Jurassic and Lower Cretaceous Glendonite Occurrences and Their Implication for Arctic Paleoclimate Reconstructions and Stratigraphy

M.A. Rogov, V.A. Zakharov

Geological Institute of RAS, Moscow, Russia (E-mail: russianjurassic@gmail.com)

Since the pioneering articles by Kaplan (1978) and Kemper and Schmitz (1981) idea on using glendonites as paleotermometers became useful for investigation of rocks of the different origin (shallow and deep-marine as well as terrestrial) and age (from Neoproterozoic to Quaternary). There are no doubts that origin of these pseudomorphoses and their precursor ikaite should be restricted by very narrow temperature range (Swainson and Hammond, 2001; Selleck et al., 2007) and even highest estimated temperatures slightly above 7º C (Stein and Smith, 1986) reflect existence of such low paleotemperatures during the predominantly greenhouse Mesozoic Era. Ikaite precipitation is favored by elevated alkalinity and dissolved phosphate, and in many cases their formation is associated with organic-rich marine sediments where methane oxidation is occurring (Selleck et al., 2007). Glendonites, as a rule, occur within terrigenous members (mudstones, siltstones or sandstones), in many cases associated with other carbonate concretions or limestone bands.

There are many papers considered stable isotope value of glendonites or their occurrences in some regions or sections, but most full review of their occurrences in Arctic Mesozoic has been published at the dawn of such studies (Kaplan, 1978). Here we are presenting some additional data, received from recent field works held in Spitsbergen and Northern Siberia, which permit to date paleoclimate oscillations more precisely and revealing differences of influence of climate/current changes between the shallow and deep-water environments.

1. Stratigraphical and geographical distribution of glendonites in Arctic Jurassic and Lower Cretaceous

Glendonite concretions, especially more or less big ones, usually attracted attention of geologists due to their strange outline, and in spite of rarity of mentioning of "glendonites" such concretions well recognized through References under the names "stellate concretions" or "antraconite concretions". Nevertheless their precise dating frequently met some difficulties because fossils are not numerous and diverse at the glendonite-bearing members.

Oldest Jurassic records of such concretions are known from the Upper Pliensbachian above the Stokesi Zone and perhaps restricted to uppermost Pliensbachian Amaltheus viligaensis Zone of the Northern Siberia and lower Lena river flow. Upper Pliensbachian glendonites, discovered recently at the Northern Germany (Teichert and Luppold, 2009) also belongs to the uppermost zone of this stage. At the top of the Pliensbachian glendonites disappeared drastically, which is well corresponding with remarkable warming at the beginning of the Toarcian (Zakharov et al., 2006, among the others). Again glendonites appears at the Early Aalenian, but in this time their occurrences restricted by the western board of the Khatanga Sea. Late Aalenian glendonite distribution is close to those of the Early Aalenian, and such concretions are also mentioned from the Vilyui and Kolyma basins.

Peak of the glendonite abundance and diversity falls to the Bajocian (including also bulk of the Bathonian of the early authors). Bajocian glendonites are known from numerous localities of the Northern Siberia, Jakutia, North-East of the Russia. Bathonian glendonites are less widely ranged, and at the Lena lower flow they became smaller are disappeared at the lower part of the Bathonian. Callovian glendonites are known only from the restricted area at the Anabar Bay and Bolshoi Begitchev Island. They are known from the lowermost Callovian and from the Middle-Upper Callovian boundary beds. Precise age of the glendonites form the Kolyma basin, mentioned by Chumakov and Frakes (1997) as Callovian-Early Oxfordian, is unknown, because Middle-Upper Jurassic ammonites in this area are very rare and never been figured or described. Most probably age of their Koster Fm, as follow from the "macrocephalitids" mentioned from this formation, which should be ammonoids from the *Arctrocephalites — Arcticoceras* lineage seems to be Bathonian and, perhaps, partially Early Callovian. Upper Jurassic glendonite records from the Arctic are unknown except mentioning of the "stellate concretion" from the Upper Oxfordian of the North-East of the Russia (Paraketsov and Paraketsova, 1988). Glendonites of the Oxfordian age also were reported from the Khabeyskaya-2 well near Yenisei mouth (Zlobina, 2007), but their precise age is unknown.

Wide distribution of the glendonites began again at the Valanginian. Lower Valanginian glendonites are known from the Northern Siberia (Kaplan, 1978) and Sverdrup Basin (Kemper, 1987). Record of Lower Cretaceous (Valanginian or Hauterivian) glendonites was also reported recently from the Western Siberia (Potapova, 2006). Glendonites are also present at the uppermost Valanginian (Homolsomites bojarkensis Zone) of the Northern Siberia and Upper Valanginain age is also supposed for some glendonites from the

Deer Bay Fm of the Arctic Canada (Kemper and Jeletzky, 1979). Age of the "Valanginian" glendonites from Svalbard (Price and Nunn, 2010), according to author's data, should be corrected to Upper Hauterivian; such glendonites are present also in the authors collection. Their age is supported by data of Ershova (1972) mentioned *Simbirskites* from the uppermost 20-40 m of the Festningen section and Århus (1992) pointed out the record of *Simbirskites pavlovae* at 49,3 m below the top of Rurickfjellet Fm at the Janusfjellet. Possible erratics in the Hauterivian rocks bearing *Simbirskites* are also known from the NE Alaska (Markwick and Rowley, 1998).

Marine Barremian is unknown in Arctic except restricted area at the North-East of the Russia, and Aptian-Albian marine rocks are unknown from the Northern Siberia. Aptian-Albian glendonite occurrences are known from the Arctic Canada (Upper Aptian to Lower Albian of Sverdrup Basin, studied by Kemper (1987)). At Spitsbergen Aptian glendonite concretions presence at the shaly member containing *Tropaeum arcticum* (Stolley) and thus they are Middle Aptian in age. Possible Aptian glendonites ("stellate concretions") are also known from the NE Russia (Efimova et al., 1970). Age of the Lower Albian glendonites (?) from Spitsbergen, reported as "antraconites" (Pčelina, 1965), should be corrected to Aptian due to re-determination of some ammonites (Ershova, 1983).

2. Some peculiarities of geographical distributional of glendonites in the Jurassic of the Siberia: paleoclimates, environmental control and implication for correlation

In all studied cases beds containing glendonites are relatively poor in fossils, which showing high endemism and mainly represented by Arctic bivalves and ammonites. This is well corresponding with suggested cooling events. As a rule glendonites occur at thin bands and don't scattered through the relatively thick members. Such patch distribution of glendonites through the sections could reflect high-frequency climate oscillations. Comparison of the more or less well-dated sections of Northern Siberia situated not very far from each other has revealed that glendonite distribution has been influenced by facies and position of the sites (deep or shallow water): usually glendonites are more numerous at the more or less deep-water facies. During the Aalenian glendonites were restricted mainly by western part of the Khatanga Sea and did not occur in its eastern part. Such distribution could be connected with influence of currents. Alternatively such distributional patterns could be partially connected with peculiarities of methane seeps location at the bottom of the Jurassic sea. Comparison of the Bajocian and Bathonian glendonite occurrences in relatively deep and shallow facies showing smaller size, smaller amount of bands with these concretions and narrower stratigraphical range of shallow-water glendonites. Partially in could be connected with changes of facies from mudstones to sandstones, but also reflect higher water temperature in the shallow-water environments. Thus rare bands with glendonites at the shallow-water facies possibly could reflect most prominent cooling events. Nevertheless rarity of fossils at the Bajocian-Bathonian of the Northern Siberia still doesn't permits to test such suggestion.

Acknowledgements: This study has been supported by RFBR grants No.09-05-00456, 10-05-00276 and Program of the Presidium of RAS No.24.

Key words: Mesozoic paleoclimate; Glendonite; Integrate stratigraphy; Arctic

References:

Århus N. Some dinoflagellate cysts from the Lower Cretaceous of Spitsbergen. Grana, 1992, 31(4): 305-314.

Chumakov N.M., Frakes L.A. Mode of origin of dispersed clasts in Jurassic shales, southern part of the Yana-Kolyma fold belt, North East Asia. Palaeogeography, Palaeoclimatology, Palaeoecology, 1997, 128: 77-85.

Efimova A.F., Paraketsov K.V., Popov G.G. Kolyma-Omolon massive. In: Geology of the USSR. Vol. XXX. North-East of Russia. Geological Description. Pt.1. Nedra, Moscow, 1970: 434-444 (in Russian).

Ershova E.S. Hauterivian ammonites of Spitsbergen island. Mesozoic Deposits of Svalbard, Leningrad, 1972: 90-99 (in Russian).

Ershova E.S. Explanatory notes for the biostratigraphical scheme of the Jurassic and Lower Cretaceous deposits of Spitzbergen archipelago. PGO Sevmorgeologia, Leningrad, 1983: 88 (in Russian).

Kaplan M.E. Calcite pseudomorphosis from the Jurassic and Lower Cretaceous deposits of Eastern Siberia. Soviet Geology and geophysics, 1978, 12: 62-70 (in Russian with English abstracts).

Kemper E. Das Klima der Kreide-Zeit. Geol. Jb. Reiche A, 1987, 96: 5-185.

Kemper E., Schmitz H.H. Glendonite - Indikatoren des polarmarinen Ablagerungsmilieus. Geologische Rundshau, 1981, 70 (2): 759-773.

Kemper E., Jeletzky J.A. New stratigraphically and phylogenetically important Olcostephanid (Ammonitida) taxa from the uppermost Lower and Upper Valanginian of Sverdrup Basin, Northwest Territories. Geological Survey of Canada, Paper 79-19, 1979: 25.

Markwick P.J., Rowley D.B. The geological evidence for Triassic to Pleistocene glaciations: implications for eustasy. SEPM Special Publication, 1998 (58): 17-43.

Paraketsov K.V., Paraketsova G.V. Stratigraphy and fauna of the Upper Jurassic and Lower Cretaceous deposits of North-East of the USSR. Nedra, Moscow, 1989: 298 (in Russian).

Pčelina T.M. Stratigraphy and some compositional features of the Mesozoic deposits of central part of Western Spitsbergen. In: Data on the stratigraphy of Spitsbergen. NIIGA, Leningrad, 1965: 127-148 (in Russian).

Potapova N.I. Glendonite records in the Lower Cretaceous of the Priobskoe field. In: Trans. X Intern. M.A. Tomsk: Usov's Symp, Tomsk University Publishing, 99-100 (in Russian).

Price G.D., Nunn E.V. Valanginian isotope variation in glendonites and belemnites from Arctic Svalbard: Transient glacial temperatures during the Cretaceous greenhouse. Geology, 2010, 38: 251-254.

Selleck B.W., Carr P.F., Jones B.G. A review and synthesis of glendonites (pseudomorphs after ikaite) with new data: Assessing applicability as recorders of ancient coldwater conditions. Journal of Sedimentology Research, 2007, 77(11/12): 980-991.

Stein C.L., Smith A.J. Authigenic carbonate nodules in the Nankai Trough, Site 583. Initial Reports of the Deep Sea Drilling Project 87, 1985: 659-668.

Swainson I.P., Hammond R.P. Ikaite, $CaCO_3$•$6H_2O$: Cold comfort for glendonites as paleothermometers. American Mineralogist, 2001, 86: 1530-1533.

Teichert B.M.A., Luppold F.W. Glendonite formation in Early Jurassic dark shales: Evidence for methane seepage in northern Germany. Geochimica et Cosmochimica Acta, 2009, 73 (13), Suppl1: A1319.

Zakharov V.A., Shurygin B.N., Il'ina V.I., et al. Pliensbachian–Toarcian biotic turnover in North Siberia and the Arctic Region. Stratigraphy and Geological Correlation, 2006, 14 (4): 399-417.

Zlobina O.N. Upper Jurassic deposits of Yenisei-Khatanga basin, Siberia. In: Jurassic System of Russia: Problems of stratigraphy and paleogeography. Second all-Russian meeting. Scientific materials. Yaroslavl State Pedagogical University, Yaroslavl, 2007: 81-82 (in Russian).