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The Permian of the Transbaikal region, eastern Russia: Biostratigraphy, correlation and biogeography

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Abstract

Permian deposits in the Transbaikal region within the Mongol–Okhotsk belt and adjacent areas have been studied. The characteristics of the Permian marine and continental formations are documented, and our present understanding of the stratigraphy is presented. The constitution of the regional stratigraphic units, or horizons, is specified, and their paleontological characteristics are stated. The correlation of the horizons with the Permian global chronostratigraphical scale is rather tentative, and has been made possible only by comparison with the well-characterized sections of Northeast Russia. Incomplete faunal distribution in the sections of the Transbaikal region makes it difficult to distinguish uninterrupted zonal sequences. However, the presence of characteristic associations and often, of index-species of biozones recognized outside the Transbaikal region, makes it possible to trace and date these biostratigraphic units. The contradiction between paleobiogeographic and paleomagnetic evidence is noted, the Permian biota being represented by Boreal faunas and Angaran floras suggestive of temperate latitudes, while paleomagnetic data seem to indicate tropical latitudes for the Transbaikal Region during the Permian.

Keywords: Transbaikal region; Permian; Biostratigraphy; Biogeography

1. Introduction

The Transbaikal region in the south of Russia stretches from Lake Baikal as far as the upper reaches of the Amur River. The Permian deposits of this region are fragmentary and discontinuously distributed. In addition, they are representative of a variety of depositional environments, including shallow-marine terrigenous deposits, turbidites formed on the continental slope and its foot, and continental volcanogenic and sedimentary-volcanogenic deposits. There are no continuous sections faunalistically characterized which involve more than two or three stages. The lower and upper boundary sequences of the Permian system are also missing in this region.

Systematic study of the Permian deposits of the Transbaikal region was launched in the 1960 s, and contemporary knowledge is the result of investigations carried out by M.N. Afanasov, A.S. Biakov, V.D. Gunbin, L.A. Kozubova, G.V. Kotlyar, D.F. Maslennikov, B.I. Olexiv, L.I. Popeko and S.M. Sinitsa.

2. Tectonic position of the Permian deposits

The Permian deposits of the Transbaikal region are located in the Mongol–Okhotsk orogenic belt and adjacent areas (Fig. 1). The Mongol–Okhotsk Belt is a suture zone and is termed the Mongol–Okhotsk Suture Zone by some authors (Natal'in, 1994; Ziegler et al., 1996). Within the bounds of the Mongol–Okhotsk Belt, ribbon-like terranes that stretch for hundreds of kilometers along the main strike of the orogenic belt are recognised. They are classified as accretionary wedge terranes from the composition of the constituent rocks and structures (Parfenov et al., 2001). Two types of terrane are distinguished, those chiefly composed of turbidites and those dominated by oceanic assemblages. The first type is exemplified by the Khentey–Daurskiy Terrane and the second type by the Ononskiy Terrane (Fig. 1).

The Khentey–Daurskiy Terrane is located in the western part of the Transbaikal region. It is composed of deep-sea,

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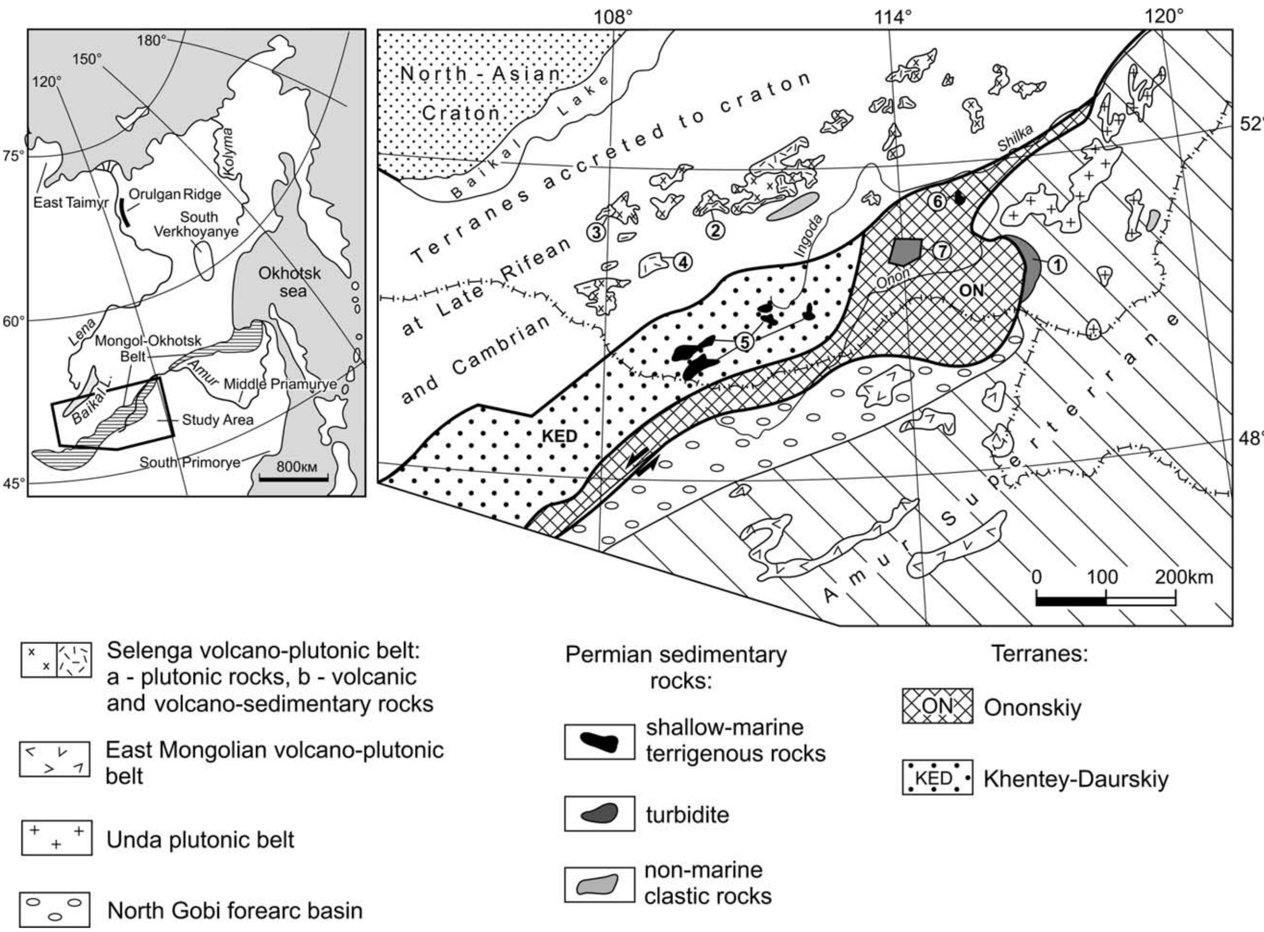

Fig. 1. Map of the Transbaikal region showing the Permian deposits locality. Encircled numbers: 1. Borzia River; 2. Kizhinga River; 3.Khilok River; 4. Chikoy River; 5. Head of Ingoda River; 6. Zhipkhoshi River; 7. Aksha-Ilinskiy Block.

severely deformed Devonian and Carboniferous flysch deposits, with subordinate horizons of cherty rocks, jaspers, andesites and andesitic-basalts. There are also Silurian deposits underlain by ophiolites in the Mongolian section of the orogenic belt. In the ophiolitic sequence, pillow lavas of MORB type and a complex of parallel dikes have been found (Tomurtogoo, 1997). Lower Permian deposits of the upper part of the Ryabinovskaya Formation form the uppermost strata of this section. They are represented by shallow-marine sandstones, siltstones and conglomerates.

The Ononskiy Terrane lies to the east of the Khentey–Daurskiy Terrane. It is a component of the Aga accretionary wedge complex, which can be traced over most of the territory occupied by the Mongol–Okhotsk Belt (Parfenov et al., 2001). A knee-shaped bend of the Ononskiy Terrane is known as the East Transbaikal sigmoid (Amantov, 1975). This sigmoid indicates sinistral strike-slip movement along the Mongol–Okhotsk Belt for about 100 km. The terrane is chiefly comprised of metamorphic greenschists, dominated by MORB basalts, with cherty-clay and cherty-rocks; sandstones and limestones are also present. Ophiolitic fragments include ultrabasic rocks, gabbro, and tonalites (Rutshtein and Chaban, 1997; Gusev and Peskov, 1996). The age of the rocks in this terrane is not clear.

Most of the metamorphic schists (Ononskaya and Kulindinskaya Formations) are dated as Late Precambrian on the basis of oncolite and catagraphite finds in the carbonate rocks (Amantov, 1975). At the same time faunalistically characterized volcanogenic-and-cherty rock assemblages of the Lower-Middle Devonian, demonstrating a structural unity with the Ononskaya Formation, are distinguished in the Ononskiy Terrane (Rutshtein and Chaban, 1997). This raises doubts about the Riphean age of the metamorphic assemblages.

Within the Ononskiy Terrane in the Transbaikal region, faunistically characterized Upper Devonian and Lower and Middle Carboniferous deposits are also present, represented mainly by shallow-marine terrigenous deposits (sandstone, siltstone and conglomerates), as well as rare rhyolite, dacite and tuff, which overlie the Ononskaya Formation and the Lower-Middle Devonian deposits unconformably (Rutchtein, 1992; Kotlyar and Popeko, 1967). Lower Permian shallow-marine terrigenous deposits overlie both Carboniferous deposits and metamorphic schists of the Ononskaya Formation unconformably. The section is topped by Upper Triassic marine deposits capping thick Carboniferous units unconformably. However, sections of Upper Permian–Triassic rocks (sandstones and siltstones, cherty rocks and basalts), presumably uninterrupted, have been identified from the Aksha–

Ilinskiy Block (7 in Fig. 1), an independent equidimensional fault-bounded block which adjoins the East Transbaikal sigmoid on the west, and may be part of the Aga accretionary complex. The thick Upper Devonian, Carboniferous and Lower Permian shallow-marine units noted above are the accumulations of a forearc basin. From carbonate rocks, which contain Early Permian Tethyan fusulinids in the south of the East Transbaikal region (Amantov, 1963), it is concluded that the accretionary complex formed in the Late Paleozoic and Early Mesozoic.

A collage of terranes accreted to the North Asian craton at the end of the Late Precambrian and the Early Paleozoic are located to the north of the Mongol–Okhotsk Belt in the Transbaikal region and Mongolia (Fig. 1). The southern bounds of the belt are defined by the Amur Superterrane (microcontinent), which is composed of Archean crystalline assemblages, Riphean metamorphic units, of a type different from those in the Ononskiy Terrane, and also thick and deformed Cambrian terrigenous and carbonate deposits. Early Paleozoic granite batholiths are characteristic of this superterrane, and Late Paleozoic and Mesozoic granitoids are also present. Thin shallow-marine deposits of the Devonian and Carboniferous are present locally. Zonenshain et al. (1990) believe that all the terranes to the south of the Mongol–Okhotsk Belt were amalgamated to form the Amur microcontinent by the end of the Paleozoic, during the closure of the South Mongol tectonic zone.

The recognition of accretionary wedge terranes within the Mongol–Okhotsk orogenic belt suggests that magmatic arcs formed during the subduction and closing of the ocean that existed prior to the formation of the belt. The Selenga volcano-plutonic belt of Pennsylvanian-Early Triassic age, located to the north of the Mongol–Okhotsk Belt, stretches for about 2000 km in the northern Mongolia and Transbaikal region (Gordienko, 1987; Kazimirovskiy et al., 1998; Kozubova et al., 1982) (Fig. 1). This belt is composed of andesites, trachytic andesites, dacites, andesitic-basalts, rhyolites and trachytic rhyolites, intercalated with continental clastic rocks. The plutonic rocks are granodiorites, granites, granosyenites and monzonites. As distinct from the sodium calc-alkaline series formed above a subduction zone, the rocks of the Selenga Belt are defined as subalkaline, characterized by a high K_2O content (Kovalenko et al., 1983). The construction of the belt terminated with bimodal alkali magmatism approximately at the Permian–Triassic boundary. Kozubova et al. (1982) note zoning in the distribution of magmatic assemblages in the lower part of the belt section, which is characteristic of continental margin magmatic arcs related to subduction. In the south-eastern part of the belt, near the boundary with the Mongol–Okhotsk Belt, the assemblages are represented by fully differentiated calc-alkaline volcanic and plutonic assemblages, which become increasingly alkaline in a northerly direction. These magmatic assemblages indicates the position of the ancient active margin of the continent at the boundary with the Mongol–Okhotsk Ocean. At the same time, there are similarities between the Selenga volcano-plutonic belt and magmatic formations, which characterise transform boundaries on the continent (Khanchuk, 1998). The increased alkalinity of the Selenga rocks may be attributed to the oblique position of the subduction zone, which is governed by convergence of the oceanic plate with the southern (in the modern coordinates) margin of the Siberian continent. It is presumed that the Khentey–Daurskiy Terrane of accretionary wedge origin was associated with the formation of the Selenga magmatic arc.

The East Mongol volcano-plutonic belt is located in Mongolia, to the south of the Transbaikal sector of the Mongol–Okhotsk Belt (Fig. 1). Zonenshain et al. (1990) suggest that it was related to the subduction zone in the Mongol–Okhotsk Belt. The East Mongol Belt is composed of andesites, dacites and rhyolites of the calc-alkaline series, trachytic rhyolites, and subalkaline granites (Kovalenko and Yarmolyuk, 1990). The Northern Gobi Trough stretches along its northern margin, and is composed of Carboniferous flysch deposits and Permian and Early Triassic shallow-marine deposits with horizons of volcanic rocks. This trough can be regarded as the forearc basin of the East Mongol magmatic arc.

In the northern part of the Amur Superterrane the Unda granitoids,which form the Unda plutonic belt, represent the eastward extension of the magmatic arc. They are batholith-like bodies of gabbro-diorites, granodiorite, rare granite and leucogranite. These plutonic rocks occur as pebbles in Upper Permian conglomerates. Petrochemically and geochemically, these granitoids correspond to those of active continental margins (Yefremov et al., 1998). The Borzia Trough in the Borzia River Basin, an extension of the Northern Gobi forearc basin in Mongolia, adjoins the East Transbaikal sigmoid of the Mongol–Okhotsk Belt on the east. It is filled by Upper Permian marine sandy-siltstone and conglomerate of the Borzinskaya Group, which, based on different estimates, is 6000 to 8000 m thick. Possibly, it is also a forearc basin of a single active continental margin. The accretionary complex of the Ononskiy Terrane, the Borzia forearc basin and the Unda plutonic belt are structures formed at the active margin of the Amur Superterrane.

3. Biostratigraphy and correlation

In line with the stratigraphic rules accepted in Russia (Zhamoida et al., 1992), the term ‘horizon’ is used in this paper, together with a geographic name, to define the main regional correlationable stratigraphic unit within a geologic region, sedimentary basin or paleogeographic province. A horizon includes several coeval local units (suites or formations) distinguished mainly by their facies. The geographic distribution of formations is restricted to a structural zone or a part of a geological region. The main biostratigraphic unit used is the zone. Where uninterrupted zonal successions are not present in the study area, and when sediments containing organic remains underlie or overlie deposits lacking organic remains, auxiliary biostratigraphic units ‘beds with fauna’ are also used.

The Permian deposits of the Transbaikal region are divided into seven stratigraphic horizons: the Zhipkhoshinskiy, Kizhiginskiy, Alentuiskiy, Antiinskiy, Sosucheiskiy,

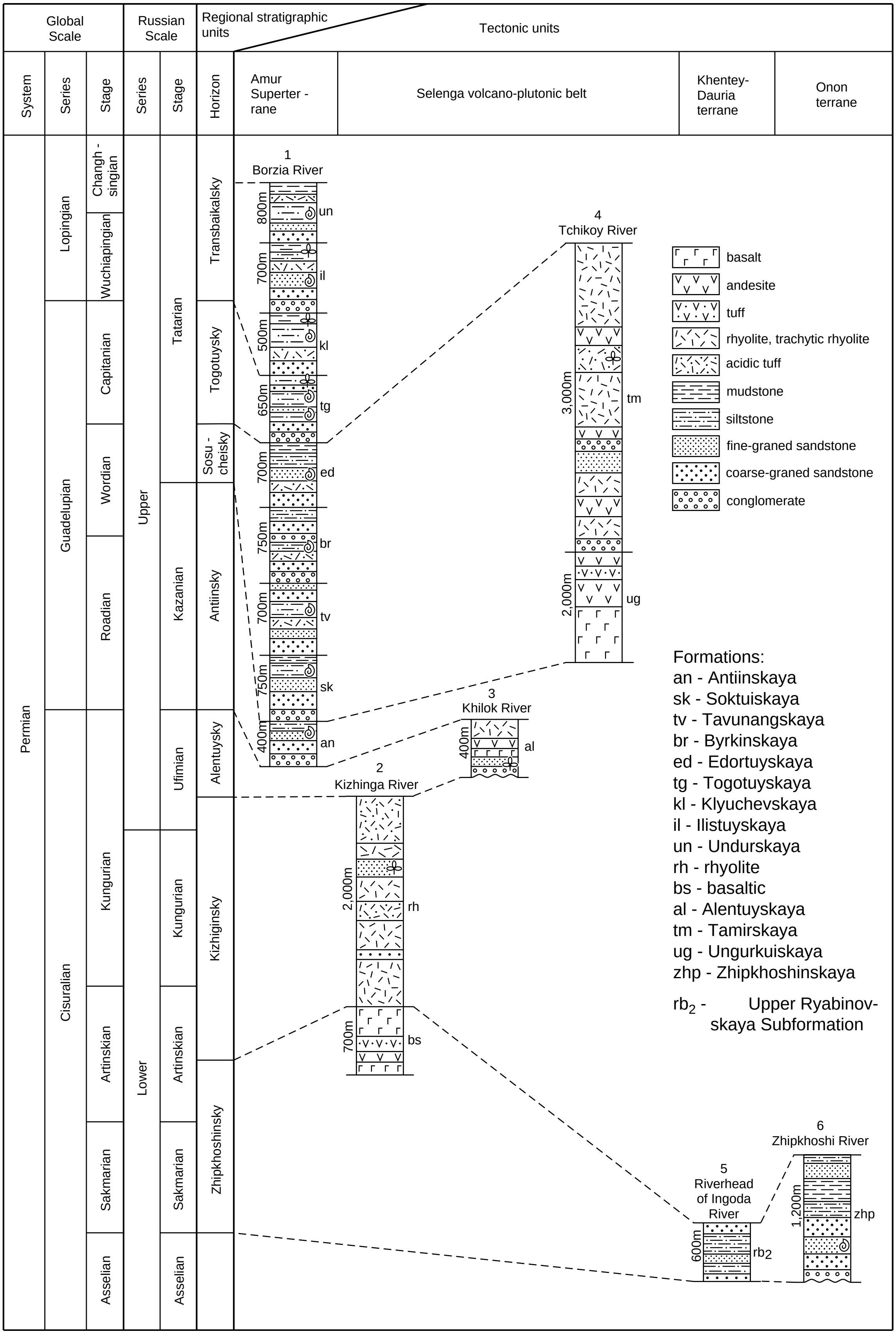

Fig. 2. Correlation of sections in the Permian deposits of the Transbaikal region.

Table 1
The succession of faunal and floral assemblages in the Permian of the Transbaikal region

Global Scale			Russian Scale		Regional stratigraphic units, faunal and floral assemblages				
System	Series	Stage	Series	Stage	Horizon	Brachiopods	Bryozoa	Bivalves	Plants
Permian	Lopingian	Changhs.	Upper	Tatarian	Zabaikalskiy	*Attenuatella* sp.			*Zamiopteris* cf. *tajluganensis, Z.pseudotriquetra*, *Paracalamites* sp., *Cordaites* sp., *Chiropteris palmilobata*, *Pursongia* sp., *Tatarina* sp.
		Wuchiap.						Beds with *Polidevcia zabaikalica*	
	Guadalupian	Capitanian			Togotuiskiy	Beds with *Cancrinelloides* cf. *curvatus*	*Stenopora borsiensis, Dyscritella spinosa, Permofenestella labuensis*	Beds with *Maitaia bella*	*Zamiopteris* cf. *tajluganensis*, *Tajmyropsis* sp., *Pursongia tunguskana*, *Samaropsis pseudotriquerta*
		Wordian			Sosucheiskiy	Beds with *Cancrinelloides obrutschewi*		Beds with *Merismoptera macroptera*	*Cordaites* cf. *gracilentus*, *C.* cf. *incina*, *C. angustifolius*, *C. insignis, Rufloria* sp.
						Beds with *Magadania bajkurica – M.modotonensis*	Beds with *Maychella metaporata*	Beds with *Aviculopecten* cf. *kolymaensis*	
		Roadian		Kazanian	Antiinskiy	*Terrakea* sp. *Olgerdia* sp.	Beds with *Dyscritella turbini– Permofenestella olexivi*	Beds with *Kolymia plicata*; Beds with *Kolymia* cf. *inoceramiformis*	
	Cisuralian	Kungurian		Ufimian	Alentuiskiy				*Crassinervia parva*, *Petchoria maletaensis*, *Colepcarpus quadratus*
			Lower	Kungurian	Kizhiginskiy				*Koretrophyllites* cf. *setosus*, *Paracalamites* cf. *crassus*, *Rufloria theodori*, *R.* cf. *derzhavini, Cordaites singularis*, *Crassinervia kuznetskiana*
		Artinskian		Artinskian	Zhipkhoshinskiy	Beds with *Jakutoproductus zabaikalicus – Anidanthus halinae*		Beds with *Polidevcia jamesi*	
		Sakmarian		Sakmarian					
		Asselian		Asselian					

Togotuiskiy and Zabaikalskiy Horizons (Fig. 2; Table 1). Two of them (the Kizhiginskiy and Alentuiskiy Horizons) are represented by continental formations; the rest are marine assemblages (Turbin et al., 1995; Kotlyar et al., 2002). Correlation of these horizons with the International Permian Time Scale is by comparison with the well-characterized sections of Northeast Russia (Kashik et al., 1990). Brachiopods play the leading role in the correlation of the marine deposits.

The poor preservation of faunal remains and their irregular distribution within sections prevent the recognition of uninterrupted zonal biostratigraphic successions. Nevertheless, characteristic fossil associations, guide forms and index-species of biostratigraphic zones recognised in areas outside the Transbaikal region has made it possible to correlate the biostratigraphic units (Table 1).

3.1. The Zhipkhoshinskiy Horizon

The Zhipkhoshinskiy Horizon was defined by Kotlyar (1967). Its stratotype is the section of the Zhipkhoshinskaya Formation located in the watershed of the Zhipkhoshi and Bereia Rivers, on the north bank close to the mouth of the Aga River. This formation forms the upper unit of the Upper Paleozoic deposits of the Chironskiy Trough. It is represented by the intercalation of conglomerates, sandstones and siltstones with arkose and greywacke sandstones predominating. The Zhipkhoshinskaya Formation overlies the Bashkirian deposits of the Shazagaituiskaya Formation unconformably, and there is a hiatus separating the two formations. In the marginal parts of the trough an angular unconformity separates the Zhipkhoshiskaya Formation from the underlying metamorphic assemblages of the Ononskaya Formation. In the Zun–Shiveya River Basin, the Zhipkhoshiskaya Formation forms a number of tectonic blocks, and is characterized by brachiopods, bivalves, rare bryozoans and crinoids. The Zhipkhoshinskiy Horizon also includes the upper subformation of the Ryabinovskaya Formation in the Khentey–Daurskiy Terrane and a thick basalt-andesite series of the Selenga volcano-plutonic belt.

Beds with *Jakutoproductus zabaikalicus–Anidanthus halinae* have been recognized in the Zhipkhoshinskiy Horizon. They are distinguished by the appearance and wide distribution of *Jakutoproductus zabaikalicus* Kotlyar, whose shells often form monotaxic single-species shell beds and dominate all sections. *Anidanthus halinae* (Kotlyar) was also observed in this horizon, but is subordinate, both numerically and in frequency of occurrence. *Anidanthus boikowi* (Stepanov) and *Tomiopsis laevis* Kotlyar are also present. The dominant species in these beds is *Jakutoproductus zabaikalicus* Kotlyar, which is very similar to *J. verchoyanicus* (Fredericks); the latter being the dominant species in the *Jakutoproductus verchoyanicus–Spirelytha fredericksi* Zone of South Verkhoyanye (Kletz, 1995). The presence of *J. zabaikalicus* in the Zhipkhoshinskiy Horizon, in addition to the accompanying species, means that these beds can be compared with the *Jakutoproductus verchoyanicus–Spirelytha fredericksi* Zone of South Verkhoyanye.

In South Orulgan deposits bearing *Jakutoproductus verchoyanicus* (Fredericks), *Anidanthus halinae* (Kotlyar) and *A. boikowi* (Stepanov), correspond to these beds (Solomina, 1981). The beds are distinguished mainly in the lower part of the Zhipkhoshinskaya Formation, and provide a good marker horizon. The age of the beds with *Jakutoproductus zabaikalicus–Anidanthus halinae* is conventionally defined as Sakmarian-Early Artinskian by analogy with the South Verkhoyanye and north-eastern Russia divisions, in which *Uraloceras* sp. has been found, together with the brachiopods *J. verchoyanicus* and *A. boikowi*.

Bivalve beds with *Polidevcia jamesi*, common in the Zun–Shiveya River Basin, correspond to beds with *Jakutoproductus zabaikalicus–Anidanthus halinae*. Apart from the most frequent index-species *Polidevcia jamesi* Biakov, other species include *Palaeoneilo postolegi* Biakov, rare *Permophorus oblongus* (Meek and Hayden), and also sporadic *Polidevcia kolyvanica* Muromceva and *Cypricardinia* cf. *borealis* Muromceva. These bivalve beds are correlated with the middle and upper part of the bivalve zone *Palaeoneilo parenica* in Northeast Asia, which corresponds to most of the lower part of the Munugudzhakskiy Horizon. This zone is correlated with the Asselian to the lower half of the Artinskian Stage (Biakov, 2000); therefore, beds with *Polidevcia jamesi* are correlated with the Sakmarian to lower half of the Artinskian Stage.

3.2. The Kizhinginskiy Horizon

The Kizhinginskiy Horizon is conventionally referred to the upper part of the Artinskian and the greater part of the Kungurian (excluding the top) (Turbin et al., 1995). The stratotype is a thick sequence of acid volcanics, intercalated with clastic sedimentary rocks, in the Kizhinga River Basin (Selenga Belt). The sequence rests conformably on basic volcanics, conventionally referred to Sakmarian and the lower part of the Artinskian (Turbin et al., 1995). Interbeds of volcanogenic-sedimentary rocks hold plant remains of *Koretrophyllites* cf. *setosus* Radczenko, *Paracalamites* cf. *crassus* Gorelova, *Rufloria theodorii* (Zalessky and Tchirkova) S.Meyen, *R.* cf. *derzhavini* (Neuburg) S.Meyen, *Cordaites singularis* (Neuburg) S.Meyen, *Crassinervia kuznetskiana* (Chachlov) Neuburg, *C. prokopiensis* (Chachlov) Radczenko. The assemblage contains species characteristic of the Ishanovskiy, Kemerovskiy and Usyatskiy Horizons of the Kuznetsk Basin. The Borgoiskaya Formation in the Selenga River Basin and a thick unit of acid volcanics in the Ortinka River Basin are conventionally also referred to the Kizhinginskiy Horizon (Kotlyar et al., 2002).

3.3. The Alentuiskiy Horizon

The Alentuiskiy Horizon corresponds to the very top of the Kungurian (equivalent to the Ufimian of the Russian Scale) as it contains plant remains characteristic of the Mitinskiy Horizon of the Kuznetsk Basin in West Siberia. The stratotype of this horizon is the section of the formation of the same name on the north bank of the Khilok River. The formation contains conglomerates, conglomerate breccia, trachyte, trachytic rhyolite, trachytic-andesite, basaltic andesite, tuffaceous sandstone and rhyolite. The tuffaceous sandstones include the following plant remains: *Crassinervia parva* Radczenko, *C. ovata* Radczenko, *Petchoria maletaensis* Radczenko and *Lepeophyllum* aff. *actaeanelloides* (Geinitz) Zalessky. The Gunzanskaya Formation in the Selenga Belt and the thick Gryazinskaya sequence from the Nerchinskiy Zavod area in the northern part of Amur Superterrane are also included in this horizon (Turbin et al., 1995; Kotlyar et al., 2002).

3.4. The Antiinskiy Horizon

The Antiinskiy Horizon corresponds to the Roadian and the lower part of the Wordian (or the Kazanian Stage of the Russian Scale). The stratotype is the section of the Antiinskaya Formation in the Turga River Basin. The Antiinskaya Formation is the lower member of the rhythmically deposited Borzinskaya Group, which is divided into nine conformable formations: the Antiinskaya, Tavunangskaya, Soktuiskaya, Byrkinskaya, Edortuiskaya, Togotuiskaya, Klyuchevskaya, Ilistuiskaya and Undurskaya Formations, in ascending order. Each of the formations is a first order sequence, whose base is made up of conglomerate, or coarse-grained sandstone, changing upsection to finer-grained sandstone, siltstone and tuff (Kotlyar et al., 1990). The lower contact of the Borzinskaya Group is faulted.

The Antiinskiy Horizon is characterized by the remains of bryozoans, brachiopods, bivalves, crinoids and nautilids. Among the brachiopods *Terrakea* sp., *Rhynchopora lobjaensis* (Tolmatchev), *Olgerdia* sp., *Neospirifer* ex gr. *neostriatus* Fredericks have been recorded. Crinoids are represented by one species, *Pentagonopternix borsjiensis* (Yeltysheva and Stukalina). A nautiloid of the Liroceratidae family has also been recorded.

Beds with the bryozoan assemblage *Dyscritella turbini–Permofenestella olexivi* are recorded in the Antiinskiy Horizon. This assemblage is represented by numerous colonies of the index-species *Dyscritella turbini* Romantchuk, *Permofenestella olexivi* Popeko and the accompanying species *Maychella zabaikalica* Popeko, *Fenestella intuberculata* Popeko, *Laxifenestella borealis* Popeko, *Stenopora borsiensis* Popeko and also *Maychellina orientalis* (Popeko), *Permofenestella mushnikovi* Popeko, *P. colymaensis* (Nekhoroshev), *P. labuensis* (Morozova), *Spinofenestella antiensis* (Popeko) etc. Based on the presence and dominance in the beds of *Dyscritella turbini* Romantchuk and *Permofenestella labuensis* (Morozova), this assemblage can be correlated with the middle-upper parts of the Omolonskiy Horizon in Northeast Russia (Morozova, 1981) and with beds containing the Tsaganulskiy bryozoan assemblage in Southeast Mongolia (Pavlova et al., 1991; Manankov, 1999).

In the stratotype area beds with *Kolymia* cf. *inoceramiformis*, corresponding to the lower part of the Antiinskaya Formation, and beds with *Kolymia plicata* present in the upper part are found in the Antiinskiy Horizon. In the lower beds, besides the index-species *Kolymia* cf. *inoceramiformis* Licharev, other representatives of unidentified *Kolymia* species are present. These beds are correlated with a bivalve zone of the same name in the middle part of the Omolonskiy Horizon in Northeast Russia and correspond with the regional brachiopod *Omolonia snjatkovi* Zone. In the upper beds, only the index-species *Kolymia plicata* Biakov is observed. These beds are correlated with a bivalve zone of the same name in Northeast Russia corresponding to the regional brachiopod *Terrakea borealis* and *T. korkodonensis* zones (Kotlyar et al., 2002).

3.5. The Sosucheiskiy Horizon

The Sosucheiskiy Horizon was distinguished by Kotlyar (1967), uniting the Soktuiskaya, Tavunangskaya, Byrkinskaya and Edortuiskaya Formations. The stratotype of this horizon is located in the Borzya River Basin in the tributaries of the Edortui, Tavunanga, and Byrka Rivers and on the watershed of the Ilistui–Malyi Soktui River. It rests conformably on the Antiinskiy Horizon. The Sosucheiskiy Horizon is characterized by numerous remains of brachiopods, bryozoans and bivalves.

The Sosucheiskiy Horizon is divided into two parts based on the brachiopods. Beds with *Magadania bajkurica–M. modotonensis* are distinguished in the lowest part of the Soktuiskaya Formation, which makes up the lower part of the horizon. Beds with *Cancrinelloides obrutchewi–Attenuatella olexivi* are found in the upper part of the Soktuiskaya Formation, as well as in the overlying Tavunangskaya, Byrkinskaya and Edortuiskaya Formations, all of which corresponding to the upper part of the Sosucheiskiy Horizon. The brachiopod assemblage in the beds with *Magadania bajkurica–M. modotonensis* includes the species *Magadania bajkurica* (Ustritsky), which is widespread in the Boreal realm. Besides this species, the brachiopod assemblage generally also includes *M. modotonensis* Kotlyar, *Rhynchopora lobjaensis* (Tolmatchew), *Neospirifer subfasciger* Licharew, *N.* cf. *moosakhailensis* (Davidson) and *Bajtugania boguchanica* Solomina. Based on the presence of the first index-species, the beds correspond to the *Magadania bajkurica* Zone in Northeast Russia (Kashik et al., 1990). They can also probably be correlated with the *Olgerdia zavadovskyi* Zone in West Verkhoyanye (Budnikov et al., 1998), which is to some degree indicated by the occurrence of representatives of the genus *Terrakea* in both areas. Apart from the above-mentioned regions, a similar brachiopod assemblage also containing *Magadania bajkurica* (Ustritsky) is known in East Taimyr, in the lower 100 m of the Upper Baikurskiy Subhorizon (Ustritskiy and Tchernyak, 1963). The beds are conventionally dated as the beginning of the second half of the Late Wordian.

Beds with *Cancrinelloides obrutschewi–Attenuatella olexivi* are directly overlie beds bearing *Magadania bajkurica–M. modotonensis*. The lower boundary of the beds containing *Cancrinelloides obrutschewi–Attenuatella olexivi* is determined by the appearance of the index-species and the accompanying assemblage. This assemblage includes *Cancrinelloides obrutschewi* (Licharew), *C. licharewi* Kotlyar, *Megousia zabaikalica* Kotlyar, *Olgerdia ganelini* Grigorjeva, *O. zavaodovskyi* Grigorjeva, *Cleiothyridina* cf. *nikolaevi*

Grunt, *Crassispirifer* cf. *monumentalis* Abramov and Grigorjeva, *Attenuatella olexivi* Kotlyar. This assemblage is noted for its great taxonomic diversity and the domination of *Attenuatella olexivi* Kotlyar. Most of these species have also been found outside the Transbaikal region and correspond to the *Cancrinelloides obrutschevi* Zone in Northeast Russia (Kashik et al., 1990) and Verkhoyanye (Budnikov et al., 1998). Outside the above-mentioned regions analogues of these beds have been recognized in the Uldzinskaya Formation in Northeast Mongolia, based on the presence of *Cancrinelloides obrutschewi* (Licharev) and *C. licharewi* (Kotlyar) (Grigorieva et al., 1977); in the Selanderskaya Formation in Spitsbergen, in view of the presence of *Spitzbergenia loweni* (Wiman), a species that is very close to *Cancrinelloides ochotica* Zavodowsky, and *Spitzbergenia alferovi* (Miloradovich) (Ustritskiy, 1979). In Novaya Zemlya, the analogues of the beds are recognized in the Shadrovskaya Formation. The *Cancrinelloides obrutschewi* Zone is also recognized beyond Russia in North Yukon, Canada (Waterhouse, 1971). The age of these beds is Late Wordian (or Early Tatarian, in the Russia Scale).

Bryozoan beds with *Maychella metaporata* correspond to brachiopod beds with *Magadania bajkurica–M. modotonensis*, i.e. the lower part of the Soktuiskaya Formation. The beds directly overlie those containing *Dyscritella turbini–Permofenestella olexivi*. The lower boundary is delineated by the appearance and wide distribution of the index-species *Maychella metaporata* Romantchuk, and also *Dyscritella spinosa* Romantchuk, *Maychella tuberculata* Morozova, *Streblascopora* ex gr. *gracilis* Romantchuk. They are accompanied by *Stenopora borsiensis* Popeko, *Maychellina orientalis* (Popeko), *Permofenestella mushnikovi* Popeko, *P. kolymaensis* (Nekhoroshev) and *P. labuensis* (Morozova), passing from the subjacent deposits. The presence of the species *Maychella tuberculata* Morozova and *Dyscritella spinosa* Romantchuk allows correlation of the beds with the lower part of the Middle Osakhtinskaya Subformation in Middle Priamurye (Morozova, 1970), characterized by a mixed Boreal–Tethyan faunal assemblage. *Permofenestella labuensis* (Morozova), *P. kolymaensis* (Nekhoroshev) and *Maychellina orientalis* (Popeko) [a species close to *M. nervosa* (Morozova)], make it reasonable to correlate the beds with the upper part of the Omolonskiy Horizon in Northeast Russia (Morozova, 1981). The former species is also widely known also in the analogues of the Sosucheiskiy Horizon in Mongolia (Gorjunova and Morozova, 1979).

In the same interval as the brachiopod beds with *Magadania bajkurica–M. modotonensis*, i.e. in the lower part of the Soktuiskaya Formation, bivalve beds with *Aviculopecten* aff. *kolymaensis* are distinguished. Besides the index-species *Aviculopecten* aff. *kolymaensis* Maslennikov, there are also rare *Wilkingia bulkurensis* (Muromzeva) and sporadic *Merismopteria* sp. By their stratigraphic position, these bivalve beds correspond to the *Kolymia multiformis* bivalve Zone in Northeast Russia that is distinguished in the upper part of the Omolonskiy Horizon (Kashik et al., 1990), and can be dated as Late Wordian (or Early Tatarian) (Kotlyar et al., 2002).

The bivalve beds with *Merismopteria macroptera* correspond to the upper part of the Soktuiskaya Formation. Besides the index-species *Merismopteria macroptera* (Morris), these beds contain a great diversity of specimens, including numerous *Streblopteria alenae* Biakov, sporadic *Leptodesma indistincta* Biakov, *Cyrtorostra nana* Biakov, *Myonia* aff. *gibbosa* (Maslennikov), *Astartella* cf. *permocarbonica* (Tschernyshew) and rare *Wilkingia bulkurensis* (Muromzeva). The beds with *Merismopteria macroptera* can be correlated with those of the same name from Northeast Russia, where they are discriminated in the lower part of the *Maitaia bella* Bivalve Zone, which roughly corresponds to the regional *Cancrinelloides obrutschewi* Zone (excluding the upper part) (Kotlyar et al., 2002).

Besides the above-mentioned formations, the Ungurkuiskaya and Tamirskaya Formations located in the Selenga volcano-plutonic belt are conventionally referred to the Sosucheiskiy Horizon (Turbin et al., 1995; Kotlyar et al., 2002). The Ungurkuiskaya Formation is represented by alkaline basalt, andesite and tuffaceous sediments. The Tamirskaya Formation is made up of rhyolite, dacite, trachyte, trachytic rhyolite, tuff and ignimbrite with subordinate andesite, trachytic andesite and rare horizons of conglomerate and sandstone. The Tamirskaya Formation is characterized by a Cordaitales flora, among which *Cordaites* cf. *gracilentus* (Gorelova) S.Meyen, *C.* cf. *incina* (Radczenko) S.Meyen, *C.* cf. *candalepensis* (Zalessky) S.Meyen, *C. insignis* (Radczenko) S.Meyen and *Lepeophyllum* sp. are present. A similar assemblage of plant remains is also known from the Uldzinskaya Formation in Northeast Mongolia, which occurs with the Sosucheiskaya brachiopod assemblage (Durante, 1976). The entire Uldzinskaya Formation can be also included in the Sosucheiskiy Horizon.

3.6. The Togotuiskiy Horizon

The Togotuiskiy Horizon is one of characteristic rock units in the Borzia Trough. The stratotype of the horizon is the section of the Togotuiskaya Formation in the Togotui River Basin. It conformably overlies the Sosucheiskiy Horizon. Brachiopod beds with *Cancrinelloides* cf. *curvatus* have been recorded from the upper part of this formation, corresponding to the upper part of the Togotuiskiy Horizon. The assemblage of these beds is extremely limited, and besides the index-species *Cancrinelloides* cf. *curvatus* (Tolmatchew), it is represented by three species: *Rhynchopora lobjaensis* (Tolmatchew), *Penzhinella micluchomaclayi* (Zavodowsky) and *Attenuatella olexivi* Kotlyar. The brachiopod community contains also numerous representatives of the genus *Neospirifer*, however, they are so poorly preserved that they cannot be identified beyond the generic level. Based on the presence of the index-species and wide distribution of the genus *Attenuatella*, these beds are considered to correspond to the *Cancrinelloides curvatus* Zone of the upper part of the Gizhiginskiy Horizon in the Northeast Russia (Kashik et al., 1990), the middle part of the Dulgalakhskiy Horizon of Verkhoyanye (Budnikov et al., 1996, 1998), and belong to the Capitanian (or the lower part of the Upper Tatarian in the Russian Scale).

Associated bivalve beds with *Maitaia bella* are characterized by rare finds of the index-species *Maitaia bella* Biakov and numerous *Polidevcia zabaikalica* Biakov. The beds with *Maitaia bella* correspond to the *Maitaia bella* Zone in Northeast Russia, where this zone corresponds to the Gizhiginskiy Horizon and is well correlated across the whole Boreal realm (Biakov, 1999; Kotlyar et al., 2002).

The remains of the bryozoans *Stenopora borsiensis* Popeko, *Dyscritella spinosa* Romantchuk and *Permofenestella kolymaensis* (Nekhoroshev); the crinoid *Pentagonopternix borsjiensis* (Yeltysheva and Stukalina) and the plant remains, *Zamiopteris* cf. *tajluganensis* Gorelova, *Tajmyropsis* sp., *Pursongia tunguskana* Neuburg and *Samaropsis pseudotriquerta* Neuburg are present in the Togotuiskiy Horizon, together with brachiopods and bivalves, and are generally characteristic of the upper strata of the Middle Permian.

The presence of the ammonoids *Timorites* sp. and *Neopronorites* sp. (Okuneva and Zakharov, 1992) in the upper part of the Togotuiskiy Horizon is extremely important. Elsewhere in East Asia, representatives of *Timorites* have been encountered in the extreme upper part of the Middle Osakhtinskaya Subformation in Middle Priamurye, in the Chandalazskiy Horizon in South Primorye at the level of the *Parafusulina stricta* Fusulinid Zone, and also from Japan (upper Kattizawa Stage of the Kanokura Series and middle part of the Oyakezima Formation) (Kotlyar et al., 1999). The presence of *Timorites* indicates that the Togotuiskiy Horizon may be referred to the Capitanian.

3.7. The Zabaikalskiy (Transbaikal) Horizon

The Zabaikalskiy (Transbaikal) Horizon is the uppermost unit in the Borzia Trough. It comprises the Klyuchevskaya, Ilistuiskaya, and Undurskaya Formations. Its stratotype is in the basins of the Klyuchevskaya, Ilistui, and Kore–Kondui Rivers. It rests conformably on the Togotuiskiy Horizon and is characterized by a strongly depleted assemblage of organic remains. The brachiopods are represented by only one unidentified species of *Attenuatella*; bivalves are represented by *Polidevcia zabaikalica* Biakov and *Polidevcia* sp. and plant remains by *Zamiopteris* cf. *tajluganensis* Gorelova, *Equisetites* sp., *Paracalamites* sp., *Cordaites* sp., *Chiropteris palmilobata* Zalessky, *Pursongia* sp. and *Tatarina* sp.

Beds with *Polidevcia zabaikalica* have been recognised in the Klyuchevskaya and Ilistuiskaya Formations in the Zabaikalskiy Horizon (Kotlyar et al., 2002). They are characterized only by the index-species *Polidevcia zabaikalica* Biakov, which is close to *P. magna* (Popow), a typical element of the Late Khivachian communities in Northeast Russia (Biakov, 2000).

The whole faunal and floral assemblage is characteristic of the very end of the Permian Period. The complete extinction of brachiopods and bryozoans at the boundary between the Togotuiskiy and Zabaikalskiy Horizons, and only a few bivalves in the latter horizon, is analogous to the change of communities noted at the end of the Permian in Verkhoyanye, northeastern Russia and in Middle Priamurye. This change in communities and also the stratigraphic position make it possible to correlate the Zabaikalskiy Horizon with the upper part of the Dulgalakhskaya Formation in Verkhoyanye and the Upper Osakhtinskaya Subformation in Middle Priamurye. Apparently, it also corresponds to the lower part, and, possibly, to the entire Khivachskiy Horizon in Northeast Russia, both of Late Permian (Lopingian) age.

4. Paleobiogeography

Faunal assemblages characterizing the Permian sections of the Transbaikal region are represented by typical Boreal associations. *Timorites* sp., which is present in the Togotuiskiy Horizon, is an exception. This genus has a rather narrow stratigraphic distribution and has been encountered mainly at lower latitudes of the Tethyan Realm. In the Russian Far East (Middle Priamurye and South Primorye) and in Japan (South Kitakami), *Timorites* has been found in association with brachiopods and bryozoans of mixed Tethyan and Boreal type. In the Transbaikal region, the genus is associated with brachiopods, bryozoans, and bivalves of Boreal type. Evidently, at the beginning of the Capitanian age, *Timorites* reached the Angaran coast of the Tethyan Basin, expanding its range, which may have been expedited by the possible climatic warming during the Capitanian, as well as the nektonic dispersal of the ammonoid genus.

In the Permian, a flora of Angaran type existed in the Transbaikal region, which was noted for its deciduous plants and wood with growth rings. These characteristics are indicative of seasonal climate in the midlatitudes where this flora grew. These forms have been detected both in the northern (Selenga volcano-plutonic belt) and in the southern (East Mongolian Belt and Borzia Trough) adjacent areas to the Mongol–Okhotsk belt. One cannot but pay attention to the discrepancy between the above mentioned evidence and the results of paleomagnetic investigations, which indicate sub-tropical latitudes for the Permian marine deposits of the Transbaikal region. The paleolatitude of the Zhipkhoshinskaya Formation has been determined as 24.4° and of the lower strata of the Borzinskaya Group, as 20.9° (Kravchinsky et al., 2002). One of the tasks of further investigations will involve the search for the reasons for these contradictions.

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