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Significance of Caucasian Sections for Working out Carbon-Isotope Standard for Upper Permian and Lower Triassic (Induan) and Their Correlation with the Permian of North-Eastern Russia*

Yuri D Zakharov
Far Eastern Geological Institute, *Russian Academy of Sciences* (*Far Eastern Branch*), *Vladivostok* 690022, *Russia*
Alexander S Biakov
North-East Interdisciplinary Scientific Research Institute, *Russian Academy of Sciences* (*Far Eastern Branch*), *Magadan* 685000, *Russia*
Aymon Baud
Musee de Geologie, *BFSH2-UNI*, 1015 *Lausanne*, *Switzerland*
Heinz Kozur
Rézsü u. 83, *H*-1029 *Budapest*, *Hungary*

ABSTRACT: Data obtained on conodont distribution in the Permian-Triassic Sovetashen Section of Transcaucasia provide further limitations on the age of the carbon-isotopic anomalies discovered by Baud et al. (1989). The significance of Caucasian sections for working out the carbon-isotope standard for the Upper Permian and Lower Triassic (Induan) is shown. Original data on carbon-isotope composition of bivalve and brachiopod shells from Permian sediments of North-Eastern Russia (Omolon and Okhotsk areas) have been obtained, which may be used for their correlation.

KEY WORDS: Armenia, North-Eastern Russia, Permian, Triassic, conodonts, ammonoids, bivalves, brachiopods, isotopic composition, paleotemperatures, correlation.

INTRODUCTION

Data on isotopic composition of Permian and Triassic organogenic carbonates of Transcaucasia, North Caucasus and south Far East (Primorye and Japan) have been published during the last fifteen years (Zakharov et al., 2001, 2000a, b, 1999a, b, 1998, 1997a, b, 1996a, b; Baud et al., 1989). But information on Permian-Triassic isotopic paleotemperatures obtained in the Caucasus area, as in other regions of the world, is very restricted (Zakharov et al., 2001, 2000a, b, 1999c).

Eight anomalously high $\delta^{13}C$ values ($2.8\times10^{-3}-3.8\times10^{-3}$) were determined by A. Baud, W. T. Holser and M. Magaritz in samples of organogenic carbonates collected in the Sovetashen Section (Transcaucasia) in 1984 and published in 1989 (Baud et al., 1989). These samples have been dated according to Kotlyar et al. (1983), whose publication contains information concerning foraminifera, corals, brachiopods and ammonoids. Very important conodont material was obtained later by Grigoryan (1990a, b), but the most significant paleontological part of his thesis has not been published. Recently we were able to copy some parts of his thesis, and H. Kozur revised Grigoryan's main paleontological determinations.

The present paper contains new data on the distribution of Late Permian and Early Triassic cono-

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donts in the Sovetashen Section and original information on the isotopic composition of Middle and Late Permian invertebrate shells from north Russian Far East.

MATERIAL AND METHODS

Oxygen and carbon isotopes were determined by us from Permian bivalve and brachiopod shells collectée! by A. S. Biakov in north Russian Far East. Isotope measurements were made at the Analytical Center of the Far Eastern Geological Institute, using a Finnigan MAT-252 mass spectrometer. The labora-tory gas standard used in the measurements was cali-brated relative to calcite NBS (National Bureau of Standards) 19 and equals (1. 8 + 0. 10) X 10^{-3} for oxygen relative to PDB (belemnite of the Pee Dee Formation) and (— 0. 9 + 0. 10) X 10^{-3} for carbon. Re-producibility of replicate standards was always better than 0. $10X10^{-3}$.

For détermination of paleotemperatures some bivalve shells characterized by best preserved microstructure were used.

DESCRIPTION OF THE MIDDLE, UPPER PERMIAN AND LOWER TRIASSIC OF THE SOVETASHEN SECTION, TRANSCAUCASIA

In descending order, the séquence of Permian and Early Triassic sédiments in the Sovetashen Section (right side of the Gortun River, Village of Sovetashen area, Armenia) is as follows (Fig. 1).

Lower Olenekian

Interval "c" without ammonoids

17. Grey and pink, thin and médium bedded fucoid limestone with thin interbeds of conglomerate in the lower and upper parts (30. 3 m) (Fig. 1).
    ConodontS; *Eurygnathodus costatus* (Staesche) , *E. para-costatus* Wang ck Cao, *Neospathodus dieneri* Sweet, *"N. cristagali* (Huckriede)" *(~N. dieneri* or JV. *cristagali)* , JV. *pakistanensis* Sweet, *Neospathodus zvaageni* Sweet (Grigoryan, 1990b; revised by H. Kozur). *Ozvenites* Beds
16. Grey and brownish-grey fucoid limestone with calcareous clay and algae limestone layers (26. 0 m). ConodontS; *Eurygnathodus paracostatus* (Wang &- Cao), *Neospathodus dieneri* Sweet, " *N. cristagali* (Huckriede)" *(~N. dieneri* or JV. *cristagali)* (Grigoryan, 1990b; revised by H. Kozur). The thickness of the Lower Olenekian is 56.3 m.

Induan

Interval "b" without ammonoids

15. Grey and greyish-pink limestone with rare calcareous clay layers in the lower part and alternation of grey fucoid limestone, algae limestone and calcareous clay in the middle and upper parts (43. 1 m).
    ConodontS; *Neospathodus dieneri* Sweet, "JV. *cristagali* (Huckriede)" *(~N. dieneri* or JV. *cristagali),* JV. *pakistanensis* Sweet (Grigoryan, 1990b; revised by H. Kozur).
14. Grey and pink, thin bedded limestone, with lenses of algal limestone (6. 2 m).
    ConodontS; ? *Clarkina planata* (Clark)? (= *"Gondolella carinata* Sweet") , " *Hindeodus parvus* Kozur ck Pjatako-va" (Grigoryan, 1990b; revised by H. Kozur). *Kymatites* Beds
13. Grey, brownish-red, lilac and yellow, thin bedded limestone (11. 3 m).
    ConodontS; *Hindeodus postparvus* Kozur *(= " Hindeodus parvus* Kozur &- Pjatakova") , *Clarkina kr y st y ni* Orchard (= *"Gondolella carinata* Sweet"), *Clarkina carinata* (Sweet), *Szveetospathoduskummeli* (Sweet), *"Gondolella nevadensis* Clark", *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b; revised by H. Kozur); bivalves: *Claraia* sp. ; ammonoids: *Lytophiceras* sp. (Kotlyar et al. , 1983). *Lytophiceras médium* Beds
12. Brownish-red, lilac and yellowish-grey, thin bedded limestone, with interlayers of calcareous mudstone (1. 8 m). ConodontS; *Isarcicella isarcica* (Huckriede), *Clarkina carinata* (Sweet), *Hindeodus parvus* Kozur ck Pjatakova, *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b; con-firmed by H. Kozur), bivalves: *Claraia* sp. , ammonoids: *Lytophiceras* sp. (Kotlyar et al. , 1983). Interval "a" without ammonoids
11. Red algae limestone, substituting by maris (3. 4 m).
    ConodontS; *Hindeodus parvus* Kozur &- Pjatakova, *Hindeodus turgidus* Kozur, Mostler &- Rahimi-Yazd, *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b; partly con-firmed by H. Kozur).
    The thickness of the Induan is 65. 6 m. The total thickness of Lower Triassic sédiments in the Sovetashen Section is 121.9 m.

Dorashamian

Pleuronodoceras occidentale-Xenodiscus Jubilaearis Zone

10. Redish-brown mudstone (0. 15 m).
    ConodontS; *Hindeodus prae parvus* Kozur (= *"Hindeodus parvus* (Kozur ck Pjatakova)"), *"Hindeodus turgidus* Kozur, Mostler &- Rahimi-Yazd", *Hindeodus typicalis* (Sweet) *,"Gondolella carinata* Sweet", *Clarkina changxs-ingensis* Wang &- Wang (Grigoryan, 1990b; revised by H. Kozur); brachiopod: *Haydenella* sp. (G. V. Kotlyar's détermination) (Zakharov, 1985). *Paratirolites kittli* Zone
9. Red, pink and grey, thin bedded limestone (3. 4 m).
    ConodontS; *Clarkina deflecta* Wang &- Wang (— "*Gondolella" subcarinata* (Sweet)), *Clarkina nodosa* Kozur,

Clarkina iranica Kozur (= "*Gondolella changxingensis* Wang & Wang"), *Hindeodus typicalis* (Sweet), *Hindeodus julfensis* (Sweet) (Grigoryan, 1990b; revised by H. Kozur); foraminifera: *Neoendothyra* sp.; brachiopods: *Araxathyris araxensis* minor Grunt; ammonoids: *Paratirolites kittli* Stoyanov, *P. vediensis* Shevyrev, *Abichites mojsisovicsi* (Stoyanov), *Abichites stoyanovi* (Kiparisova) (Kotlyar et al., 1983).

Shevyrevites shevyrevi Zone

8. Grey limestone, interlaying with mudstone (0.75 m).
   Conodonts: "*Gondolella*" *subcarinata* (Sweet), "*Gondolella changxingensis* Wang & Wang", "*Gondolella planata* Clark", *Clarkina deflecta* (Wang & Wang), *Hindeodus typicalis* (Sweet), *Hindeodus julfensis* (Sweet) (Grigoryan, 1990b; partly confirmed by H. Kozur); ammonoids: *Shevyrevites shevyrevi* Teichert & Kummel (Kotlyar et al., 1983).

Iranites transcaucasius and *Dhulfites spinosus* Zones

7. Grey and pink limestone with thin layer of mudstone in its middle part (0.65 m).
   Conodonts: "*Gondolella*" *subcarinata* (Sweet), "*Gondolella changxingensis* Wang & Wang" (Grigoryan, 1990b); ammonoids: *Iranites transcaucasius* (Shevyrev), *Dzhulfites nodosus* Shevyrev (Kotlyar et al., 1983).

Phisonites triangulus Zone

6. Grey and pink limestone (0.1 m).
   Conodonts: "*Gondolella*" *subcarinata* (Sweet), *Hindeodus typicalis* (Sweet), *Hindeodus julfensis* (Sweet) (Grigoryan, 1990b); ammonoids: *Phisonites* sp. (Kotlyar et al., 1983).

The thickness of the Dorashamian is 5.05 m.

Dzhulfian

Vedioceras ventrosulcatum Zone

5. Light-grey, spotted, intermediate bedded limestone (2.4 m).
   Conodonts: *Clarkina orientalis* (Barskov & Koroleva), "*Gondolella planata* Clark", *Hindeodus julfensis* (Sweet), *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b; partly confirmed by H. Kozur); foraminifera: *Neoendothyra* sp.; brachiopods: *Haydenella minuta* Sarytcheva, *Araxathyris araxensis minor* Grunt; nautiloids: *Syringonautilus*? *vagus* Shimansky; ammonoids: *Pseudogastrioceras abichianum* (Möller), *Pseudotoceras* sp., *Avushoceras* sp., *Vedioceras umbonovarum* Ruzhencev (Kotlyar et al., 1983).

Araxoceras latissimum Zone

4. Light-grey, in some places pinkish and spotted, thin and intermediate bedded limestone (3.8 m).
   Conodonts: *Clarkina leveni* (Kozur, Mostler & Pjatakova), *C. niuzhyangenis* (Li) (="*Gondolella bitteri* Kozur") (in the lower part), *Clarkina orientalis* (Barskov & Koroleva), "*Gondolella planata* Clark", *Hindeodus julfensis* (Sweet), *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b; revised by H. Kozur); foraminifera: *Neoendothyra* sp., *Nodosaria dzhulfensis* Reitlinger, *N. piricamerata* Efimova, *Geinitzina sosninae* G. Vuks; corals: *Pentaphyllum* sp. (Kotlyar et al., 1983).

Pseudodunbarula arpaensis-Araxilevis intermedius Zone

3. Greenish-grey and light-grey, spotted, sandy limestone (1.2 m).
   Conodonts: *Clarkina leveni* (Kozur, Mostler & Pjatakova), *Clarkina niuzhyangensis* (Li) (="*Gondolella bitteri* Kozur"), *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b; revised by H. Kozur); corals: *Pentamplexus leptoconicus* (Abich); brachiopods: *Tschernyschewia typica* Stoyanow, *Spinomarginifera helica* (Abich), *Araxathyris araxensis araxensis* Grunt (Kotlyar et al., 1983).
2. Dark-grey and black limestone with rare chert boulders at the base (8.35 m).
   Conodonts: *Clarkina leveni* (Kozur, Mostler & Pjatakova), *Clarkina niuzhyangensis* (Li) (="*Gondolella bitteri* Kozur"), *Hindeodus typicalis* (Sweet), *Hindeodus julfensis* (Sweet) (Grigoryan, 1990b; revised by H. Kozur) in the upper part of the member.
   Hemigordius irregulariformis-Orthotetina azarjani Zone (upper part, lowermost Dzhulfian)

1b. Dark-grey limestone with interlayers of mudstone (4.6 m).
   Conodonts: *Clarkina niuzhyangensis* (Li) (="*Gondolella bitteri* Kozur"), *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b; revised by H. Kozur); foraminifera: *Codonofusiella uniqua* Chedija, *Boultonia* sp., *Reichelina* sp.; brachiopods: *Orthotetina dzhulfensis* Sokolskaya (Kotlyar et al., 1983).
   The thickness of the Dzhulfian is 20.35 m. The total thickness of Upper Permian sediments in the Sovetashen Section is 25.4 m.

Midian

Hemigordius irregulariformis-Orthotetina azarjani Zone (lower part)

1a. Dark-grey limestone with large chert boulders (0.7 m).
   Conodonts: ? *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b), foraminifera.

The total thickness of the exposed part of the Permian and Lower Triassic of the Sovetashen Section is 148 m.

PERMIAN-TRIASSIC CARBON-ISOTOPE ANOMALIES AND PALEOTEMPERATURES FROM ORGANOGENIC CARBONATES OF TRANSCAUCASIA AND NORTH CAUCASUS

The nine Middle-Late Permian and Early Triassic $\delta^{13}C$ events (positive anomalies) discovered in Caucasus were named by us as "A"-"I" (Fig. 2). Three anomalies ("A", "B" and "C") were recognized within the *Hemigordius irregulariformis-Orthotetina azarjani* and *Pseudodunbarula arpaensis-Araxilevis intermedius* Zones. The men-

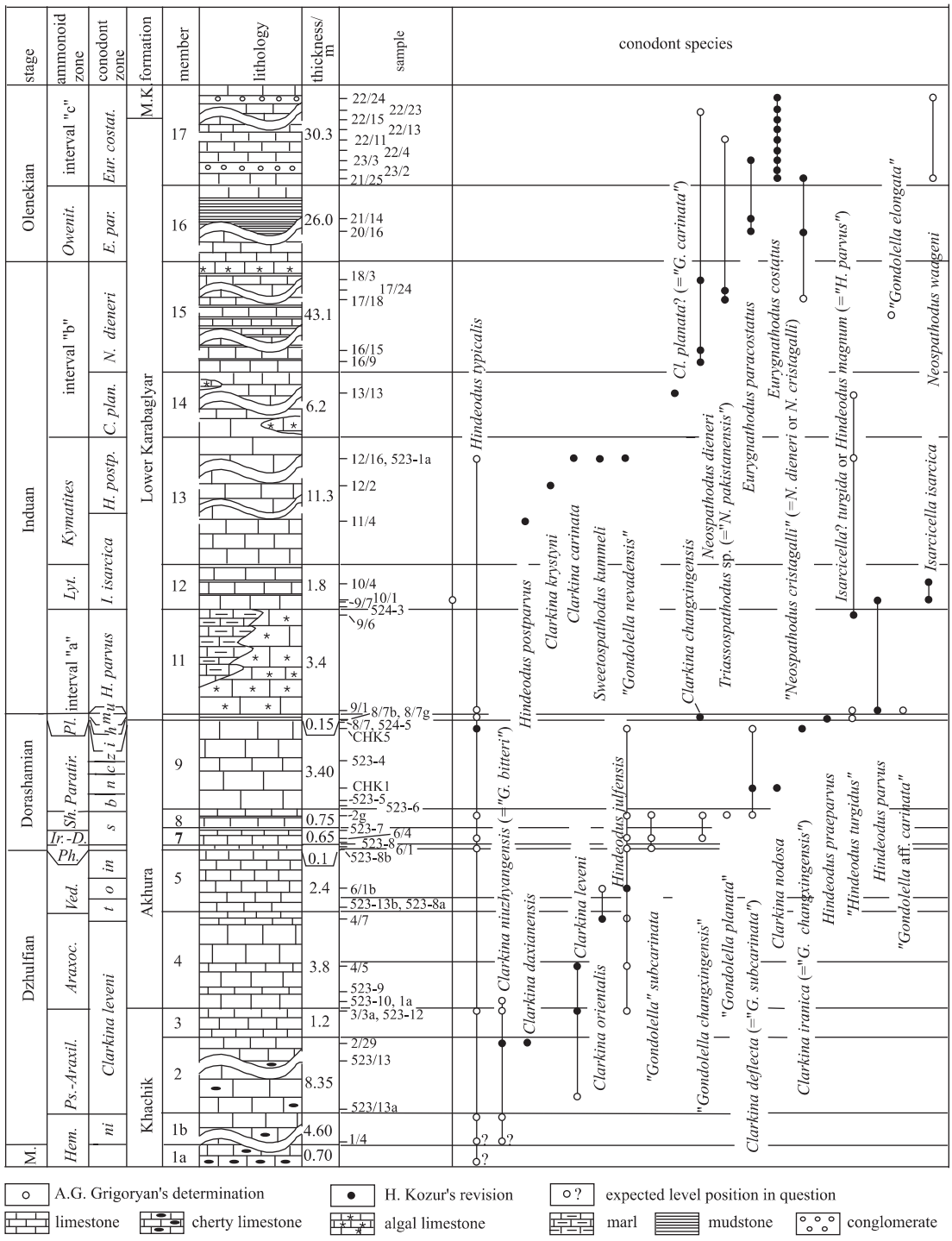

Figure 1. Conodont distribution in the Permian and Lower Triassic of the Sovetashen Section in Transcaucasia. M.. Midian; *Hem.. Hemigordius irregularifformis-Orthotetina azarjani*; *Ps.-Araxil.. Pseudodunbarula arpaensis-Araxilevis intermedius*; *Araxoc.. Araxoceras latissimum*; *Ved.. Vedioceras ventrosulcatum*; *Ph.. Phisonites triangularis*; *Ir.-D.. Iranites transcaucasius-Dzhulfites spinosus*; *Sh.. Shevyrevites shevyrevi*; *Paratir.. Paratirolites kittli*; *Pl.. Pleuronodoceras occidentale-Xenodiscus jubilaearis*; interval "a". interval "a" without ammonoids; *Lyt.. Lytophiceras medium*; interval "b". interval "b" without ammonoids; *Owenit.. Owenites*; interval "c". interval "c" without ammonoids; conodont zones of the Iranian-Transcaucasian area; *ni. Clarkina niuzhyangensis*; *t. Clarkina transcaucasica*; *o. Clarkina orientalis*; *in. Clarkina inflecta*; *s. Clarkina subcarinata*; *b. Clarkina bachmanni*; *n. Clarkina nodosa*; *c. Clarkina changxingensis-Clarkina deflecta*; *z. Clarkina zhangi*; *i. Clarkina iranica*; *h. Clarkina hauschkei*; *m. Clarkina meishanensis-Hindeodus praeparvus*; *u. Merrillina ultima-Stepanovites ? mostleri*; *H. postp.. Hindeodus postparvus*; *C. plan.. Clarkina planata*; *E. par.. Eurygnathodus paracostatus*; *Eur. costat.. Eurygnathodus costatus*.

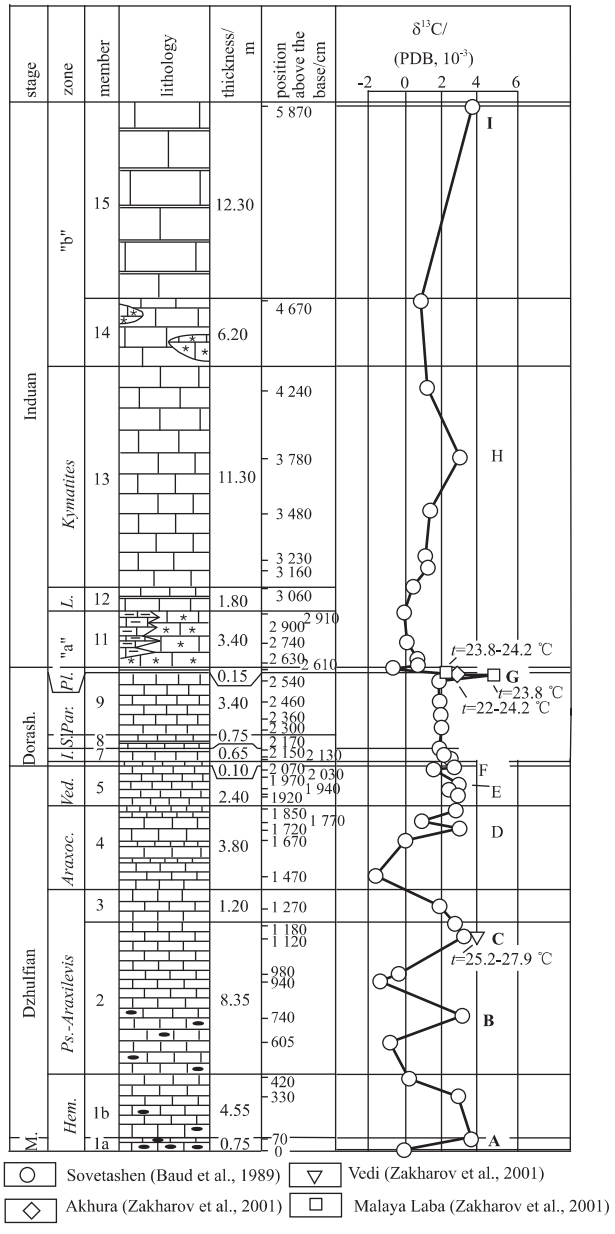

Figure 2. Carbon-isotope data for the Upper Permian and Lower Triassic of the Caucasus area (Transcaucasia and North Caucasus) and Late Permian isotopic paleotemperatures. *I.*. *Iranites transcaucasius*; *S.*. *Shevyrevites shevyrevi*; *Par.*. *Paratirolites kittli*; "a". interval "a" without ammonoids; L.. *Lytophiceras medium*; "b". interval "b" without ammonoids. Other abbreviations as in Fig. 1.

tioned interval, with the exception of, apparently, its lowermost part characterized by big chert inclusions, corresponds to the Early Dzhulfian *Clarkina niuzhuangensis* and *Clarkina leveni* (lower part) Zones. Anomaly "C" is known also from the Vedi Section in Transcaucasia, where well preserved Early Dzhulfian brachiopod shells were also used for oxy-

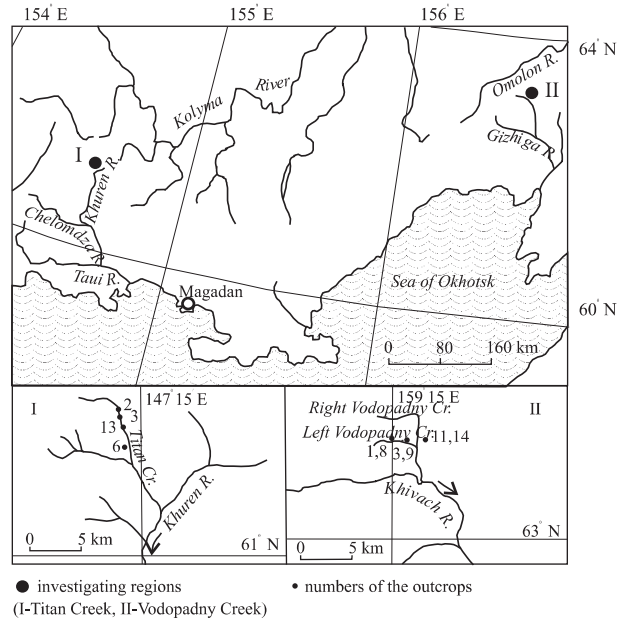

Figure 3. Map showing the position of the Khuren (Ⅰ) and Khivach (Ⅱ) River basins, Omolon and Okhotsk areas, north Russian Far East.

gen-isotope paleotemperature calculations (25.2—27.9 ℃) (Zakharov et al., 2001, 2000a).

Anomaly "D" was discovered in the upper part of the Dzhulfian *Araxoceras latissimum* Zone (upper part of the *Clarkina leveni* Zone).

Anomalies "E" and "F" were determined in the upper part of the Late Dzhulfian *Vedioceras ventrosulcatum* Zone within the (*Clarkina inflecta* Zone of earliest Changhsingian in age).

Late Dorashamian positive anomaly "G" of the *Paratirolites kittli* Zone was found in Caucasus outside the Sovetashen Section. *Paratirolites kittli* time is characterized by somewhat lower paleotemperatures than those calculated from Early Dzhulfian organogenic carbonates: 22.0—24.2 ℃ (for Akhura region in Transcaucasia) and 23.8 ℃ (for Malaya Laba River, North Caucasus) (Zakharov et al., 2001, 2000a).

In the uppermost Permian represented by the uppermost part of the *Paratirolites kittli* Zone (*Clarkina iranica* Zone) and *Pleuronodoceras occidentale-Xenodiscus jubilaearis* Zone (*Clarkina hauschkei* to *C. meishanensis-Hindeodus praeparvus* Zone) only negative $\delta^{13}C$ excursion was recognized (-0.8×10^{-3}). The calculated paleotemperatures for the *Pleuronodoceras occidentale-Xenodiscus jubilaearis* Zone level in North Caucasus (23.8—24.2 ℃) are comparable with those for the *Paratirolites*

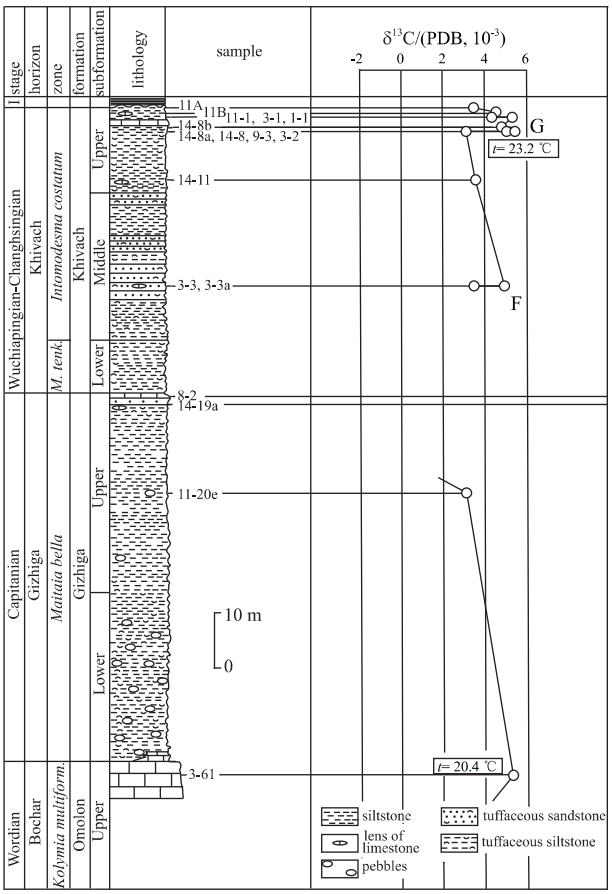

Figure 4. Late Wordian and Wuchiapingian-Changhsingian carbon-isotopic anomalies of the Omolon area (Khivach River basin) and isotopic paleotemperatures. I. Induan; *Kolymia multiform.*. *Kolymia multiformis*; *M. tenk.*. *Maitaia tenkensis*.

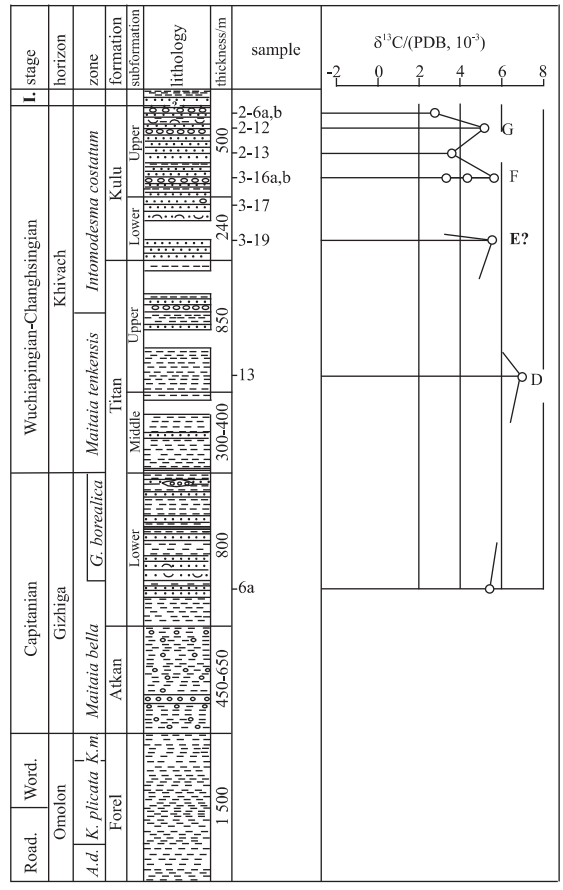

Figure 5. Wuchiapingian-Changhsingian carbon-isotopic anomalies of the Okhotsk area (Khuren River basin), north Russian Far East. Road.. Roadian; Word.. Wordian; I.. Induan; *A. d.*. *Aphanaia dilatata*; *K. plicata*. *Kolymia plicata*; *K. m.*. *Kolymia multiformis*; *G. borealica*. *Glyptoleda borealica*.

kittli Zone. According to data on Ca/Mg ratio (Zakharov et al., 2001), paleotemperatures in Transcaucasia became lower only at the beginning of the Induan (interval "a" without ammonoids and *Lytophiceras medium* Zone). Somewhat warmer conditions seem to have appeared only after *Lytophiceras medium* time or at its very end.

The positive anomalies "H" (3.1×10^{-3}) and "I" (3.8×10^{-3}) of the Induan were recognized only in the middle (*Hindeodus postparvus* Zone) and upper (*Neospathodus dieneri* Zone) parts of the Sovetashen Section.

PERMIAN CARBON-ISOTOPE ANOMALIES AND PALEOTEMPERATURES FROM ORGANOGENIC CARBONATES OF NORTH-EASTERN RUSSIA

We obtained new data on the carbon- and oxygen-isotope composition of some bivalve and brachiopod shells from the Permian of North-Eastern Russia (Omolon and Okhotsk areas) (Fig. 3) and used the Caucasus carbon-isotope standard for their correlation.

Omolon Area

In the Omolon area (Levyi Vodopadnyi and Pravyi Vodopadnyi Creeks, Khivach River basin), the Middle-Upper Permian is represented by the Omolon, Gizhiga and Khivach formations. The uppermost part of the Wordian Omolon Formation, *Kolymia multiformis* Zone, consists of limestone (about 8 m thick), containing bivalve *Kolymia* and *Maitaia* (Fig. 4).

The Capitanian Gizhiga Formation, *Maitaia bella* Zone, is a sequence of interbedded siltstone with rare pebbles, tufaceous siltstone and limestone (len-

ses), about 66 m, containing brachiopod *Cancrinelloides cf. curvatus* (Tolmatchew) and bivalve *Maitaia bella* Biakov.

The Wuchiapingian-Changhsingian Khivach Formation, *Maitaia tenkensis* and *Intomodesma costatum* Zones, is represented by an intercalation of siltstone, tufaceous siltstone with rare pebbles, tufaceous sandstone and limestone, about 69 m thick, containing brachiopods *Stepanoviella paracurvata* Zavodowsky, *Neospirifer* sp. indet., and bivalves *Intomodesma costatum* Popow, *I. turgidum* Popow, *Maitaia tenkensis* Biakov, "*Fasciculiconcha*" *tompo* (Muromzeva), *Streblopteria radiata* (Lutkevich & Lobanova).

In the Khivach Section (Levyi Vodopadnyi and Pravyi Vodopadnyi Creeks), the two positive carbon-isotopic anomalies were discovered within the Upper Permian Khivach Formation (*Intomodesma costatum*

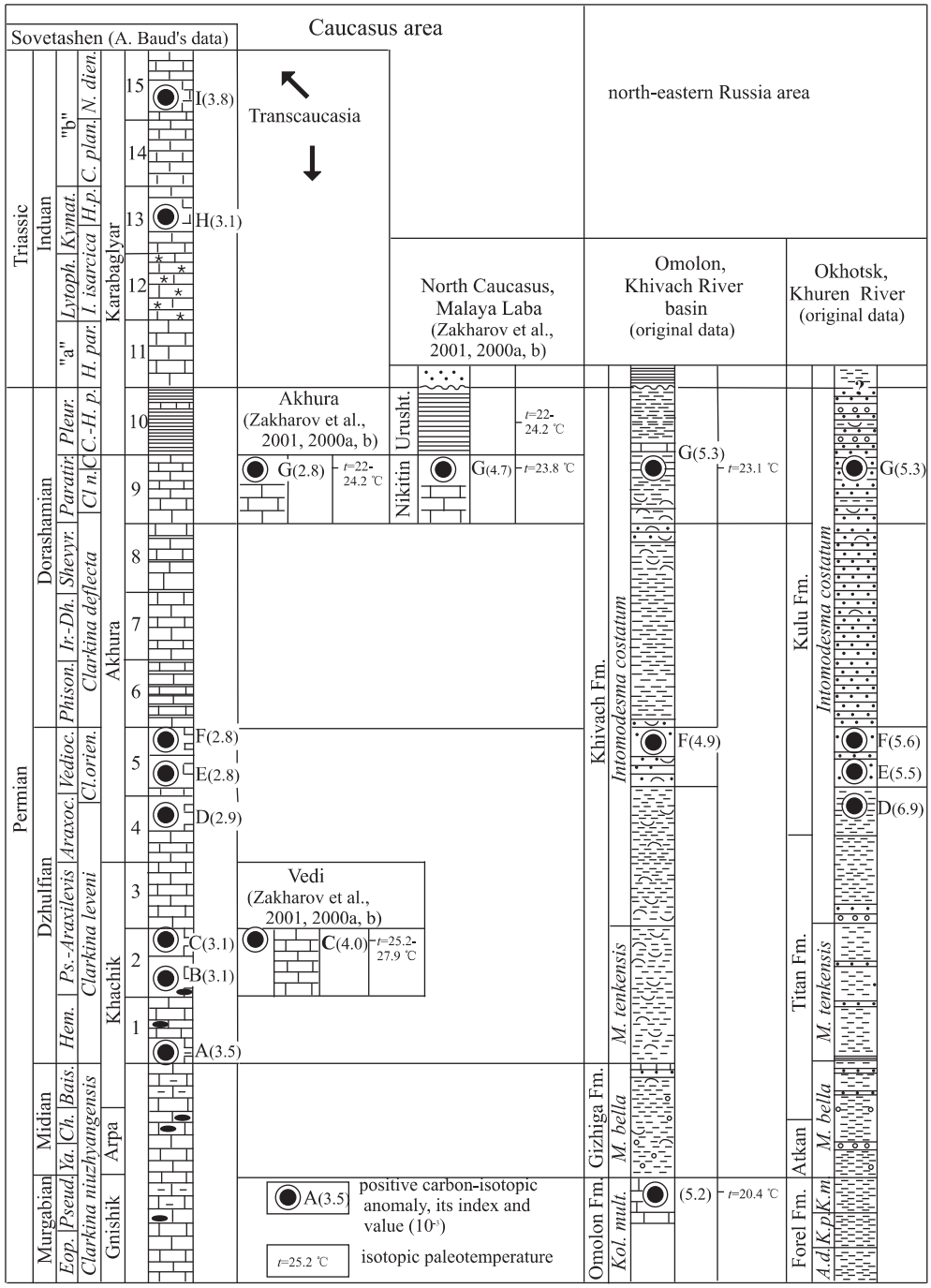

Figure 6. Correlation of the Middle and Upper Permian of Transcaucasia, North Caucasus and north Russian Far East from geochemical and paleontological data.

Zone), with values fluctuating between 4.9×10^{-3} and 5.3×10^{-3}, which are correlated by us with the Late Dzhulfian "F" and Late Dorashamian "G" (Table 1). The latter is present in the Omolon area despite some erosion recognized at the P/T boundary. Besides, the latest Murgabian (latest Wordian) carbon-isotopic anomaly (5.2×10^{-3}) was discovered in the section.

Okhotsk Area

Another Far Eastern section investigated is located in the Okhotsk area (Titan Creek, Khuren River) (Fig. 5), where the Middle-Upper Permian is represented by the Forel, Atkan, Titan and Kulu formations.

The Roadian-Wordian Forel Formation, *Aphanaia dilatata*, *Kolymia plicata* and *Kolymia multiformis* Zones, is represented by siltstone, about 1 500 m thick, and characterized by bivalve *Maitaia* ? sp. indet..

The Capitanian Atkan and Lower Titan formations, *Maitaia bella* Zone, are a sequence of interbedded siltstone with rare pebbles, sandstone, tufaceous sandstone and conglomerate (lenses), about 1 250—1 450 m thick, containing brachiopods and bivalve *Maitaia bella* Biakov.

The Wuchiapingian-Changhsingian Upper Titan and Kulu formations, *Maitaia tenkensis* and *Intomodesma costatum* Zones, are represented by an intercalation of siltstone, sandstone, tufaceous sandstone and conglomerate, about 1 990 m thick, containing brachiopod *Neospirifer* sp. indet., and bivalves *Maitaia tenkensis* Biakov, *M. hurenensis* Biakov, *Intomodesma evenicum* Kusnezov, *Myonia bicarinata* Astafieva-Urbajtis.

Four positive carbon isotope anomalies were found there within the Upper Permian of the Khuren Section (Titan Creek), with values fluctuating between 5.1×10^{-3} and 6.9×10^{-3} (Table 2). They are correlated by us with the Late Dzhulfian (latest Wuchiapingian-earliest Changhsingian) events "D", "E" and "F" and Late Dorashamian (Late Changhsingian) "G". New data confirm A. Biakov's idea, according to which at least the Wuchiapingian and most of the Changhsingian sediments are exposed in the Omolon and Okhotsk areas.

CONCLUSIONS

(1) Together with the detailed carbon isotope data of the well dated sections at Abadeh, Shahreza (Central Iran, Korte et al., 2004a, b), Jolfa and Zal (NW Iran, Korte et al., 2004c; Korte and Kozur, 2004), the Sovetashen Section (with some data from other sections of Caucasus) yields a carbon-isotope standard for the uppermost Midian, Dzhulfian, Dorashamian and lower Induan.

(2) The positive $\delta^{13}C$ excursions discovered in the bivalve shells from the Khivach, Titan and Kulu formations in North-Eastern Russia (Omolon and Okhotsk areas) are correlated by us with Events "D", "E", "F" and "G" recognized in carbonates of the *Araxoceras latissimum* (upper part) and *Vedioceras ventrosulcatum* (middle and upper parts) Zones of the Dzhulfian and *Paratirolites kittli* Zone (upper part) of the Dorashamian in the Caucasus area (Fig. 6).

(3) Oxygen-isotope investigation of a well preserved bivalve shell in the North-Eastern Russia area shows a paleotemperature value (23.1 ℃) comparable with those for the Late Dorashamian of the Akhura region in Transcaucasia (22.0—24.2℃) and Malaya Laba River basin in North Caucasus (23.8—24.2 ℃). The climate of most of the Late Permian seems to be somewhat warmer in comparison with the climate of the Middle Permian, when the paleotemperature, calculated from the isotopic composition of a well preserved bivalve shell from the Upper Wordian of the Omolon area, is only 20.1 ℃.

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Table 1 Carbon and oxygen isotope analyses for calcitic brachiopod and bivalve shells from the Permian of the Gizhiga River basin, Omolon area

sample	locality	species	stage	zone	formation	location	colour	degree of the shell structure safety	$\delta^{13}C$ (PDB)/ 10^{-3}	$\delta^{18}O$ (PDB)/ 10^{-3}	t/℃
11A(1)	Levyj Vodopadnyj Creek	*Intomodesma* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (5 mm thick)	light grey	well preserved	3.4	−8.7	—
11B(2)	Levyj Vodopadnyj Creek	*Intomodesma* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (4.9 mm thick)	light grey	well preserved	4.5	−3.9	—
11-1	Levyj Vodopadnyj Creek	*Intomodesma* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (6.0 mm thick)	light grey	well preserved	4.3	−6.0	—
3-1	Pravyj Vodopadnyj Creek	*Intomodesma* sp. indet	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (1.5 mm thick)	dark grey	intermediately preserved	5.3	−5.4	—
1-1	Pravyj Vodopadnyj Creek	*Intomodesma ex gr. costatum* Popow	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (2.5 mm thick)	grey	intermediately preserved	3.3	−5.5	—
14-8b	Levyj Vodopadnyj Creek	*Intomodesma* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (6 mm thick)	light grey	well preserved	4.8	−4.0	—
14-8a(1)	Levyj Vodopadnyj Creek	Intomodesma sp. indet.	Wuchiapingian-Changhsingin	*Intomodesma costatum*	Khivach	prismatic layer (9 mm thick)	light grey	excellently preserved	5.0	−2.6	23.1
14-8	Levyj Vodopadnyj Creek	*Neospirifer* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	area of ventral valve	light grey	well preserved	5.1	−4.2	—
9-3	Pravyj Vodopadnyj Creek	*Intomodesma turgidum* Popow	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (3 mm thick)	dark grey	well preserved	5.3	−4.0	—
3-2	Pravyj Vodopadnyj Creek	*Streblopteria radiata* (Lutkevich & Lobanova)	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	hing margin	light grey	well preserved	2.9	−4.5	—
14-11	Levyj Vodopadnyj Creek	*Intomodesma* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (9 mm thick)	light grey	well preserved	3.6	−4.4	—
3-3	Pravyj Vodopadnyj Creek	*Maitaia* sp.	Wuchiapingian-Changhsingian	*Intomodema costatum*	Khivach	prismatic layer (2 mm thick)	dark grey	intermediately preserved	4.9	−3.9	—
3-3a	Pravyj Vodopadnyj Creek	"*Fasciculiconcha*" *tompo* (Muromzeva)	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	middle part of the shell (1 mm thick)	dark grey	intermediately preserved	3.4	−3.7	—
8-2	Levyj Vodopadnyj Creek	*Maitaia bella* Biakov	Capitanian	*Maitaia bella*	Gizhiga	prismatic layer (2 mm thick)	grey	intermediately preserved	−10.1	−6.1	—
11-20E	Levyj Vodopadnyj Creek	Spiriferid brachiopod	Capitanian	*Maitaia bella*	Gizhiga	middle(?) part of the shell	light grey	well preserved	3.0	−3.4	—

continued

sample	locality	species	stage	zone	formation	location	colour	degree of the shell structure safety	$\delta^{13}C$ (PDB)/ 10^{-3}	$\delta^{18}O$ (PDB)/ 10^{-3}	t/℃
14-19a (1)	Levyj Vodopadnyj Creek	*Cancrinelloides* cf. curvatus (Tolmatchev)	Capitanian	*Maitaia bella*	Gizhiga	middle part of the shell	grey	intermediately preserved	−6.6	−8.7	—
3-61	Levyj Vodopadnyj Creek	*Maitaia* sp.	Wordian	*Kolymia multiformis*	Omolon	prismatic layer (2.5 mm thick)	grey	excellently preserved	5.2	−2.0	20.4

Table 2 Carbon and oxygen isotope analyses for calcitic brachiopod and bivalve shells from the Permian of the Khuren River basin, Okhotsk area

sample	locality	species	stage	zone	formation	location	colour	degree of the shell structure safety	$\delta^{13}C$ (PDB)/ 10^{-3}	$\delta^{18}O$ (PDB)/ 10^{-3}
2-6a(1)	Titan Creek	*Intomodesma* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (7 mm thick)	light grey	well preserved	2.7	−17.4
2-6b(1)	Titan Creek	*Myonia bicarinata* Astafieva-Urbajtis	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	upper marginal part of the large (L= 60 mm) shell	dark grey	badly preserved	−15.2	−18.1
2-12	Titan Creek	*Intomodesma evenicum* Kusnezov	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer of the large (L> 200 mm) shell	grey	intermediately preserved	5.1	−20.0
2-13	Titan Creek	*Intomodesma evenicum* Kusnezov	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (~ 4 mm thick)	light grey	well preserved	3.3	−18.7
3-16a (1)	Titan Creek	*Neospirifer* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	anterior marginal part of the ventral valve	light grey	well preserved	5.6	−16.8
3-16b (1)	Titan Creek	*Intomodesma* sp. indet.	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (6 mm thick)	dark grey	well preserved	3.3	−21.8
3-17	Titan Creek	*Polidevcia magna* (Popow)	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	middle part of the shell large (L=50 mm) shell	black	badly preserved	−14.9	−19.6
3-19	Titan Creek	*Maitaia hurenensis* Biakov	Wuchiapingian-Changhsingian	*Intomodesma costatum*	Khivach	prismatic layer (1.0 − 1.5 mm thick)	dark grey	intermediately preserved	5.5	−25.6
13	Titan Creek	*Maitaia* cf. *tenkensis* Biakov	Wuchiapingian-Changhsingian	*Maitaia tenkensis*	Khivach	prismatic layer (0.5 mm thick)	dark grey	intermediately preserved	6.9	−20.9
6a	Titan Creek	*Maitaia kolymiaformis* Biakov	Capitanian	*Maitaia bella*	Gizhiga	prismatic layer (1 mm thick)	dark grey	intermediately preserved	5.4	−19.8