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GEOCHEMISTRY

Age and Composition of Ophiloites from the Basement of the West Siberian Petroliferous Megabasin

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Ophiolites are widespread in the basement of the West Siberian petroliferous megabasin, where they occur usually along large faults that separate different lithotectonic zones [1–8 and others]. Despite the widely admitted great significance of ophiolites for understanding the structure and evolution of foldbelts, ophiolites of West Siberia remain insufficiently studied because of unavailability of data on their age.

In 2001–2006, we carried out complex geological–geophysical studies in the western and central areas of the West Siberian megabasin (Fig. 1). The results obtained made it possible to compile several maps of its basement [6, 9, and others], in particular, the geological map of the pre-Jurassic basement of the Shaim petroliferous region (scale 1: 200 000). Figure 2 demonstrates its fragment. The maps are based on petrological, geochemical, paleontological, isotopic–geochronometric, and other data derived from geophysical studies and drilling of over 500 deep wells that recovered pre-Jurassic complexes. The ArcView software was used for compiling these basement maps that represent informative geological, geophysical, and other layers superimposed successively on each other.

The wells are distributed irregularly. In areas with scarce wells, the anomalous gravity and magnetic fields that reflect differences in physical properties of lithotectonic complexes were used for defining different structures. The geologically well-studied areas served as standards for the analysis of fields. For example, serpentinite massifs are characterized by intense positive magnetic anomalies with amplitudes ranging from 100 to 300–400 nT (or higher) against the background of insignificant local distortions in the general gravity field patterns related to weak negative influence of relatively light serpentinite bodies. The density of ultramafics varies depending on the serpentinization degree. The excess density (up to +0.3 g/cm^3 relative to its average values characteristic of the Earth's crust) is typical of pyroxenites; slightly serpentinized ultramafics; gabbro; and, to a lower extent, basalts and basic tuffs.

Three structural stages are recognizable in the region under consideration. The lower structural stage (basement) is composed of rock complexes of the Uralian foldbelt. The relevant zones composed of these complexes [10] (Fig. 1) continue largely structures defined in the exposed part of the Urals [11, 12, and others]. The middle structural stage is represented by Triassic volcanogenic and subordinate terrigenous–volcanogenic sequences that fill in some grabens in the region. The upper structural stage consists of Jurassic and younger sediments of the West Siberian megabasin (1.5–2.3 km thick in the study area and thicker in northern areas). In the Shaim petroliferous region, the pre-Jurassic geological complexes constitute two principal tectonic structures: (1) Triassic Danilov Graben, which has tectonic boundaries with western and eastern Paleozoic complexes; (2) Late Paleozoic granite–schist axis (or the so-called Shaim–Kuznetsov meganticlinorium) located east of the Danilov Graben. In the southern part of the region under consideration, the granite–schist axis and Danilov Graben contact each other. In the northern area, they are separated by sandy–shaly sequences. Between the Shaim and Supra settlements in the southwest and northeast, respectively (Figs. 1, 2), the latter sequences are supplemented with the Paleozoic complex represented largely by ophiolites (serpentinite melange, gabbroids, plagiogranites, and basalts with jasper interbeds).

Ultramafic rocks representing a lower structural element of the ophiolite complex in the region are best studied in the Uzbek and Khultur exploration drilling fields. They are entirely serpentinized and usually disseminated with bastite (serpentine pseudomorphs after orthopyroxene) that constitutes up to 10–20 vol % (locally up to 35 vol %). Therefore, the rocks can be

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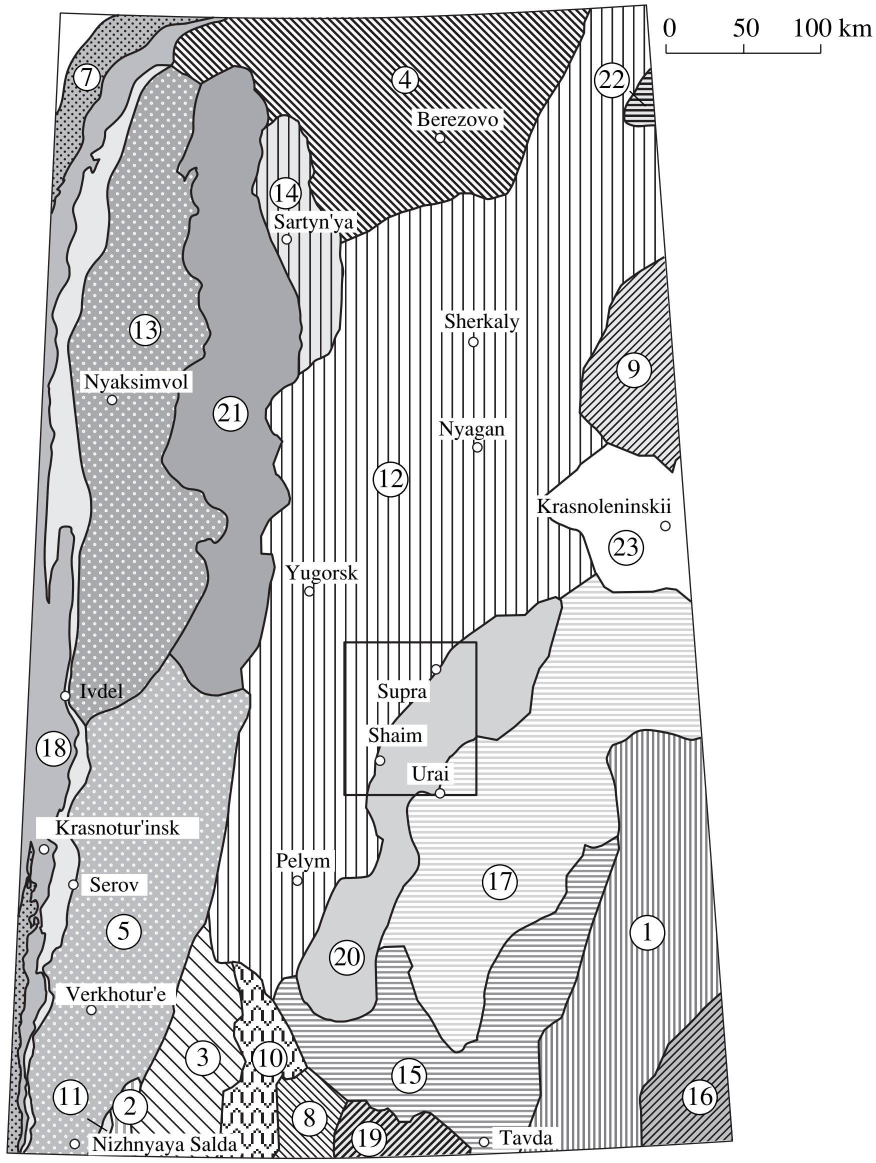

Fig. 1. Lithotectonic zones of the basement in the western part of West Siberia. Encircled numbers: (1) Tyumen–Kustanai Trough, (2) Adui, (3) Alapaevsk–Techensk, (4) Berezovo, (5) Verkhnyaya Tura–Iset, (6) East Tagil, (7) West Tagil, (8) Irbit; (9) Kazym; (10) Krasnogvardeisk, (11) Medvedevo, (12) Pelym, (13) North Sos'va, (14) Sartyn'ya, (15) Tavda, (16) Tobol–Ubogan Uplift, (17) Urai, (18) Central Tagil, (19) Shadrino, (20) Shaim–Kuznetsovo, (21) Yalbyn'ya–Ponilov, (22) Yarudei, (23) Krasnoleninsk. The rectangle designates area of Fig. 2. Figures 1 and 2 were compiled with the assistance of V.V. Kormil'tsev.

attributed to apoharzburgite serpentinites. According to petrochemical data, these serpentinites have been developed after rocks of the Alpine-type complex (lherzolites, dunites, and harzburgites). The ultramafics are characterized by elevated Ni and Cr contents (up to 2500 and 3000 ppm, respectively), which indicates their affiliation to the ophiolite association. The REE distribution in the serpentinites is identical to that in lherzolites of mid-oceanic ridges [13 and others].

The serpentinites are largely represented by antigorite varieties with relatively abundant thin chrysotile–asbestos and carbonate strings. This is related to progressive metamorphism that influenced the ophiolite sequence during intrusion of Late Paleozoic granites that are widespread in the region. In thin sections, antigorite constitutes radiaxial-fibrous and shieflike aggregates frequently with powdery accumulations of ore mineral (magnetite). According to microprobe analysis, serpentine is characterized by low FeO and Al_2O_3 contents (up to 6 and 2 wt %, respectively). Locally, it contains relict xenomorphic chrome spinel grains with rims of Cr-magnetite. In terms of the composition, chrome spinel can be classed with Fe–Al magnesian chromite with the Mg content ranging from 53 to 67% (central parts of grains).

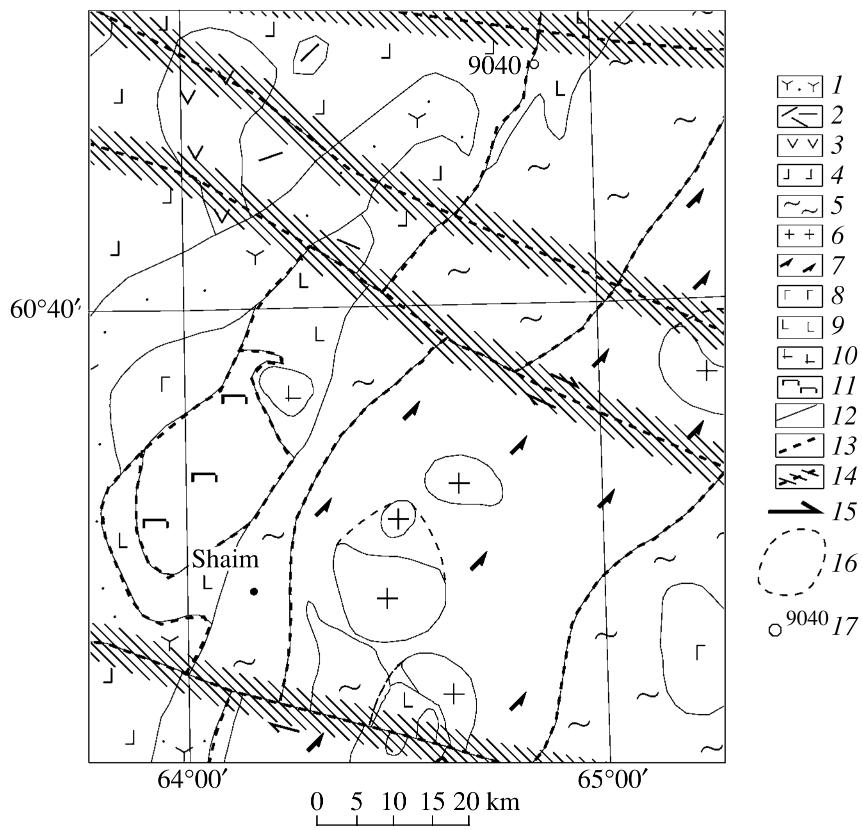

Fig. 2. Schematic geological map of the pre-Jurassic basement in the central part of the Shaim petroliferous region. (*1*) Triassic volcanics dominated by mixed tuffs; (*2*) Triassic rhyolite–basalt formation (rhyolites); (*3*) Triassic rhyolite–basalt formation (basalts); (*4*) Lower Triassic basalts; (*5*) Paleozoic terrigenous–shaly formations; (*6*) Early Permian granitoids; (*7*) metamorphic schists fringing granitoids; (*8*) gabbro; (*9*) Ordovician basic volcanics; (*10*) plagiogranites; (*11*) serpentinites; (*12*) stratigraphic and intrusive contacts; (*13*) tectonic contacts; (*14*) faults accompanied by brecciation and foliation zones; (*15*) thrusting direction; (*16*) contours of granite massifs buried beneath pre-Jurassic formations; (*17*) location of Well 9040.

Volcanics from the ophiolite complex have been studied in the Lovinskii, Filippovskii, and Yakhlinskii petroleum exploration fields of the Shaim region. They are highly altered and usually replaced entirely by carbonate–clayey material. In some basaltoids, volcanic glass is transformed into clayey aggregates, plagioclase laths are entirely carbonatized, and pyroxene grains are replaced by chlorite aggregate. Sometimes, volcanics contain relicts of primary minerals (plagioclase and clinopyroxene), while volcanic glass is missing. This feature makes Paleozoic basalts distinctly different from neighboring Triassic basalts of the Danilov Graben.

In the Filippovskii field, Well 9040 (Fig. 2) penetrated chloritized basic volcanics dominated by plagioclase-rich basaltic porphyrites in the interval of 1962–1967 m (hole bottom). They enclose a thin conformable interlayer of red bedded and bedded–brecciated jaspers (radiolarites). Poorly to moderately preserved radiolarian remains constitute up to 20–25% of the rock. Jasper sample F9040/1966 taken from the depth of 1966 m yielded the most representative radiolarian assemblage observable in both thin sections and residues (the thin sections were substantially more informative). E.O. Amon determined 25 radiolarian species belonging to 17 genera and 8 families. **Family Inaniguttidae** is represented by *Inanigutta* cf. *gansuensis* Wang, *I.* cf. *akdymensis* (Nazarov), *I.* cf. *complanata* (Nazarov), *I.* sp., *Inanibigutta* cf. *excurrens* (Nazarov), *Oriundogutta* cf. *ramificans* (Nazarov), *O.* sp., *Inanihella* cf. *bakanasensis* (Nazarov), *In.* cf. *penrosei* (Ruedemann et Wilson), *In.* sp., *Futobari* sp., *Zadrappolus* sp.; **family Entactiniidae**, by *Entactinia* cf. *atypica* Nazarov; **family Haplentactiniidae**, by *Haplentactinia* sp., *Syntagentactinia* sp., *S.* cf. *pauca* Nazarov, and *Haplotaeniatum* sp.; **family Rotasphaeridae**, by *Secuicollacta* sp. and *Rotasphaera* sp.; **family Pseudorotasphaeridae**, by *Pseudorotasphaera* sp.; **family Palaeoactinosphaeridae**, by *Palaeoactinosphaera* sp.; **family Pylentonemidae**, by *Bipylospongia* sp. and *Cessipylorum* sp.; and **family Sponguridae**, by *Pseudospongoprunum* sp. Figure 3 demonstrates SEM photographs of the most characteristic radiolarian forms.

The analysis of the taxonomic composition allows us to establish the stratigraphic position and geological age of this radiolarian assemblage as Late Ordovician (Ashgillian). This age is indicated by the following key

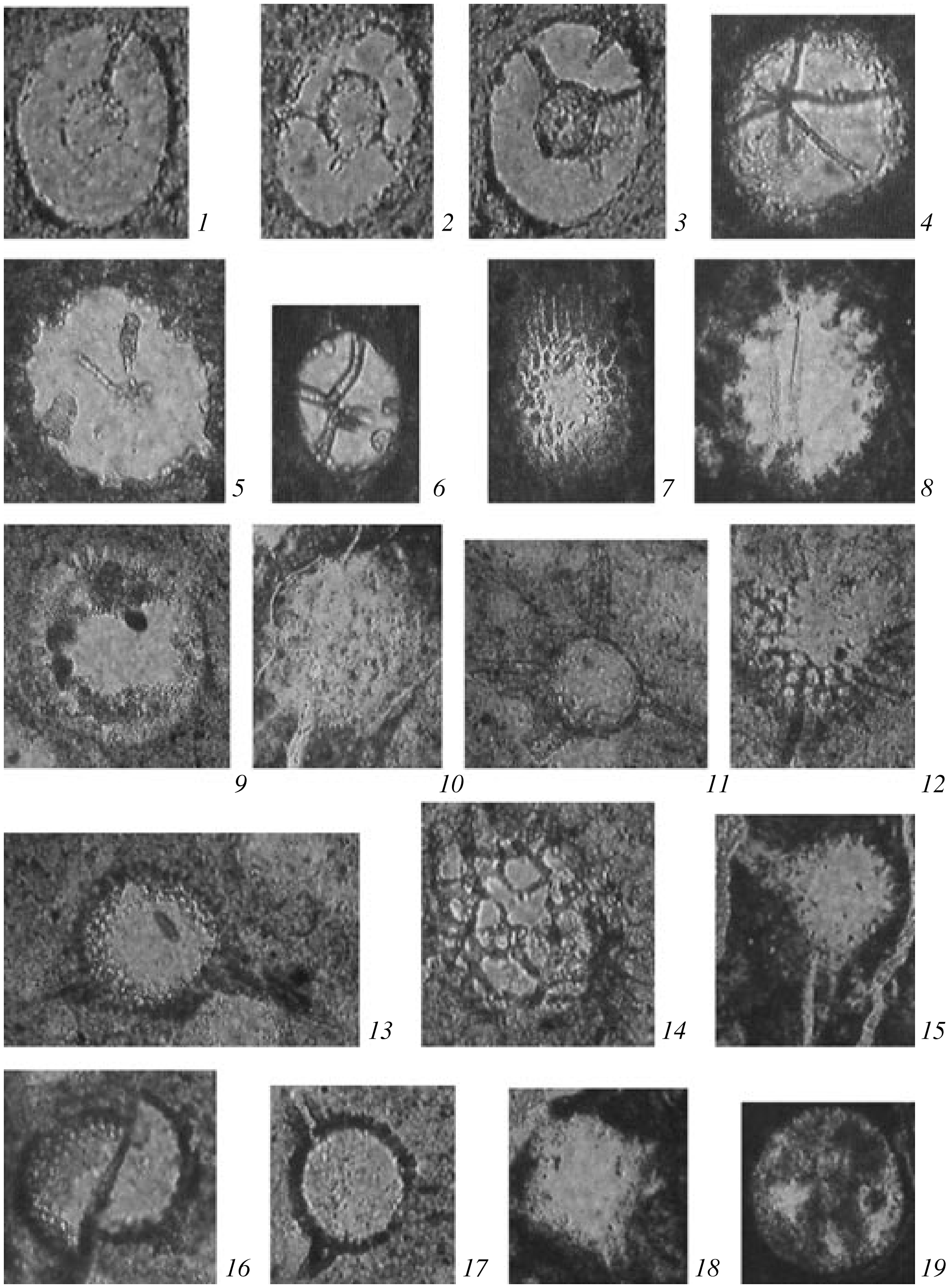

Fig. 3. Upper Ordovician radiolarians from ophiolites of the Shaim area. (*1–3*) *Inanibigutta* cf. *excurrens* (Nazarov): (*1*) Specimen 01-07-42, ×283, (*2*) Specimen 01-07-43, ×283, (*3*) Specimen 01-07-44, ×219; (*4, 5*) *Oriundogutta* cf. *ramificans* (Nazarov): (*4*) Specimen 01-06-33, ×286, (*5*) Specimen 01-06-60, ×213; (*6*) *Entactinia* cf. *atypica* Nazarov, Specimen 01-06-55, ×223; (*7*) *Bipylospongia* sp., Specimen 01-06-56, ×193; (*8*) *Haplentactinia* sp., Specimen 01-03-28, ×145; (*9*) *Inanihella* nf. *bakanasensis* (Nazarov), Specimen 01-06-22, ×170; (*10*) *Syntagentactinia* cf. *pauca* Nazarov, Specimen 01-03-36, ×175; (*11*) *Inanigutta* cf. *gansuensis* Wang, Specimen 01-07-20, ×182; (*12*) *Inanigutta* cf. *akdymensis* (Nazarov), Specimen 01-07-24, ×218; (*13*) *Inanigutta* cf. *complanata* (Nazarov), Specimen 01-07-29, ×184; (*14*) *Secuicollacta* sp. Specimen 01-07-15, ×206; (*15, 17, 18*) *Pseudorotasphaera* sp.: (*15*) Specimen 01-02-15, ×208, (*17*) Specimen 01-07-31 (with hollow channels inside main rays), ×196, (*18*) Specimen 01-02-45, ×183; (*16*) *Inanigutta* sp., Specimen 01-07-14 (broken along the microfissure), ×192; (*19*) *Cessipylorum* sp., Specimen 01-01-44, ×140.

taxa: *Inanibigutta excurrens* distributed in the Upper Ordovician of eastern and central Kazakhstan, southern Scotland, North America, the Subpolar and Southern Urals; *Inanihella bakanasensis* occurring in the Middle–Upper Ordovician of central and eastern Kazakhstan, the Subpolar and South Urals; *Inanihella penrosei* known from the Middle–Upper Ordovician of North America, eastern Kazakhstan, the South Urals, and

China; *Syntagentactinia pauca* developed in the Middle–Upper Ordovician of eastern Kazakhstan and the South Urals; *Inanigutta gansuensis* characteristic of the Middle–Upper Ordovician of China; *Inanigutta akdymensis* recorded in the Middle–Upper Ordovician of eastern Kazakhstan and the Subpolar and South Urals; *Inanigutta complanata* reported from the Middle–Upper Ordovician of eastern Kazakhstan, the Subpolar and South Urals; *Haplentactinia* sp. similar to *Haplentactinia baltica* that is a zonal species in the Upper Ordovician of the Baltic region [14, 15, and others].

The radiolarian-based age is confirmed by finds of the Middle–Late Ordovician conodont species *Peridon* sp. extracted from the same jasper interlayer using 10% hydrofluoric acid (determination by G.N. Borozdina and V.A. Nasedkina). The new find of Ordovician radiolarians widens the known distribution area of Early Paleozoic representatives of this group in the Northern Hemisphere. Judging from its taxonomic composition, the radiolarian assemblage under consideration is close to their Late Ordovician counterparts from the South Urals and Kazakhstan, which implies connections between Ordovician basins of West Siberia, the South Urals, and central and eastern Kazakhstan. Moreover, they probably constituted a single ocean.

Thus, the data obtained in the course of these studies made it possible to determine the Late Ordovician age of basalts from the ophiolitic association of the West Siberian basement in the Shaim area. It is conceivable that other complexes of this ophiolite association (serpentinites, gabbro, and others), which constitute a single crustal block of the oceanic type, are also Late Ordovician rocks. In the Urals, the Late Ordovician Shemur Complex (Tagil zone, Middle and North Urals) and the upper (also Ordovician) part of the Sugraly basalt complex (Sakmara zone, South Urals) are closest in age and composition to ophiolites of the Shaim area.

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