

GEOLOGY

Late Paleozoic Subductional and Collisional Igneous Complexes in the Naryn Segment of the Middle Tien Shan (Kyrgyzstan)

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The Late Paleozoic Tien Shan fold belt was formed in the course of subduction of the crust underlying the past Turkestan ocean under the Kazakh continent and subsequent collision of the latter with the Alai and Tarim massifs. The onset of subduction is evidenced by development of flysch sequences and olistostromes in the accretionary complex of the South Tien Shan: in the terminal Viséan–Serpukhovian (~330–325 Ma ago) in the west and in the second half of the Bashkirian Age (~315 Ma ago) in the east of the Kyrgyz Tien Shan [1].¹ The onset of collision between the Kazakh continent and Tarim Massif is dated back to the terminal Late Carboniferous based on the initiation of a foredeep along the northern margin of the latter [6]. The mature collision stage began in the mid-Asselian, when the last sea basins disappeared in the Tien Shan and granitoids intruded in its southern segment [1, 9]. The position and age of the volcanic arc that was forming in the course of convergence between the Kazakh continent and the Tarim Massif remain unclear. Recently, this problem acquired particular significance, since the data available for the territory of China imply subduction under the Tarim Massif and an Early Carboniferous age of collision, i.e., substantially older as compared with that assumed for the Kyrgyz region [7].

¹ Ages are given after [13].

The Late Paleozoic volcanic arc, well-developed in the westerly located Chatkal and Kuramin ranges [3], “disappears” east of the Talas–Fergana Fault in the Naryn segment of the Middle Tien Shan, where only single intrusions and rare outcrops of volcanic rocks are known. In this area, the age of volcanics is determined usually conditionally in wide limits: from the Vendian to the Permian. Dates obtained for intrusions largely by the K–Ar method are also ambiguous and prevent us from characterizing their ages and, consequently, interpreting the tectonic settings of their formation. For solving this problem, we have studied volcanic sections and dated granitoids of the Sonkul Massif, which represents a type object for the synonymous igneous complex.

The volcanic sequences are best exposed in the Mount Naryn and Alamashik Range area (Fig. 1, points 1, 2). The constituting rocks are represented by green-colored tuffaceous breccia-conglomerate with andesite and olivine–clinopyroxene basalt blocks scattered in the matrix composed of coarse-grained tuffstone and andesite to basaltic andesite tuff. The uniform composition, large size (0.3–0.5 m across), and poor roundness degree of rock fragments point to their deposition near the source. The dominant role of volcanics among rock fragments (up to 90%) and significant share of pyroclastic material (up to 40–80% of the matrix) characterize this source as an active volcanic edifice. The scattered distribution of rock fragments within the matrix, poor sorting of material, and obscure stratification imply that these sediments were deposited from avalanchelike flows, probably of the lahar type. Their thickness exceeds 400 m. In the southern margin of Mount Naryn, volcanics rest with angular unconformity (20°–30°) upon Lower Carboniferous limestones and are overlain with the erosional surface by the Minbuga conglomerate formation of the Kasimovian Stage. Taking into consideration the continuous underlying section ranging in age from the Early Carboniferous to the initial Bashkirian Age, the stratigraphic range of the

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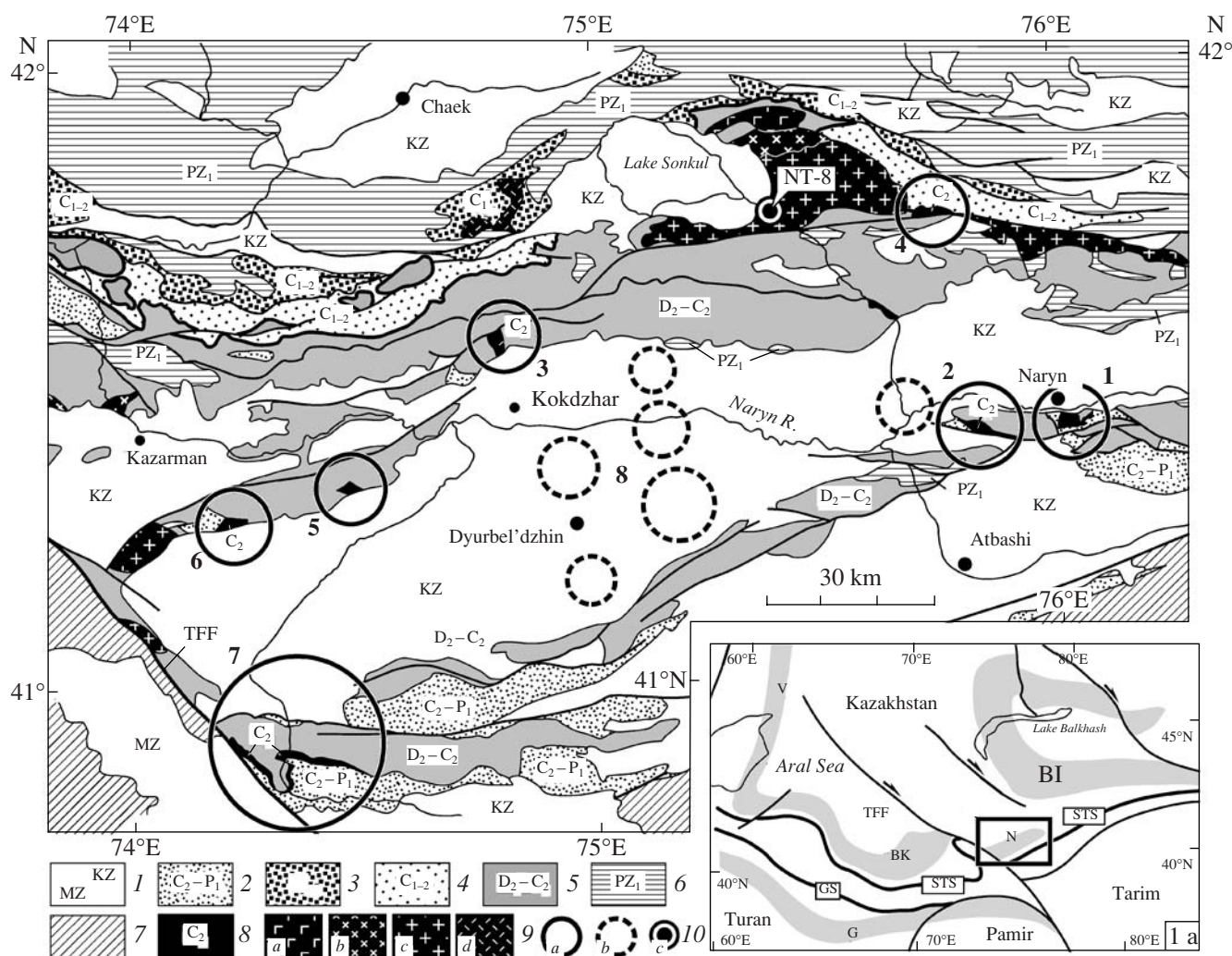


Fig. 1. Schematic distribution of Upper Paleozoic complexes in the Naryn segment of the Middle Tien Shan (after [4] modified). (1) Mesozoic and Cenozoic sediments; (2) Upper Carboniferous and Lower Permian sedimentary rocks; (3) continental redbeds; (4) dominant turbidites; (5) Devonian and Carboniferous terrigenous and carbonate sediments of the Middle Tien Shan; (6) Lower Paleozoic; (7) Paleozoic of the southern Tien Shan; (8, 9) igneous complexes: (8) Upper Carboniferous volcanic and volcano-sedimentary sequences, (9) Permian intrusions: gabbroids (a), monzodiorites (b), granodiorites and granites (c), and acid subvolcanic bodies (d); (10) distribution areas of Late Carboniferous volcanics: (proven (a) and assumed by geophysical data 9b), sampling site (NT-8) for U-Pb dating (c). The inset shows the location of the study area. The gray color designates Late Paleozoic volcanic belts: (BK) Bel'tau-Kuramin, (N) Naryn, (V) Valer'yanovskii, (BI) Balkhash-Ili, (G) Gissar. (STS) South Tien Shan Suture; (GS) Gissar Suture; (TFF) Talas-Fergana Fault.

sequence is determined in the interval of the uppermost Bashkirian-basal Kasimovian stages of the Upper Carboniferous.

Compositionally similar rocks are developed on the southern slope of the Moldotau Range 12 km north of the Kokdzhar Settlement (Fig. 1, point 3). Tuffaceous conglomerates with blocks of andesite-dacites and dacitic tuffs constitute beds 1–2 m thick alternating with tuffstone members and enclosing lava flows of andesite-dacites, clinopyroxene-plagioclase andesites, olivine-clinopyroxene basalts, and lava breccia 1 to 8 m thick. The volcanics are underlain by sandstones and clayey marls with abundant floral remains. The occurrence of *Calamites cistii* Brongniart, *C. suckowii*

Brongniart, and *Cordaites* sp. (identifications by S.V. Naugol'nykh, Geological Institute, Russian Academy of Sciences) points to a Late Carboniferous age of the host sequence (Middle-Late Carboniferous, according to the former scale), which is consistent with the data on the Mount Naryn area.

Tuffaceous breccia conglomerates similar to their varieties developed in the Mount Naryn and Alamashik Range area outcrop also north of the strike-slip fault (Nikolaev Lineament) along the Naryn-Bishkek road (Fig. 1, point 4). The rocks were considered to be Permian in age [4], although their lithological and structural features allow them to be attributed to the Upper Carboniferous. The Upper Carboniferous volcanogenic

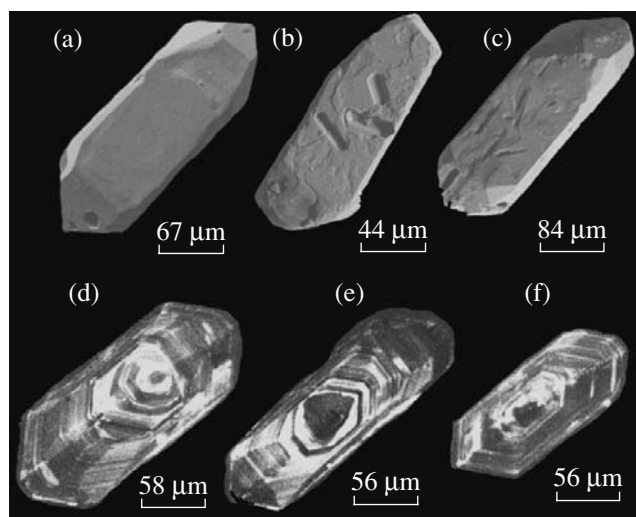


Fig. 2. Microimages of zircon crystals from biotite–amphibole porphyry-like granites (phase III) of the Sonkul Massif (sample NT-8) obtained on the scanning electron microscope ABT-55 in reflected electrons (a–c) and cathode-luminescence regime (d–f).

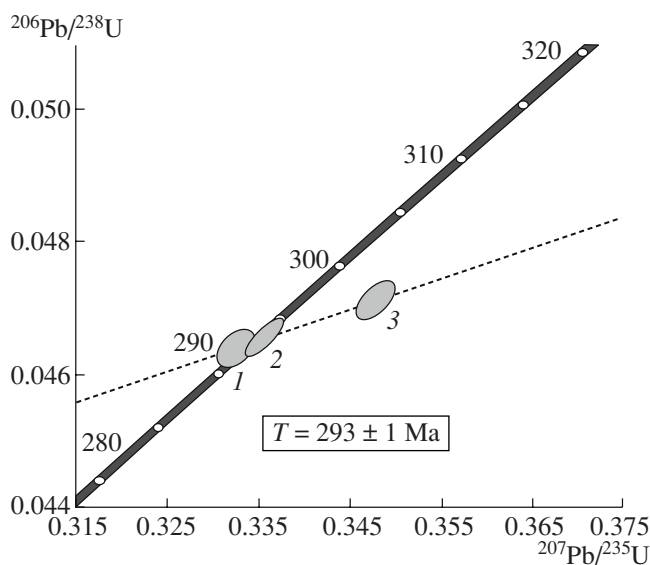


Fig. 3. Diagram with concordia for zircons from granites (phase III) of the Sonkul Massif (sample NT-8). Numbers of points correspond to ordered numbers in the table.

and volcano-sedimentary rocks are developed also on southern slopes of the Akshiiryak Range (Fig. 1, points 5, 6) and in the Dzhambandavan Range (Fig. 1, point 7), where different researchers united them into the Kenkyrcha, Kargalyk, and Dzhambandavan formations [5]. According to magnetometric, gravimetric, and seismic exploration data (V.I. Mitroshin, A.D. Pavlenkin), the Upper Carboniferous volcanics outcropping on the slopes of the Naryn Depression are traceable under the Cenozoic sediments in its central areas (Fig. 1, points 2, 8).

All the above-mentioned outcrops mark the distribution area of Late Carboniferous volcanics that

involves the Naryn Depression and adjacent ranges (Fig. 1). A significant share of these volcanic outcrops is likely buried under the uppermost Carboniferous–Lower Permian and Cenozoic sediments of the Naryn Depression, where they are up to several kilometers thick. In the west, the distribution area of these volcanics is limited by the Talas–Fergana strike-slip fault (Fig. 1). The reconstruction of displacements along the strike-slip fault [2] implies that the coeval belt of subductional volcanics in the Chatkal and Kuramin ranges continues this distribution area in a westerly direction (Fig. 1, inset). The period of volcanic activity in the Naryn segment corresponds to the subduction stage in the neighboring region of the South Tien Shan, and its termination is almost synchronous with the onset of collision between the Kazakh continent and the Tarim Massif [1].

The intrusive complexes in the study area are represented by the multistage Sonkul Massif (Fig. 1). The latter is composed of gabbroids, diorites, and monzonites (phase I), quartz monzonites, quartz monzodiorites, quartz diorites (phase II), and massive and porphyry-like granodiorites, granites, and granosyenites (phase III). [4]. According to K–Ar dating, the massif is 310–299 Ma old. Age estimates of other massifs belonging to the same complex vary from 324–296 (K–Ar) to 324 ± 5 Ma (Rb–Sr) [5, 8].

Sample NT-8 for U–Pb dating of the Sonkul Massif was taken from medium-grained biotite–amphibole porphyry-like granites (phase III) at a site with coordinates $41^{\circ}44'18.3''$ N, $75^{\circ}24'59.4''$ E (Fig. 1). Accessory zircon extracted from the sample is represented by sub-euhedral to euhedral transparent to semitransparent colorless or yellowish crystals of short-prismatic and prismatic habits (Figs. 2a–2c). Facets form either prisms {100}, {110} or dipyramids {211}, {111}, {101}, {102}. The internal structure of zircons demonstrates magmatic zoning (Figs. 2d–2f), a fine fissured rim with lowered birefringence, and relicts of metamictized cores, which occur in some semitransparent grains (Fig. 2e). Crystals are from 40 to 400 μ m long ($K_{\text{elong}} = 1.3\text{--}2.5$).

The U–Pb geochronological study was performed for three weights of the most transparent zircon grains picked from fractions >150 and 100–150 μ m, which were preliminarily subjected to air abrasion treatment [10]. As is evident from Fig. 3, two data points obtained for the isotopic composition of zircon (Fig. 3, 1, 2, table) are located at concordia (concordant age 293 ± 1 Ma, MSWD = 0.22, probability 0.64). A slightly older age is yielded by zircon (Fig. 3, 3, table) from the fraction >150 μ m, which is evidently enriched to some extent by an inherited component of older radiogenic lead (relicts of cores). The age of the lower intercept of discordance calculated for all the points coincides with the concordant age (293 ± 1 Ma), and its upper intercept corresponds to an age of 2346 ± 660 Ma (MSWD = 0.013). Taking into consideration the morphological

U–Pb geochronological data on zircons from granites (phase III) of the Sonkul Massif (sample NT-8)

Ordered number	Fraction (μm) and its characteristic	Weight, mg	Content, ppm		Isotopic ratio					<i>Rho</i>	Age, Ma		
			Pb	U	$^{206}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}^a$	$^{208}\text{Pb}/^{206}\text{Pb}^a$	$^{207}\text{Pb}/^{235}\text{U}$	$^{206}\text{Pb}/^{238}\text{U}$		$^{207}\text{Pb}/^{235}\text{U}$	$^{206}\text{Pb}/^{238}\text{U}$	$^{207}\text{Pb}/^{206}\text{Pb}$
1	100–150, A 10%	0.19	32.4	617	1911	0.0520 ± 1	0.2378 ± 1	0.3325 ± 10	0.0464 ± 1	0.44	291 ± 1	292 ± 1	284 ± 6
2	>150, A 50%	0.61	22.5	431	3971	0.0523 ± 1	0.2429 ± 1	0.3355 ± 7	0.0465 ± 1	0.81	294 ± 1	293 ± 1	298 ± 2
3	>150, A 10%	0.21	32.3	608	3187	0.0537 ± 2	0.2440 ± 1	0.3486 ± 12	0.0471 ± 1	0.49	304 ± 1	297 ± 1	356 ± 7

Note: Isotopic ratios are corrected for blank and ordinary lead; (A 10%) quantity of matter removed by the air-abrasion treatment of zircon grains; (*Rho*) coefficient of correlation of errors for $^{207}\text{Pb}/^{235}\text{U}$ – $^{206}\text{Pb}/^{238}\text{U}$ values. The error values correspond to the last significant numerals after the comma. The Pb and U isotope composition was measured at the mass-spectrometer Finnigan MAT 261 in the static regime. Experimental data processing was conducted using the PbDAT [11] and ISOPLOT [12] programs. In age calculations, conventional constant values of uranium decay were used [15]. Corrections for ordinary lead are introduced according to model values [14]. All the errors are given at the level 2σ .

properties of the examined zircon grains, we consider the concordant age value of 293 ± 1 Ma as reflecting crystallization of the melt parental for granitoids of the massif in question.

The data presented indicate that the convergence of the Kazakh continent and the Tarim Massif was accompanied by formation of the volcanic arc in the Naryn segment of the Middle Tien Shan. The age of volcanism is consistent with that of the subduction onset, which is derived from other data. The obtained age value for the Sonkul Massif (293 ± 1 Ma) implies the formation of granite intrusions in the Middle Tien Shan at the mature stage of collision between the Kazakh continent and Tarim Massif, not in the course of subduction as was assumed previously. The problem of relationships between Late Paleozoic subduction systems in the Kyrgyz and Chinese segments of the Tien Shan needs additional research.

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