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MINERALOGY

Glendonites in the Aptian Stage (Lower Cretaceous) of Western Siberia

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Abstract—The first occurrence of glendonites (pseudomorphs of calcite after the cold-water mineral ikaite) from the Aptian Stage (the Tanopcha Formation) of Western Siberia is described. A review of the Aptian–Albian glendonite record in other regions of the world is provided, and the significance of these occurrences for clarifying the climate of the terminal part of the Early Cretaceous is discussed. Aptian glendonites from Northeastern Russia are shown.

Keywords: ikaite, Arctic, climate, paleogeography

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INTRODUCTION

Among the various indicators of the climate of the geological past, glendonites, calcite pseudomorphs after ikaite that occur from the Paleoproterozoic to the Holocene primarily in marine deposits, hold one of the most prominent places. Ikaite (hexahydrate of calcium carbonate, $CaCO_3 \cdot 6H_2O$) is stable under natural conditions in a narrow temperature range (not above 7°C). The crystals and aggregates of ikaite have a very distinctive appearance, which makes it possible to identify glendonite occurrences easily even from fragmentarily preserved samples and leached voids [1, 2]. The factors controlling the precipitation and spatial distribution of ikaite are not yet clear, but a necessary condition for their presence is low ambient temperature.

In the Lower Cretaceous, glendonites occur at high latitudes in both the Southern and Northern Hemispheres of the Earth. In Siberia, they have been known until recently from the Ryazanian, Valanginian, and Hauterivian stages [2]. Younger Aptian–Albian glendonites were described or mentioned from other Arctic regions, such as Svalbard, Northern and Northeastern Greenland, the islands of Arctic Canada, and Koryakia and Chukotka [2–4].

MATERIALS

During the study of the core from a well drilled at the Tambeiskoye field on the Gyda Peninsula, a small glendonite was found in one of the samples from the Tanopcha Formation (the Aptian Stage) at a depth of

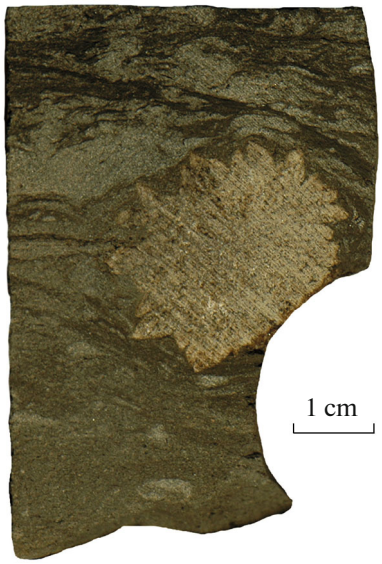

Fig. 1. The appearance of glendonite from the Tanopcha Formation (the Aptian) of the Tambeiskoye field in a cut core.

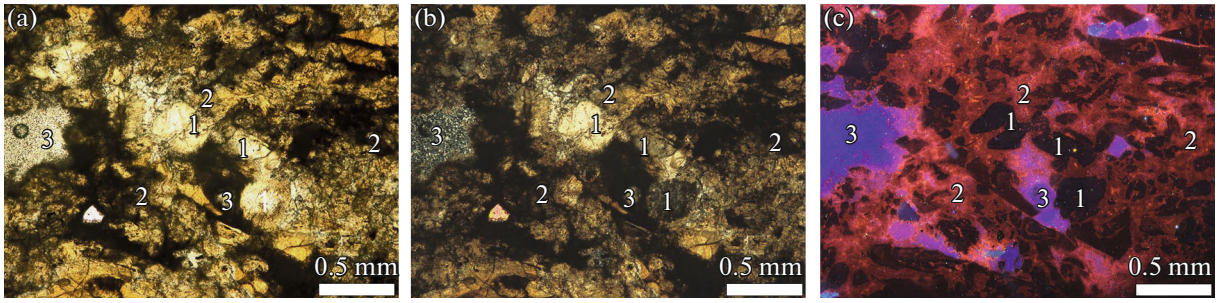

Fig. 2. Images of glendonite in transmitted light (a) plane-polarized light, (b) cross-polarized light, and (c) cathodoluminescence: 1, calcite formed during the dehydration of ikaite; 2, cement calcite; 3, chalcedony.

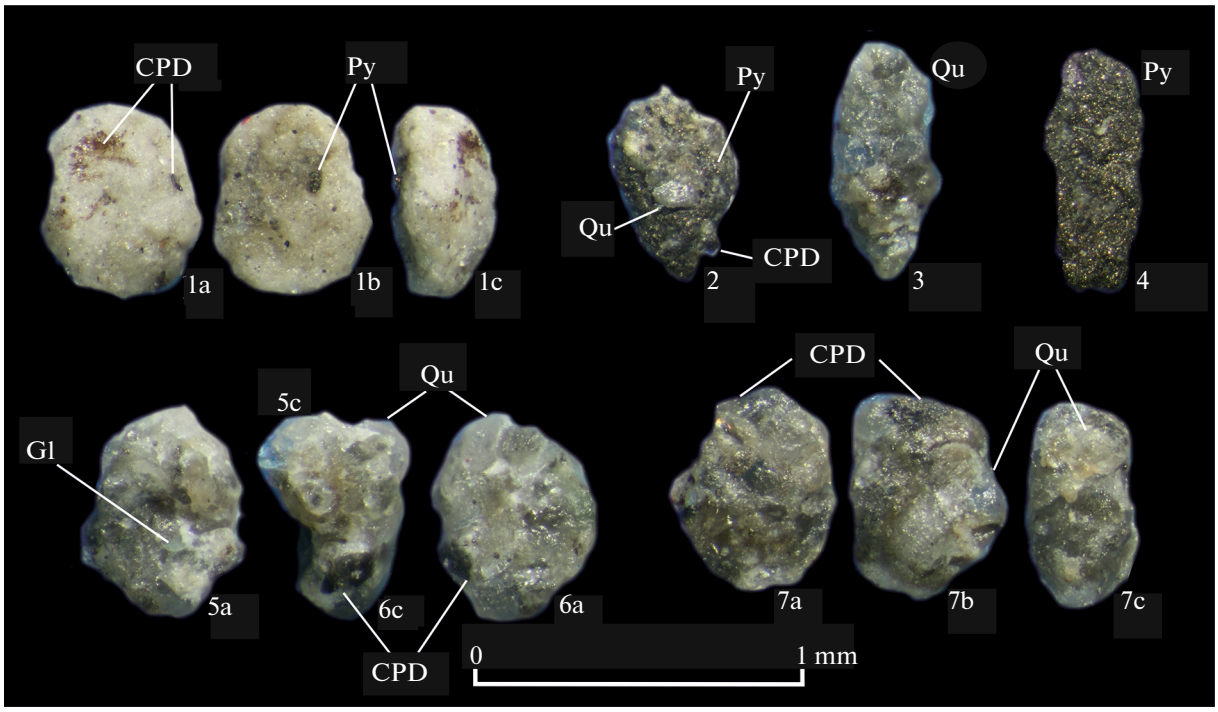

Fig. 3. Beach-bar agglutinating foraminifera from the well core with glendonite (depth of 1781.47 m). 1, *Tolypammina* sp.; 2, *Lagenammina agglutinans (*Tairov, 1961); 3, *Reophax* sp.; 4, pyritized *Bulbobaculites* spp.; 5–6, conglomerate foraminifera: 5, *Haplophragmoides* sp.; 6, *Cribrostomoides* sp.; 7, *Recurvoides* sp. Qu, quartz; Gl, glauconite; Py, pyrite; CPD, carbonized plant detritus.

1781.47 m by G.A. Galadzhyan (St. Petersburg Branch, All-Russia Research Geological Oil Institute (VNIGNI)) (Fig. 1). It was delivered to us for further study. The glendonite, isometric in shape, is ~3 × 3 cm in size and belongs to the most typical morphotype ("rosette" according to the traditional classification [4]). The host rock is represented by silty sandstone with carbonate cement. Microscopically, the glendonite consists of calcite crystals from 0.05 to 0.5 mm in size (Fig. 2). Yellowish brown crystals, consisting of about 20–30% pseudomorphs, are recognized in transmitted light; these crystals do not luminesce. Another type of calcite crystals is colorless, showing dark red luminescence during cathodoluminescence. This type of calcite surrounds the yellowish brown crystals. The previous studies evidenced that this structure is common for glendonites: the yellowish brown crystals form during the dehydration of ikaite, while the lighter form during relatively later cementation [5]. The central part of the glendonite is composed of chalcedony with blue cathodoluminescence.

The microfauna in the sample is represented by a benthic agglutinating foraminiferal community that is typical for beach-bar facies: numerous primitive forms and representatives of Haplophragmoididae with an inequigranular agglutinin in both composition and size: quartz, pyrite, glauconite, and carbonized plant detritus (CPD) (including vitrinite and sporopollenin

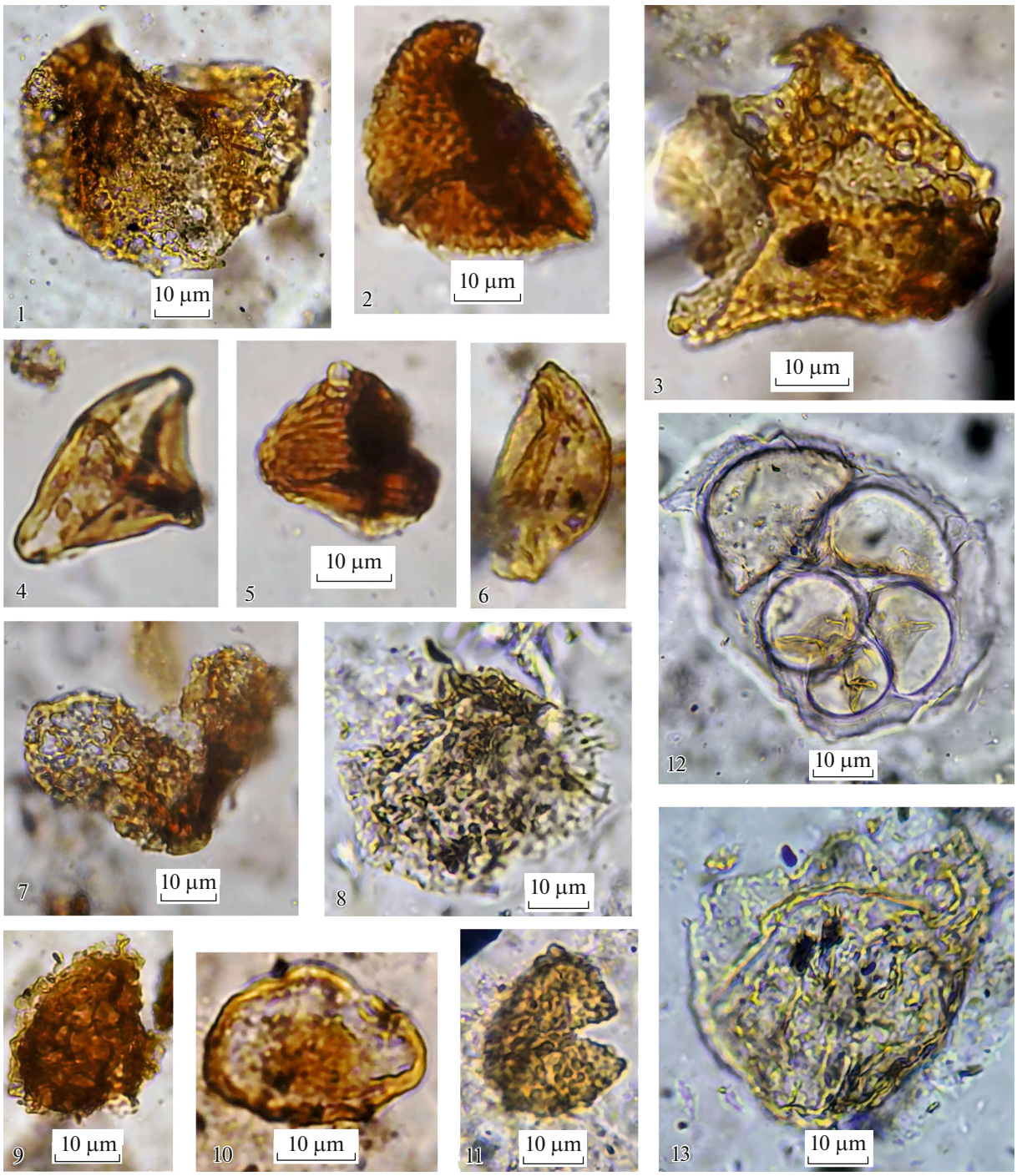

Fig. 4. Microfossils (spores, pollen, dinocysts, microforaminifera) from the well core with glendonite (depth of 1781.47 m). (1) *Pinuspollenites* sp; (2) *Sestrosporites pseudoalveolatus* (Couper) Dettmann; (3) *Trilobosporites* sp.; (4) *Gleicheniidites* sp.; (5) *Cicatricosisporites* sp.; (6) *Ginkgocycadophytus* sp.; (7) *Podocarpidites* sp.; (8) *Chlamydophorella* sp.; (9) *Lycopodiumsporites* sp.; (10) *Sphagnum* sp.; (11) *Trilites tuberculiformis* Cookson; (12) Lining of the Haplophragmoididae microforaminifera (first chamber and first whorl; (13) *Cassiculosphaeridia* sp.

undetectable remains of plant origin) (Fig. 3). The taxonomic composition, size, and shape of the quartz grains of the agglutinate in the washed powder of the sample are characteristic of bar facies in the littoral and upper sublittoral zones. In the Tambei area, this appearance of the foraminiferal community and washed powder is typical for the interval of the TP_1–TP_{18} layers.

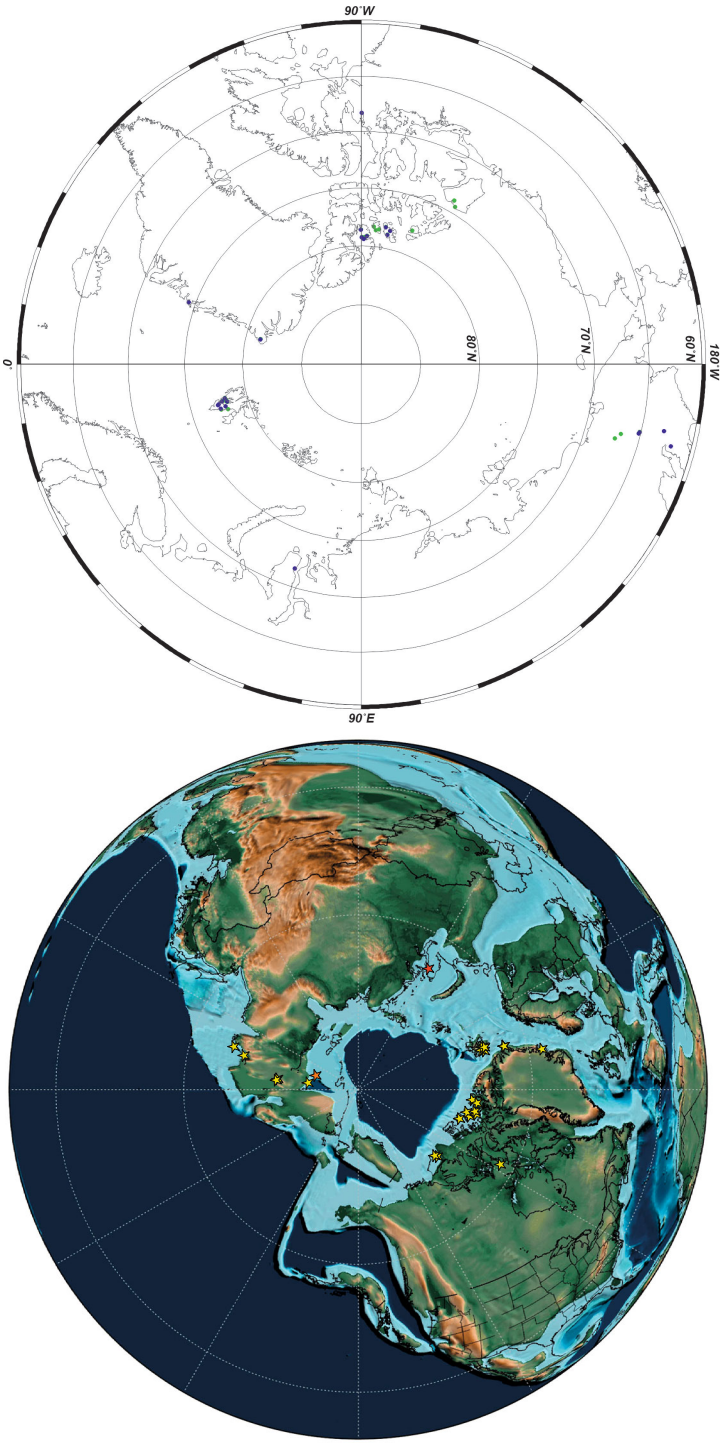

Fig. 5. Geographic distribution of the Aptian–Albian glendonites in the Northern Hemisphere. (a) On a modern geographic basis (the Aptian finds are marked in green; the Aptian–Albian and the Albian, in blue), the map was prepared using the OceanData-View program [16]; (b) using paleogeographic reconstruction according to [17] (the sample studied in this work is marked with a red star, the Aptian glendonites of Northeastern Russia shown in Fig. 7 are marked with an orange star, and other finds are designated by yellow stars).

Comprehensive palynological studies of the sample were conducted. The sediments studied are characterized by a low abundance of predominantly poorly preserved palynomorphs. The spectrum of the Early Cretaceous composition is dominated by bisaccate pollen of gymnosperms (Disaccites gen. sp. indet.,

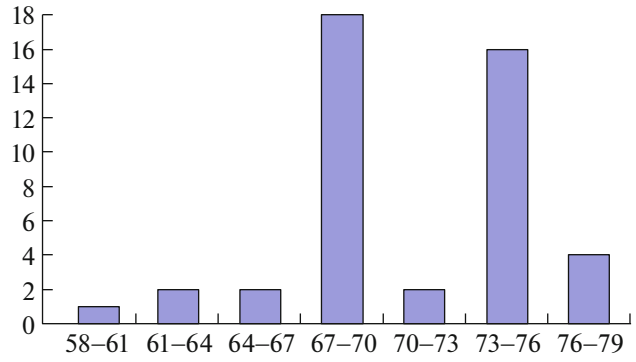

Fig. 6. Distribution of the Aptian–Albian glendonites by paleolatitudes (calculated based on the data from paleolatitude.org [18]).

Pinuspollenites spp., *Podocarpidites* spp.). Monosulcates and Taxodiaceae are rare. Among the sporophytes, representatives of Cyathea, Gleichenia, and Osmunda ferns were present, and Sphagnum mosses were noted. *Cicatricosisporites* spp. occurred frequently; the species *Sestrosporites pseudoalveolatus* (Couper) Dettmann (Fig. 4.2) and a fragment of the spore *Trilobosporites* sp. were detected (Fig. 4.3). The studied sample was also found to contain a few dinocysts (or their fragments) of a wide stratigraphic range, isolated representatives of colonial algae *Botryococcus* sp., and microforaminiferal linings.

The spore–pollen composition of the palynological spectrum is conditionally comparable to the zonal Aptian assemblage (SPA V) [6] but without numerous and diverse spores of Gleichenia, which are typical for Aptian–Albian palynological complexes. The macerate obtained after technical preparation of the rock sample is equally abundant with mineral and organic components. There are numerous mineral crystals of primarily medium (20–40 μm) and large (over 50 μm) sizes, as well as problematic detritus which is mainly medium-sized (20–40 μm) and is usually carbonized. Finely-dispersed amorphous organic matter was noted. The palynological spectrum exhibits terrestrial and marine palynomorphs that often have numerous mechanical injuries to their linings. The composition of the organomacerate is typical for a tracheal palynofacies with features of a mineral source and indicates coastal–marine shallow-water sedimentation conditions with a high level of hydrodynamic activity of the environment.

DISCUSSION

In Lower Cretaceous sediments, glendonites occur in both hemispheres of the Earth; finds are restricted to two main stratigraphic intervals: the Ryazanian–Hauterivian stages (glendonites are often found in Siberia within this interval) and the Upper Aptian–Middle Albian [2]. The find of glendonites from the Upper Barremian of the Barents Sea shelf is the only one known outside of these intervals [7].

A large number of glendonite finds in the Middle Aptian–Middle Albian interval agrees well with the understanding of drastic cooling during this time, which was noted at both high and low paleolatitudes and was recorded on global curves of changes in the Earth's average surface temperature [8–10]. The Aptian–Albian glendonites are especially abundant in two regions, in Svalbard and on the islands of Arctic Canada (Figs. 5a, 5b). At the end of the Early Cretaceous period, both regions were located at transpolar latitudes (Figs. 5, 6). At the same time, the mass occurrences of glendonites are likely to reflect the level of prior studies of these regions, as well as the influence of local environmental factors of the sedimentation basin that controlled the precipitation of ikaite. Note that most of the data on the Aptian–Albian glendonites from Svalbard were obtained in the past ten years [1, 4, 11], while the works published earlier mentioned only a few finds of "star-shaped concretions" or "anthraconites" in these sediments. The Lower Cretaceous glendonites from Arctic Canada were actively studied by E. Kemper in the 1970s–1980s [12], which aroused interest among researchers in the glendonites from this region.

The finds of Aptian–Albian glendonites in Northeastern Russia were frequently mentioned in the published works on regional geology (most often as "star-shaped concretions" [13] and less often as "glendonites" [14]) but were not accompanied by images or detailed descriptions of these pseudomorphs. Therefore, the nature of these "star-shaped concretions" remained debatable. The images of indisputable glendonites from the Aptian sediments in Northeastern Russia were discovered in the report [15] only recently (reproduced in this work, Fig. 7). The glendonites here are represented by two morphotypes which are common for coeval glendonites from Arctic Canada [3] and Svalbard [1].

Despite a high level of prior studies, Cretaceous glendonites were unknown in Western Siberia until recently. This is partly due to the fact that glendonites did not draw the attention of the geologists who described the core. However, we recognized indisputable glendonites in the photos of the Ryazanian–Hauterivian cut core in the unpublished reports. The analysis of the geographical distribution of the finds of the Lower Cretaceous glendonites in Western Siberia showed that they are restricted to the deepest parts of the paleobasin, where the bottom water temperature was the lowest, or to the shallow-water areas exposed to cold-water currents [15].

The composition of the microfossil assemladges and the composition of the host sediments confirm that the studied glendonites are associated with the upper sublittoral zone. In Svalbard, the first finds of the Aptian glendonites are noted in the Dalkjegla For-

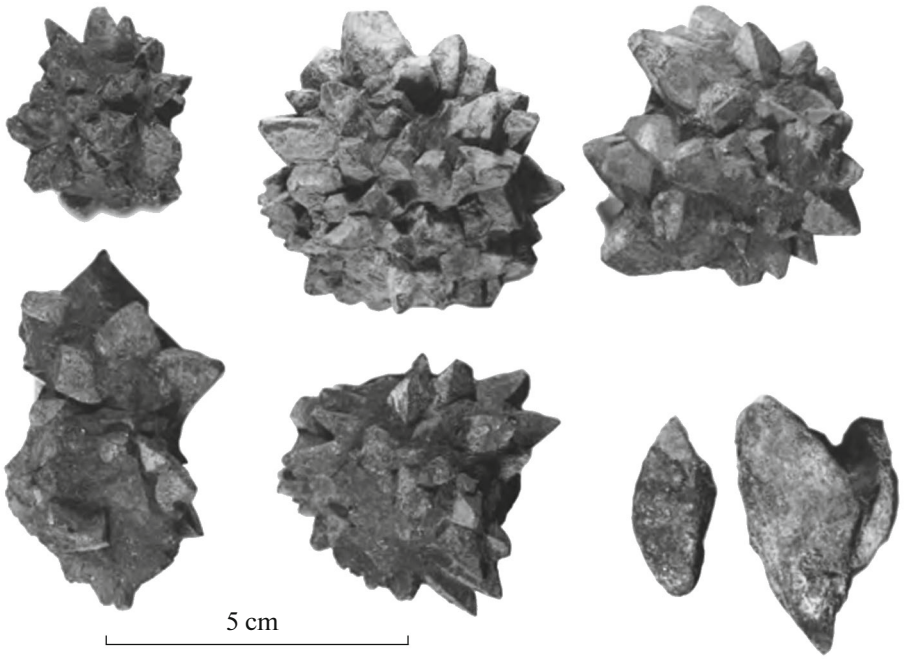

Fig. 7. Aptian glendonites from the Orlovskaya River (the locality is marked with an orange star in Fig. 5b, after [15]).

mation, which is composed of similar facies [1]. The glendonites were likely to appear in such shallow-water sediments due to the onset of the first phase of cooling during the Middle Aptian, but we cannot exclude the influence of cold currents, which facilitated the crystallization of ikaite.

All known finds of the Aptian–Albian glendonites in the Northern Hemisphere were discovered in high-latitude sections, the paleolatitudes of which indicate their location predominantly beyond the Polar Circle. Out of 48 localities of the Aptian–Albian glendonites recorded in the author's database [2], over 90% (44 out of 48) were located north of the 66th paleoparallel (Fig. 6). This is also true for the sole occurrence of the Aptian glendonites that we know in Western Siberia.

CONCLUSIONS

Glendonites are abundant in Middle Aptian–Middle Albian sediments at high latitudes in the Northern Hemisphere. These finds mark the cooling events at the end of the Early Cretaceous period. Until recently, they were discovered primarily in Arctic Canada, Svalbard, Northern and Northeastern Greenland, and Northeastern Russia. The presence of glendonites in the Aptian (the Tanopcha Formation) in Northwestern Siberia (Gyda Peninsula) was established for the first time. This find is likely to be coeval with the oldest Aptian glendonites from Svalbard, which are also restricted to the shallow-water coastal facies.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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Supplementary data: http://jurassic.ru/_pdf/glendonites_apt-alb.pdf