ISSN 1028-334X, Doklady Earth Sciences, 2010, Vol. 430, Part 2, pp. 172–175. © Pleiades Publishing, Ltd., 2010.
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GEOLOGY

First $^{40}Ar/^{39}Ar$ Age Determinations on the Malkhan Granite–Pegmatite System: Geodynamic Implications

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Presented by Academician M.I. Kuz'min April 6, 2009

Received May 13, 2009

Abstract—The Malkhan granite–pegmatite system located in Central Transbaikalia, in the southwestern portion of the Malkhan–Yablonovy structure–formational zone of the Caledonian folding comprises two granite massifs (Bolsherechensk and Oreshny) and a miarolitic pegmatite field of the same name, which adjoins the Chikoi deep-seated fault and Lower Cretaceous Chikoi rift depression in the north. The first $^{40}Ar/^{39}Ar$ data were obtained on porphyritic biotite granites of the Oreshny massif and on K-feldspar, muscovite, and lepidolite from the Oktyabrskaya pegmatite vein. According to these data, the age of the granite–pegmatite system is 123.8–127.6 Ma, which is consistent with the age of Lower Cretaceous rocks from the Chikoi depression. The intimate spatial relationship and isochronism between the Chikoi depression and the Malkhan granite–pegmatite system are strongly suggestive of a rift regime that affected its evolution, thus highlighting the need to regard the evolution of this system as being intimately related to depression development. Such a model can easily be realized within the framework of the concept of a metamorphic core complex, which was used to explain the nature of Transbaikal-type rift depressions and conjugate granite–gneiss swells.

DOI: 10.1134/S1028334X10020054

The Malkhan granite–pegmatite system in Central Transbaikalia comprises two granite massifs separated by a miarolitic pegmatite field of the same name, which represent one of the largest known sources of gem-quality tourmaline in Eurasia. The geological, geochemical, and mineralogical features of granites and pegmatites from the study area were described in detail in previous studies [1–4 and others]. However, the lack of age data precludes any precise interpretation of the geodynamic setting of this granite-pegmatite system. This study attempts to fill this gap by providing the first $^{40}Ar/^{39}Ar$ age determinations on granites and pegmatites.

The study area is situated in the southern foothills of the Malkhan Range, in the southwest of the Malkhan–Yablonovy (Malkhan) structure–formational zone of the Caledonian folding. The latter spatially coincides with the northwestern edge of a zoned magmatic area comprising the Khentey–Dauria batholith core in its center and rift zones along its periphery [5], or more precisely, it follows the outlines of the Tugnui–Khilok sector of the West Transbaikalia rift area [6]. The study area is an uplift bounded towards the NNW and SSE by the Khilok and Chikoi deep-seated faults, respectively, along which rift depressions of the same name developed during the Mesozoic (K_1). There are a number of large anticlines and synclines that within this uplift. The Malkhan pegmatite field is confined to the anticline of the same name and is located near its southeastern border with the Chikoi depression, at the junction between the EW Chikoi deep-seated fault and the NW Cheremkhovo–Yasytai fault zone adjoining from the south [7].

The geological framework of the Malkhan pegmatite field (figure) is basically composed of parametamorphic rocks of the Upper Proterozoic Malkhan series and orthometamorphic rocks of the Lower Paleozoic Malkhan complex, as well as Mesozoic granitoids and pegmatites. The Malkhan series is mostly composed of amphibole, amphibole–biotite, and biotite, often foliated, schists of the amphibolite metamorphic facies. These rocks form an EW-trending band that typically has tectonic contacts with Lower Cretaceous conglomerates of the Chikoi depression and are crosscut by the intrusive bodies of the Malkhan complex, which were metamorphosed under amphibolite facies conditions. The Malkhan complex consists of metagabbroids (amphibolites), amphibole metadiorites, and amphibole–biotite quartz gneiss–granites. The rocks of the Malkhan series and the Malkhan complex are intruded by Mesozoic granites, which belong to two granite massifs, the large Bolsherechensk and smaller Oreshny (7 × 5 km) the latter being located 2.5–4 km to the southwest, as well as by abundant pegmatites. These massifs comprise prevailing subalkaline and minor amounts of calc–alkaline porphyritic biotite granites. A small southeastern portion

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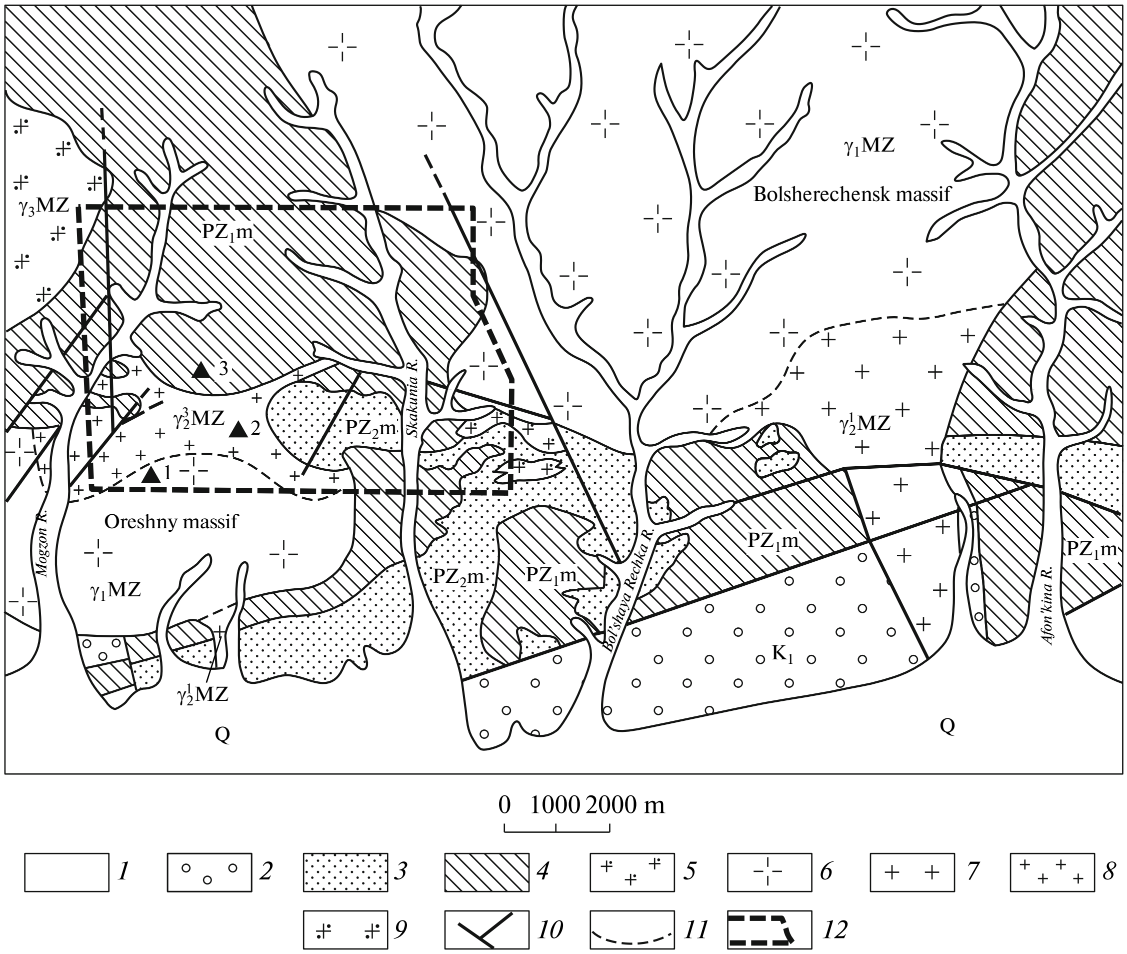

Geological sketch map of the Malkhan pegmatite field (after [1]). (*1*) Quaternary deposits: gravel, sand (Q); (*2*) Lower Cretaceous conglomerates of the Chikoi depression (K_1); (*3*) undifferentiated meta-rocks of the Upper Proterozoic Malkhan series: biotite, biotite–amphibole, and amphibole schists (PR_2m); (*4*) undifferentiated meta-rocks of the Lower Paleozoic Malkhan complex: metagabbroids, metadiorites, quartz metadiorites, biotite, and biotite–amphibole gneiss–granites (PZ_1m); (*5*) ultrametamorphic biotite leucogranites of the same complex (PZ_1m); (*6–9*) Mesozoic (Lower Cretaceous based on new ^{40}Ar/^{39}Ar data) granites (MZ): (*6*) biotite porphyritic granites γ_1, (*7*) biotite leucogranites γ_2^1, (*8*) two-mica leucogranites γ_2^2, (*9*) vein (dykes, sills) biotite, two-mica granites, aplites γ_3; (*10*) faults; (*11*) facies boundaries; (*12*) Malkhan field outlines. Filled triangles show the localities of samples collected for Ar–Ar age determination (for coordinates see table): (1) Porphyritic biotite granite, (2) two-mica leucogranite, (3) pegmatite (Oktyabrskaya vein).

of the Bolsherechensk massif is dominated by subalkaline biotite leucogranites; and the northern part of the Oreshny massif comprises a marginal zone of two-mica leucogranites with a large dike-shaped apophyse cutting across ortho-rocks of the Malkhan complex. Both massifs are characterized by a gradual transition from the porphyritic granite to the leucogranite.

Almost all of the Malkhan pegmatites are confined to the roof pendant between the Bolsherechensk and Oreshny massifs, which are most likely parts of a single pluton. The country rocks of the pegmatites are mostly ortho-rocks of the Malkhan complex. The pegmatites are also present in leucogranites of the Oreshny massif; however, they are characterized by practically no miaroles or gem mineralization. The majority of tourmaline-rich pegmatite veins lies close to the dyke-shaped apophysis of leucogranites at the northern exocontact of the Oreshny massif, at a distance no less than 250 m from granites (figure).

For ^{40}Ar/^{39}Ar dating of the Malkhan granite–pegmatite system, we studied two samples of mica from granites in the northern part of the Oreshny massif, one sample of K–feldspar and two samples of mica from the Oktyabrskaya tourmaline-rich pegmatite vein. As can be seen from the table, all samples define a broad plateau ranging from 71.6 to 99.9% of the total ^{39}Ar released. Plateau ages for all study samples fall within the range 123.8–127.3 Ma, being almost completely consistent with their integrated ages of 124.0–127.6 Ma. The granite ages in turn are in all cases con-

$^{40}Ar/^{39}Ar$ mineral ages for granites from the Oreshny massif and Oktyabrskaya pegmatite vein

Rock	Mineral	^{39}Ar, %	Plateau age, Ma	Integrated age, M	Sample locality
Porphyritic granite	Biotite	71.6	125.3 ± 1.1	124.0 ± 1.2	50°38.08′ N, 109°52.25′ E
Two-mica leucogranite	Muscovite	92.2	125.1 ± 1.1	126.2 ± 1.2	50°38.61′ N, 109°53.18′ E
Pegmatite	K–feldspar	92.7	123.8 ± 1.1	124.7 ± 1.1	50°39.09′ N, 109°52.79′ E
	Muscovite	99.0	127.3 ± 1.1	127.6 ± 1.2	
	Lepidolite	99.9	126.1 ± 1.1	126.1 ± 1.1	

Note: ^{39}Ar is the proportion of isotope released in the age spectra plateau (% of the total ^{39}Ar released). The analyses were performed at the Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences.

gruent with the age of the studied pegmatite vein. It is noteworthy that K–feldspar from the graphic pegmatite, reflecting the early magmatic phase of the vein formation, yielded an Ar–Ar age of 1.4–2.9 Ma younger than the age of muscovite and lepidolite, which can be attributed to late magmatic and hydrothermal events. Therefore, correct geological interpretation would be impossible on the basis of age discrepancies between the samples analyzed. Thus, the interval 123.8–127.6 Ma is interpreted as the likely age of the granite–pegmatite system as a whole. The Ar–Ar ages obtained for different minerals from various rock types of the granite–pegmatite system generally have an insignificant scatter, which may be indicative of the relatively high reliability of the dataset.

The Malkhan granite–pegmatite system adjoins on its southern boundary the Chikoi deep-seated fault, which has until recently been considered to be the western segment of the Mongol–Okhotsk suture zone [5, 8]. New data which have recently been obtained on the lithospheric structure and geodynamics of Central Asia using a system of transects revealed that the above suture zone runs some 150 m to the south and the Chikoi fault is one of the largest accompanying structures that were either formed or reactivated during collision of the Siberian and Mongol–Chinese continents in the Early–Middle Jurassic [9, 10]. At the Jurassic–Cretaceous boundary, the collision regime was followed by a rifting phase, which culminated in the formation of numerous depressions in the Transbaikalian region. The Chikoi depression, coincident with the zone of the Chikoi deep-seated fault, exemplifies the structures having typical attributes of half-grabens [11].

The close location and isochronism between the Chikoi depression and the Malkhan granite–pegmatite system are strongly suggestive of a rift regime that affected its evolution, thus highlighting the need for regarding the evolution of this system as being intimately related to depression development. Such a model can be easily realized within the framework of the concept of a metamorphic core complex, which was used to explain the nature of Transbaikal-type rift depressions and conjugate granite–gneiss swells. The idea is that the substantial crustal extension and formation of rift half-grabens by simple shear causes uplifting of the lying wall of the structure (relative to the fault). This leads to exposure of rocks affected by dynamo–thermal metamorphism within depths of 5–15 km [11], which is manifested in the study area by cataclasis and gneissification of rocks in the northern limb of the rift structure. The intensity of these processes increases from north to south, towards the Chikoi fault, which is most clearly reflected in granitoids of the Malkhan complex [1]. In addition, a decrease in pressure due to crustal extension and uplift of the northern block of the rift in combination with high heat flow and fluid circulation in the zone of the deep-seated fault promoted palingenesis of the Early Paleozoic substrate and generation of granitic magma that gave rise to the Malkhan granite–pegmatite system.

Lower Cretaceous granites are not shown on the available geological maps of the study area. At the same time, as can be seen in a number of reports on exploration activity undertaken by Sosnovgeologiya and Baikalkvartssamotsvety enterprises in the 1980s, the granites from the Bolsherechensk and Oreshny massifs were conditionally, and perhaps unfoundedly, attributed to the Upper Jurassic Kharalga complex identified in the adjacent Dauria zone. Later, these granites were described as Mesozoic without assignment to any period or complex [1, 2]. As opposed to the Kharalga granites, porphyritic biotite granites which constitute much of the Oreshny and Bolsherechensk massifs exhibit a 2- to 4-fold depletion in Li, Rb, Be, Sn, and F and a 2- to 4-fold enrichment in Ba and Sr. Two-mica leucogranites from the Oreshny massif show a closer geochemical affinity to the Kharalga granites; however, they differ very substantially in the F content (2800 and 580 ppm, respectively) [1, 12]. The granites of both studied massifs are strongly different petrographically from those of the Malkhan complex. However, granites visually identical to the granites of Bolsherechensk and Oreshny massifs can be found at a distance of several tens of kilometers to the west and east of the Malkhan field.

In the West Transbaikal rifting system some Early Cretaceous Rb–Sr ages were previously obtained for alaskite granites and pegmatites from the Yablonovy

Range, as well as similar K–Ar ages for pegmatites from the Zagan and Yablonovy Ranges [13]. According to data in [13], the Mesozoic magmatic episode that took place in the reactivation zone adjoining the Mongol–Okhotsk fold belt in the north has resulted in production of small bodies of pegmatoid granites and pegmatites rather than extensive granitoid bodies. However, the presence of two large well-studied granite massifs, which have a surface area of over 200 km^2 and potential for further extension, suggests that granitoid magmatism related to Lower Cretaceous rifting has played a much greater role within the Malkhan zone of the Caledonides.

ACKNOWLEDGMENTS

This work was supported by grant nos. 10-0500964 and NSh-3047.2008.5.

The authors thank A.V. Travin and his colleagues for performing age determinations.

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