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ORIGINAL ARTICLE

Abundances of chemical elements in granitoids of different geological ages and their characteristics in China

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Abstract Actual granitoid analytical data of 767 composited samples are presented here. The data source is 6080 samples collected mainly from 750 large- to middle-sized granitoid bodies across China. Data from the composited samples, which includes that of 70 elements, is analyzed according to geological age — Archeozoic (Ar), Proterozoic (Pt), Eopaleozoic (Pz_1), Neopaleozoic (Pz_2), Mesozoic (Mz), and Cenozoic (Cz) — and three major compositional varieties, e.g. alkali-feldspar granite, syenogranite and adamellite. Petrochemical parameters, trace-element content and rare-earth element (REE) distributions of the different rock types and geological ages are characterized, and change tendencies through Archean to Cenozoic time are recorded. The comprehensive analytical data presented here has not been previously published. This significant data set can be used as fundamental information in studies of basic China geology, magma petrogenesis, ore exploration and geochemistry.

1. Introduction

The variation in abundance of chemical elements in granitoids is seen as an important part of the study of element abundances of the Earth's crust. Since Daly (1933) first published the average chemical composition of major elements in the world's granitoids, much further information and data have been successively published around the world including China by many authors using different methods of calculation (Nockolds, 1954; Turekian and Wedepohl, 1961; Vinogradov, 1962; Li and Yio, 1963; Beus, 1972; Le Maitre, 1976; Yan and Chi, 1997; Li et al., 1998; Shi et al., 2005a,b, 2007).

On the basis of actual analytical data from about 500 granitoid bodies in eastern China and some collected major element data from granitoid bodies in western China, Yan and Chi (1997) calculated the average values of 76 elements or components in acidic rock of

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different geological ages in five geotectonic units: the Xing'an-Jihei orogenic zone, Inner Mongolia; the North China platform; the Qinling–Dabieshan orogenic zone; the Yangtze platform (East); and South China system of folds. Similarly based on analytical data, Shi et al. (2005a,b, 2007) discerned the abundances of about 70 chemical elements and their compositions in Chinese granitoids in general and in various types of granite of different ages and tectonic settings. Furthermore, much data and information about the chemical composition of Chinese granites (granitoids), both on a regional scale and in single granite plutons, has been published by the Guiyang Institute of Geochemistry of Chinese Academy of Sciences (1979), The Science Exploration Team of Qinghai-Tibet Platean of the Chinese Academy of Sciences (1982), Lu (1987), Wang (1987), Yu et al. (1987), Zhang and Sun (1988), Liao (1989), Wang (1989), Zhang (1990), Li and Wang (1991), Zhang et al. (1994), Wang and Zhang (2001), and Xu et al. (2001). Although much useful compositional research has thus been done, a national and systematic research program on actual multielement abundances of different granitoid rock types from different geological ages is still lacking. As yet, there are no average values of chemical compositions and element abundances of different granitoids of different geological ages calculated exclusively from Chinese data; this paper addresses that problem.

2. Methodology

Some topics discussed here regarding distribution of Chinese granitoid samples (Fig. 1), sample collecting, sample preparation and method of calculating the abundance value have previously been discussed by Shi (2003) and Shi et al. (2005b). About 70 elements from granitoid samples in eastern China, including alkali feldspar granite, syenogranite, admellite, granodiorite, etc., have been analyzed using 15 analytical methods by analytical laboratories relying mainly on instrumental neutron activation analysis (INAA) and X-ray fluorescence spectrometry (XRF; Yan and Chi, 1997). The specific analytical methods applied to various elements in the granitoid samples from western and southeastern China are as follows: non-fire atomic absorption spectrometry (AAN) – Au; emission spectrometry (ES) – Ag, B, Sn; atomic fluorescence spectrometry (AFS) – As, Ge, Hg, Sb, Se; potentiometry (PO) – CO_2; fused disc X-ray fluorescence spectrometry (FU-XRF) – SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5; gravimetry (GR) – H_2O^+; volumetry (VOL) – FeO; inductively coupled plasma masses (ICP-MS) – Bi, Cd, Co, Cs, Cu, Ga, Hf, Mo, Ni, Sc, Ta, Tl, U, W, Ce, Dy, Er, Eu, Gd, Ho, La, Lu, Nd, Pr, Sm, Tb, Tm, Y, Yb; inductively coupled plasma optical emission spectrometry (ICP-OES) – Be, Cr, Li; ion selective electrode (ISE) – F; and pressed disc X-ray fluorescence spectrometry (XRF) – Ba, Cl, Mn, Nb, P, Pb, Rb, S, Sr, Th, Ti, V, Zn, Zr. For major elements, the sum of the contents of compositions must lie within the range of 99.00%–100.70%.

National preliminary geochemical certified reference materials (CRMs) and confidential duplicates were used to carefully monitor analysis quality. The analytical precision was evaluated by the relative deviations (RD) of 35 confidential duplicates. The accuracy of analyses was evaluated by the relative errors (RE) of

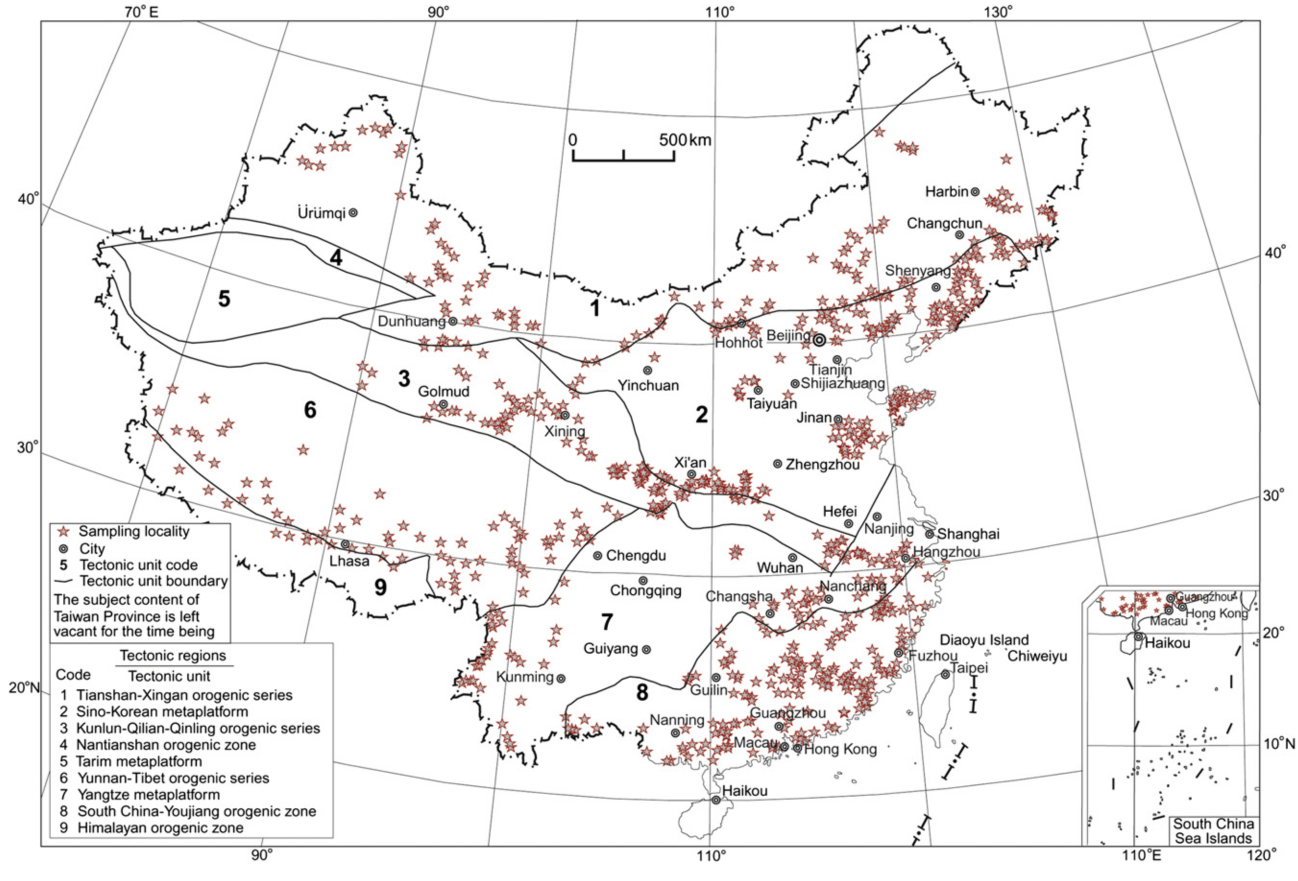

Figure 1 Sampling localities of granitoid samples in China used in this paper (after Shi et al., 2005b).

Table 1 Total average chemical composition and element abundance from granitoid samples of different geological ages in China.

Ages	Ar	Pt	Pz_1	Pz_2	Mz	Cz
Nc	34	87	66	136	379	31
Ns	290	848	483	981	3233	61
SiO_2	72.43	72.22	70.93	71.59	72.42	73.84
TiO_2	0.26	0.25	0.31	0.33	0.26	0.22
Al_2O_3	14.23	14.12	14.63	14.47	14.14	13.90
Fe_2O_3	1.39	0.89	0.74	0.97	0.86	0.53
FeO	0.62	1.00	1.31	1.28	0.94	1.26
MnO	0.032	0.040	0.048	0.050	0.046	0.048
MgO	0.42	0.40	0.73	0.61	0.46	0.34
CaO	1.15	1.13	1.62	1.69	1.18	1.43
Na_2O	3.73	3.81	3.10	3.69	3.58	3.19
K_2O	4.23	4.07	4.35	3.92	4.48	4.70
P_2O_5	0.08	0.06	0.11	0.10	0.09	0.09
H_2O^+	0.96	0.90	0.98	0.75	0.74	0.52
CO_2	0.17	0.22	0.25	0.27	0.20	0.37
TFe_2O_3	2.12	2.18	2.36	2.47	1.98	1.77
Ag	50	53	55	51	53	39
As	0.6	0.7	1.0	1.3	0.9	0.8
Au	0.40	0.30	0.37	0.41	0.35	0.29
B	6.0	3.7	5.2	5.7	3.6	4.2
Ba	929	720	597	574	519	366
Be	1.7	1.7	3.1	2.0	3.2	4.3
Bi	0.07	0.09	0.19	0.11	0.16	0.14
Cd	40	50	69	64	50	38
Cl	59	64	53	65	56	79
Co	3.4	2.5	3.6	4.6	2.5	1.8
Cr	6.7	5.0	9.9	6.0	5.0	3.4
Cs	1.7	1.6	6.6	3.8	3.8	8.4
Cu	6.8	5.2	6.7	5.5	4.4	3.5
F	340	367	504	394	510	844
Ga	18	18	17	18	18	19
Ge	1.10	1.10	1.20	1.30	1.31	1.52
Hf	4.4	4.6	4.5	4.8	5.0	5.2
Hg	6.5	5.0	6.0	5.5	5.0	4.1
Li	12	11	31	20	21	34
Mn	250	311	365	375	359	347
Mo	0.32	0.35	0.43	0.49	0.57	0.42
Nb	11.0	11.0	12.8	10.5	15.9	14.8
Ni	4.1	3.0	6.8	4.9	4.2	2.4
P	327	273	492	462	405	392
Pb	19	26	33	21	27	29
Rb	118	109	185	123	169	262
S	70	80	100	88	90	89
Sb	0.12	0.12	0.13	0.16	0.12	0.08
Sc	3.6	4.7	5.7	6.2	4.5	6.6
Se	0.029	0.024	0.031	0.019	0.020	0.005
Sn	1.0	1.3	3.4	1.8	2.0	7.2
Sr	235	190	153	199	174	125
Ta	0.64	0.85	1.33	1.00	1.45	2.02
Th	9.9	9.1	18.6	12.4	18.3	23.9
Ti	1358	1438	1776	1856	1390	1271
Tl	0.68	0.59	0.93	0.64	0.89	1.39
U	1.20	1.48	3.55	2.12	3.30	6.43
V	19	16	30	30	21	19
W	0.24	0.33	0.97	0.58	0.83	1.35
Zn	34	42	45	48	42	40
Zr	142	146	152	141	149	129

(*continued on next page*)

Table 1 (*continued*)

Ages	Ar	Pt	Pz_1	Pz_2	Mz	Cz
La	39	28	38	28	35	34
Ce	74	52	68	53	65	61
Pr	–	6.60	7.77	6.01	6.82	7.35
Nd	25.7	23.4	27.6	21.7	25.8	25.4
Sm	3.40	3.94	5.12	4.22	4.60	6.18
Eu	0.78	0.86	0.86	0.85	0.79	0.65
Gd	4.5	3.7	4.4	4.1	4.7	6.1
Tb	0.39	0.52	0.69	0.58	0.65	0.92
Dy	–	4.2	3.8	3.9	3.8	5.1
Ho	–	0.78	0.77	0.78	0.76	1.01
Er	–	2.32	2.13	2.22	2.20	2.63
Tm	–	0.40	0.38	0.38	0.38	0.44
Yb	0.91	1.83	2.00	2.11	2.16	2.72
Lu	0.16	0.28	0.31	0.34	0.35	0.40
Y	18.0	17.0	21.7	19.1	20.5	27.2

Nc = number of analyzed composited samples. Ns = number of collected samples. Content units: 10^{-9} for Au, Ag, Cd, Hg; 10^{-2} for major elements; 10^{-6} for others. Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic. "—" represents no statistical significance due to insufficient numbers of analyzed data.

98 internationally accepted confidential CRMs compared with the actual determinations with their certified values (Shi et al., 2005b).

The element-ranking sequence of Thompson (1982) and chondrite data of Hermann (1970) were used to normalize the data in this paper. Classification and naming of granitoids follows the Quartz-Alkali feldspar-Plagioclase (QAP) triangle diagram according to the scheme recommended by the Igneous Rock Classification Committee of the International Union of Geological Sciences (IUGS) (Shi, 2003). The "granitoids" include acidic intrusive rocks and middle-acidic intrusive rocks in the QAP triangle diagram, such as alkali feldspar granite, syenogranite, adamellite, granodiorite, quartz monzonite and quartz monzodiorite.

3. Element abundance

The average chemical compositions and abundances of about 70 chemical elements in collective Chinese granitoids and, specifically, in alkali feldspar granite, syenogranite and adamellite are listed in Tables 1–4. The data is sorted by the geologic age (Ar, Pt, Pz_1, Pz_2, Mz and Cz) of about 750 representative granitoid bodies on the Chinese mainland (Shi, 2003).

4. Element abundance tendencies of granitoids through time

4.1. Characteristics of element abundance

It is difficult to analyze and study directly the features of element abundances of the granitoids from different geological ages without comparing standards because the content levels, grades and units of different elements are different. In order to analyze clearly and simply the characteristics, the element abundances are first standardized using the national element abundances of granitoids (NEAG, Shi et al., 2005b). As compared to the NEAG, the element abundances of granitoids through time have different distribution patterns and present different characters.

Archean (Ar): the elements that are concentrated in the oldest granitoids are lithophiles B, Ba and Sr, siderophiles Fe, Co and Cr, and chalcophiles Cu, Se and Hg. Lithophile elements of Na, Al, Si, K and Zr and chalcophile elements of Au, Ga and Ag are close to the NEAG. Lithophile elements of Cs, W and U are relatively poor.

Proterozoic (Pt): the elements concentrated in Pt granitoids are lithophiles Na, Sr and Ba and chalcophiles Cu and Se. Lithophile elements of Al, Si, K and Zr, siderophile elements of Fe, Ti, Cr and Sc and chalcophile elements of Zn, Ga, Ag, Hg and Pb are close to the NEAG. Lithophile elements of Cs and W are relatively poor.

Early Paleozoic (Pz_1): the elements concentrated in early Paleozoic granitoids are lithophiles Li, Be, Ba, B, Rb, Cs, W, Th and U, siderophiles Mg, V, Ti, Co, Cr, Ni, P, Ca and Sc and chalcophiles Cu, Zn, Se, Ag, Cd, As, Hg, Pb, Bi, Sn and S. Lithophile elements of Al, Si, K, Zr and Ta, siderophile elements of Mn, and chalcophile elements of Au and Sb are close to the NEAG. No one element is poor. Clearly, element abundances of Pz_1 granitoids are on the high side, and of those the most evident are the siderophile elements.

Later Paleozoic (Pz_2): the elements concentrated in the later Paleozoic granitoids are lithophiles B and Sr, siderophiles Fe, Mg, V, Ti, Co, Cr, Ca, Sc, Ni, P and Mn and chalcophiles Cu, Au, Zn, Cd, As, Sb and Hg. Lithophile elements of Na, Al, Si, Li, Zr, Cs, Ba, Hf and Mo and chalcophile elements of Ga, Ge, Ag and S are close to the NEAG. No one element is seen to be poor. Element abundances of Pz_2 granitoids are also clearly on the high side.

Mesozoic (Mz): the distinctive feature of most elemental abundances in Mesozoic granitoids is that they are commonly higher than those of other ages. The abundances of most elements are close to the NEAG (Shi et al., 2005b). Lithophile elements of K, Rb, Be, Nb, Ta, W, Mo, Th and U and chalcophile elements of Pb, Bi and S are observably concentrated.

Cenozoic (Cz): the obvious feature of elemental abundances in the Cenozoic granitoids is that Cs, U and Sn are intensively concentrated, especially lithophiles Li, Be, Nb, Rb, Ta, W and Th, the siderophile Sc and chalcophiles Ge and Pb. Lithophile elements of B, Na, Al, Si, K and Hf, siderophile elements of Mn, P and Ca, and chalcophile elements of Zn, Ga, Bi and S are close to the NEAG. The chalcophile element Se is evidently poor.

Table 2 Total average chemical composition and element abundance of alkali feldspar granite of different geological ages in China.

Ages	Ar	Pt	Pz_1	Pz_2	Mz	Cz
Nc	8	21	12	13	109	9
Ns	62	221	107	106	1026	21
SiO_2	74.73	75.14	75.46	74.69	75.61	74.69
TiO_2	0.17	0.16	0.16	0.15	0.15	0.12
Al_2O_3	13.35	12.76	13.31	13.00	12.83	13.85
Fe_2O_3	1.51	0.80	0.62	0.96	0.75	0.43
FeO	0.40	0.53	0.74	0.44	0.44	0.76
MnO	0.021	0.028	0.036	0.037	0.037	0.043
MgO	0.17	0.23	0.35	0.14	0.15	0.19
CaO	0.63	0.47	0.42	0.50	0.43	0.52
Na_2O	3.07	3.63	2.62	3.58	3.52	3.20
K_2O	5.45	4.82	4.95	4.71	4.73	4.93
P_2O_5	0.05	0.04	0.05	0.04	0.03	0.10
H_2O^+	0.90	0.87	0.96	0.67	0.67	0.71
CO_2	0.15	0.24	0.18	0.15	0.21	0.42
TFe_2O_3	1.72	1.72	1.56	1.22	1.29	1.22
Ag	48	62	57	75	56	42
As	0.6	0.7	1.0	1.2	0.9	1.3
Au	0.30	0.30	0.24	0.42	0.30	0.27
B	5.3	3.3	8.0	3.5	2.4	9.2
Ba	832	379	280	418	181	118
Be	2.6	2.5	4.0	3.7	4.6	10.3
Bi	0.08	0.11	0.47	0.10	0.24	1.24
Cd	20	50	70	50	60	76
Cl	64	56	57	45	45	31
Co	1.7	0.9	1.8	0.9	0.9	0.9
Cr	4.4	2.8	4.0	2.0	2.0	1.9
Cs	1.7	2.4	9.6	3.1	2.9	18.2
Cu	4.6	5.1	6.0	2.7	3.5	3.1
F	309	367	361	204	431	586
Ga	18	17	16	17	18	21
Ge	1.04	1.56	1.10	1.40	1.50	2.21
Hf	4.3	5.5	4.7	5.5	5.3	4.0
Hg	6.0	4.8	4.9	5.7	6.0	4.4
Li	8	10	25	11	14	23
Mn	165	222	278	283	293	316
Mo	0.45	0.51	0.81	0.43	0.84	0.40
Nb	17.0	13.5	18.0	15.0	23.0	19.5
Ni	2.7	1.9	5.0	3.2	2.5	2.1
P	212	170	237	154	142	416
Pb	20	29	33	23	28	41
Rb	191	163	264	164	224	409
S	70	70	75	100	90	101
Sb	0.14	0.16	0.12	0.15	0.11	0.07
Sc	2.2	3.8	5.1	2.8	2.7	6.0
Se	0.026	0.022	0.018	0.015	0.020	0.010
Sn	1.3	2.2	7.7	2.0	2.2	10.6
Sr	128	68	50	51	54	43
Ta	0.47	1.21	2.18	1.35	1.93	4.25
Th	18.8	11.4	19.0	15.9	21.8	24.8
Ti	1140	842	838	835	855	585
Tl	0.93	0.80	1.34	0.71	1.05	2.50
U	1.58	3.19	5.85	2.71	4.18	17.43
V	12	11	13	14	12	8
W	0.35	0.70	2.22	0.64	1.10	2.05
Zn	25	36	33	40	33	40
Zr	136	125	135	143	137	96

(*continued on next page*)

Table 2 (*continued*)

Ages	Ar	Pt	Pz_1	Pz_2	Mz	Cz
La	42	35	36	32	33	22
Ce	85	65	60	63	61	44
Pr	–	4.18	5.50	–	7.26	4.58
Nd	29.5	23.3	30.9	26.9	24.0	16.5
Sm	3.40	4.84	6.60	4.40	4.60	4.53
Eu	0.61	0.51	0.52	0.47	0.39	0.35
Gd	5.2	6.3	7.8	4.9	6.2	3.7
Tb	0.38	0.97	1.12	0.55	0.75	0.77
Dy	–	5.1	5.7	–	7.6	4.5
Ho	–	1.08	1.20	–	1.55	0.94
Er	–	3.02	3.45	–	4.44	2.94
Tm	–	0.53	0.62	–	0.83	0.61
Yb	1.06	3.70	3.07	2.10	3.08	3.96
Lu	0.18	0.50	0.52	0.31	0.51	0.61
Y	24.5	28.0	31.9	21.5	29.0	26.7

Nc = number of analyzed composited samples. Ns = number of collected samples. Content units: 10^{-9} for Au, Ag, Cd, Hg; 10^{-2} for major elements; 10^{-6} for others. Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic. "—" represents no statistical significance due to insufficient numbers of analyzed data.

4.2. Evolutionary tendencies of element abundance with geological age

The differences of average components in granitoids between two consecutive geological ages represent an important indication that chemical evolution has taken place. However, comparisons of average components are just an estimate for the comparisons of the total average values of the different geological ages and do not mean that the evolutionary features applying to every local region or every granitoid body has the same evolutionary features to the total average values (Guiyang Institute of Geochemistry of Chinese Academy of Sciences, 1979).

Throughout the time sequence ($Ar \rightarrow Pt \rightarrow Pz_1 \rightarrow Pz_2 \rightarrow Mz \rightarrow Cz$), the elemental abundances of Table 1 indicate that the contents of Ba and Se show a clear decreasing trend, whereas Be, Ge and Hf have an increasing trend (Fig. 2); other elements have no evident increasing or decreasing trends. Among lithophile elements, the contents of Li, Be, Cs, Ta, W, Th, U, K/Na and Rb/Sr are lower in the Archean but higher in the Cenozoc; changes in SiO_2 and Al_2O_3 are very small. Most siderophile elements are on the high side in the early and late Paleozoic, but are on the low side in the Cenozoic (Fig. 2). Light rare earth elements (LREE) are higher in the early Paleozoic, and heavy rare earth elements (HREE) are the highest in the Cenozoic.

Overall, most of the element contents have no clear or regular evolutionary tendency in relation to time, which suggests that the granitoids over time lack a unified evolutionary character. Obvious reasons for this might be that granitoids of different geological ages have had different geneses, different spatial distributions, and originated as the consequence of variable tectono/magmatic processes.

4.3. Element abundances of alkali-feldspar granite

For siderophile elements, the variation patterns for Mg, Co, Cr and Ni in the granitoids are found to be accordant (Fig. 3). They show the highest values in Pz_1 and lower values for other ages. V contents in Pz_1 and Pz_2 are higher than those for other ages. Contents of Fe and Ti decrease from Ar to Cz and the content of Mn increases from Ar to Cz. However, the change in Ca content is not obvious among different ages.

With respect to lithophile element contents, the change patterns of Li, Be, B, Rb, Nb, Ta, W, Mo and Th are basically the same. Overall, they increased from the Archean to the Cenozoic. W shows its highest value in the Paleozoic, but has the lowest value in the Archean; however, other lithophile elements show the lowest values in Ar and the highest in Cz. In contrast, the contents of Zr, Ba and Hf decrease from the Archean to the Cenozoic.

From their compositional variations (Fig. 3), chalcophile elements can be divided into three groups: 1) Ga, Ge, Cd, As, Pb, S; 2) Cu, Au, Zn, Se, Ag, Sb, Hg; and 3) Bi and Sn. Basically, Ga, Ge, Cd, As, Pb and S increase from Ar to Cz; they show the lowest values in Ar and the highest in Cz. The variation patterns of Cu, Au, Zn, Se, Ag, Sb and Hg are less clear, but there is still a decreasing tendency from Ar to Cz. The change tendencies of Bi and Sn are absolutely accordant. The differences among Ar, Pt, Pz_2 and Cz ages are not large; the contents of Bi and Sn are distinctly higher in the Pz_1, and show the highest values in the Cz.

4.4. Element abundances of syenogranite

As shown in Fig. 4, for the contents of lithophile elements, the variation patterns of Li, Be, Rb, Nb, Ta, W, Mo and Th are basically the same, but overall increase from Ar to Cz, showing the lowest values in Ar and the highest in Cz. However, the contents of Zr and B decrease from Ar to Cz. The changes in Ba and Hf are not large.

For siderophile elements, the patterns of contents of Mg, V, Co, Cr and Ni are accordant with the highest values in Pz_1 and lower in other ages. The content of Fe decreases from Ar to Cz, whereas changes of Mn, Ti and Ca contents are unclear and only a little higher in Pz_1.

The variation patterns of the chalcophile elements can be divided into three groups: 1) Ga, Ge, Cd, As, Pb, S, Se, Bi; 2) Cu, Au, Zn, Ag, Sb, Hg; and 3) Sn. As seen in Fig. 4, the distribution curves of Ga, Ge, Cd, As, Pb, S and Bi resemble a "saddle" except for Se content, which decreases from Ar to Cz. The contents are higher in Pz but

Table 3 Total average chemical composition and element abundance of syenogranite of different geological ages in China.

Ages	Ar	Pt	Pz_1	Pz_2	Mz	Cz
Nc	20	43	41	76	212	15
Ns	171	373	298	517	1820	30
SiO_2	71.98	72.99	70.81	72.71	72.13	72.76
TiO_2	0.28	0.19	0.31	0.25	0.28	0.25
Al_2O_3	14.27	14.18	14.65	14.03	14.32	13.76
Fe_2O_3	1.36	0.80	0.69	0.85	0.90	0.47
FeO	0.84	0.85	1.44	1.09	1.03	1.38
MnO	0.040	0.034	0.048	0.043	0.048	0.048
MgO	0.50	0.33	0.77	0.43	0.55	0.37
CaO	1.31	1.28	1.64	1.31	1.47	1.45
Na_2O	3.77	3.87	3.05	3.71	3.61	3.15
K_2O	4.15	4.12	4.29	4.22	4.40	4.66
P_2O_5	0.09	0.05	0.11	0.08	0.10	0.07
H_2O^+	0.96	0.72	0.96	0.64	0.71	0.49
CO_2	0.17	0.17	0.34	0.27	0.20	0.36
TFe_2O_3	2.18	1.71	2.44	2.06	2.10	1.93
Ag	51	43	55	51	52	35
As	0.6	0.6	1.0	1.2	0.9	0.6
Au	0.40	0.32	0.40	0.41	0.35	0.25
B	4.0	3.4	4.4	5.1	3.8	2.7
Ba	960	984	610	587	657	402
Be	1.7	1.7	2.9	2.4	3.0	4.3
Bi	0.06	0.07	0.18	0.15	0.15	0.08
Cd	42	40	70	64	50	31
Cl	59	56	51	60	54	96
Co	3.8	1.5	4.0	3.0	2.9	2.2
Cr	7.4	5.0	10.5	4.0	5.0	4.3
Cs	1.7	1.5	6.5	3.9	4.3	9.4
Cu	7.0	4.3	5.9	4.8	4.6	3.2
F	362	268	524	376	536	1076
Ga	18	18	17	18	18	19
Ge	1.10	1.00	1.27	1.38	1.31	1.59
Hf	4.6	4.4	4.5	4.7	4.8	5.2
Hg	7.5	5.0	6.0	5.0	5.0	4.0
Li	13	11	32	20	22	42
Mn	307	256	369	335	371	345
Mo	0.36	0.34	0.36	0.56	0.52	0.60
Nb	11.0	11.2	12.8	11.2	15.0	15.4
Ni	3.2	3.0	6.6	4.2	4.3	2.5
P	408	225	505	371	421	339
Pb	21	27	36	24	28	29
Rb	118	129	184	157	171	268
S	70	60	100	88	80	102
Sb	0.11	0.10	0.13	0.14	0.12	0.08
Sc	3.8	2.9	6.5	5.5	4.6	7.1
Se	0.030	0.024	0.041	0.018	0.020	0.004
Sn	1.0	1.3	3.1	2.6	1.9	6.1
Sr	235	225	162	158	230	125
Ta	0.70	0.90	1.32	1.19	1.43	2.02
Th	11.5	9.9	19.7	15.1	19.0	28.5
Ti	1680	1218	1776	1391	1549	1469
Tl	0.69	0.63	1.01	0.79	0.89	1.41
U	1.35	1.52	3.75	2.31	3.41	6.45
V	20	15	31	22	24	21
W	0.25	0.31	0.88	0.76	0.70	1.22
Zn	36	36	46	43	40	40
Zr	144	141	149	134	154	153

(*continued on next page*)

Table 3 (*continued*)

Ages	Ar	Pt	Pz_1	Pz_2	Mz	Cz
La	39	28	39	28	37	45
Ce	77	50	73	52	66	81
Pr	–	7.02	8.30	6.17	6.78	9.94
Nd	27.7	24.4	28.8	21.7	26.4	34.4
Sm	4.10	3.55	5.26	4.30	4.60	7.31
Eu	0.83	0.76	0.86	0.72	0.82	0.86
Gd	3.1	3.7	4.4	4.5	4.6	6.6
Tb	0.39	0.48	0.73	0.64	0.63	1.16
Dy	–	3.3	4.1	4.3	3.8	5.6
Ho	–	0.66	0.85	0.91	0.73	1.10
Er	–	1.94	2.31	2.54	2.14	3.10
Tm	–	0.35	0.38	0.43	0.38	0.54
Yb	0.91	1.53	2.00	2.40	1.94	3.36
Lu	0.19	0.24	0.31	0.36	0.30	0.52
Y	18.0	17.0	21.6	21.9	19.2	31.7

Nc = number of analyzed composited samples. Ns = number of collected samples. Content units: 10^{-9} for Au, Ag, Cd, Hg; 10^{-2} for major elements; 10^{-6} for others. Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic. "—" represents no statistical significance due to insufficient numbers of analyzed data.

lower at other ages. The variation regularities of Cu, Au, Zn, Ag, Sb and Hg are accordant. Overall, they have a tendency to decrease from Ar to Cz. The content of Sn increases from Ar to Cz with the lowest value in Ar and a sharp increase from Mz to Cz.

4.5. Element abundance of adamellite

Of the lithophile element contents, the evolving patterns of Li, Be, Rb, Nb, Ta, W, Mo and Th are basically the same (Fig. 5). Overall, they increase from Ar to Cz with the lowest values in Ar and the highest in Cz. B content is highest in the Ar and lowest in the Pt. The content of Ba decreases from the Ar to the Cz, whereas those of Zr and Hf show an ascending trend.

For siderophile elements, evolving patterns in time of Mg, V, Co and Cr are not clear. The content of Ni decreases from the Ar to the Cz. The change of Fe content is not distinct. However, Mn, Ti and Ca contents increase from Ar to Cz.

The variation patterns of the contents of chalcophile elements (Fig. 5), can be divided into three groups: 1) Ga, Ge, Cd, As, Pb, S; 2) Cu, Au, Zn, Se, Ag, Sb, Hg; and 3) Sn and Bi. For Ga, Ge, Cd, As, Pb and S, except for the As content, which increases from Ar to Cz, temporal changes are not clear. Basically, patterns of Cu, Au, Zn, Se, Ag, Sb and Hg are accordant and overall, the tendency is for a decrease from the Ar to the Cz. Contents of Sn and Bi show the lowest values in Ar and Cz, and the highest in Pz_1.

5. Petrochemistry and element-ratio characteristics

5.1. Characteristics at different geological ages

The differing petrochemical parameters and some element ratios for granitoids of different geological ages in China are listed in Table 5.

Ar: Rb/Sr, Sr/Ba and the Differentiation Coefficient (DC) have the lowest values and Nb/Ta presents the highest values among all ages. Furthermore, δEu is also higher, which indicates that the differentiation degree is low. A/CNK > 1.1. C/ACF is lower.

Pt: The feature is that K/Rb, Ti/V and δEu serve as the highest values and C/ACF acts as the lowest values among all ages. A/CNK > 1.1.

Pz_1: σ is the lowest value and Na′ is the highest value among all ages. $Mg^{\#}$ is the biggest value but Fe′ and K + Na are the lowest values. Ti/V is the lowest value. A/CNK > 1.1, C/ACF is the highest value. This indicates that the alkalinity is lowest.

Pz_2: K/Na and f are the lowest value but K′ and Sr/Ba are the highest value among all ages. A/CNK is close to 1.1. C/ACF is the highest value.

Mz: Among the granitoids of different ages, σ and K + Na have the highest values. This shows that the alkalinity is the highest. DC value is the second one among different ages and only lower than that of Cz. δEu is lower and only higher than that of Cz, but lower than that of other ages. This indicates that the differentiation degree is relative high. A/CNK = 1.1, C/ACF serves as the lowest value.

Cz: K/Na is the highest value but K′ and Na′ are the lowest values among all ages. Fe′ is the highest value and $Mg^{\#}$ is the lowest value among various ages. Rb/Sr and DC are the highest, but K/Rb, Nb/Ta and δEu are the lowest values among different ages. This indicates that the differentiation degree of granitoids of Cz is the highest and the alkalinity is relative low. A/CNK value is close to 1.1 and C/ACF value is higher.

5.2. Evolution of chemical components and elements through time

In the evolutionary sequence from $Ar \rightarrow Pt \rightarrow Pz_1 \rightarrow Pz_2 \rightarrow Mz \rightarrow Cz$, the σ values, petrochemistry and element ratios of granitoids of every geological age are less than 3.3 and belong to the calc-alkali series (Table 5). Although the differences are not too large, there are still some undulations. The σ value of Pz_1 is lower and that of Mz is higher.

Alkalinity (σ, K + Na) does not monotonously increase or decrease from the Ar to the Cz, but has a lumpy profile, being higher in the Ar, and slightly falling in the Pt until it rapidly decreases to its lowest point in the Pz_1; alkalinity increases from the Pz_1 to the Pz_2, until in the Mz it attains the highest values; then alkalinity decreases to the Cz.

Table 4 Total average chemical composition and element abundance of adamellite from different geological ages in China.

Ages	Ar	Pt	Pz_1	Pz_2	Mz	Cz
Nc	6	20	12	38	52	6
Ns	57	205	69	292	379	7
SiO_2	70.83	67.65	68.80	67.03	66.89	68.83
TiO_2	0.30	0.48	0.41	0.47	0.49	0.41
Al_2O_3	14.86	15.32	15.36	15.71	15.51	15.22
Fe_2O_3	1.43	1.13	0.91	1.18	1.01	1.17
FeO	1.43	1.98	1.51	2.18	2.27	1.85
MnO	0.034	0.066	0.059	0.066	0.070	0.063
MgO	0.81	1.54	1.22	1.30	1.51	1.34
CaO	2.40	2.67	2.92	3.03	3.29	3.06
Na_2O	4.52	4.28	3.79	3.77	3.40	3.84
K_2O	2.39	2.49	3.07	2.75	3.28	2.86
P_2O_5	0.09	0.13	0.13	0.13	0.14	0.10
H_2O^+	1.14	1.19	1.01	0.87	0.98	0.51
CO_2	0.23	0.31	0.22	0.31	0.20	0.35
TFe_2O_3	2.51	3.61	3.08	3.68	3.70	3.14
Ag	54	57	47	42	51	45
As	0.7	0.9	0.7	1.4	1.1	1.8
Au	0.45	0.32	0.30	0.40	0.40	0.51
B	11.3	3.9	4.7	7.0	5.3	4.6
Ba	898	727	690	608	636	470
Be	0.8	0.9	2.2	1.6	1.9	1.6
Bi	0.07	0.06	0.12	0.10	0.11	0.05
Cd	51	51	60	60	54	30
Cl	34	66	63	67	158	204
Co	6.8	8.8	6.8	7.5	8.5	7.7
Cr	12.9	23.5	17.8	16.0	18.2	16.7
Cs	1.3	1.6	3.6	4.1	4.0	5.0
Cu	10.5	10.1	8.7	8.5	6.4	8.1
F	345	442	516	422	514	274
Ga	18	18	18	19	18	16
Ge	0.90	1.05	1.16	1.18	1.20	1.35
Hf	4.4	4.5	4.8	4.9	5.3	6.2
Hg	6.5	6.0	4.1	6.3	5.0	3.9
Li	14	14	28	22	25	22
Mn	264	510	445	514	538	478
Mo	0.20	0.29	0.36	0.38	0.41	0.38
Nb	6.5	9.0	11.3	9.2	11.3	7.6
Ni	12.7	8.0	9.2	7.2	6.9	6.7
P	400	565	638	600	636	488
Pb	10	16	24	18	19	16
Rb	65	68	108	93	114	114
S	90	80	70	78	100	50
Sb	0.12	0.12	0.15	0.17	0.14	0.09
Sc	4.1	7.4	6.8	7.8	8.8	7.6
Se	0.033	0.036	0.020	0.019	0.017	0.010
Sn	0.8	1.1	2.5	1.6	1.7	1.0
Sr	496	388	374	310	353	261
Ta	0.29	0.62	0.98	0.83	1.05	1.02
Th	4.9	7.3	15.0	10.8	12.9	12.1
Ti	1729	2770	2342	2722	2769	2166
Tl	0.35	0.37	0.65	0.55	0.59	0.54
U	0.86	1.18	2.96	1.81	2.22	1.89
V	38	55	47	54	54	45
W	0.19	0.20	0.30	0.35	0.49	0.56
Zn	42	57	47	56	52	36
Zr	144	150	157	147	148	139

(*continued on next page*)

Table 4 (*continued*)

Ages	Ar	Pt	Pz_1	Pz_2	Mz	Cz
La	28	27	35	28	34	29
Ce	50	52	67	53	65	52
Pr	–	8.54	7.89	5.50	7.16	5.71
Nd	21.9	23.4	26.7	20.4	26.0	19.3
Sm	3.05	3.80	4.61	4.04	4.60	3.51
Eu	1.02	1.05	0.97	0.98	1.01	0.82
Gd	3.8	3.6	3.7	3.4	4.5	3.1
Tb	0.37	0.51	0.48	0.52	0.66	0.53
Dy	–	4.5	2.7	3.2	4.0	2.9
Ho	–	0.86	0.51	0.63	0.79	0.60
Er	–	2.44	1.41	1.90	2.24	1.74
Tm	–	0.41	0.24	0.34	0.38	0.30
Yb	0.55	1.68	1.34	1.84	2.01	1.95
Lu	0.11	0.26	0.22	0.29	0.32	0.32
Y	9.5	13.0	13.0	17.1	18.0	19.1

Nc = number of analyzed composited samples. Ns = number of collected samples. Content units: 10^{-9} for Au, Ag, Cd, Hg; 10^{-2} for major elements; 10^{-6} for others. Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic. "—" represents no statistical significance due to insufficient numbers of analyzed data.

Analyzing the differentiation degrees of magma, those of the Ar and Pt are lower; the Mz and Cz are higher, and the Pz is intermediate. Overall, the tendency is showed that the differentiation degree of Ar is lower, then evolving until it reaches the highest value in the Cz (Fig. 6).

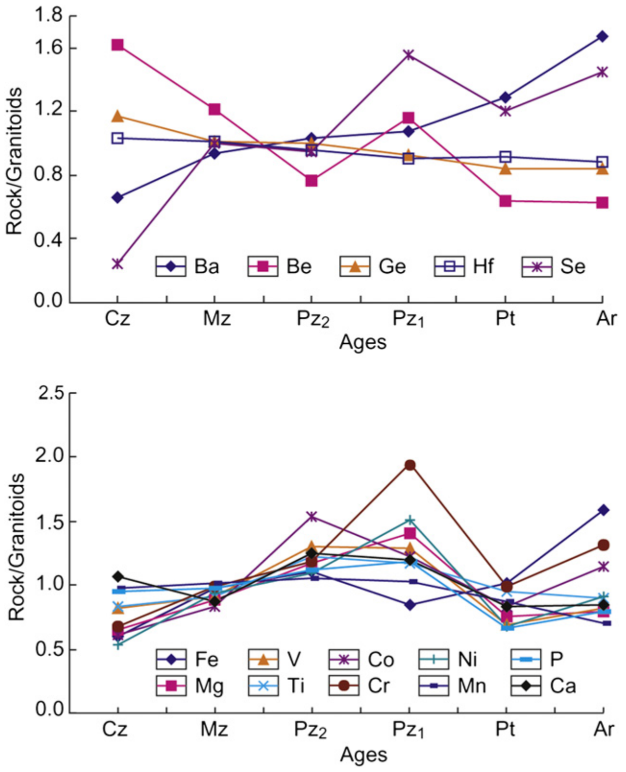

Figure 2 Evolving tendencies of element contents in granitoids of different geological ages related to geological ages in China, based on abundance data of granitoids from Shi et al. (2005b). Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic.

The f value is highest in the Ar; falls slightly in the Pt, increases in the Pz_1, and then decreases to its lowest value in the Pz_2. The f value then increases to the Cz, where it reaches to its peak.

The Fe' value shows a downward trend from Ar to Pz_1 then rises from Pz_2, through Mz, until reaching its highest point in the Cz. In contrast, the evolving trends of the $Mg^{\#}$ values are just the reverse.

The highest K/Na values are in the Cz, followed by the Pz_1, and the Ar, A/CNK values highest in Pz_1. Changes of C/ACF values are not too large with those in the Pz being slightly highest.

6. Trace elements

6.1. The spider diagram

The distribution of the trace elements in the granitoids can be discussed using a spider diagram (Rollison, 1993; Shi et al., 2008). In spider diagrams element contents are normalized by chondrite values summarized by Hermann (1970), as shown in Fig. 7.

In China's granitoids the strongly incompatible elements are greatly concentrated and the content level of compatible elements is lower. The principal character of the spider diagram of trace elements is that it possesses clear positive anomalies of Rb and Th and negative anomalies of Nb, Sr, P and Ti (Shi et al., 2005b).

The granitoids also have a one-high-point and four-low-points distribution pattern as seen in the spider diagram for Chinese granitoids (Shi et al., 2005b). The differences among the distribution position of the curves are not very large. However, there are some differences in the intensity of positive and negative anomalies of the different granitoids. The intensity of positive anomalies of Rb and Th from the Ar to the Cz are crescent-shaped. Negative anomalies of Nb for Ar, Pt and Pz_2 are relatively strong, but those for Cz, Mz and Pz_1 are relatively poor. The negative anomaly of Sr in the Cz is the strongest and that of Ar is the poorest. Negative anomalies of P for the Ar and Pt are much stronger than those for other ages. For Ti, negative anomalies are lowest in the Ar and Cz.

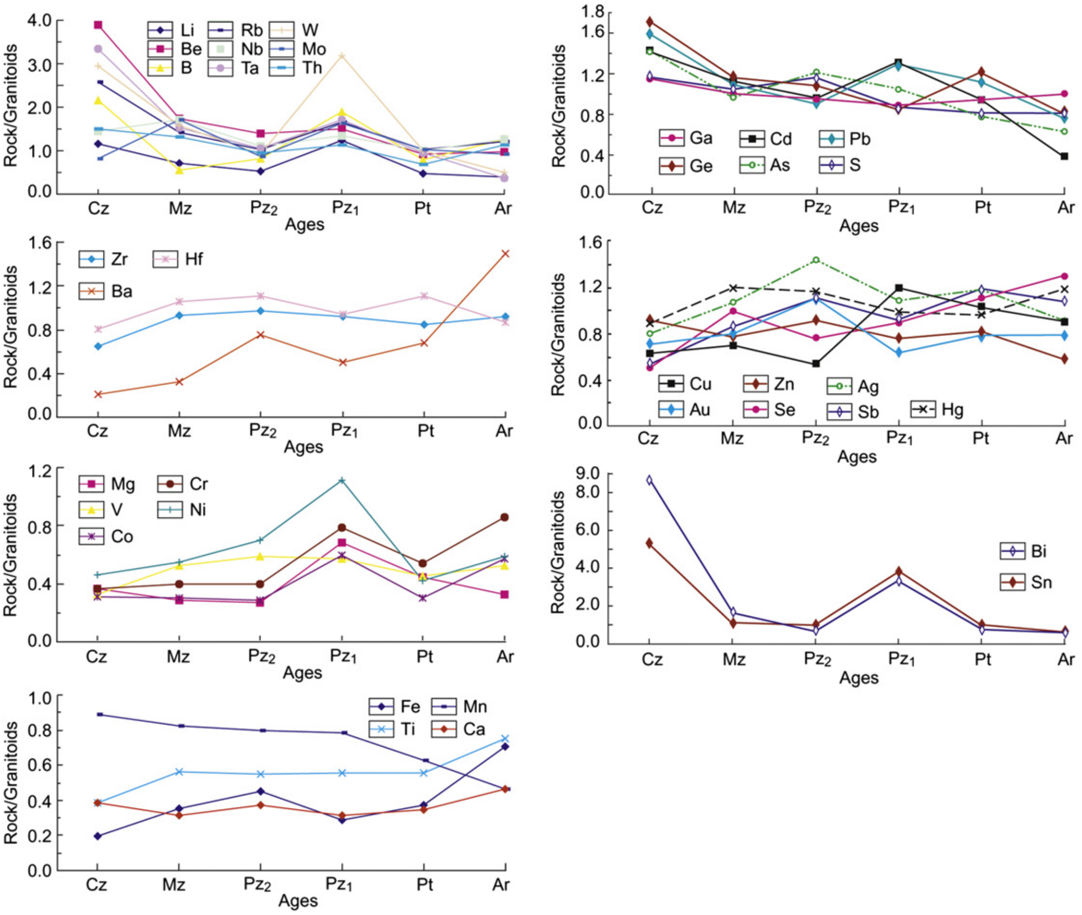

Figure 3 Evolving tendencies with time of element contents in alkali feldspar granite in China, based on abundance data of granitoids from Shi et al. (2005b). Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic.

6.2. Distribution characters of REE

Chondrite-normalized REE distribution patterns of the granitoid rocks, alkali feldspar granite, syenogranite and adamellite in the different geological ages are shown in Fig. 8. It can be seen that the same type of rock at different times possesses a similar distribution pattern and that the different granitoid types have different distribution patterns. From alkali feldspar granite → syenogranite → adamellite, the negative Eu anomaly intensity declines gradually. The negative Eu anomaly of alkali feldspar granite is most distinct with their partitioning curves assume a "V" model. The negative Eu anomaly of adamellite is indistinct and their partitioning curves basically assuming a "\" model, whereas the intensity of the anomaly of syenogranite is intermediate between that of alkali feldspar granite and adamellite.

For alkali feldspar granite, the partitioning curves of HREE for Mz and LREE for Ar are basically at the top position (Fig. 8), and the partitioning curve of LREE for Cz and HREE for Ar are basically at the bottom position. Moreover, the negative Eu anomaly for Cz is the strongest and that for Ar is the weakest.

For syenogranite, the REE partitioning curve of Cz is basically at the top position. The LREE partitioning curve of Pz_1 and Pt is generally at the bottom position and the HREE partitioning curve of Ar is basically at the bottom position. The negative Eu anomaly for Pz_2 is the strongest and that for Pz_1 and Cz is the weakest.

For adamellite, the LREE partitioning curves present the upper and lower parts. Mz and Pz_1 are basically at the upper position and the others are basically at the lower position. For the HREE partitioning curves, Ar is at the lowest position. As a whole, the negative Eu anomaly is not distinct. The negative Eu anomaly for Cz is the strongest and that for Pt is the weakest.

7. Conclusions

(1) The average chemical composition and element abundances of about 70 chemical elements in granitoids, alkali feldspar granite, syenogranite and adamellite of different ages are calculated and presented. The analytical data is derived from 767 composited samples collected from about 750 large- to middle-sized granitoid bodies across China. These abundance values, derived from actual analytical data but not collected from previously published data, are the first to be published in China and the world. They can be useful as important fundamental information in the study on basic geology, ore exploration and geochemistry.

(2) The distribution patterns of element exhibit distinctly different features. As for an evolutionary sequence from Ar → Pt → Pz_1 → Pz_2 → Mz → Cz, however, most of the element contents have no clear evolutionary tendency. This suggests that the granitoids from different geological times do not have a unified evolutionary feature.

(3) The elements that concentrate in the Ar granitoids are lithophile elements of B, Ba and Sr, siderophile elements of Fe, Co and Cr, and chalcophile elements of Cu, Se and Hg. Elements observed to concentrate in the Pt granitoids are

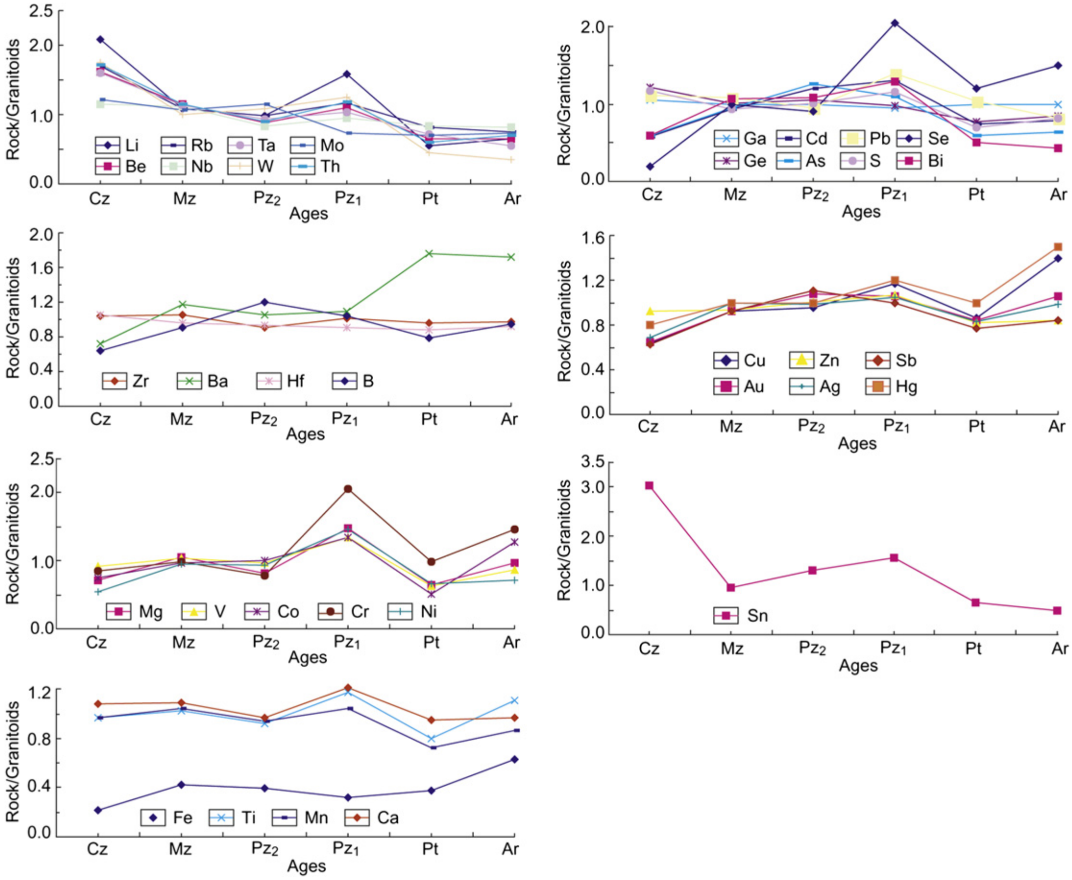

Figure 4 Evolving tendencies with time of element contents in syenogranite in China, based on abundance data of granitoids from Shi et al. (2005b). Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic.

lithophile elements of Na, Sr and Ba and chalcophile elements of Cu and Se. The elements seen to concentrate in the Pz_1 granitoids are lithophile elements of Li, Be, Ba, B, Rb, Cs, W, Th and U, siderophile elements of Mg, V, Ti, Co, Cr, Ni, P, Ca and Sc, and chalcophile elements of Cu, Zn, Se, Ag, Cd, As, Hg, Pb, Bi, Sn and S. Those elements that evidently concentrate in the Pz_2 granitoids are lithophile elements of B and Sr, siderophile elements of Fe, Mg, V, Ti, Co, Cr, Ca, Sc, Ni, P and Mn and chalcophile elements of Cu, Au, Zn, Cd, As, Sb and Hg. The distinct point of element abundances in the Mz granitoids is that they are commonly higher than those of other ages. In general, the abundances of most elements are, as might be expected, close to the average values of China. An obvious point of element abundances in Cz is that Cs, U and Sn are intensively concentrated. Other elements that exhibit concentration in the Cz granitoids are lithophile elements of Li, Be, Nb, Rb, Ta, W and Th, siderophile elements of Sc and chalcophile elements of Ge and Pb.

(4) The petrochemical parameters and element ratios of granitoids through time are different. For the **Ar**, Rb/Sr, Sr/Ba and DC are the lowest values and Nb/Ta is the highest among all ages. For the **Pt**, K/Rb, Ti/V and δEu serve as the highest values and C/ACF acts as the lowest among all ages. For the **Pz_1**, σ is the lowest value and Na′ is the highest among all ages; $Mg^{\#}$ has the largest value, but Fe′ and K + Na are the lowest values; Ti/V is the lowest value and C/ACF is the highest value. K/Na and *f* are the lowest values for the **Pz_2**, but K′ and Sr/Ba have the highest values among all ages. Among **Mz** granitoids of different ages, σ and K + Na act have the highest values, which demonstrate that alkalinity is dominant. For the **Cz**, K/Na has the highest value but K′ and Na′ are the lowest values among all ages; Fe′ is the highest value and $Mg^{\#}$ is the lowest value among various ages; Rb/Sr and DC are the highest, but K/Rb, Nb/Ta and δEu are the lowest values among the different ages. This indicates that the differentiation degree of Cz granitoids is the highest with relatively low alkalinity.

(5) The evolving tendencies of element abundances in different granitoid rock types are different throughout time. From Ar to Cz, element abundances in the different granitoids have different evolutionary patterns.

(6) The spider diagrams of trace elements normalized by chondrite in granitoids of different geological ages exhibit the clear positive anomaly of Rb and Th and the negative anomalies of Nb, Sr, P and Ti. This is called a one-high-point and four-low-points distribution pattern. The intensity of positive and negative anomalies of granitoids differs through time.

(7) Chondrite-normalized REE distribution patterns for alkali feldspar granite, syenogranite and adamellite also present distinct characters through time. The same type of rock at different times possesses a similar distribution pattern and different granitoid rocks have different distribution patterns. The negative Eu anomaly of alkali feldspar granite is most distinct with the partitioning curves assuming a “V” model. The negative Eu anomaly of adamellite is indistinct and the

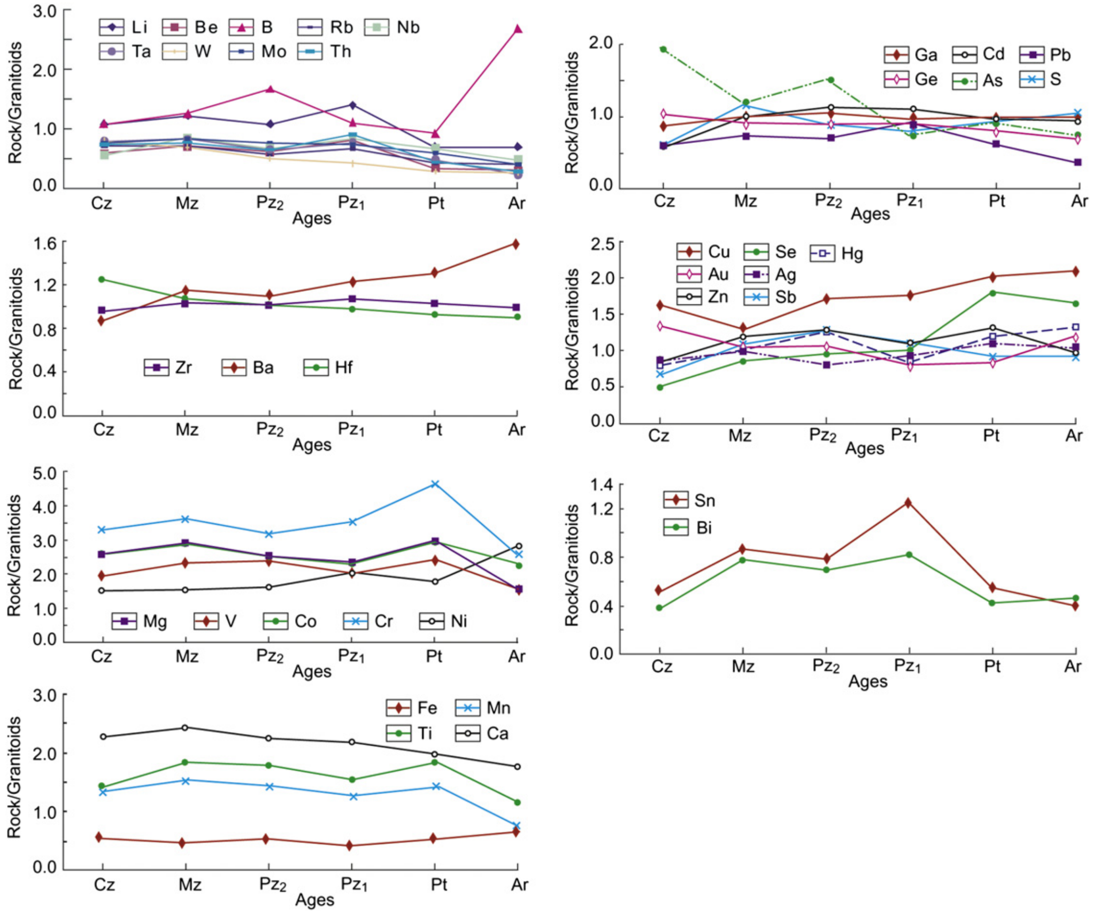

Figure 5 Evolving tendencies with time of element contents in adamellite in China, based on abundance data of granitoids from Shi et al. (2005b). Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic.

Table 5 Petrochemical parameters and some element ratios for granitoids of different geological ages in China.

Ages	Cz	Mz	Pz_2	Pz_1	Pt	Ar
σ	2.015	**2.209**	2.022	***1.989***	2.125	2.153
f	**59.602**	55.583	***51.532***	58.412	51.707	53.141
K′	***40.398***	44.417	**48.468**	41.588	48.293	46.859
Na′	***149.168***	153.014	155.681	**161.159**	156.732	156.202
Fe′	**84.087**	79.646	78.641	***73.741***	82.675	82.887
$Mg^{\#}$	***15.913***	20.354	21.359	**26.259**	17.325	17.113
K/Na	**1.475**	1.251	***1.063***	1.405	1.071	1.134
K + Na	7.884	**8.060**	7.603	***7.454***	7.879	7.960
A/CNK	***1.07***	1.10	1.08	**1.15**	1.11	1.11
C/ACF	0.14	0.12	**0.15**	**0.15**	***0.11***	0.12
Rb/Sr	**2.091**	0.974	0.617	1.208	0.574	***0.502***
K/Rb	***74.43***	110.03	132.22	97.95	**155.14**	148.79
Sr/Ba	0.343	0.334	**0.347**	0.256	0.264	***0.253***
Nb/Ta	***7.344***	10.985	10.426	9.646	13.018	**17.188**
Ti/V	66.92	66.19	61.89	***59.63***	**89.84**	71.45
DC	**78324.25**	9792.92	536.82	2494.61	401.44	***230.96***
δEu	***0.351***	0.567	0.676	0.589	**0.741**	0.674

$\sigma = (K_2O + Na_2O)^2/(SiO_2-43)$; $f = 100 \times (Na_2O + K_2O)/(Na_2O + K_2O + CaO)$; $K' = 100 \times K_2O/(Na_2O + K_2O)$; $Na' = 100 \times Na_2O/(Na_2O + K_2O)$; $Fe' = 100 \times (FeO + Fe_2O_3)/(MgO + FeO + Fe_2O_3)$; $Mg^{\#} = 100 \times MgO/(MgO + FeO + Fe_2O_3)$; $\delta Eu = 2Eu_N/(Sm_N + Gd_N)$; $A/CNK = Al_2O_3/(CaO + Na_2O + K_2O)$; $C/ACF = CaO/(Al_2O_3 + CaO + FeO + Fe_2O_3)$; $DC = (Be \times W \times Rb \times Nb \times La \times Th)/(Cr \times V \times Cu)$. A/CNK and C/ACF are calculated by molecule percentage, others by percentage. δEu is normalized by the Chondrite data of Hermann (1970). The max. value of a parameter is in Bold, the min. value of a parameter is in Bold italic.

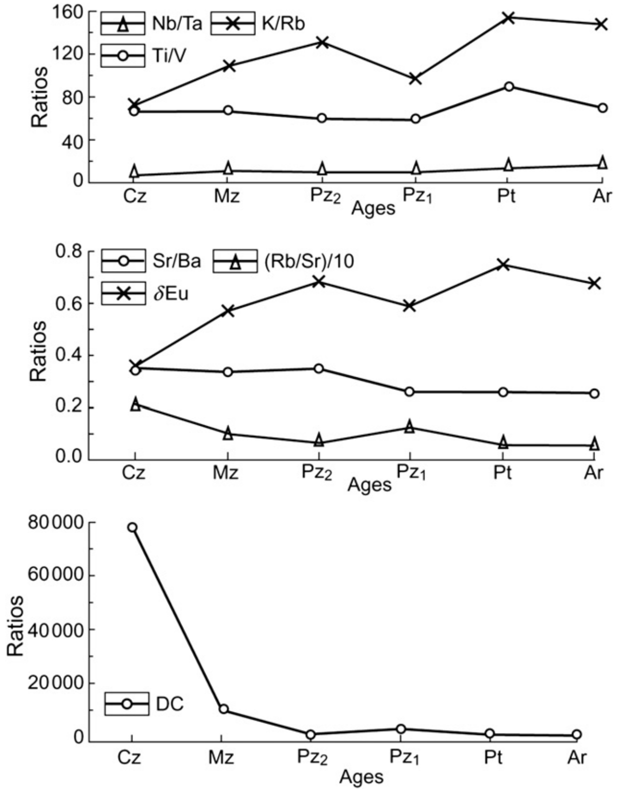

Figure 6 Evolving tendencies with time of element ratios in granitoids of different geological ages in China. Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic.

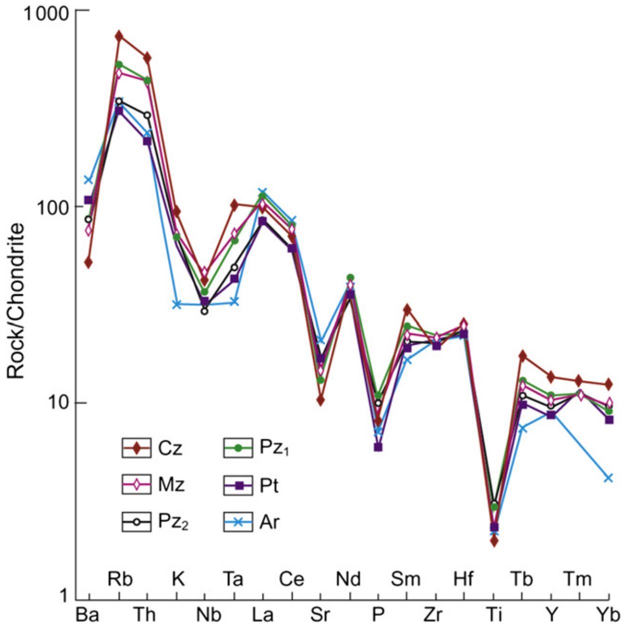

Figure 7 Chondrite-normalized spider diagram of trace elements for granitoids of different geological ages in China, based on chondrite data of Hermann (1970). Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic.

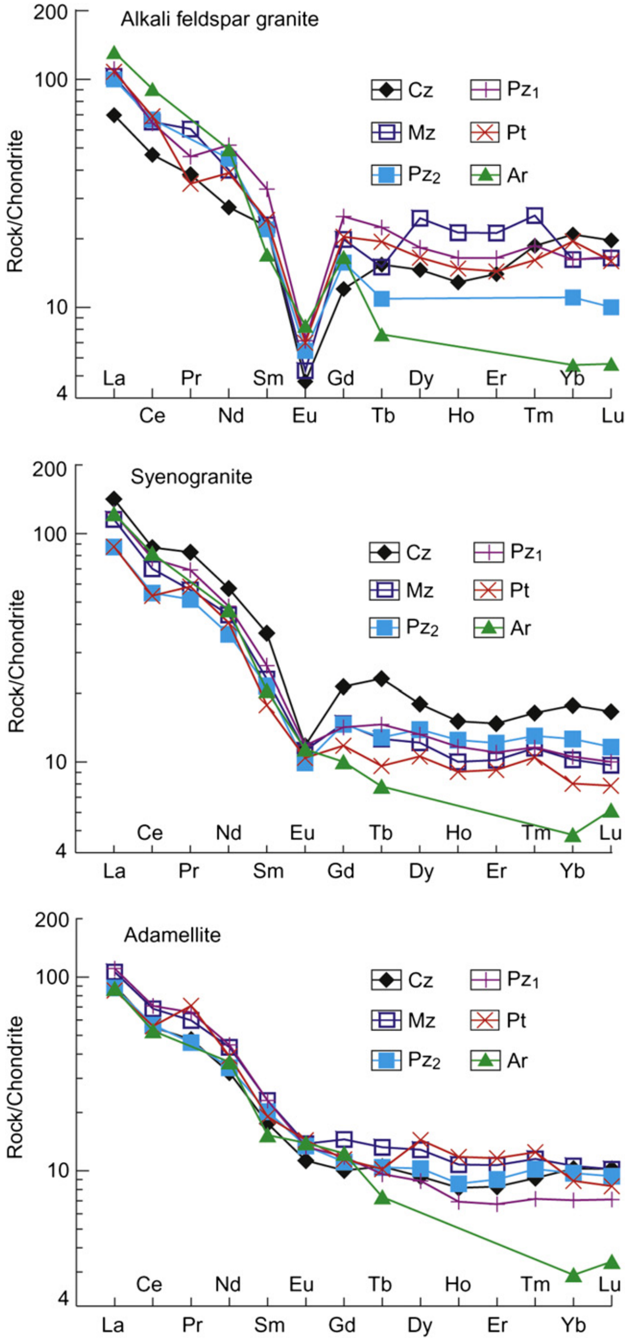

Figure 8 Chondrite-normalized REE distribution patterns of granitoids in different geological ages, based on chondrite data of Hermann (1970). Cz = Cenozoic; Mz = Mesozoic; Pz_2 = Neopaleozoic; Pz_1 = Eopaleozoic; Pt = Proterozoic; Ar = Archeozoic.

partitioning curves basically assume a “\” model. However, the intensity of the negative Eu anomaly of syenogranite is between that of alkali feldspar granite and adamellite.

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