PETROLOGY AND ISOTOPIC SYSTEMATICS OF KHUNGARIISK GRANITES AS A KEY TO THE HISTORY OF early CRETACEOUS COLLISION IN THE SIKHOTE ALIN FOLD BELT, FAR EASTERN RUSSIA

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ABSTRACT

Data on trace element contents and isotopes (Sr, Nd) in the Khungariisk granites, metamorphic rocks and migmatites from the Anyui block of the Sikhote Alin nappe fold system are obtained. Similar trace and rare earth element concentrations in the granites and metamorphic rocks of the Anyui block, and similar isotopic (Sr and Nd) compositions allow to conclude that the Khungariisk granites formed by anatectic melting of Precambrian continental crust as a result of early Cretaceous collision of the microcontinent with the Asian continent.

INTRODUCTION

The origin of the Khungariisk granites of the Sikhote Alin (southeast Russia) are hypothesized to be associated with early Cretaceous collision of the Anyui microcontinent with Asia (Natal'in, 1991). We are conducting an isotopic and geochemical study of these granites in order to 1) determine their origin, 2) to determine the age and characteristics of the sources for the granitic magmas, and 3) to further investigate how the Khungariisk granites are related to accretion of the Anyui microcontinent.

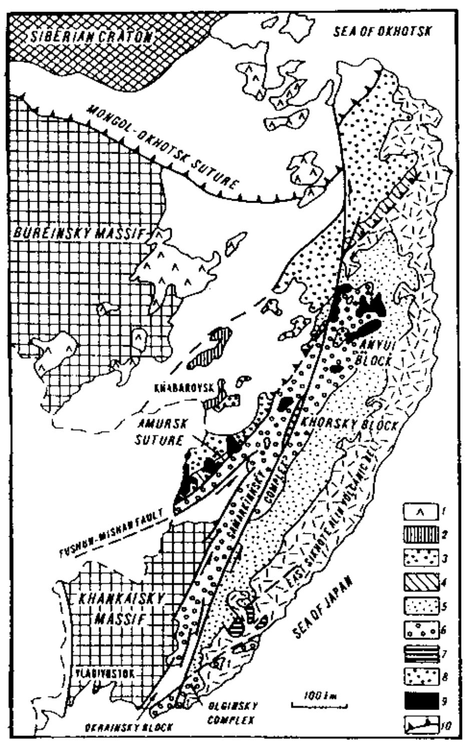


Fig. 1. Tectonic scheme of Russian Far East (after Natal'in and Faure, 1991)
Khingan-Okhotsk active continental margin: 1 - Khingan-Okhotsk volcanic-plutonic belt; accretionary prism: 2 - Khabarovsky complex, 3 - Amursky complex, 4 - Kiselevsk-Manominsky complex; 5 - Zhuravlevsk-Tumninsky depression; 6 - Jurassic accretionary complexes (Samarkinsky and Olginsky) displaced from sites of their origin along strike-slip faults; 7 - early Cretaceous Taukhinsky accretionary complex; 8 - outcrops of metamorphic rocks; 9 - Khungariisk granites; 10 - sutures.

Possibly the only exposures of the accreted microcontinent are in the Anyui dome of the Sikhote Alin (Fig. 1). Elsewhere the only evidence for the type of underlying continental crust may come from investigation of the Khungariisk granites and xenoliths of metamorphic and sedimentary rocks. Here we report trace element and isotopic (Sr and Nd) compositions of the granites and metamorphic rocks and migmatites from the Anyui dome. Trace and REE concentrations were measured at the University of Oregon by instrumental neutron activation, and isotopic compositions were measured at the University of Washington on a seven-collector, VG-sector mass spectrometer.

GEOLOGIC SETTING

The Khungariisk massifs (105-131 Ma) are high-alumina, two-mica granites that are widespread in the central Sikhote Alin (Eezokh et al., 1967). Their outcrops form a narrow band 500 km long stretching from the Bikin river basin in the southwest to the Gour river basin in the northeast Sikhote Alin (Fig. 1). This band spacially coincides with the position of the Amursk suture (Fig. 1). Granites form bodies of various sizes from small dikes to batholiths up to a thousand square km in area. They are massive or gneissic rocks typically containing xenoliths of hornfelsic sedimentary and metamorphic rocks, gabbro and amphibolites. The composition of the granite does not change as a function of host rock or location. Mineral paragenesis are characterized by two feldspars with plagioclase dominant and cordierite, and chemically correspond to calc-alkaline granites (Table 1).

Table 1. Chemical composition of the Khumgarinsk series granites

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O	Total
Aert.3	71.43	0.13	14.76	1.04	1.76	0.04	0.69	1.68	3.76	3.85	0.08	0.67	99.71
Gob.1	65.23	0.61	15.38	1.33	3.75	0.03	2.40	2.67	3.43	4.18	0.16	0.73	99.64
Vas.1	66.75	0.57	15.81	0.83	3.57	0.03	1.69	2.39	3.43	4.01	0.16	0.71	99.72
Vas.5	74.42	0.08	13.71	0.71	1.33	0.02	0.49	0.84	2.76	5.06	0.10	0.30	99.77
Vas.7	67.62	0.56	15.21	1.38	3.07	0.04	1.89	2.52	3.18	3.62	0.16	0.96	99.88

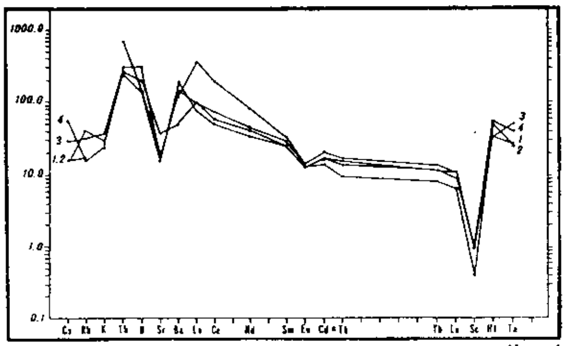


Fig. 2a. Distribution of chondrite normalized incoherent, trace and rare earth elements:
1 - Gob.1, 2 - Agus.1, 3 - Bir.1, 4 - Gob.3

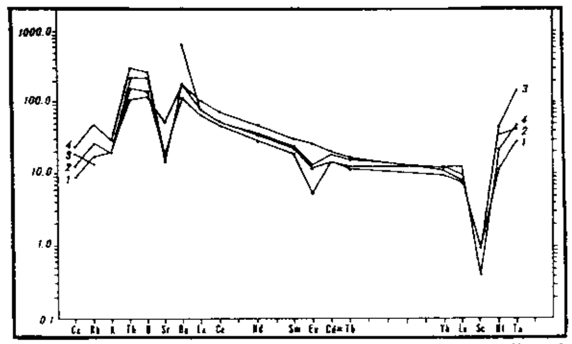


Fig. 2b. Distribution of chondrite normalized incoherent, trace and rare earth elements:
1 - An.3, 2 - An.6, 3 - An.4, 4 - An.1

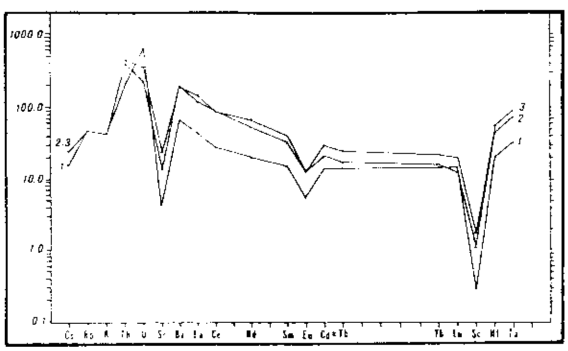


Fig. 2c. Distribution of chondrite normalized incoherent, trace and rare earth elements:
1 - Vas.5, 2 - Vas.1, 3 - Vas.7

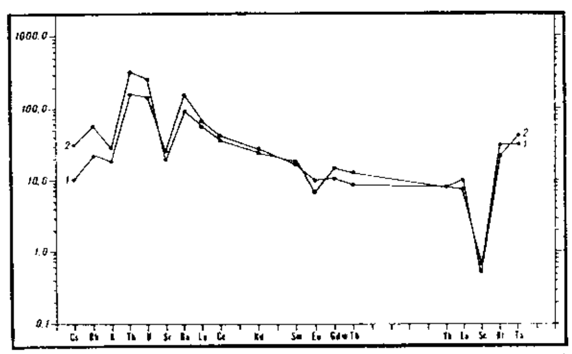


Fig. 2d. Distribution of chondrite normalized incoherent, trace and rare earth elements:
1 - Aert.2, 2 - Aert.3

ANALYTICAL DATA[2]

The distribution of trace and rare earth elements (REE)(Fig. 2) in the Khungariisk granites is quite consistent. The elemental concentrations are within the standard geochemical range for calc-alkaline granites and grano-д

[2] *Symbols used in all Figures*: Aert.2 - microquarzite from Anyui block; Aert.3 - granite from Gobile massif; An.1 - granite from Anyui block; An.3 - microquarzite from Anyui block; An.4 - garnet-biotite schist from Anyui block; An.6 - migmatite from Anyui block; Bir.1 - granite from Birsky massif; Agus.1 - fine-grained garnetiferous leucocratic granite from a dike intruding Agusinsky massif; Gob. 1 - granite from Gobile massif; Gob. 3 - migmatite from Anyui block; Vas. 1 - granite from Vasil'yevsky massif; Vas. 5 - gneissoid granite from Vasil'yevsky massif; Vas. 7 - granite from Vasil'yevsky massif

diorites (Geochemical..., 1993). Spider diagrams of gneiss, micro-quartzite and migmatite from the Anyui dome (Fig. 2) show patterns similar to those of the Khungariisk granites. We observed no significant variations in the trace element distributions among the studied massifs (Fig. 3).

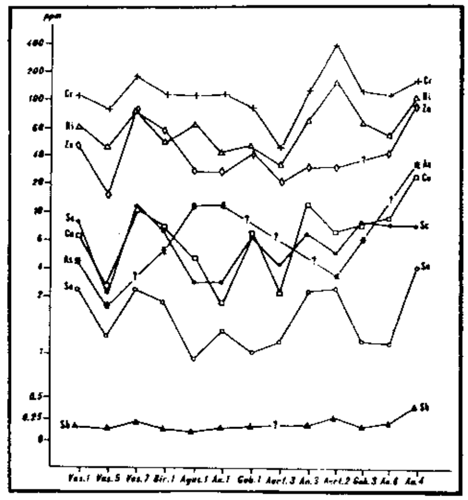
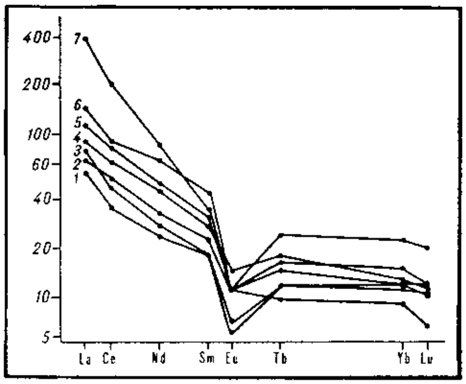


Fig. 3. Trace element contents (ppm) in samples of granites and metamorphic rocks:
Vas.1 - granite from Vasil'yevsky massif; Vas.5 - gneissoid granite from Vasil'yevsky massif; Vas.7 - granite from Vasil'yevsky massif; Bir.1 - granite from Birsky massif; Agus.1 - fine-grained garnetiferous leucocratic granite from a dike intruding Agusinsky massif; An.1 - granite from Anyui block; Gob.1 - granite from Gobile massif; Aert.3 - granite from Gobile massif; An.3 - microquarzite from Anyui block; Aert.2 - microquarzite from Anyui block; Gob.3 - migmatite from Anyui block; An.6 - migmatite from Anyui block; An.4 - garnet-biotite schist from Anyui block.

REE distribution in granites (Fig. 4a) is characterized by light rare earth element (LREE) enrichment (Ce/Yb = 12 - 26). All granites show a negative Eu anomaly. One sample (Agus-1) is exceptional because of its extreme LREE enrichment (Ce/Yb = 92.8).

REE contents of the gneisses, microquartzites and migmatites (Fig. 4b) are similar to that described for the granites. Ce/Yb varies from 17 to 26. A weak negative Eu anomaly is observed in the migmatites, but not in the metamorphic rocks.



← Fig. 4a. Chondrite normalized REE contents in granites: 1 - Aert.3; 2 - Gob.1; 3 - An.1; 4 - Bir.1; 5 Vas.1; 6 - Vas.7; 7 - Agus.1

Fig. 4b. Chondrite normalized REE contents in metamorphic rocks of Anyui block: 1 - Aert.2; 2 - An.3; 3 - An.6; 4 - Gob.3; 5 - An.4 →

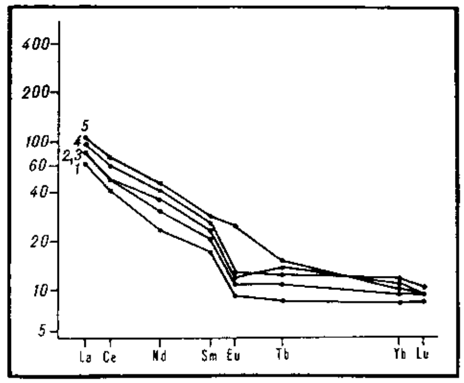


Table 2 presents calculated initial $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of the granites, and the same ratios for the Anyui dome samples calculated for 120 Ma in order to compare with the granite compositions. In the Nd-Sr isotope diagram (Fig. 5) Nd and Sr isotope compositions are strongly anticorrelated, and nearly all lie in quadrant IV, compositions characteristic of Precambrian continental crust. Initial Sr isotope compositions range from 0.703045 to 0.709775, and initial Nd composition ranges from Epsilon Nd = - 0.2 to - 4.7. These compositions indicate the granites were derived at least in part from remelting Precambrian continental crust (Faure, 1989).

Further evidence of an old source comes from 2-stage, depleted-mantle model ages calculated for the analyzed samples (Table 2). The model ages of the granites are within a very narrow range of 0.9 to 1.1 Ga for all but the Birsk massif which has a slightly older model age of 1.25 Ga.

These model age distributions and the constant REE patterns indicate that 1) the source for the Kungariisk granites was quite uniform over the sampled region and 2) continental crust at least approximately 1.0 Ga was melted or assimilated during production of the granitic magmas.

Samples of the Anyui migmatite and quartzite have less radiogenic Nd compositions than the granites (initial Epsilon Nd = -5.4 to -7.3) and therefore older model ages of 1.3 to 1.5 Ga. One sample (An-4 schist) has isotopic compositions similar to that expected for island-arc related rocks.

Because the isotopic compositions of the Anyui dome samples span the observed range for the granites, it is possible that the granites were derived exclusively from remelting of this type of continental crust.

The relation of measured $^{87}Sr/^{86}Sr$ to Rb and Sr concentrations and to $^{87}Rb/^{86}Sr$ for the granites are shown in Fig. 6. Sr isotope ratios do not correlate with Sr concentration (which ranges from 112 to 232 ppm).

Table 2. Isotope geochronological data for granites and metamorphic rocks

Sample	[Rb] ppm	[Sr] ppm	[Nd] ppm	[Sm] ppm	143Nd/144Nd cor±	E(0)Nd cor±	87Sr/86Sr cor±	E(0)Sr cor±	87Rb/86Sr	Initial 87Sr/86Sr	147Sm/144Nd	T(DM) L&HNd	E(T)Nd	Age(GA)
Aert.2	66.48	180.44	17.449	3.2446	0.512201±7	-8.53±0.27	0.714801±9	146.22±0.28	1.0663	0.712982	0.1125	1.45	-7.26	0.120
							0.714807±10	146.30±0.28						
Aert.3	195.68	144.47	16.843	3.6000	0.512576±8	-1.21±0.31	0.709730±7	74.24±0.20	3.9198	0.703045	0.1293	0.90	-0.19	0.120
An.1	160.10	111.54	16.322	3.3788	0.512519±6	-2.32±0.23	0.712018±9	106.71±0.26	4.1539	0.704934	0.1252	0.98	-1.24	0.120
							0.712020±11	106.74±0.31						
An.4	44.68	573.70	27.500	5.7730	0.512775±6	2.68±0.23	0.704379±6	-1.72±0.17	0.2254	0.703995	0.1270	0.59	3.73	0.120
An.6	82.55	176.19	23.269	4.6035	0.512303±5	-6.53±0.20	0.711968±7	106.00±0.20	1.3559	0.709656	0.1197	1.30	-5.37	0.120
		176.19												
Bir.1	116.38	172.17	29.239	5.7784	0.512339±7	-5.83±0.27	0.713111±8	122.23±0.23	1.9562	0.709775	0.1195	1.25	-4.67	0.120
Agus 1	51.29	232.16	61.257	redo	0.512503±7	-2.63±0.27	0.707179±9	38.03±0.26	0.6394	0.706089	REF	REF	REF	0.120
							0.707180±7	38.04±0.20						
Gob.1	126.82	155.78	23.926	4.9922	0.512454±6	-3.59±0.23	0.710968±5	91.81±0.14	2.3560	0.706950	0.1262	1.08	-2.53	0.120
Gob.3	48.20	405.87	28.406	redo	0.512254±7	-7.50±0.27	0.708889±8	62.30±0.23	0.3437	0.708303	Value	Value	Value	0.120
							0.708881±11	62.19±0.31						
Vas.1	150.66	161.65	20.931	6.0000	0.512488±7	-2.93±0.27	0.711426±8	98.31±0.23	2.6972	0.706826	0.1734	1.09	-2.58	0.120
							0.711387±6	97.76±0.17						
Vas.5	141.10	73.48	9.457	2.0965	0.512502±6	-2.66±0.23	0.716152±7	165.39±0.20	5.5569	0.706675	0.1341	1.02	-1.71	0.120

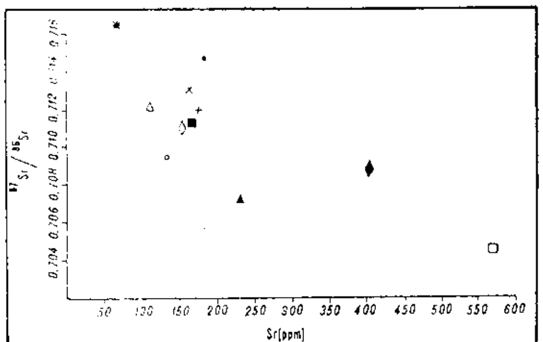


Fig. 6a. Diagram of measured $^{87}Sr/^{86}Sr$ versus concentration of Sr (ppm)(symbols as in Fig. 5)

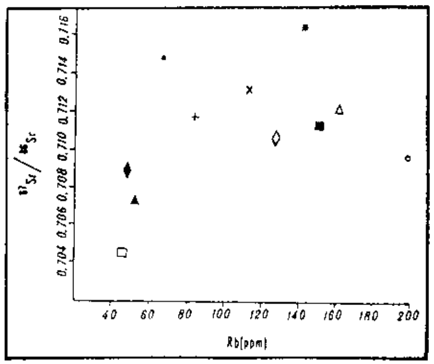


Fig. 6b. Diagram of measured $^{87}Sr/^{86}Sr$ versus concentration of Rb (ppm)(symbols as in Fig. 5)

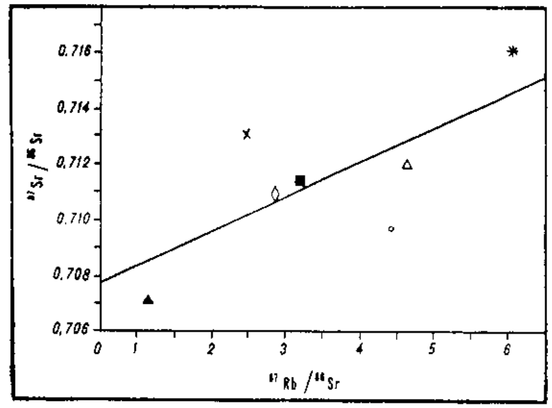


Fig. 6c. Rb-Sr isochron of Khungariisk series granites (symbols as in Fig. 5)

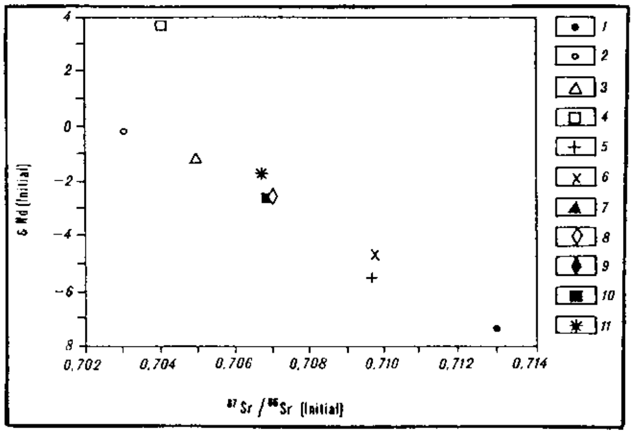


Fig. 5. Isotope compositions of Nd and Sr in granites and metamorphic rocks.
1 - Aert.2; 2 - Aert.3; 3 - An.1; An.3; 4 - An.4; 5 - An.6; 6 - Bir.1; 7 - Agus.1; 8 - Gob.1; 9 - Gob.3; 10 - Vas.1; 11 - Vas.5; Vas.7.

The isotope ratios show a weak correlation with Rb concentration (which ranges from 116 to 196 ppm) and a rough correlation with $^{87}Rb/^{86}Sr$ ratio. There is no interpretable age information preserved in the $^{87}Rb/^{86}Sr$ versus $^{87}Sr/^{86}Sr$ isochron plot.

Based on their geologic setting and petrologic and geochemical characteristics, the Khungariisk granites are S-type granites formed during continental- microcontinent collision. The presence of 1) xenoliths of metamorphic rocks in the granites, 2) the similarity of the trace and REE characteristics of the granites with the Anyui block metamorphic rocks, and 3) the overlap of isotopic compositions and Nd model ages of the granites and metamorphic rocks suggest that the granites may have originated by melting of the Anyui crust. We suggest that the Khungariisk granites formed by anatectic melting of continental crust as a result of early Cretaceous collision of the Anyui microcontinent with the Asian continent.

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