ISSN 1028-334X, Doklady Earth Sciences, 2018, Vol. 478, Part 2, pp. 161–165. © Pleiades Publishing, Ltd., 2018.
Original Russian Text © Y.D. Zakharov, M. Horacek, Y. Shigeta, A.M. Popov, T. Maekawa, 2018, published in Doklady Akademii Nauk, 2018, Vol. 478, No. 5, pp. 556–560.

GEOLOGY

N and C Isotopic Compositions of the Lower Triassic of Southern Primorye and Reconstruction of Habitat Conditions of Marine Organisms after Mass Extinction at the End of the Permian

Y. D. Zakharov[a, *, **], M. Horacek[b], Y. Shigeta[c], A. M. Popov[a], and T. Maekawa[d]

Presented by Academician A.I. Khanchuk September 1, 2015

Received September 17, 2015

Abstract—Data on the N and C isotopic composition are presented for the Lower Triassic claystones of the Abrek section of southern Primorye (Far East). The results showed five N isotopic intervals and several negative C isotopic excursions of the Induan–lower Olenekian stages of the Abrek section.

DOI: 10.1134/S1028334X18020204

The importance of the results of N, C, and O isotopic geochemical studies for paleoecological interpretations and geological correlations has been shown by many researchers [1–7]. At the same time, the corresponding data on the Lower and Middle Triassic are incomplete in many world regions including the southern part of the Russian Far East.

Major attention in our work is paid to the N and C isotopic composition of the Lower Triassic marine sedimentary rocks of the Abrek section of southern Primorye and discussion of the problems of habitat conditions with respect to recovery of biota after mass extinct at the end of the Permian. The $\delta^{15}N$ and $\delta^{13}C_{org}$ values of 207 samples taken by Y.D. Zakharov from clayey rocks with an interval of ~50 cm were analyzed, using EA-ConFlo-IRMS, a Flash EA (Thermo, Bremen/Germany), connected via a CONFLO IV (Thermo, Bremen/Germany) and MAT-23 mass-spectrometer (Thermo, Bremen/Germany) in Wieselburg, Austria (HBLFA Francisco-Josephinum). The results of these detail isotopic studies revealed five N isotopic intervals (I–V) and 36 subdivisions, as well as several negative C isotopic excursions.

[a] *Far East Geological Institute, Far East Branch, Russian Academy of Sciences, Vladivostok, 690022 Russia*
[b] *BLT Wieselburg Research Center Francisco-Josephinum, Wieselburg, 3250 Austria*
[c] *National Museum of Nature and Science, Tsukuba, 305-0005 Japan*
[d] *Kumamoto University, Kurokami, 860-8555 Japan*
**e-mail: yurizakh@mail.ru*
***e-mail: yurizakharov@fegi.ru*

Interval I with frequent oscillation of negative (to –4‰) and positive (up to +2.2‰) $\delta^{15}N$ values is identified in the lower part of member 4 of the Induan Lazurninskaya Formation. This interval also exhibits a negative C isotopic excursion (–26‰), which is designated in our work as minimum "a."

Interval II, which is distinctive mostly for the positive $\delta^{15}N$ values (up to 8‰), is identified in members 4 (upper part), 6, and 7 of the Lazurninskaya Formation and members 8–11 of the Zhitkovskaya Formation of the early Olenekian age. It shows some negative C isotopic digressions (b–f), most of which reach –26‰. The boundary between the Induan and Olenekian stages is located apparently below the minimum "d" (in M. Horacek's opinion, it might be tentatively correlated with the rise labelled as "e" in Fig. 2).

Interval III, which is characterized by mostly negative $\delta^{15}N$ values (to –5.8‰), is determined in members 12 (excluding the lower layers), 13, and 14 (lower part) of the Zhitkovskaya Formation. This interval shows four negative C isotopic digressions (g–j): –26, –27, and –26.8‰.

Interval IV with frequent variations of negative (to –2.1‰) and positive (up to +1.8‰) $\delta^{15}N$ values is typical of the intermediate part of member 14 of the Zhitkovskaya Formation. The single negative C isotopic excursion (–30‰) is designated as minimum "k."

Interval V, which is characterized by mostly positive $\delta^{15}N$ values (up to 1.0‰), is identified in the uppermost part of member 14 of the Zhitkovskaya Formation along with a negative C isotopic digression (–9.8‰) designated as minimum "l."

The reason for origination of negative C isotopic excursions including one of the largest Permian–Triassic boundary layers is still debatable. There exists the opinion [1, 7–9] that most negative C isotopic excursions were mostly caused by activation of mantle plume volcanism in northern Siberia. The Abrek section, however, exhibits only small fluctuations of the $\delta^{13}C$ values. The position of negative C isotopic digressions probably reflects certain cycles of oscillation in the sea level in the late Induan and early Olenekian. The most intensive inputs of the organic matter of marine origin to sediments are associated with transgressions.

The literature data indicate low $\delta^{18}O$ values of organic apatite of the Lower Triassic conodonts from the paleoequatorial regions of southern China [2–4], Iran [7], Armenia [10], and the southern middle paleolatitudes of the Salt Range [5]. They correspond to the highest (28–45°C) paleotemperatures of waters in the case of normal salinity and the absence of diagenetic components. The Permian paleotemperatures, which are based on the O isotopic composition of apatite from southern China and Iran, are significantly lower (20–34°C) [4, 7] but are comparable with those calculated by the O isotopic composition of calcite of well-preserved brachiopod shells of Transcaucasia (22.0–27.9°C) [11].

The thermometry of the Lower Triassic of the Boreal area is based on the O isotopic composition of well-preserved (aragonite) ammonoid shells from Arctic Siberia [11, 12]. Both early and late Olenekian diagenetically unaltered ammonoid shells of this region also showed low $\delta^{18}O$ values, which may indicate high temperatures of waters (33–37 and 40°C, respectively) under normal salinity.

Three scenarios can be proposed to explain the low $\delta^{18}O$ values typical of the Early Triassic low, middle, and high paleolatitudes:

(1) The Early Triassic was a period of extremely high temperatures in the low and high paleolatitudes.

(2) It was a period of almost global low salinity of the World Ocean.

(3) Early Triassic marine basins with significantly lower salinity could have existed only within the Boreal area, and the regions of extremely high temperatures were limited to the low and middle paleolatitudes. The extremely high temperatures (42–45°C), which were calculated by the O isotopic composition of some conodonts of Iran [7], are outside the limit of the existence of proteins of live organisms and could have been caused by some diagenesis of biogenic apatite or some change in the O isotopic composition of waters under the influence of local desalination. The third scenario is most preferable.

The variation curve of $\delta^{15}N$ values of the Lower Triassic clayey rocks of the Abrek section is somewhat similar to the paleotemperature curve, which is based on the O isotopic data on organic apatite from the Lower Triassic Nammal section of the Salt Range [5] (Fig. 1).

With respect with this, the data of [6] are interesting, because they are evidence of the important role of the marine N cycle in long-term climate change. It is shown that cool and cold intervals of the Neoproterozoic and Phanerozoic glacial periods are characterized by high $\delta^{15}N$ values, whereas warm and hot greenhouse intervals have relatively lower values.

The general data on the N isotopic composition of the Neoproterozoic and Phanerozoic rocks and the similarity between the N and O isotopic (paleotemperature) curves of southern Primorye and the Salt Range [5] may be indirect evidence that probably intervals with high (positive) $\delta^{15}N$ values of the Lower Triassic section of Abrek Bay significantly reflect a dominant lower temperature condition in comparison with intervals with lower $\delta^{15}N$ values (Fig. 2). The high temperatures could have been a result of the release of a large volume of greenhouse gases including N_2O under the influence of volcanic processes [6, 14]. This is consistent with the data on the Late Permian negative N isotopic excursion, which was recently found in the Meishan, Taipin, and Dzoden sections of southern China, where it accompanies the Late Permian negative C isotopic anomaly [14].

Many researchers consider that climatic changes, most of all, sharp warming, were the main reason for mass extinct of organisms at the Permian–Triassic boundary [2–5, 8]. Complete understanding of the role of the thermal effect, however, requires acceptance of the evidence of a short-term drop in temperatures at the beginning of the Induan Stage. This evidence includes the results of study of Ca–Mg ratio of carbonates from the Permian–Triassic boundary layers of Transcaucasia [11], the O isotopic composition of Permian and Triassic conodonts of Kuh-e-Ali Bashi in northern Iran [7], and O isotopic data on continental carbonates of the Russian Platform, as well as some paleobotanic evidence [15]. However, it is quite true that the thermal effect was one of most serious barriers to recovery of biota in the Early Triassic.

If we accept the correct assumption that the fluctuating N isotopic composition of the Abrek section significantly corresponds to the temperature changes, we can suggest that the mollusk taxa of this section were most diverse in the Late Induan–Early Olenekian lower temperature periods. This suggestion is quite consistent with data on the distribution of the Lower Triassic mollusks of the Salt Range [5]. A similar correlation, e.g., between sharks and conodonts, however, lacks support (Fig. 2). Brachiopods used favorable conditions for their active recovery significantly later than ammonoids: at the beginning of the Late Olenekian period.

Thus, the N and C isotopic data of the Abrek section indicate evident unstable habitat conditions of

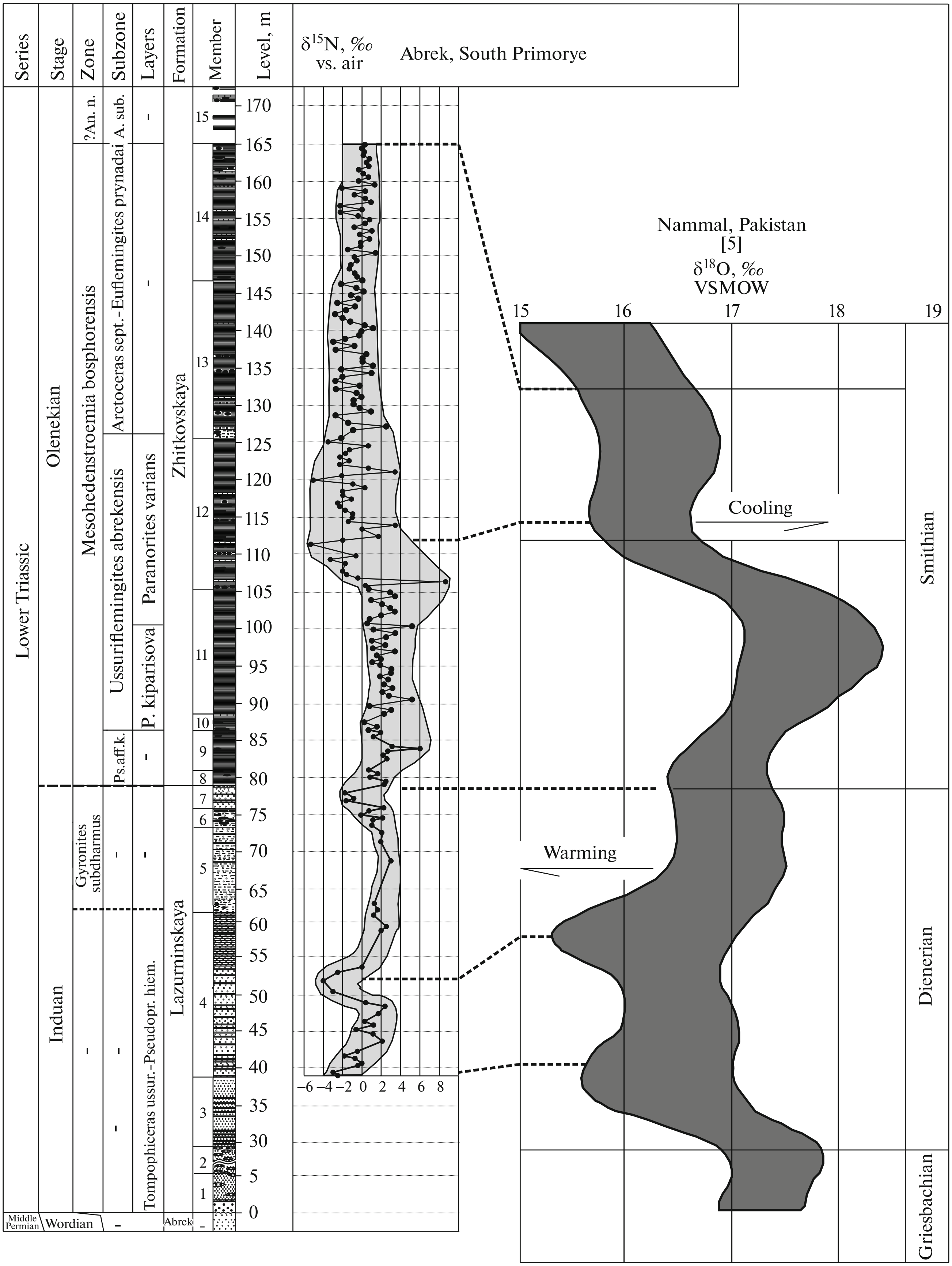

Fig. 1. Comparison of N isotopic curves of the Abrek section and the lower part of the Nammal section [5].

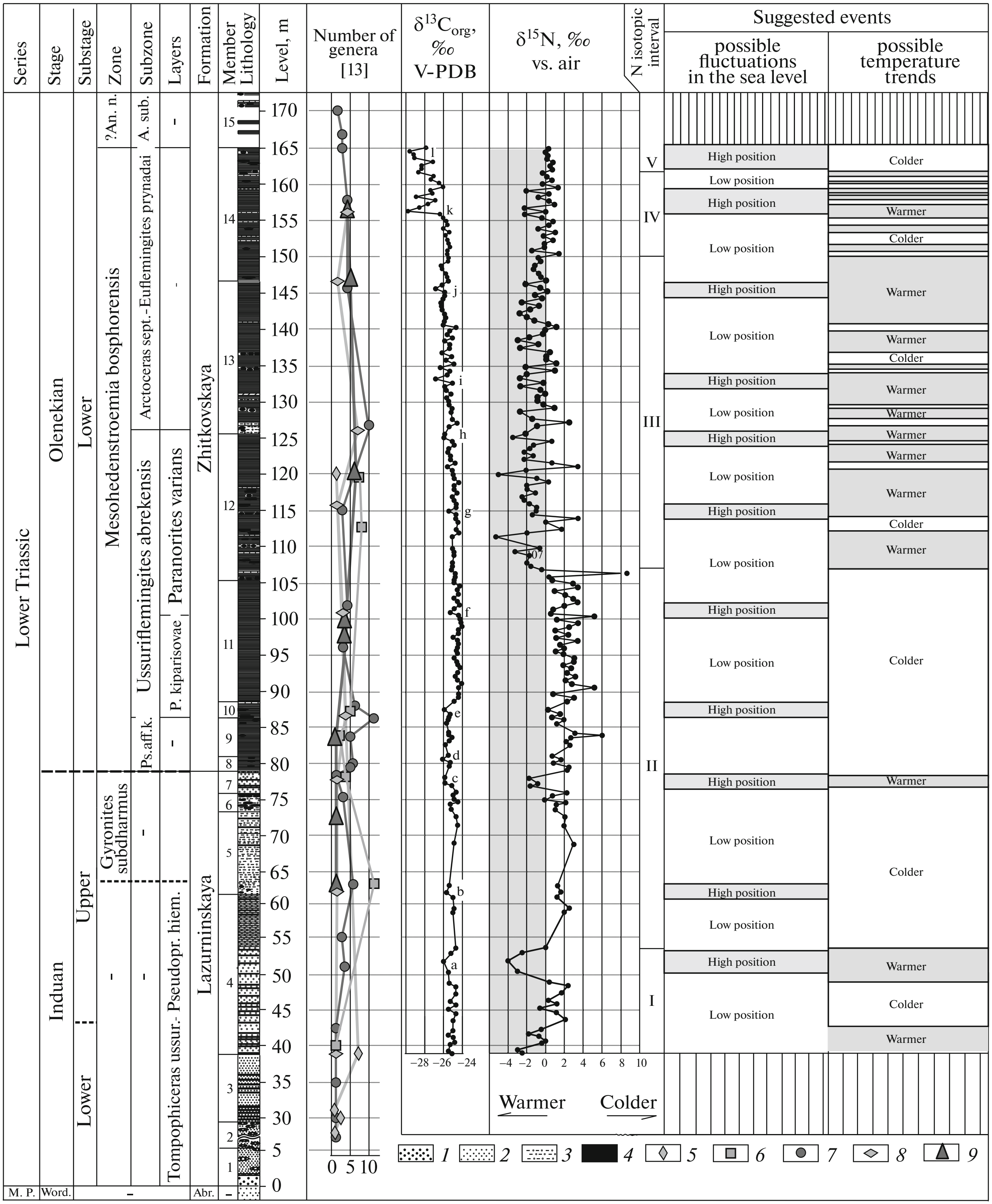

Fig. 2. Position of negative C isotopic digressions and N isotopic intervals and their subdivisions in the section of the Induan and Lower Olenekian rocks of Abrek Bay. *1*, Conglomerate; *2*, sandstone; *3*, sandy siltstone; *4*, claystone; *5*, brachiopods; *6*, bivalves; *7*, ammonoids; *8*, conodonts; *9*, sharks (teeth). U.P., Upper Permian; W., Wordian; ?An. n., ?*Anasibirites nevolini*, *Ps*. aff. *k*., *Pseudaspedites* aff. *Kvansianus*; *A*. sub., *Arctoceras subhydaspis*; *Tompophiceras ussur.-Pseudopr. hiem.*, *Tompophiceras ussuriense-Pseudoproptychites hiemalis*; *P. kiparisovae, Parahedenstroemia kiparisovae*; Ab., Abrek.

the Induan and Olenekian periods, which could have been caused by some global events including uneven manifestation of tectonic and mantle plume volcanic activity.

ACKNOWLEDGMENTS

Sample preparation by C. Panzenbook and isotope measurements by E. Riegler zre thankfully acknowledged. This work was supported by the Russian Foundation for Basic Research, project no. 18-05-00023A.

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Translated by I. Melekestseva