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Rock Series and Genetic Types of Granitoids in the Western Kunlun Orogenic Belt, China

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Abstract A systematic geological and geochemical study was conducted for the granitoids of different periods in the western Kunlun orogenic belt. The study indicates that the granitoids belong to tholeiitic, calc-alkaline, high-K calc-alkaline, alkaline and shoshonitic series, and that there are 5 genetic types, i.e., I-, S-, M-, A- and SH-type, of which SH-type is first put forward in this paper, which corresponds to shoshonitic granitoids.

Key words: granitoid, rock series, genetic type, western Kunlun orogenic belt

1 Introduction

The western Kunlun orogenic belt, including the western Kunlun Mts, Karakorum Mts and part of the Pamirs, is a component part of the Qinghai-Tibet plateau. Because of its special tectonic position, located in the junction between the Pal-Asia and the Tethyan tectonic domain, it has important research significance. The magmatism in the study area was strong and granitoids are widespread. Although many earlier researchers (e.g. Wang Yuzhen et al., 1987; Fang Xilian et al., 1990; Jiang Chunfa et al., 1992; Zhang Yuquan et al., 1989; Xu Ronghua et al., 1994; Ding Daogui et al., 1996; Pan Yusheng, 1996) studied the granitoids, their studies were carried on just along the China-Pakistan and Xinjiang-Tibet highways with the emphasis on chronology in stead of such topics as rock series and genetic type of granitoids (only calc-alkaline series and I-type granites have been reported). In this work, a geological and geochemical study of 22 representative granitoid plutons of different periods was carried out in the hinterland of the western Kunlun orogenic belt, such as Oytag, 128 km, northern Talong, west side of Datong, northern and western Kuda, Kongur, Andax, Akeax, Kaxlam, Qiukutai, Mazar, Xaidulla, Kunjirap, Kalaqigu, Luobugaizi, Wupulang, Mingteke, Aranbaotai, Kuzigan, Karibasheng and Zankan (Fig. 1). The rock series of granitoids in the study were demonstrated and their genetic types were classified.

2 Regional Tectonics and Space-time Distribution of Granitoids

There are developed five suture zones from north to south in the western Qinghai-Tibet plateau (Pan Yusheng, 1994; Deng Wanming, 1995): (1) Oytag-Kuda-Subashi suture zone; (2) Mazar-Kangxiwar suture zone; (3) Ta'axi-Hongshanhu suture zone; (4) Bangonhu-Nujiang suture zone; and (5) Yarlung Zangbo suture zone. Except the Yarlung Zangbo suture zone, these suture zones extend to the study area (Fig. 1). From north to south the tectonic units are the Tarim basin, western Kunlun terrane, Taxkorgan-Tianshuihai terrane, Karakorum terrane and Gangdise terrane.

According to isotopic ages determined in this work and by previous researchers and the tectonomagmatic period classification scheme formulated by the former Ministry of Geology and Mineral Resources (1989) in combination with the contact relationships and petrographical and geochemical characteristics of the intrusions, Jiang Yaohui (1999) divided the granitoids of the intrusions, Jiang Yaohui (1999) divided the granitoids into 6 intrusive cycles, i.e. late Proterozoic, Caledonian, Hercynian, Indosinian, Yanshanian and Himalayan, and further into 9 intrusive periods, i.e. the late stage of the late Proterozoic (629.9 Ma), early

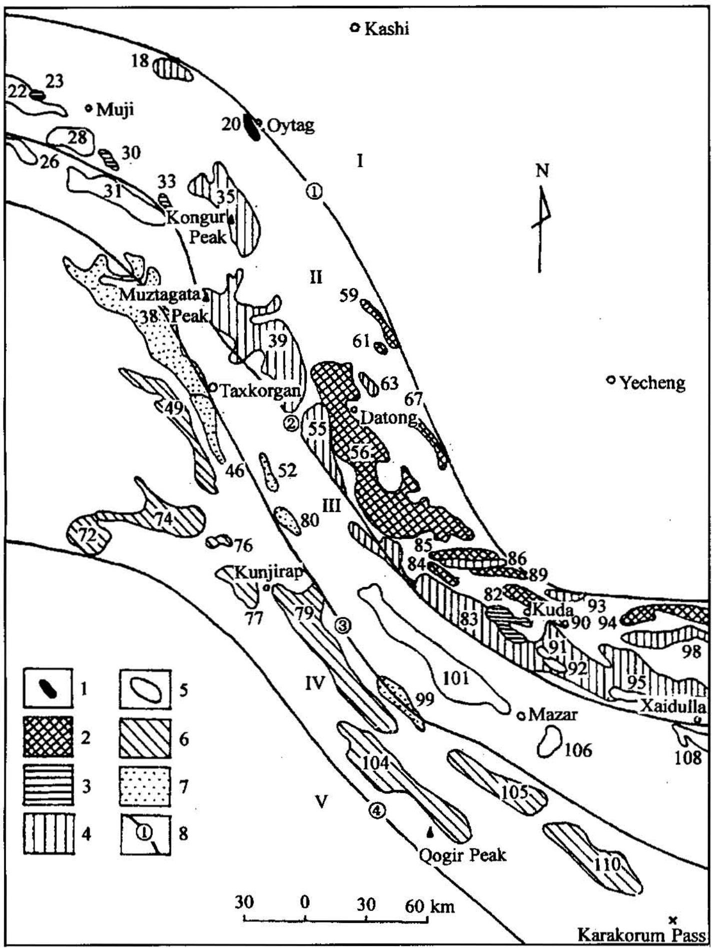

Fig. 1. A map showing the distribution of granitoids in the western Kunlun orogenic belt (modified after Wang Yuzhen et al, 1987).

1-Late stage of the late Proterozoic: Oytag (20); 2-early Caledonian: Awaleke (61), Kegang (67), 128 km (89) and northern Talong (94); middle Caledonian: west side of Datong (56); late Caledonian: Quepuhe (84), northern Kuda (90); 3-late Hercynian: western Kuda (82); 4-late Indosinian: Kongur (35), Muztagata (39), Andax (55), Akeax (83), Kaxlam (93); 5-early Yanshanian: Qiukutai (31), Mazar (101), Xaidulla (108), southern Kuda (91), north side of Victory Bridge (92), northern Heiqia (95); 6-late Yanshanian: Early Cretaceous: Luobugaizi (74), Kalaqigu (76), Kunjirap (77) and Keleqinhe (104); late Cretaceous: Aranbaotai (49), Mingteke (72), Wupulang (79) and Agele (105); 7-Himalayan: Karibasheng (38), Kuzigan (46), Zankan (80), Tatulugou (99); 8-suture and its number: ①Oytag-Kuda- suture zone; ②Mazar-Kangxiwar suture zone; ③Ta'axi-Hongshanhu suture zone; ④Bangonghu-Nujiang suture zone. I-Tarim basin; II-western Kunlun terrane; III-Taxkorgan-Tianshuihai terrane; IV-Karakorum terrane; V-Gangdise terrane. 18–110 denote the numbers of intrusions (Wang Yuzhen et al., 1987).

Caledonian (528–495 Ma), middle Caledonian (478.8 Ma), late Caledonian (450–389 Ma), late Hercynian (274–278 Ma), late Indosinian (227.6 Ma), early Yanshanian (207.8–156.8 Ma), late Yanshanian (110.9–75.1 Ma), Himalayan (48–11.45 Ma). It can be seen in Fig. 1 that on the whole the granitoids have a NW-SE-striking distribution, parallel to the four suture zones. The granitoids from the late stage of the late Proterozoic to the Caledonian are distributed mainly in the north part of the western Kunlun terrane on the south side of the Oytag-Kuda-Subashi suture zone, those from the late Hercynian to the late Indosinian mainly in the south part of the western Kunlun terrane on the north side of the Mazar-Kangxiwar suture zone; those of the early Yanshanian mainly in the Taxkorgan-Tianshuihai terrane on the north side of the Ta'axi-Hongshanhu suture zone with a minor part in the western Kunlun terrane, and those from the late Yanshanian to Himalayan mainly in the Karakorum terrane on the north side of the Bangonghu-Nujiang suture zone. It is clear that the granitoids become younger gradually from north to south in space. Their spatial and temporal distribution pattern shows that they are closely related with the regional tectonic evolution.

3 Series of Granitoids

In this work, the contents of major, rare earth and trace elements from 22 granitoid plutons (Table 1) and the Sr, Nd and O isotope compositions and the compositions of rock-forming minerals from 9 representative granitoid plutons (Table 2) were determined. On the basis of these results together with previously published data, we have done the classification of rock series. Rock alkalinity was determined by means of the Wright (1969) method and the classification of rock series was done by using the AR-SiO_2 diagram (Fig. 2) as well as the Rittmann Index (σ) and K_2O-SiO_2 diagram (Fig. 3). The results indicate that the granitoids in the study area belong to low-K tholeiitic (the late stage of the late Proterozoic), calc-alkaline (late Hercynian), high-K calc-alkaline (early Caledonian, and early and late Yanshanian), shoshonitic (middle and late Caledonian, Himalayan) and alkaline (late Indosinian) series, respectively.

3.1 Low-K tholeiitic series

The Oytag pluton belongs to this series. The rocks are rich in SiO_2 (73.36% to 77.58%) and Na_2O (4.70% to 5.76%), poor in K_2O (0.06% to 0.88%) and Al_2O_3

Table 1 Average chemical compositions of granitoids of different rock series and genetic types in the western Kunlun orogenic belt

Rock series	Low-K tholeiitic series	Calc-alkaline series	High-K calc-alkaline series		Shoshonitic series	Alkaline series	Rock series	Low-K tholeiitic series	Calc-alkaline series	High-K calc-alkaline series		Shoshonitic series	Alkaline series
Genetic type	M	I	I	S	SH	A	Genetic types	M	I	I	S	SH	A
Number of samples	4	6	31	7	34	20	Sample number	4	2	13	5	26	9
SiO_2	75.35	65.04	62.38	72.36	65.33	72.60	Sc	8.72	7.3	9.00	4.15	6.52	2.6
TiO_2	0.18	0.52	0.68	0.24	0.55	0.20	V	31.6	81.9	96.0	18.6	74.0	19.1
Al_2O_3	12.09	15.67	16.14	14.20	14.94	13.57	Cr	31.9	39.4	53.7	11.4	35.1	18.1
Fe_2O_3	0.93	1.02	1.15	0.50	1.75	0.72	Zn	36.4	90.8	81.4	46.6	138.5	50.5
FeO	1.41	3.57	4.00	1.48	1.93	1.49	Rb	8.0	82.2	136.0	312	231	241
MnO	0.06	0.10	0.14	0.05	0.08	0.05	Ba	177	1530	989	423	2646	524
MgO	0.18	1.51	2.43	0.48	1.31	0.40	Sr	62.3	333	406	179	1093	104
CaO	1.97	3.89	4.61	1.36	3.43	1.28	Th			13.4	17.3	53.8	33.0
Na_2O	5.19	4.04	3.10	3.06	3.63	3.57	U			3.3	5.8	7.36	5.0
K_2O	0.51	2.61	3.09	4.68	5.52	4.66	Nb	4.07	17.4	13.2	16.2	22.6	17.4
P_2O_5	0.06	0.17	0.21	0.12	0.23	0.08	Zr	111	200	163	107	232	150
Na_2O+K_2O	5.70	6.65	6.19	7.74	9.15	8.23	Y	43.4	26.5	20.5	19.0	31.5	33.2
K_2O/Na_2O	0.10	0.65	1.00	1.50	1.52	1.31	F			491	895	1748	500
A/CNK	<1	<1	<1	>1.1	<1	<1.05	ΣREE	115.75	204.66	227.88	138.82	461.68	245.11

Note: Samples were analyzed at the Nanjing Institute of Geology and Mineral Resources, Ministry of Land and Resource and the Central Laboratory of Xinjiang Bureau of Geology and Mineral Resources with the wet chemical method for major elements, AAS for Rb and ICP for others.

Table 2 Sr, Nd and O isotope compositions of the granitoids in the western Kunlun orogene

Period	Intrusion (No.)	Sample No.	Lithology	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{87}Sr$	I_{Sr}	ε_{Sr}	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	I_{Nd}	ε_{Nd}	T_{DM} (Ma)	$\delta^{18}O$ (‰)
Himalayan	Karibasheng	T1-1	Biotite	0.5953	0.709229	0.709144	66.1	0.07678	0.512256	0.512255	−7.5	997	11.88
Late	Kunjirap	H-1	Monzonitic					0.1103	0.512168	0.512148	−8.9	1448.2	8.78
Early	Mazha (101)	MZ-4	Monzonitic	1.283	0.71283	0.709455	73.5	0.1182	0.512245	0.512209	−7.2	1445.3	9.98
Late	Konggur	YQ-2	Granite										10.96
Late	West Kuda	SE-2	Granodiorite	0.7787	0.711491	0.708433	60.5	0.1235	0.512337	0.512114	−8.5	1375.2	6.87
Late	North Kuda	KD-2	Granite	4.255	0.736426	0.712493	120.2	0.08229	0.512408	0.512195	1.09	862.8	11.58
Middle	West side of	D019	Quartz	0.2859	0.710268	0.708318	62.4	0.1085	0.512219	0.511879	−11.8	1349.9	4.36
Early	128 km (89)	E-4	Granodiorite	4.931	0.710814			0.109	0.512288	0.511935	−10.6	1256.4	6.82
Late late Proterozoic	Oytag (20)	WY-11	Plagiogranit	0.4325	0.706613	0.702588	−16.1	0.2154	0.512971	0.51205	4.34	629.9*	
		WY-17	Plagiogranit					0.1832	0.512978				6.58
		WY-18	Plagiogranit					0.2031	0.512668				
		WY-18	Plagioclase					0.2188	0.51291			599.8*	

Note: Sr and Nd isotopic analysis by the Institute of Geology, Chinese Academy of Geologica Sciences; O isotopic analysis by the Nanjing Institute of Geology and Mineral Resources, Chinese Academy of Geologica Sciences; * calculated based on initial value of the ophiolite.

(11.54% to 13.22%) with A/CNK<1 and σ=0.96–1.08 (<1.8). In the K_2O-SiO_2 diagram (Fig. 3), the compositions are plotted in the field of the low-K tholeiitic series. The granites have relatively low ΣREE (91.58×10^{-6}–167.54×10^{-6}, averageing 115.75×10^{-6}, Table 1) and LREE/HREE (0.58–0.73) with slightly negatyive negative Eu anomalies (δEu=0.56–0.90, averageing 0.71), belonging to the LREE-depletion pattern. All trace elements have low contents except Y and Sc (Table 1). The whole-rock $\delta^{18}O$, I_{Sr}, ε_{Sr} and ε_{Nd} value are 6.58‰, 0.7026, −16.1, and 4.34, respectively. The compositions are plotted in the field of the mantle source in the t-I_{Sr} diagram.

3.2 Calc-akaline series

The western Kuda pluton belongs to this series. The rocks have SiO_2 content of 59.73–71.04%, and high Al_2O_3 (13.56%–16.90%) and CaO (2.10%–5.97%) with A/CNK<1, (K_2O+ Na_2O)=5.59–7.46% , K_2O/ Na_2O<1, and σ=1.69–2.58 (between 1.8 and 3.3 mostly). The compositions are plotted in the calc-alkaline rock field in the AR-SiO_2 diagram (Fig. 2) and plotted in the field of the calc-alkaline series in the K_2O-SiO_2 diagram (Fig. 3). The granitoids have moderate ΣREE (179.3×10^{-6}–230.01×10^{-6}, averaging 204.66×10^{-6}, Table 1) with LREE/HREE=2.99–5.97, belonging to the LREE enrichment pattern, and δEu=0.64–1.01. The contents of transition elements are relatively high and LILE is selectively rich, whereas HFSE is relatively depleted (Table 1). The whole-rock $\delta^{18}O$, I_{Sr}, εSr and εNd values are 6.87 ‰, 0.7084, 60.5, and −8.5, respectively. The compositions are plotted in the field of the mantle-crust-mixing source in the t-I_{Sr} diagram.

3.3 High-K calc-alkaline series

This series has two different geochemical characteristics in the study area. (1) The granitoids with A/CNK<1: the plutons, such as those in 128 km, northern Talong, Qiukutai, Mazar, Xaidulla, Kunjirap, Kalaqigu, Luobugaizi, belong to this case. The rocks have SiO_2 content of 52.46–70.69%, and high contents of Al_2O_3 (13.46–18.98%) and CaO (2.30–7.19%) with (K_2O+ Na_2O)=4.95–7.75% , K_2O/ Na_2O=0.42–1.61 (averaging 1.00), σ=1.38–3.47 (mostly between 1.8 and 3.3). The compositions are plotted in the calc-alkaline rock field in the AR- SiO_2 diagram (Fig. 2) and plotted in the field of the high-K calc-alkaline series in the K_2O-SiO_2 diagram (Fig. 3). The granitoids have

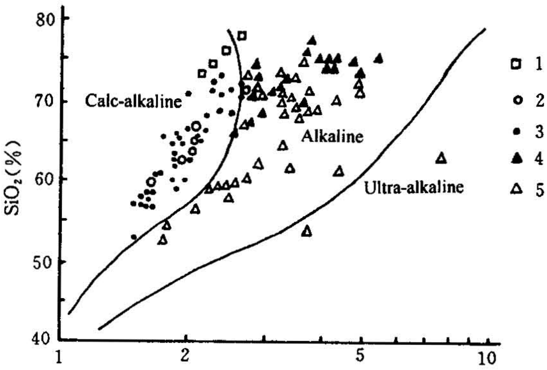

Fig. 2. AR- SiO_2 diagram (Wright, 1969).
1-Late stage of the late Proterozoic; 2-late Hercynian (2 samples from Kashi Geological Party, 1985); 3-early Caledonian (6 samples from Ding Daogui et al., 1996), early Yanshanian (2 samples from Ding Daogui et al., 1996), early Cretaceous (3 samples from Ding Daogui et al., 1996) and late Cretaceous; 4-Indosinian (8 samples from Ding Daogui et al., 1996); 5-middle and late Caledonian (3 samples from Ding Daogui et al., 1996), Himalayan (4 samples from Zhang Yuquan et al., 1994).

moderate ΣREE (130.75×10^{-6}–399.78×10^{-6}, averaging 226.70×10^{-6}, Table 1) with LREE/HREE=2.04–7.91, belonging to the LREE enrichment pattern, and δEu=0.50–0.96 (mostly between 0.70 and 0.90). The contents of transitional elements are relatively high and LILE is selectively rich, whereas HFSE is relatively depleted (Table 1). The whole-rock $\delta^{18}O$, I_{Sr}, εSr and εNd value are 6.82–9.98‰, 0.7095, 73.5 and −7.2–−10.6, respectively, with the composition values plotted in the field of the lower-crust source in the t-I_{Sr} diagram. (2) The granitoids with A/CNK>1.1: the plutons such as those in Wupulang, Mingtiegai and Aranbaotai

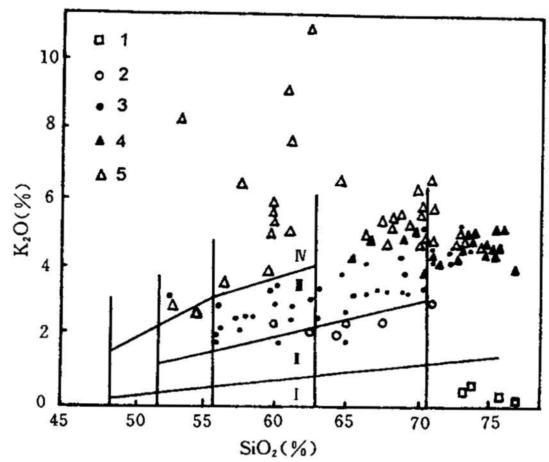

Fig. 3. K_2O-SiO_2 diagram (Peceerillo et al., 1976).
I-low-K tholeiitic series; II-calc-alkaline series; III-high-K calc-alkaline series; IV-shoshonitic series. Symbols the same as in Fig. 2.

belong to this case. The rocks have SiO_2 content of 70.95–73.92%, Al_2O_3 content of 12.55–16.68% and CaO content of 0.97–1.54%, and the content of K_2O+Na_2O is largely between 7% and 8% with K_2O/Na_2O=1.25–1.91 (averaging 1.50) and σ=1.80–2.32. The compositions are plotted in the calc-alkaline rock field in the AR-SiO_2 diagram (Fig. 2) and plotted in the field of the high-K calc-alkaline series in the K_2O-SiO_2 diagram (Fig. 3). The granitoids have low ΣREE (86.13×10^{-6}–212.35×10^{-6}, average 138.82×10^{-6}, Table 1) with LREE/HREE=2.07–3.57, and show moderately negative Eu anomalies with δEu=0.55 (averaging value). The notable feature of the trace elements is evident enrichment of Rb, while other elements have relatively low contents (Table 1). In addition, the rocks have high content of volatile F (1320×10^{-6} at highest, averaging 895×10^{-6}).

3.4 Shoshonitic series

The plutons, such as those in the west side of Datong, northern Kuda, Kuzigan, Karibasheng and Zankan, belong to this series. The rocks have SiO_2 content of 52.77–74.47% with CIPW Ne (or Q)<5% in basic rocks, and high content of K_2O+ Na_2O (mostly >8%) with the compositions plotted in the alkaline rock field in the AR-SiO_2 diagram (Fig. 2), suggesting that the rocks belong to the alkaline series. The rocks are equivalent to a basalatite-latite-trachyte-rhyolite assemblage in the TAS diagram, suggesting that they belong to the SiO_2-saturated alkaline series, and they are plotted in the field of the shoshonitic series in the K_2O-SiO_2 diagram (Fig. 3). The Fe content is lower than that of the alkaline series and shows an evolution tendency similar to calc-alkaline rocks (Jiang Yaohui et al, 1999a; 2000a) in the MgO-FeO* diagram (Morrison, 1980). The Al_2O_3 content (13.01–19.20%) is not only high but in a wide range. The granitoids have high ΣREE (273.28×10^{-6}–778.45×10^{-6}, averaging 461.68×10^{-6}, Table 1) with LREE/HREE=4.34–34.80 and are enriched obviously in LREE and LILE, whereas HFSE is relatively depleted (Table 1). In addition, the rocks have high content of volatile F (6480×10^{-6} at highest, averaging 1747.5×10^{-6}). The above features can be compared with those of shoshonitic rocks summarized by Morrison (1980). On the one hand, the Sr, Nd and O isotopic compositions of the shoshonitic series in the study area show the features of most shoshonitic rocks, that is, their source region is the metasomatic mantle, as exemplified by the middle Caledonian pluton (on the west side of Datong) with the whole-rock $\delta^{18}O$=4.36‰, I_{Sr}=0.7083 and ε_{Nd}=−2.78, discussed in detail by Jiang Yaohui (1999); on the other hand, such compositions show an unique feature of the study area, that is, the soure region is the crust, as exemplified by the late Caledonian (Jiang Yaohui et al., 1999b) and Himalayan granitoids (Jiang Yaohui, 1999) with the whole-rock $\delta^{18}O$=11.58–11.88‰, I_{Sr}=0.7091–0.7125 and ε_{Nd}=1.09–−7.5.

3.5 Alkaline series

The plutons such as those in Kongur, Andax, Akeax and Kaxlam belong to this series. The rocks have SiO_2 content of 65.48–77.12%, and low content of Al_2O_3 (11.44–16.13%, averaging 13.57%), CaO (0.42–2.87%, averaging 1.28%) and MgO (0.02–1.24%, averaging 0.40%) with A/CNK<1.05. They have high content of total alkalis (mostly K_2O+Na_2O>8%, averaging 8.23%). The composition values are plotted in the alkaline rock field in the AR-SiO_2 diagram (Fig. 2), suggesting that the rocks belong to the alkaline series. The granitoids have ΣREE content of 188.38×10^{-6}–377.45×10^{-6} (averaging 245.11×10^{-6}, Table 1). With an increase of acidity, LREE is reduced while HREE increases, and the Eu depletion becomes more evident. For example, the LREE/HREE ratio varies from 6.50 to 0.63 and δEu from 0.75 to 0.05 in the Kongur plution as the rock changes from monzogranite at the low-SiO_2 end-member to high-silica granite at the felsic end-member (Jiang Yaohui et al., 2000b), which is similar to the case of A-type granite from the Chaelundi complex in eastern Australia (Landenberger et al., 1996). The transitional elements and Sr and Ba are depleted, whereas HFSE is relatively enriched (Table 1). In the normalized primitive mantle patterns diagram, one can see clearly the valleys corresponding to Ba and Sr and peaks to La, Nd, Zr, Sm and Y. The whole-rock $\delta^{18}O$ value is 10.96‰.

4 Genetic Types of Granitoids

There are no less than 20 classification criteria for the genetic types of granites. The most common one is ISMA classification. I-, S- and M-type granites emphasize their material sources: I-type coming from igneous rocks or the lower crust; S-type from sedimentary rocks or the upper crust; and M-type from the mantle. A-type granites emphasize the forming tectonic environment (anorogenic or post-orogenic extended environment) and compositional features (alkaline, anhydrous or aluminous). In terms of rock series, I- and S-type granites are mainly classified into the calc-alkaline or high-K calc-alkaline series, M-type granites belong to the tholeiitic series and A-type granites are of the alkaline series. The rock series is a regional rock assemblage. Rocks from the same series are genetically related in both chemical and mineralogical compositions, but rocks from different series are different in their forming environments, material sources and forming processes. On the contrary, the petrogenetic information of rocks may be reflected by the rock series and geochemical features. Accordingly, based on mainly rock series in combination with petrographical and mineralogical features, we have divided the granitoids in the study area into 5 genetic types, which are discussed below.

4.1 M-type

Granitoids of the late stage of the late Proterozoic (Oytag pluton) belong to this type. The rock type is plagiogranite consisting mainly of plagioclase, quartz and hornblende, in which the plagioclase is identified as albite (Jiang Yaohui et al., 2000c). The rocks belong to the low-K tholeiitic series with the geochemical characteristics of the above-mentioned low-K tholeiitic series.

4.2 I-type

Granitoids of the early Caledonian, late Hercynian, and early and late Yanshanian belong to this type. Their rock assemblages are quartz monzodiorite-quartz monzonite-granodiorite (Jiang Yaohui et al., 1999c) or quartz monzodiorite-granodiorite-monzonitic granite (Jiang Yaohui et al., 2000b;2000d; 2000e), consisting mainly of plagioclase, orthoclase, quartz, biotite and hornblende, in which the plagioclase belongs to andesine or occasionally labradorite, or oligoclase in the case of acidic rocks; and the biotite is magnesio-biotite (Jiang Yaohui, 1999; Jiang Yaohui et al, 2000d; 2000e). The rocks belong to the calc-alkaline or high-K calc-alkaline series (A/CNK<1) and have geochemical characteristics of these two series as mentioned above.

4.3 S-type

Granitoids of the late Cretaceous belong to this type. The notable feature is that there are muscovites varying in amount in the rocks, forming a rock assemblage of two-mica monzonitic granite–two-mica granite. The granites consist mainly of microcline, plagioclase, quartz, biotite and muscovite, in which the plagioclase is oligoclase. The rocks belong to the high-K calc-alkaline series, but A/CNK>1.1, and have the geochemical features of this rock series.

4.4 A-type

Granitoids of the late Indosinian belong to this type. The rock assemblage is quartz monzonite-monzonitic granite-granite (Jiang Yaohui et al., 2000b), consisting mainly of orthoclase, plagioclase, quartz, biotite and hornblende, in which the plagioclase is albite, biotite belongs to ferribiotite and is interstitial to light coloured minerals, showing its late crystallization and anhydrous features (Jiang Yaohui et al., 2000b). The rocks belong to the alkaline series and have the geochemical features of this rock series as discussed above.

4.5 SH-type

This study reveals that there exists granitoids of another type differing from the 4 types as described previously, which belongs to the shoshonitic series. The representative is granitoids of the middle and late Caledonian, and Himalayan. The rocks form the following assemblages: (quartz) monzodiorite-(quartz) monzonite-quartz syenite (Jiang Yaohui et al., 1999a), monzonitic granite-granite (Jiang Yaohui et al., 1999b), and biotite (monzonitic) granite-diopside granite-diopside syenite (Jiang Yaohui et al., 2000a). Rocks of this type consist mainly of orthoclase, plagioclase, quartz, biotite, diopside and achromaite, in which the plagioclase is oligoclase and biotite is eastonite (Jiang Yaohui, 1999; Jiang Yaohui et al., 1999a, 1999b, 2000a). They have geochemical characteristics of the shoshonitic series. It is clear that they differ obviously from the above M-, I-, S- and A-type granitoids, thus named "SH-type granitoid" in this paper.

The shoshonitic series was confined to volcanic rocks in the past (Iddings JP, 1892; Joplin GA, 1968; Peceerillo A et al., 1976). Having studied the ore-bearing porphyries in the Goonumbla district, Australia, Muller et al (1993) considered that such rocks belong to the shoshonitic series. Recently, Zhang Yuquan et al (1998) demonstrated that ore-bearing porphyries of the Yulong copper ore belt in eastern Tibet also belong to the shoshonitic series. The shoshonitic granitoids discussed in this paper can also be compared with the shoshonitic rocks summarized by Morrison (1980) in terms of their geochemical features. It can be seen that rocks of the shoshonitic series are not confined to volcanic rocks, but include intrusive rocks. Just as volcanic rocks of the shoshonitic series were separated from the cale-alkaline series and alkaline series, SH-type granitoids should also be independent from I- and A-type granrtoids. Especially, the development of this granitoid type in different intrusive cycles and periods is of important significance for analysing tectonomagmatism of the western Kunlun orogenic belt.

5 Conclusions and Significance

There exist 5 series of granitoids in the western Kunlun orogenic belt, i.e., low-K tholeiitic, calc-alkaline, high-K calc-alkaline, alkaline and shoshonitic series.

Geneticaly there are M-, I-, S-, A- and SH-type granitoids in the western Kunlun orogenic belt, in which the SH type is corresponding to shoshonitic granitoids.

The study has revealed that granitoids of different rock series and genetic types in the western Kunlun orogenic belt are quite distinct in geological and geochemical characteristics. Besides, they do not have identical forming tectonic environments (Jiang Yaohui, et al., 2000f). Therefore, they have become a "probe" or "window" to study the tectonic evolution of the western Kunlun orogenic belt. A thorough study of this problem has scientific importance for clarifying the coupling relationship between the essential factors of the lithospheric evolution such as magmatism, orogeny, crustal uplift and mineralization, so as to raise the overall level of the research on the Qinghai-Tibet plateau.

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