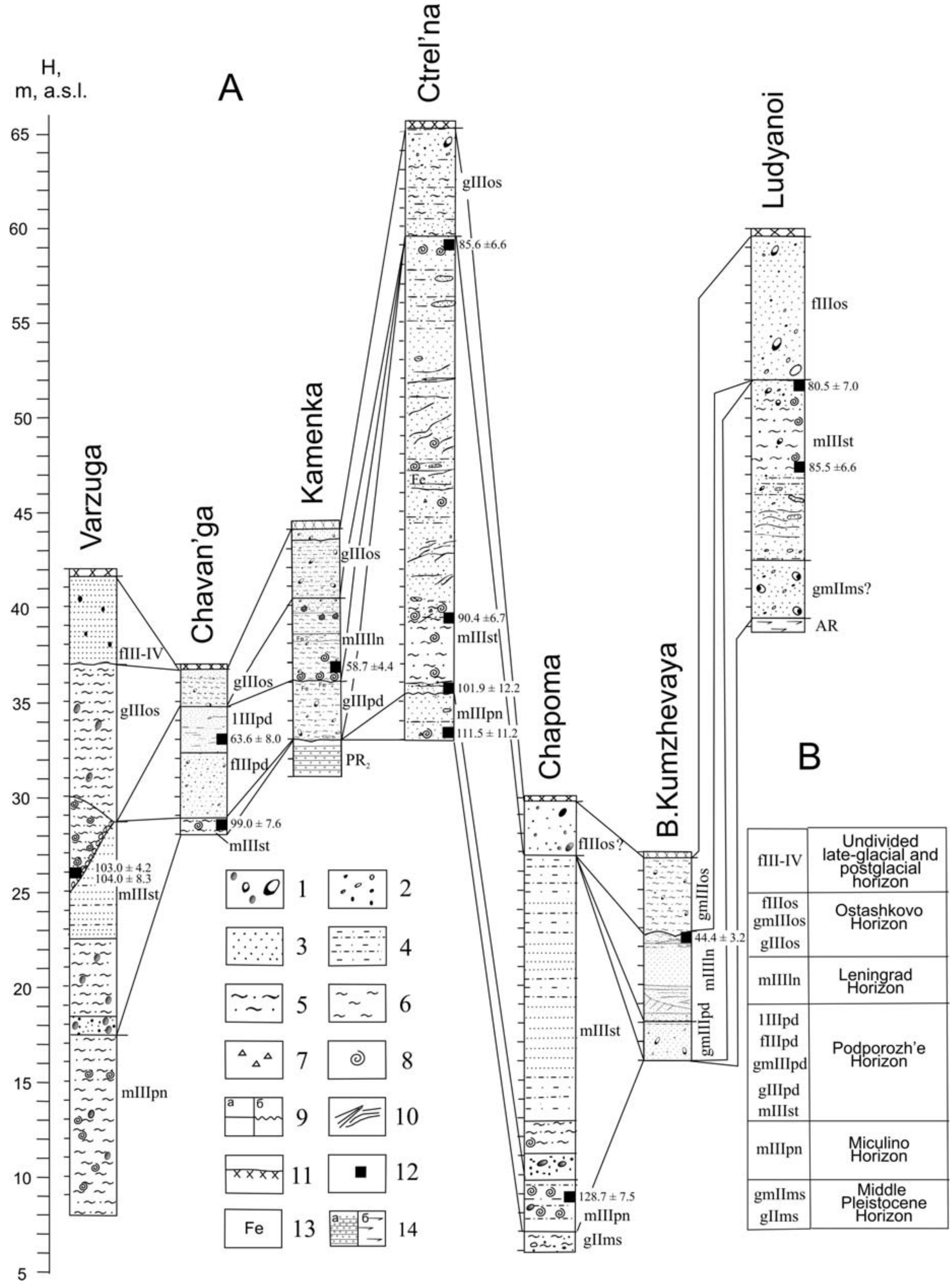

Fig. 2. Geological structure and correlation of examined sections (A) and quaternary stratigraphic scheme of the Kola Peninsula (B). Section location is shown in Fig. 1.

1 - boulders; 2 - gravel and pebble; 3 - sand; 4 - sandy loam; 5- loam; 6 - clay; 7- shingle and grus; 8 - detritus and intact molluscan shells; 9 - (a) bed boundaries and (b) erosion surfaces; 10 - structures; 11 - soil; 12 - sampling sites for geochronological dating (numbers designate the sediment age); 13 - ferrugination; 14 pre-Quaternary sediments; (a) red-colored arkosic sandstones and (b) gneisses.

The ESR/OSL-age of the Ponoi Beds ranges from approximately 120--130 to 100--105 ka. This unit, which is composed of compact clays, loams, sandy loams, and fine-grained sands, is exposed in the lower parts of the examined sections along the Varzuga, Strel'na, and Chapoma rivers (Fig. 2A). It overlies the Moscovian till, which is exposed in the Chapoma River valley at an altitude of 5--7 m. In other sections, the base of this unit is not observed and its roof occurs at 35 masl (Strel'na section). In the Varzuga section, the lower marine sequence occupies a peculiar position: it is probably deformed and occurs immediately beneath the Ostashkovian moraine at 25--30 masl [1].

Paleoecological reconstructions [1--3] demonstrate that the sea basin, where this sequence accumulated, was characterized by a more favorable environment as compared with the modern one. The water salinity was close to the normal one, and its temperature was higher than in the present-day White Sea, which is typical of the first optimum of the Mikulinian (Eemian) Interglacial now correlated with oxygen isotope substage (OISS) 5e. All the data unambiguously indicate the Mikulinian age of the Ponoi Beds, which accumulated during the Boreal transgression.

Two stratigraphically higher marine sequences are depleted in organic remains and composed of shallow-water near-shore and coastal facies. It was previously thought that they form a single unit accumulated during the Middle Valdaian transgression [1], which is correlated with oxygen isotopic stage (OIS) 3 (further in the paper, the Late Pleistocene is subdivided into the first Moscovian--Valdaian interglacial climatic optimum (Eemian Mikulinian OISS 5e), the early Valdai (OISS 5d—OISS 5a) and the Valdai Pleniglacial - early Pleniglacial (OIS 4), middle Pleniglacial (OIS 3) and late Pleniglacial (OIS 2). This subdivision scheme reflects new concepts [5]). The bedding conditions and structural--textural features of upper marine sequences (Fig. 2A), ESR-age of subfossil molluscan shells, and OSL-age of host sediments imply that they formed in the course of low-amplitude transgressions that followed the Boreal transgression.

It is established that the middle marine sequence, traditionally called the Strel'na Beds [1], corresponds to the early Valdai. In the southern Kola Peninsula, the early Valdaian sea appeared no less than 100--80 ka ago as a low-amplitude transgression interrupted by short-term regressions and erosion during interstadial coolings. The early Valdaian sea accumulated intricate sequences of mainly sand, loam, and sandy loam. Paleontological remains enclosed in these sediments indicate ecological conditions close to the modern one or colder [2, 3]. The most complete section of the Strel'na Beds is exposed and studied in the eponymous river valley at the altitude of 35--60 m, where they rest upon the eroded surface of the Ponoi Beds (Fig. 2A). The lower part of the Strel'na Beds, composed of compact loam with abundant molluscan shells, is exposed under fluvioglacial sands near the water level of the Chavan'ga River at the altitude of 29 masl or lower. The Strel'na Beds (loams and sandy loams with molluscan shells, pebbles, boulders, and fine- to medium-grained sands with lenses of coarse-grained varieties) sandwiched between glacial sediments are observed at 42--52 masl near the Ludyanoi Creek mouth. Similar sediments are also recorded along the Varzuga and Chapoma river valleys, where they overlie the eroded surface of the Ponoi Beds (Fig. 2A).

The data obtained correlate with the assumption of a new (Belomorian) transgression phase [6] after short-term regression of the Boreal sea and significant erosion of the relevant sediments. The geological position of the upper Valdaian marine sequence in the examined sections (Fig. 2A; Varzuga, Strel'na, Chapoma, and Ludyanoi sections) indicates that the marine regime in the White Sea existed during the entire period, which correlates with OIS 5. The maximal depth of the sea in the study area did not exceed a few tens of meters. The shoreline of the early Valdaian sea fluctuated within a depth range of approximately 50--100 m above the present-day sea level during transgressions and regressions.

The beginning of the early Valdaian Pleniglacial (OIS 4) was marked by a distinct cooling, which is reflected in the sediments of the glacial paragenetic association in the Chavan'ga, Kamenka, and Bol'shaya Kumzhevaya sections (Fig. 2A). According to the available regional stratigraphic scheme, these sediments correspond to the Podporozh'e glacial horizon [7]. Norwegian scientists [8] established the existence of ice-free environments 150--71 ka ago in the immediate vicinity of the Scandinavian glaciation center. According to computer-based modeling data of Swedish and American researchers, the eastern part of the Kola Peninsula was free of ice of the Scandinavian center until approximately 70 ka ago [9]. The formation of the Podporozh'e glacial horizon in the Terskii Coast of the White Sea was likely related to the development of the Kara glacier, rather than the Scandinavian glacier, in this area during the early Pleniglacial (OIS 4). This assumption is indirectly supported by finds of carbonate rock pebbles and boulders that are unknown in the Kola Peninsula but typical of Paleozoic rocks in the northern Russian Platform [10].

The Podporozh'e Horizon is overlain by the third marine sequence of interglacial origin (according to our geological data and subfossils therein [1, 3, and others]). The obtained geochronological dates point to its Middle Pleniglacial age (OIS 3). The sequence (sands, sandy loams, and loams) is overlain by marine or glaciomarine sediments (Fig. 2A) and correlated with the Leningrad [7] Horizon (Fig. 2B).

Thus, it is established that the geological--stratigraphic position of the Upper Pleistocene marine sediments in the southern Kola Peninsula was determined by development of at least three transgressions. The last transgression predated the Early Pleniglacial continental glaciation. Geochronological data indicate the Mikulinian age of the first transgression, which correlates with the Boreal transgression in the northern East European Plain. This is indicated by the presence of the Ponoi marine beds (Fig. 2B). The second transgression, which correlates with the Strel'na marine bed, has an early Valdaian age (Fig. 2B). These two transgressions were successively developed in the continuously existing sea from 130 to 80--70 ka ago. This period correlates with the entire OIS 5. The marine environment was successively interrupted by glaciation (OIS 4), and the late Pleistocene transgression III 60--40 ka ago was referred to the Middle Pleniglacial (OIS 3). The relevant marine sediments (Leningrad Horizon) are everywhere overlain by the Late Valdaian glacial sediments that make up the Ostashkovian Horizon (Fig. 2B).

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