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Geological Structure and Historical Development of Pre-Jurrasic Basement of West Siberia Oil- and Gas-Bearing Megabasin Karabash Zone

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Abstract

An additional comprehensive study of the west Siberia Karabash zone basement has been conducted. Core samples from more than 300 wells that opened the rocks of the basement were analyzed by different methods. A new map of the pre-Jurassic basement of Karabash zone of the west part of the Khanty-Mansi Autonomous Okrug (KhMAO) has been made. For the first time for the West Siberia megabasin U-Pb dating was made for samples from Shaim-Kuznetsovsk meganticlinorium and late to middle Devonian ages were obtained. The Devonian ages was obtained for metamorphic complexes of the region and, in general, for the basement of West Siberia. The complexes considered as Precambrian before that. The obtained results enable significantly to clarify more exact history of pre-Jurassic rock forming for the basement of the west part of West Siberia craton and its structure in the limits of Karabash zone. Thus, obtained data testify that in pre-Jurassic basement of the west part of the West Siberia (Karabash zone), filling grabens basalt effusion began during Permian time (probably at the end of early Permian) at sublatitudinal compression, that is, at collision, possibly immediately after or subsynchronously with the origin of the granite. On the edge of Permian and Triassic (or in early Triassic), sublatitudinal compression changed into stretching, and submeridional grabens came to existence and basalt effusion came up to the maximum.

Keywords

Zircon, Age Definition, West Siberia, Pre-Jurassic Basement, Triassic Graben-Rifts

1. Introduction

Recently, we have conducted an additional comprehensive study of the West Siberia Karabash zone basement (**Figure 1**) using core samples from more than 300 wells that opened the rocks of the basement. The study utilizes petrography, petro-geochemistry, geochemistry, geochronology and biostratigraphy methods. The Devonian ages were obtained for metamorphic complexes of the region and, in general, for the basement of West Siberia. The complexes considered as Precambrian [1] before that. We take into account these new data as well as data obtained earlier (by ourselves and our predecessors) along with several seismo-profiles that give a lot of diverse information on deep structure of the region [2] [3], the map of gravitational anomalous field (GAF), maps of anomalous magnetic field (AMF) with a scale of 1:200,000, a new map of the pre-Jurassic basement of Karabash zone of the west part of the Khanty-Mansi Autonomous Okrug (KhMAO).

The cartographic model development process was based on ArcGIS technologies and other applications. The model of the basement represents a multi-layered structure of metadata in vector and raster formats in coherent absolute geographical space. The research purpose is to construct a new geological map of the area that allows to discuss more exact history of pre-Jurassic formation of the basement; to explain our geodynamic scheme of stretching and compressing of

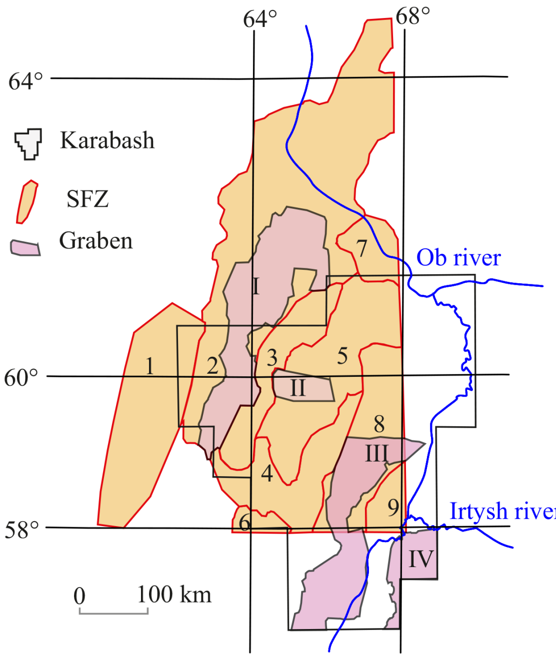


Figure 1. Karabash zone of West Siberia and earlier defined (Sazhnova *et al.*, 2006) structural formational zones (SFZ). SFZ: 1—Verkhotursk-Isetsk; 2—Pelym containing Danilovka graben (I); 3—Shaim-Kuznetsovsk; 4—Tavda; 5—Uray containing Polovinka graben (II); 6—Shadrinsk; 7—Krasnoleninsk. 8—Tyumen-Kustonay bending flexure containing Tyumen graben and 9—Tobolsk-Ubogan uplifting. Grabens: I—Danilovka, II—Polovinka, III—Tyumen, IV—Ashlyk. The red lines are contours of SFZ, the blue lines are rivers, and the grey lines are contour of Karabash area (**Figure 2**).

earth's crust; and make more exact time of filling graben basalt effusion.

On the basis of conducted studies, a well-founded version of the geological structure of the territory was proposed (**Figure 2**).

2. Geological and Geophysical Background

2.1. Geology

A modified and replenished geological map of the pre-Jurassic basement of the west part of the West Siberia plate is based on complex geological and geophysical studies and has been mapped earlier in big territory segments [4] [5]. We conducted structural and formational regionalization of the pre-Jurassic basement of the west part of KhMAO (**Figure 1**) together with Yu. N. Fedorov, V. V. Kormil'tsev, etc. [6]. We marked out 9 submeridional structural and formational zones (SFZ) differing in the set and structure of the compiled formations, geological development history and physical fields, respectively. Judging by sharp changes of lithological rock complexes and the character of physical fields, we suggest that all submeridional contacts between different SFZ in the region under study are tectonic.

Triassic graben-rifts were superimposed on these Paleozoic structures. They are shown in **Figure 1** and can be traced with Triassic formations in **Figure 2**. The most studied graben-rift is the westernmost Danilovka graben (**Figure 1**, I). Polovinka sublatitudinal graben (**Figure 1**, II) is situated eastward of Danilovka graben. Another two Triassic graben-rifts—Tyumen (**Figure 1** III) and extreme eastern Ashlyk (**Figure 1**, IV)—make up most of the south-east sector of the map.

In the basement of stratificated formations of Karabash, there are metamorphized strata that earlier (before our studies) were considered as Precambrian and are mainly represented by sialic schists - green chlorite-albite, epidote-albite, epidote-amphibolite and other schists and significantly less often by gneiss. As a rule, they have a low enough degree of metamorphism in the limits of the greenschist facies and seldom - lower parts of amphibolite facies. These metamorphites constitute a part of trans-Ural anticlinorium (in the very western edge of the map). Eastward, these strata form so-called "granite-schists axis" (our name), or more precisely, Shaim-Kuznetsovsk (**Figure 1**, Shaim-Kuznetsovsk SFZ) uplifting (or meganticlinorium), and contain a lot of granite massifs. In the north-east part of the map, metamorphic strata form a part of Kraskoleninsk arch (**Figure 1**, Krasnoleninsk SFZ).

At the end of the Paleozoic geodynamical history of the region was a collision accompanied by piling up, metamorphism, intrusion of granites and new continental crust formation. One of the biggest blocks of this crust is Shaim-Kuznetsovsk meganticlinorium (**Figure 1**, Shaim-Kuznetsovsk SFZ), which is represented by a chain of monzodiorite-granosyenite massifs and their metamorphic schist flanking. The metamorphic rocks are dominated by quarts-sericite, sericite-quarts, albite-chlorite-quarts, and graphite-quarts schists that originated in

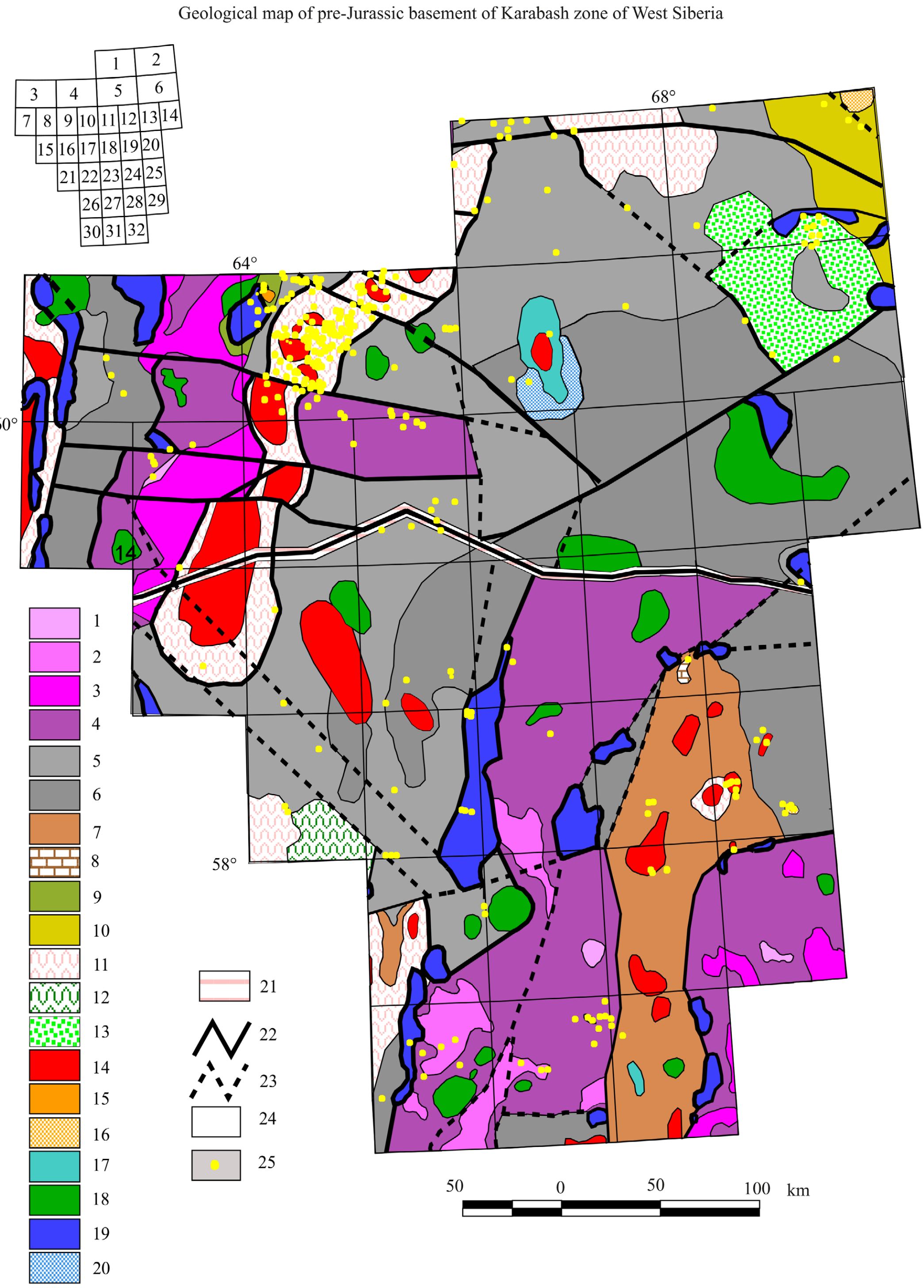


Figure 2. The geological map of Karabash zone (made by Ivanov K. S. and Kostrov N. P.). The layout of the map sheets 1:200,000 is shown in the left upper corner. 1—Triassic liparites; 2—basalt-terrigenous Triassic formation; 3—effusive rocks with prevalence of tuffs with hybrid composition; 4—basalt of early Triassic; 5—terrigenic-schist formation of Carboniferous; 6—effusive rocks of D_3-C_1; 7—Devonian volcanogenic-sedimentary strata; 8—limestones of D2-3; 9—basalt porphyrites, diabases, jasper of lower Paleozoic; 10—volcanogenic and volcanogenic-sedimentary island-arc strata of late Ordovician-middle Devonian; 11—sialic gneiss, shales; 12—amphibole shales; 13—green chlorite-albite shales; 14—granitoids; 15—plagiogranites; 16—granodiorites; 17—diorites; 18—gabbro; 19—serpentinites, ultrabasites; 20—pyroxenites, dunite; 21—schistosity zone; 22—faults; 23—supposed faults; 24—grid of 1:200,000 map; 25—wells.

conditions of the greenschist and more rarely in condition of the lower of amphibolite facies. The surface of the pre-Jurassic basement within the limits of the Shaim-Kuznetsovsk SFZ is 1.4 - 1.7 km in depth, according to numerous wells that opened the basement rocks.

2.2. Geophysics

Creating the map (**Figure 2**) we used gravitational (**Figure 3**) and anomalous geomagnetic field maps (AMF), **Figure 4**, as well as the data obtained from boreholes. We include in the analyses maps of physical fields because boreholes unevenly spaced and their depths are limited by law in Russia. The first natural question is that whether or not we applied reduction to the pole (RTP) of the AMF map.

There are a lot of publications on reduction to the pole including comprehensive reviews that pointed out on the main troubles and limitations of the method as well as overcoming the limitations. The algorithm can perform the reduction to the pole stably at any magnetic latitude, and the constructed RTP field yields a good representation of the true field at the pole even when the reduction is carried out at the equator [7]. The RTP method requires knowledge of the direction of magnetization, often assumed to be parallel to the ambient field, as would be the case if remanent magnetization is either negligible or aligned parallel to the ambient field. If such is not the case, the reduced-to-the-pole operation will yield unsatisfactory results. Reduction to the pole is now routinely applied to all data except for data collected at high magnetic latitudes [8]. The modified DRTP (differential reduction-to-the-pole) operator successfully reduces the magnetic anomalies at low latitudes to the pole [9]. Guspí F. and Novara I. [10] have developed an equivalent-source method for performing reduction to the pole and related transforms from magnetic data measured on unevenly spaced stations at different elevations. The equivalent source is composed of points located vertically beneath the measurement stations, and their magnetic properties are chosen in such a way that the reduced-to-the-pole magnetic field generated by them is represented by an inverse-distance Newtonian potential. Zhang *et al.* [11] present a stable RTP approach using a nonlinear threshold method with better RTP performance for magnetic data at low latitudes. In the new nonlinear thresholding RTP (NTRTP) method, the routine RTP operator is divided into two parts (the real part and the imaginary part), which are modified respectively based on a nonlinear threshold to suppress the large amplitude linked to instability. A Taylor series iterative (TSI) method is proposed to improve the stability and accuracy of RTP at low latitudes by Hao *et al.* [12]. Finally, combined with the reduction to the equator (RTE), the RTP factor of magnetic data at any latitude is achieved [12]. Remanent magnetisation adversely impacts the success of the transformation. The analitic-sygnal amplitude (ASA) of the data of the zeroth-order gives good results on synthetic data provided that any noise is handled appropriately [13].

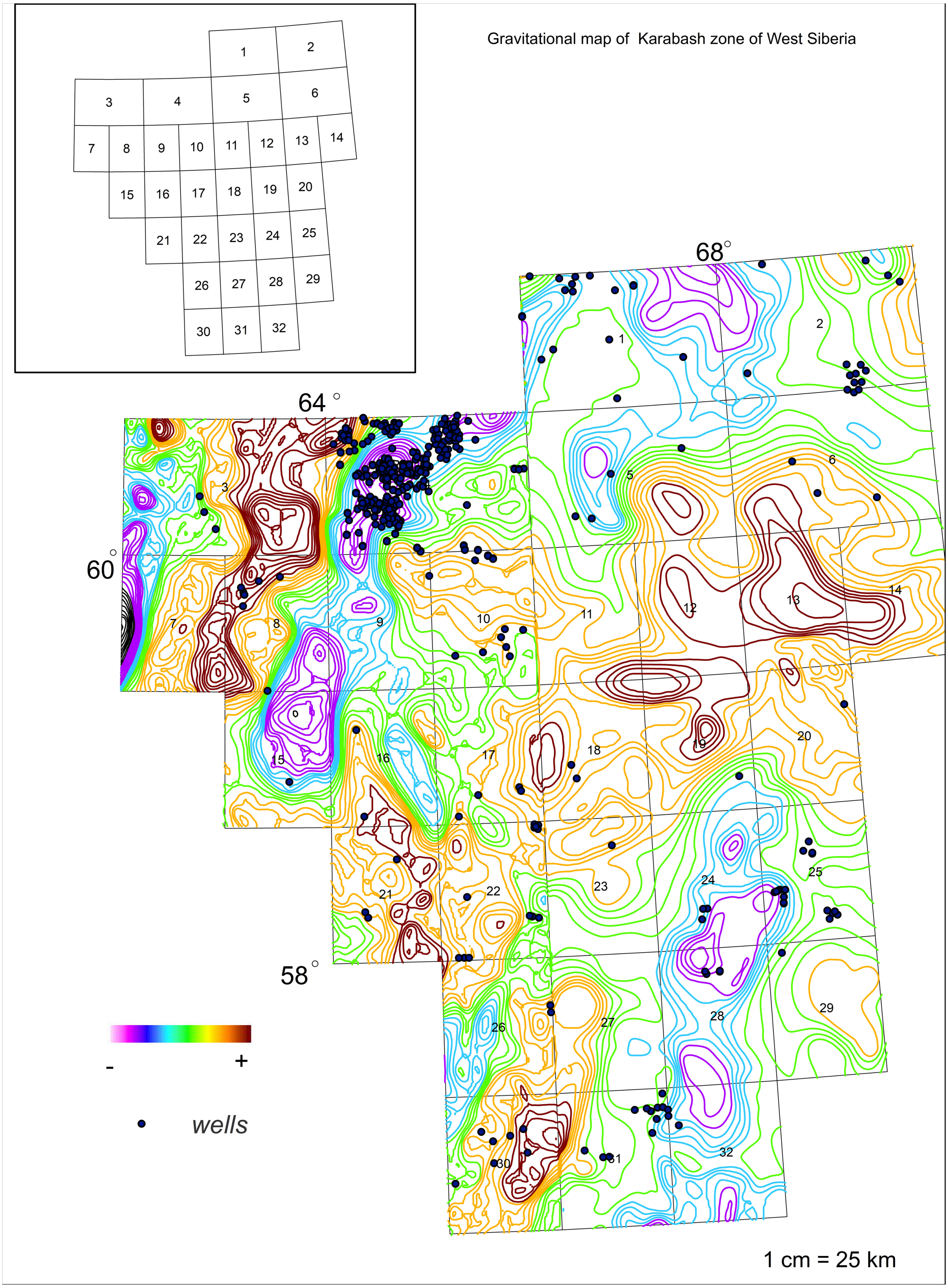


Figure 3. Gravitational schematic map of the area.

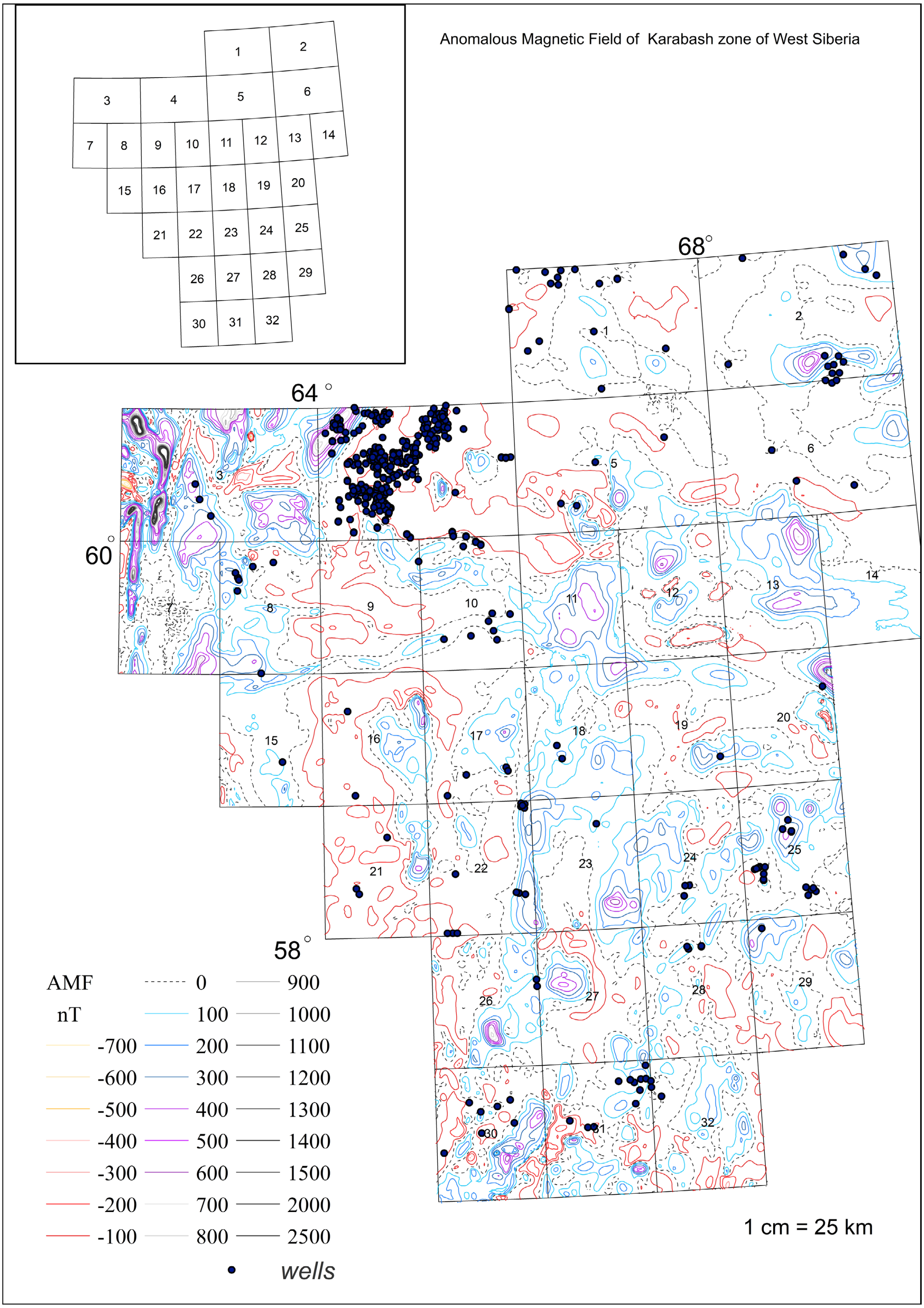


Figure 4. Schematic anomalous magnetic field (AMF) map of the area.

We consider that there is no need to reduce to the pole the AMF map (**Figure 4**) at our latitudes. Besides, it is possible that in the area there are geological bodies at the depth of about 10 km with remanent magnetization opposite to the currect AMF [14].

Schistosity zone with the fault clearly visible on the AMF at the square 8 to 9 (**Figure 4**).

3. Study Methods and Samples

3.1. Methods

For the rocks and constituent minerals, a complex set of up-to-date methods for substance research was applied. The chemical composition of the minerals was tested with electron probe X-ray spectrum microanalysis using CAMECA SX 100 at The Federal State Institution of Science the Zavaritsky Institute of Geology and Geochemistry of the Ural Branch of the Russian Academy of Sciences (IGG UB RAS) in Yekaterinburg, Russia, and JEOL-733 Superprobe devices at the federal state budgetary institution of Science Institute of Mineralogy of the Ural Branch of the RAS (Institute of mineralogy UB RAS) in Miass, Russia, etc. The silicate analysis of the rocks was conducted with electron probe X-ray spectrum analysis devices CPM-18 and EDX-100 at IGG UB RAS (Russia, Yekaterinburg). The geochemical characteristics of the rocks were obtained by mass-spectroscopy with inductively coupled plasma (ICP-MS) using ELAN-9000 and Element2 devices at IGG UB RAS (Russia, Yekaterinburg). Zircons were analysed with a high-resolution ionic microprobe SHRIMP-II at the Centre of Isotopic Research (CIR) of Federal State Budgetary Institution A.P. Karpinsky Russian Geological Research Institute (VSEGEI) in St. Petersburg, Russia.

3.2. Samples

3.2.1. Samples from Shaim-Kuznetsovsk Meganticlinorium

Chemical compositions of the metamorphic rocks of Shaim-Kuznetsovsk meganticlinorium usually are similar to each other. By content, SiO_2 of 51.61 - 63.34 weight percentage, the studied rocks are possibly classified as metamorphic. The content of Al_2O_3 in rocks is 11.58 - 15.43 and $Na_2O + K_2O$ is 3.03 - 6.26 weight percentage. A trend of rare earth elements (REE) distribution normalized to chondrite demonstrates a sharp predominance of the light lanthanides over the heavy ones and the absence of europium anomaly (**Figure 5**).

For the first time for the West Siberia megabasin, we conducted U-Pb dating (SHRIMP II by zircon) for two samples of two-mica schist from Shaim-Kuznetsovsk meganticlinorium. The samples were taken from wells To10804 (the core from the depth of 1768 m) and To1857 (the core from the depth of 1738 m) of Tolum oil prospecting square. The zircons from the sample To1857/1738 range from 50 to 200 μm. The minerals have a pink colour and rhythmic-zonal internal structure, often with sectorial structures. The crystals are well facetted, having prismatic habitus sometimes with development of two dipyramids and basal pinacoid. From the sample To1857/1738, we analysed 7 zircon crystals. Most concordant ages fell into the range of 369 - 395 Ma (**Figure 6(a)**), but some were more ancient, and some were younger: 2709, 503, 426, 295 and 261 Ma.

In the sample To10804/1768, the zircons have slightly pink colour and grain size from 60 to 170 μm. The zircons occur as well facetted crystals of prismatic appearance, sometimes with basal pinacoid development. In the sample To10804/1768, we analysed 10 zircon crystals. Practically all obtained datings lay on the concordia 358 - 385 Ma, excluding crystal №9 that is more ancient 453 Ma (**Figure 6(b)**). The most "ancient" dating of 2709, 503 Ma (To1857/1738m) was obtained in the central parts of crystals that probably are xenogenic.

We interpret single "young" datings of two-mica rocks of 295 and 261 Ma and earlier obtained ages from quarts-sericite schists by K-Ar method 277 - 302 Ma (Ivanov *et al.*, 2005, etc.) as rock metamorphism age that is near to the age of

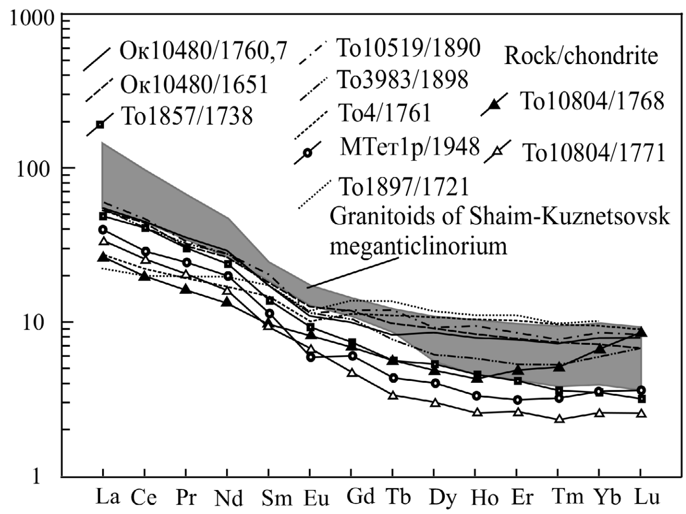


Figure 5. Diagram of REE distribution normalized to chondrite from the metamorphic rocks of Shaim-Kuznetsovsk meganticlinorium.

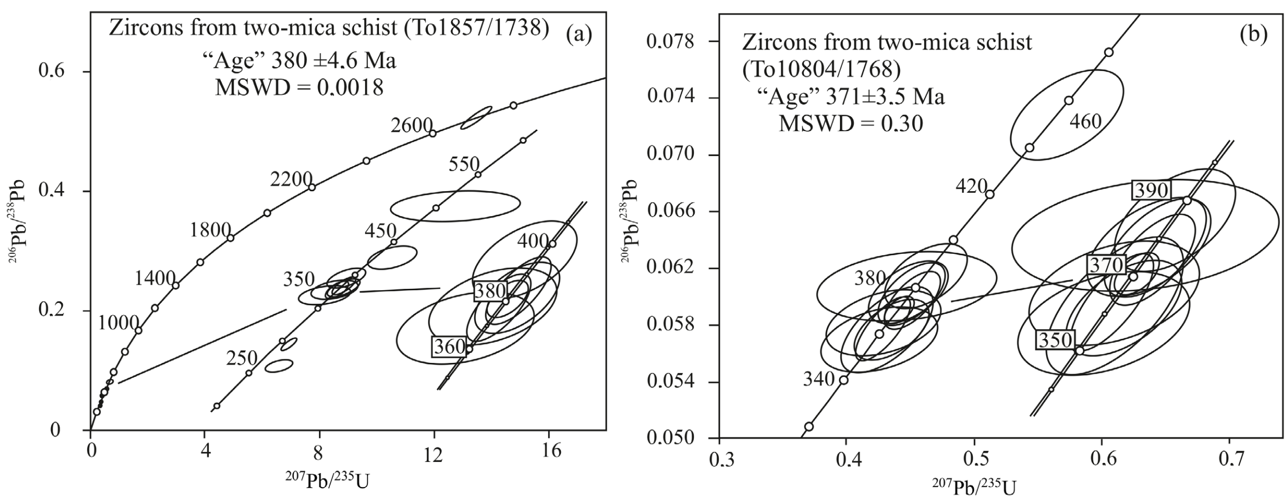


Figure 6. Concordia diagram for the zircon from two-mica schists of Tolum: (a) well 1857 (To1857) and (b) well 10,804 (To10804). MSWD—middle square weighted deviations.

formation of monzodiorite-granosyenite massifs of Shaim region. Out of 17 analysed zircons, 15 had middle-late Devonian ages and two had late-Ordovician-early-Silurian ages. Thus, the main part of protolith for the metamorphic rocks of Shaim-Kuznetsovsk meganticlinorium apparently have later and middle Devonian ages (395 - 358 Ma), which is in agreement with earlier obtained dating by U-Pb method ID-TIMS (Isotope Dilution Thermal Ionization Mass Spectrometry) from analysing zircons of quarts-sericite schists of the area [15].

3.2.2. Samples from Granitoids of Nyalinsk Square

The zircons from granitoids of Nyalinsk (**Figure 2**, square 2) well 13 are up to 250 μm. They have different (whitish, light pink and brown) colours and rhythmical zonal internal structure, often with sectorial structure. The crystals are well facetted and have habitus from short prismatic to isometric, usually with development of two dipyramids and absence of basal pinacoid. The obtained U-Pb datings well fit concordia [16] in the band of 441 - 444 Ma that is on the border of Silurian and Ordovician.

3.2.3. Samples from Late Carboniferous Collisional Granitoids of Shaim-Kuznetsovsk

The zircons selected for U-Pb dating have a grey-pink colour and size of 0.3 mm. The crystals have complex faceting. Among simple forms, two tetragonal prisms and three tetragonal dipyramids were distinguished. In cathodoluminescence rays, the zircons demonstrate complicated internal structures. In some crystals, growth zones of late generation are clearly visible.

U-Pb age definition by single zircons was made on an ion microprobe SHRIMP-II at CIR VSEGEI. From granosyenite, 7 crystals were analysed, by which 12 age definitions were made. The main portion of zircon ages ranges from 291.7 to 309.5 Ma with average 301.6 ± 3.6 Ma (**Figure 7(a)**). Similar age was established also for other squares from Shaim-Kuznetsovsk meganticlinorium, for example, for Vostochno-Okunevsk granite (**Figure 7(b)**) as well as for Kamensk and

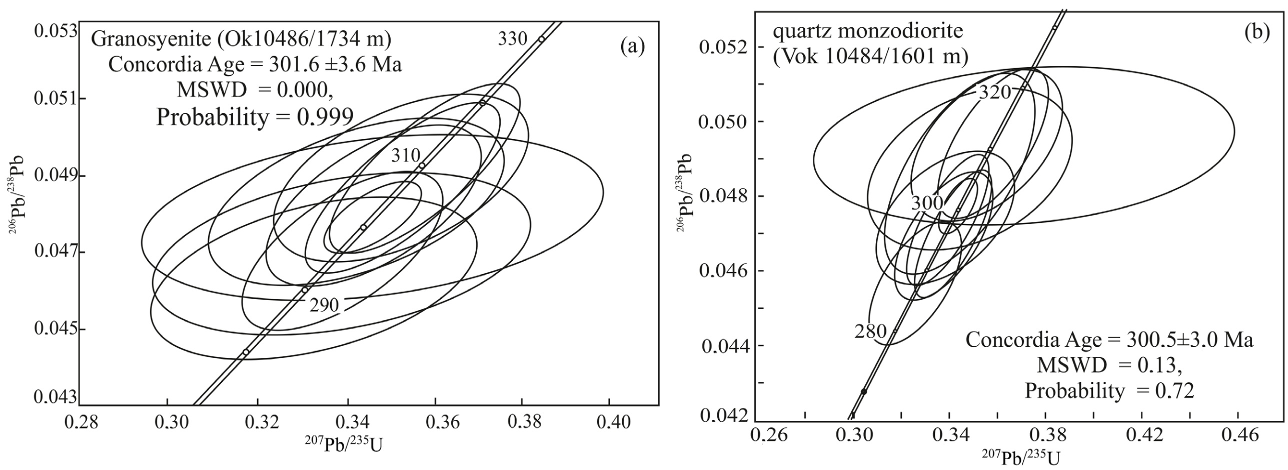


Figure 7. Isotopic U-Pb diagram with concordia for zircons from granitoids of Okunevsk (a) and Vostochno-Okunevsk (b) squares (**Figure 2**, square 4). MSDF is middle square weighted deviations.

Severo-Kamensk squares situated significantly northward, indicating simultaneous origin of Shaim-Kuznetsovsk meganticlinorium granites.

3.2.4. Samples from Late Paleozoic Collisional Granitoids

On the whole, the study of material composition of the granitoid shows that the rocks were subjected to intense secondary changes and active tectonic processing. This is proved with dating by the K-Ar method (K = 3.55%; $^{40}Ar_{rad}$ = 57.60 ng/g; T = 220 ± 8 Ma; IGG UB RAS, analyst B. A. Kaleganov). The dating obviously shows not the time of magmatic intrusion of the rock, but the date of superposition of secondary changes. The K-Ar method like the Rb-Sc method gives understated rock age of 247.4 ± 9.1 Ma.

The zircon forms well generated two-headed crystals and their fragments (see Figure 8(a)). Most of the crystals have corroded facets that indicate partial dissolution, confirming the superposed secondary changes. The studied zircons give concordant age 277.5 ± 2 Ma (Figure 8(b)). In addition, several grains registered with other datings: 298, 266, 231 and 60 Ma. The most "ancient" age was in the kernel of zircon, but the youngest (60 Ma) age was obtained in the edge zone.

Thus, we conclude that granitoids of Vostochno-Shebursk square (Figure 2, square 5) underwent multiple stages of transformation induced by different processes and shifted isotopic-age marks of the rock. Based on these results, it is possible to suggest that magmatic intrusion and crystallization of granite intrusion happened in lower Permian time.

Young datings from 266 to 66 Ma were obtained from rock analyses (K-Ar, and Rb-Cs methods) and from some analyses of accessory minerals, reflecting the influence of different stages of tectonomagmatic activation taking place often in the pre-Jurassic basement of West Siberia [17].

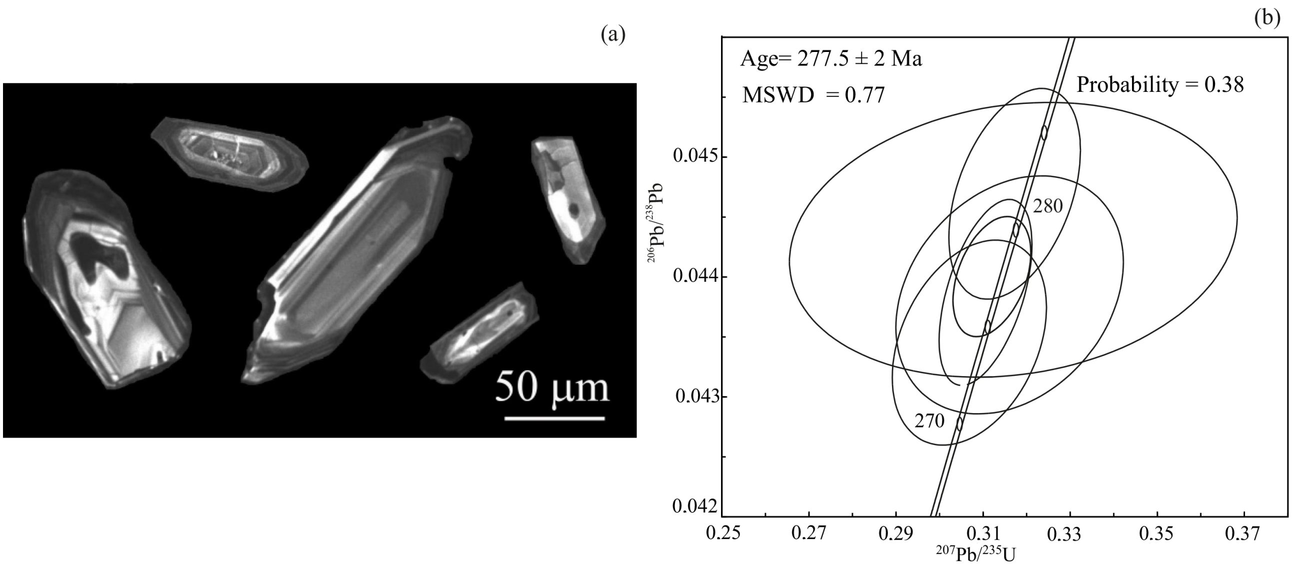


Figure 8. Cathodoluminescence images of the zircons from Vostochno-Shebursk square (a) and SHRIMP-II isotopic U-Pb diagram with concordia for zircons from Vostochno-Shebursk square (b).

The only "ancient" (298 Ma) dating was established in the kernel of zircon that probably is a xenogenic one. This can be explained because in the frame of granitoids of Vostochno-Shebursk square, there are terrigenous-schist complexes of middle-upper Paleozoic, and schists of Carboniferous age prevail. It is possible this zircon was trapped by granitoids during melting of these sediments.

3.2.5. Samples from Triassic Formations

The dating was performed by the K-Ar method at the Institute of Mineralogy UB RAS under the guidance of A. V. Tavrin. From the separated pyroxene monofractions from the samples of basalts of Symoriyakh 10，249 (depth of 2138 m) (is about 71 km to the north from the northern border of squarer 4 on Figure 2 in the limits of Danilovka graben Figure 1, I) well, the age obtained for the Danilovka graben is 249.4 ± 4.5 Ma. By pyroxene from basalts of Kruglaya 1p (depth 1900 m) (south border of square 4 near to the N-E corner of square 9 on Figure 2) well drilled, the age obtained for the Polovinka graben is 275.7 ± 10.4 Ma (Figure 9).

4. Geological Formations of Karabash Zone

4.1. The Volcanites of the Ophiolite Complex

The ophiolite complex on the map (Figure 2) is a chain of porphyrites, diabases, jasper, gabbro, and serpentinites stretching along eastern border of Danilovka graben (the north-west corner of square 4 in Figure 2). The most ancient strata of Karabash zone that were given faunistic characteristics belong to the late Ordovician and are ophiolite complexes represented by fresh ultrabasites (lherzolite), gabbroids, and basalts containing thin interlayers of red jasper with radiolarians and conodonts. These complexes were revealed in the west part of the map, straight to the west of metamorphic strata of Shaim-Kuznetsovsk uplift.

The volcanites of the ophiolite complex were studied in the Lovinsk, Filippovsk and Yakhlinsk oil prospecting squares situated in the limit of Danilovka graben (Figure 1, I). They were strongly changed, often completely substituted

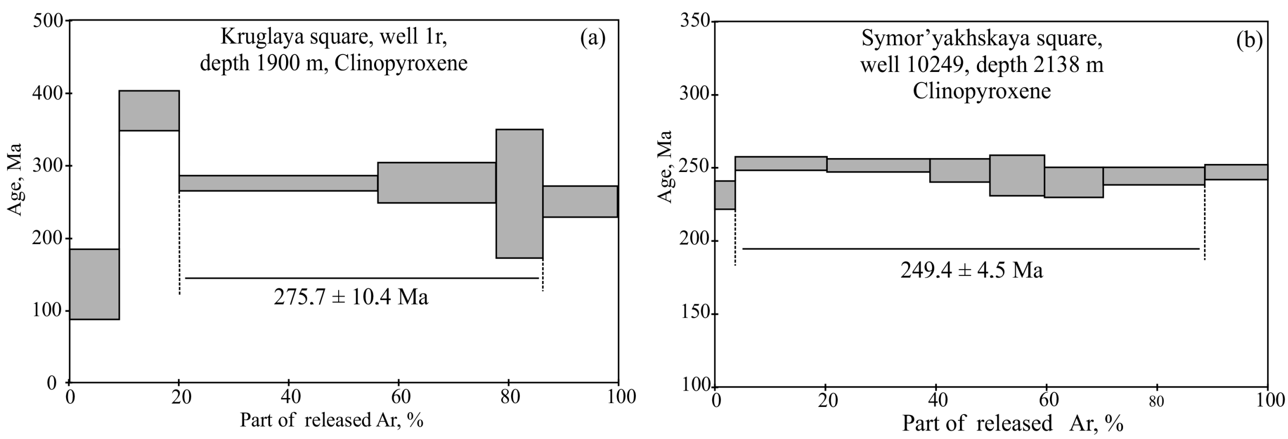


Figure 9. Ar-Ar age of pyroxene from basalts of West Siberia Shaim region grabens: from well Kruglaya 1P (depth 1900 m) (a) and well Symoriyakh 10,249 (depth 2138 m) (b).

with carbonate-argillic material. Often, one can observe basaltoids where volcanic glass was converted to clay mass, laths of plagioclase are completely carbonized and the mineral individuals of clinopyroxene are substituted with chlorite aggregate. In volcanites in rare instances, it is possible to observe relicts of primary plagioclase and pyroxene while volcanic glass is never kept. This clearly distinguishes Paleozoic basalts from near laying almost unchanged Triassic basalts of Danilovka graben. In the limits of Filippovsk square the well 9040 (32 km to the north from the middle of the northern border of the square 4 in **Figure 2**) in the range of 1962 - 1967 m (bottomhole) opened changed chloritized basic effusives, among which plagioclastic porphyrites of basaltic composition prevail. A small conformable interlayer of red schistose and schistose-brecciated jaspers (radiolarians) is observed among these effusives. The most representative radiolaria complex is extracted from the sample of jasper Fil9040/1966 collected at 1966 m of the well. The analysis of systematic composition allows to define a stratigraphic position and geological age of the studied radiolaria complex as Late Ordovician (Ashgillian, that is now known as upper part of Katian & Hirnantial stage) [18].

4.2. Volcanogenic-Sedimentary Devonian Strata

Volcanogenic-sedimentary Devonian strata and the middle-upper Devonian limestones are more developed at the south-east part of the map, where they form Tobolsk anticline. Volcanogenic-sedimentary Devonian strata occupy the western and eastern zones on the geological map. The western zone (not a very big one) is situated in the west part of square 26 (see scheme in the upper left corner of **Figure 2**) and is characterized by weak (order of −6 to −2 mGal) negative GAF. AMF above the formation is weakly negative (from −150 to −100 nT) and have a quiet character excluding the south periphery of the formation, where one can observe a positive anomaly about 200 nT in the epicentre. The eastern zone of volcanogenic-sedimentary Devonian strata stretches in meridional direction from the south to the north, occupying almost the entirety of squares 32, 28, and 24 (see the scheme in the upper left corner of **Figure 2**) and partly occupying north squares 19 and 20 and west of 25. GAF above of the formation is order of −10 mGal and disturbed by negative anomalies from granitoid bodies embraced within the formation. On the whole, the field has a quiet character. AMF have a mosaic structure with local positive (around 200 nT in the epicenter) and negative (about −150 nT in the epicenter) anomalies.

The formation is confirmed by wells (from south to north) Pokrovsk 11, Sogrinsk 1, Mendeleevsk 1, 2, and 3, Teterevsk 98, and Tobolsk 5 (**Figure 2**, square 24).

4.3. Limestones D_{2-3}

Limestones D_{2-3} are surrounded by a volcanogenic sedimentary formation and are situated at the south-eastern corner of square 19 (see the scheme in the upper left corner of **Figure 2**) in the periphery (from −8 to −4 mGal, **Figure 3**) of the negative GAF. AMF above the formation (**Figure 4**) partly is due to a strongly magnetized serpentinite body (a positive part) and partly due to deep (as one can see from the gradient of AMF) bodies magnetized in the opposite direction of the modern magnetic field. Well Srednenyurolsk 41 confirms the formation.

4.4. Effusive Rocks of D_3-C_1

The widest spreading Paleozoic formations are carboniferous strata and younger mainly Visean Stage terrigenous-carbonates, and close to them more deep-water terrigenous-schists and siliceous-terrigenous-schists strata. The carboniferous strata on the map were marked out as effusives (basalts, andesite-basalts and their tuffs) of the upper Devonian-lower Carbon.

4.5. Basalt-Terrigenous Triassic Formation, Effusive Rocks with Prevalence of Tuffs with Hybrid Composition, Basalt of Early Triassic

The typical features of basalts, andesite-basalts, andesites and their tuffs are porphyritic structures and a considerable degree of secondary greenstone changes and mainly island arc geochemical characteristics.

4.6. Terrigenic-Schist Formation of Carboniferous

Terrigenous-schist formation of Carboniferous is built with mainly early Carboniferous clay and carbonaceous-clay-siliceous schists interleaved with quartz and often polymictic aleurolites, sandstones, gritstones and limestones. The latter have quite numerous organic residues, among which the leading role belongs to foraminiferal sediments by which Visean-Bashkirian age of the stratum was determined [19]. The formation is presented on the Karabash zone geological map mainly by a wide belt encompassing to the east the "granite-schist axis" (Shaim-Kuznetsovsk meganticlinorium) and basalts of Polovinka graben. The formation also extends to the "axis" from the south and south-east. A small area of the formation can be seen north-west of the "granite-schist axis". The rocks of the formation are opened in the wells (from south-west to north-east) Andreev 10,374, 10,373, and 10,372; Slavin 10,336, from the latter to south-east—Slavin 9055, Slavin 10340, and Semividov 5; further to the east—Srednemulym 156, 10,463, 10,446, and 10,449, etc. The formation is confirmed by the wells in square 4 (see the scheme in the upper left corner of **Figure 2**) from west to east: Maloteterev 1272, Vostochno-Uray 201, and Malotap 1 and 3; in square 5—Sogom 1; in square 1—Ontokh 11 and Severo-Shatsk 1 and 3; in square 5—Sogom 1; in square 1—Ontokh 11, Severo-Shatsk 33, and Yuzhno-Talinsk 874, etc.; in square 2—Zapadno-Tashinsk 10 and Yuzhno-Galyanov 19, etc.

4.7. Serpentinites, Ultrabasites

Ultrabasic complexes of ophiolitic type are widely spread in the basement of

Karabash zone, where they are situated along tectonic zones in the form of linear stretched bodies. We have considered in detail jointly with V. A. Simonov the ultrabasites from the west part of Karabash zone (in the limit of Shaim oil-and-gas bearing region), but with a great degree of probability, one can assert that the rest of "linear" ultrabasites of the given zone are similar to them. We have shown that in the basement of Karabash zone, there are two ophiolite ultrabasic complexes. The features of intensely serpentinized ultrabasites of the first group are high chromium content of chromespinelides indicative of a considerable degree of partial melting (more than 25%) of ultrabasic rocks. That fact points to the restite nature and supra-subductional island-arc situation of these ultrabasites' genesis.

4.8. Early Paleozoic Granites and Granodiorites (Supra-Subductional)

The given types of granitoids (granites and granodiorites) were revealed in the north-eastern corner of Karabash zone (**Figure 2**, the north-east of the square 2). The datings gives the band of 441 - 444 Ma that is on the border of Silurian and Ordovician. They were collected from the core material of the wells of Nyalinsk, Zapadno-Nyalinsk, and Severo-Nyalinsk oil-and-gas prospecting squares situated to the north and north-east from the city of Khanty-Mansiysk on the right bank of the river Ob. Several wells situated on these squares opened Paleozoic basement, represented by middle-coarse-grainy granitoids. In the upper part of the basement, the rocks were exposed to the secondary low temperature alterations. In thin sections, the granitoids were built of quartz aggregate, plagioclase (albite), carbonate (ferruginous dolomite and siderite), chlorite (by primary biotite) and mica (secondary muscovite). On the place of potash feldspar, one can see the gathering of clay minerals. Zircon and fluor apatite prevail over accessory minerals. In addition, in veinlets of siderite baryte clusters occur, and throughout of the rock matrix small (up to 5 μm) silver grains are spread.

Thus, the rocks were subjected to propylitization with intense development of the secondary low temperature minerals (albite, sericite and carbonate). These changes are intensely developed in the basement of West Siberia, especially at the contact of pre-Jurassic complexes with incumbent sedimentary cover. Taking into account the low temperature character of granitoid change, we suppose that zircon, as a stable mineral is not exposed to the secondary transformations and retained its primary isotopic composition.

The geochemical characteristics of granitoids allow us to classify them as I-type. REE distribution in the rocks is characterized by gradual increases of light lanthanides and the absence of any anomalies. In large part, according to petro-geochemistry data, granitoids of Nyalinsk square (**Figure 2**, square 2) are sharply distinct from Shaim-Kuznetsovsk meganticlinorium granitoids that developed westward and belong to Uralides.

On the Ural, similar supra-subduction granitoids of the active continental margin were formed much later, from the late Devonian [20]. Therefore, we suppose that the studied granites belong to the Altaic (Altai-Sayan) folded system. At early Paleozoic time, the Altai-Sayan region was represented basically with island-arc systems, accretion subduction zones and margin continental magmatic arcs [21]. Here, according to current geotectonical reconstructions [22], during the late Cambrian and early Ordovician, there were collisions of the Kuznetsk-Altai arc with Siberia craton. It was fixed by folding, metamorphism and granitoid intrusion. Similarity of structures and complexes not only in the early but also in the middle and late Paleozoic allows us to consider paleozoides of Kazakhstan as well as those of the Altai-Sayan region as elements of the single active margin of Siberia craton.

4.9. Late Carboniferous Collisional Granitoids of Shaim-Kuznetsovsk Meganticlinorium

This type of granitoids is studied in detail in the western part of Karabash zone, in the basement of Shaim region, and in Shaim-Kuznetsovsk meganticlinorium. Here, we found two types of granitoids: widely developed monzodiorite-granite series observed as "granite-schist axis" and a local andesite body tearing ophiolite association. For each type, ages were obtained by isotopic and chemical U-Pb dating.

Within the limits of Shaim-Kuznetsovsk meganticlinorium, several granite plutons of round or frequently oval form and size of 30 × 17 km were mapped. Granitoids and their metamorphic framing were opened by numerous wells on several squares. Some plutons do not appear on the pre-Jurassic erosion level, but were revealed by geophysical methods.

U-Pb dating gives ages ranges from 291.7 to 309.5 Ma with average 301.6 ± 3.6 Ma. Late Paleozoic, early Permian age of 279 ± 7 Ma (by K-Ar method) and 284.7 ± 5.4 Ma (by Rb-Sr method) of granitoids from "granite-schist axis" were identified in the well Vostochno-Okunevsk 10,484 (**Figure 2**, square 4) at depth of 1601 m [4]. By formational belonging, these granitoids by geological, mineralogical and geochemical data are close to monzodiorite-granite series of the Ural fold belt [23].

4.10. Late Paleozoic Collisional Granitoids (Permian)

This type of granitoids was revealed in the central part of pre-Jurassic basement of Karabash zone (eastward Shaim oil-and-gas prospecting region), **Figure 2**, square 5 (see the scheme in the upper left corner of **Figure 2**). According to geophysical data, a granitoid body breaks through ultrabasite complexes of concentric-zonal type. The intrusion has an elongated form 20 × 30 km and extends from north to south. The granitoid sampled from the well Vostochno-Shebur/sk 28 from depth of 2528 m has a gneiss texture. Its structure is small- and medium-grained and cataclastic to fragmental. The relict texture is a porphyraceous hypidiomorphic grains one that was preserved very badly. Mineral compositions are microcline, plagioclase, quartz, muscovite (rarely biotite), accessory and secondary minerals. Potassic feldspar is represented by microcline with typical lattice pattern. It forms weak idiomorphic grains up to 3 mm in diameter. It is slightly pelletized.

Plagioclase (andesite) is partly pelletized. Muscovite (partly primary) forms idiomorphic scales, sheaves, and fans between grains of feldspars. The smaller needles and laths are members of grinded aggregate heal veinlets and cracks in minerals. Quartz forms "interlayers" and lenses between other minerals, mainly as an aggregate of big (1 - 3 mm) xenomorphic grains and sometimes fine-grained allotriomorphic formation along borders. Quartz is deformed and goes out mosaic. Accessory minerals are titanite, apatite, zircon, and monazite. Rock petrochemistry and mineral composition point out that the granitoid belongs to acid differences of normal and low-alkali row and, apparently, belongs to much modified granite. Trace element composition is fully typical for acid rock. Showing sharp increase of light lanthanides and absence of any kind of anomalies, REE distribution strongly differs from that of nearby situated granitoids of Shaim-Kuznetsovsk meganticlinorium. For the latter monzodiorite-granite complexes, it is typically more gently sloping in light REE increase and sub-alkali rock composition [5].

On the whole, based on comparative petrochemical characteristics of acid rocks of both types, it is possible with a high degree of confidence refer to the granite of Vostochno-Shebursk square as collisional (S-type) formations.

4.11. Triassic (Late Permian-Triassic) Formations

Triassic (late Permian-Triassic) formations in the limits of the geological map of the pre-Jurassic basement of Karabash zone form 4 main structures (graben-rifts). The most western Danilovka graben (**Figure 1**, I) have been studied comprehensively: many wells opened Triassic formations, and numerous geophysical studies were conducted. This allows us to carry out computer modelling of the graben-rift deep structure. In Polovinka graben (**Figure 1**, II) situated to the east of Danilovka, Triassic formations were characterized by a few wells that were studied in great depth. Another two Triassic graben-rifts Tyumen (**Figure 1**, III) and extreme eastern Ashlyk (**Figure 1**, IV) take up a big part of the south-east corner of the map. They have been studied not enough by drilling, but the available core material lets us conduct a series of sophisticated geochemical studies (in particular of the Tyumen intrusion).

Among Triassic formations of greatest abundance are basalt and rhyolite-basalt formations (turinsk series and its analogs) mainly filling some grabens. In Karabash zone of the west part of the region, there are Danilovka (**Figure 1**, I), Polovinka (**Figure 1**, II) and other structures.

5. Discussion

The age of metamorphic rocks of Shaim-Kuznetsovsk meganticlinorium has been discussed by many scientists. According to some authors [24], a part of the crystal schists of Shaim uplifting is related to Ordovician, and some schists and phyllites are related to Silurian. According to the existing schemes of partition and correlation of West Siberia basement formations, the most ancient strata are metamorphic ones forming kernels of anticlinoriums [19]. Thus, some authors [1] contend that the metamorphic strata of nonsegmented Precambrian occurred in the basement of the profile of Sherkaly, Shaim and other regions. Typically, widespread conceptions considered metamorphites of greenschist facies Riphean and strongly metamorphized strata Proterozoic. Later [15], the first datings of 373 ± 17 Ma by U-Pb method (ID-TIMS) were obtained using zircons from quarts-sericite schists of Shaim-Kuznetsovsk meganticlinorium.

Thus, the main part of protolith for the metamorphic rocks of Shaim-Kuznetsovsk meganticlinorium apparently have later and middle Devonian ages (395 - 358 Ma).

The spatial orientation of Danilovka and Polovinka grabens allows us to suggest that they originated from different directions of the earth's crust movements (stress fields). Danilovka graben is a product of sublatitudinal stretching, but Polovinka graben is a product of sublatitudinal compression [16]. Thus, obtained data testify that in pre-Jurassic basement of the west part of West Siberia (Karabash zone), filling grabens basalt effusion began during Permian time (probably at the end of early Permian) at sublatitudinal compression, that is, at collision, possibly immediately after or subsynchronously with the origin of the granite [5]. On the edge of Permian and Triassic (or in early Triassic), sublatitudinal compression changed into stretching, and submeridional grabens came to existence and basalt effusion came up to the maximum.

6. Conclusions

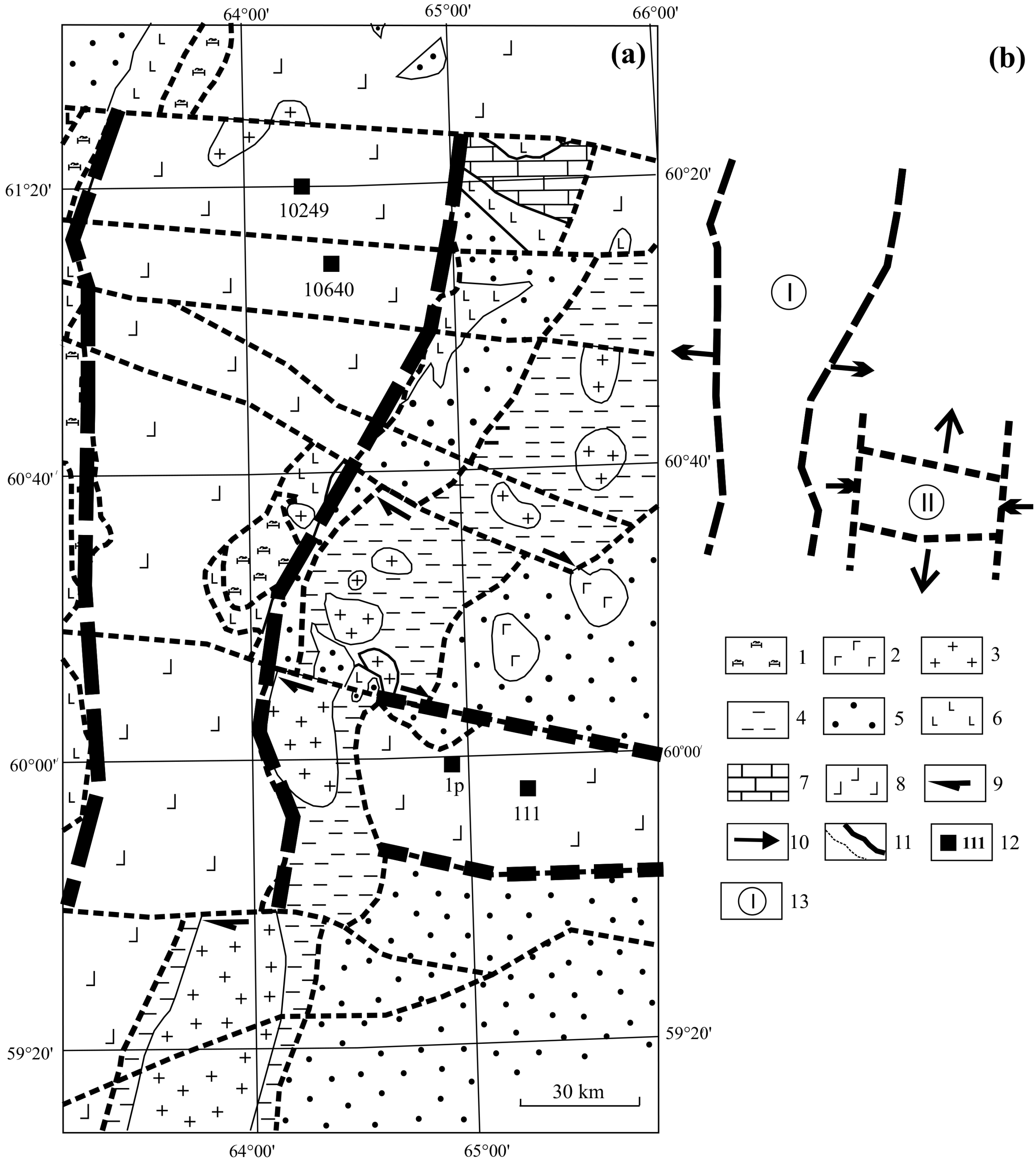
A new study of the area (the West Siberia Karabash zone basement) allowed us to come to conclusion that ages of the metamorphic complexes are Devonian. As a result, a geological map study of pre-Jurassic basement of Karabash zone (**Figure 2**) was made. For a new map construction, not only study of the materials from boreholes shown in **Figure 2** was used, but schematic gravitational and anomalous magnetic maps of the area (**Figure 3**, **Figure 4**) were analized in addition. Thus, in total, we made the conclusion:

1) The obtained results enable significantly more exact history of pre-Jurassic rock formation for the basement of the west part of West Siberia craton and its structure in the limits of Karabash zone.

2) In the basement of stratificated formations of Karabash, there are metamorphized strata that earlier (before our studies) were considered pre-Cambrian but it is late and middle Devonian (395-358 Ma).

3) Obtained data testify that in pre-Jurassic basement of the west part of West Siberia (Karabash zone) filling grabens basalt effusion began during Permian time.

4) The obtained data is explained by our geodynamic scheme of stretching and compressing of earth's crust (**Figure 10**).



1—ultrabasites, 2—gabbroids, 3—granitoids, 4—upper Paleozoic schists, 5—carbon terrigenous rocks, 6—Paleozoic basalts, 7—Devonian limestones, 8—lower Triassic basalts, 9—tectonic displacements, 10—directions of compression and stretching, 11—borders: tectonic (dotted line) and usual (line), 12—wells and well's numbers are depicted by square, and 13—volcanogenic grabens (I—Danilovka, II—Polovinka).

Figure 10. A geological map of pre-Jurassic basement of West Siberia Shaim region (a) and Geodynamic scheme of stretching and compressing of Earth's crust (b).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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