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A Gold-bearing Alkaline Pluton in Eastern Linxi District, Inner Mongolia: Its Geochemistry and Metallogenic Significance

Yongfeng ZHU*, Shihua SUN and Neng JIANG

Abstract: The Biliutai pluton, as the host of a small gold deposit, containing dark-gray enclaves, intruded into the Lower Permian volcanic-sedimentary formations in east Inner Mongolia, China. The host rocks and enclaves formed simultaneously at about 200 Ma (Rb-Sr isochron age with initial $^{87}Sr/^{86}Sr$ of 0.704). The ε_{Nd} (T) values for the enclaves (from +4.4 to +4.6) are similar to their host rocks (+3.2 to +4.8), although the values for the host rocks are relatively variable. Both enclaves and host rocks are enriched in large ion lithosphere elements and light rare earth elements but depleted in high field strength elements and heavy rare earth elements. These observations suggest that the magma was produced from subduction-modified mantle sources. The age of the mantle enrichment event, evaluated using depleted mantle Nd model ages, is 0.61 ~ 0.83 Ga. These geochemical characteristics constrain the metallogeny of the Biliutai pluton, and imply that the ore-forming materials probably were derived from lithospheric mantle.

1. Introduction

Large amount of Mesozoic magmatic rocks covered or intruded in the Permian volcano-sedimentary rocks in the Linxi district, southeastern Inner Mongolia. The Mesozoic magmatic rocks are calc-alkaline in nature and generally related with the subduction of the Pacific oceanic lithosphere under the Mongolia orogenic zone as well as the North China craton (Cheng, 1994; Zhao et al., 1984; Zhao et al., 1989). However, little information about the magmatism during the Triassic to Jurassic period, corresponding to the transition time from EW-trending Mongolian orogeny to the NNE-extended Pacific oceanic subduction framework, is known in this region.

The Biliutai pluton with an outcrop larger than 30 km^2 (Fig. 1), located at about 100 km northeast of Linxi town, is an isolated intrusive body formed during this period. A small gold deposit is mined in this pluton (Zhu et al., 1998). Its geochemical characteristics are key to understand the geological background of the magmatic evolution from Late Paleozoic to Early Mesozoic era, as well as the metallogenic evolution in this region. This study reports the mineral compositions, general geochemical and Nd–Sr isotopic data of the Biliutai pluton, and discusses its petrogenesis and metallogenic significance.

2. Geological Overview

A Lower Permian volcanic-sedimentary formation and an Upper Permian sedimentary formation directly cover on the Precambrian metamorphic rocks. The Permian volcanic rocks consist of green tuff, basalt, andesite and volcaniclastic rocks. Jurassic volcanic rocks consist of green tuff, andesite, rhyolite and volcaniclastic rocks. Mesozoic granitoids intruded into Permian and Jurassic volcanic-sedimentary formations. The Biliutai pluton, with a roughly round shape, intruded into the Permian volcanic-sedimentary formation with sharp and clear contact (Fig. 1). One small gold-bearing Ni-Cu deposit (Zhu et al., 1998) was mined in this pluton. Dark gray-colored enclaves (typically 10-15 to 20-30 cm in size) disperse throughout the Biliutai pluton with typical concentrations of about 1 % or less. The enclaves have no fine-grained margins or rings of ferromagnesian minerals or leucocratic halos, and the contact between the enclaves and host rocks is usually gradual. Enclaves locally occur in

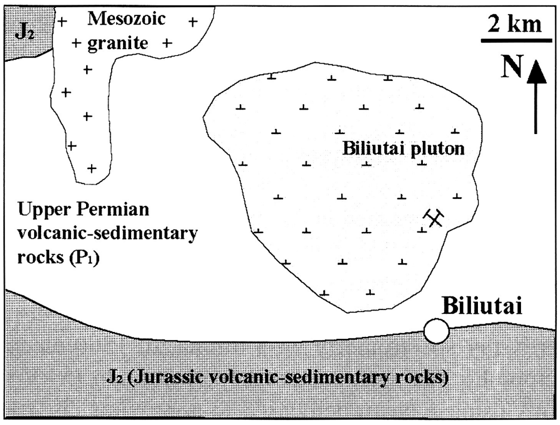

Fig. 1 Simplified geological map of the Biliutai pluton.

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Chinese Research Center for Mineral Resources Exploration, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100101, China
[e-mail: yongfeng@eyou.com]
* Department of Geology, Peking University, Beijing 100871, China

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Table 1 The chemical and Sr-Nd composition of representative host rocks and enclaves*.

No.	H6	H12	H28	HR1	HR3	HR4	Ht3	Ht4	E1	E18	Er5	Er6	Er7	Et01	Et2
Rocks	host	host	host	host	host	host	host	host	enclave	enclave	enclave	enclave	enclave	enclave	enclave
SiO_2	60.18	58.37	59.16	57.62	57.96	58.65	58.14	57.98	54.78	53.80	53.18	54.19	54.02	52.25	50.98
TiO_2	0.917	0.89	0.96	0.85	0.79	0.92	0.85	0.85	1.26	1.31	1.32	0.89	1.31	0.92	0.91
Al_2O_3	15.56	15.92	17.12	17.13	16.76	16.65	16.02	17.03	14.99	15.35	15.18	15.91	15.74	15.01	15.42
Fe_2O_3	5.90	5.44	4.94	6.74	5.62	6.01	6.01	6.22	6.92	7.94	7.62	7.94	7.94	8.94	9.31
MnO	0.08	0.07	0.04	0.15	0.17	0.06	0.12	0.16	0.11	0.15	0.11	0.18	0.18	0.16	0.16
MgO	4.03	3.91	2.98	2.88	3.46	3.24	3.98	3.24	5.39	5.39	5.81	5.31	4.98	6.09	6.54
CaO	3.73	4.84	3.97	4.52	4.35	3.91	4.01	4.28	7.37	6.22	7.05	6.07	4.12	6.75	7.89
Na_2O	4.59	5.29	3.98	4.25	4.20	4.02	3.99	3.51	4.15	5.07	4.17	4.23	5.14	3.24	2.99
K_2O	4.57	3.11	4.34	4.12	4.03	4.06	4.11	4.02	3.54	2.97	3.12	3.17	3.81	2.61	2.42
P_2O_5	0.29	0.32	0.37	0.27	0.31	0.32	0.35	0.41	0.35	0.35	0.40	0.34	0.31	0.50	0.54
LOI	0.42	1.01	1.54	1.02	1.45	1.38	1.69	1.41	1.07	1.27	1.25	1.45	1.52	1.84	1.85
Total	100.28	99.16	99.40	99.55	99.10	99.21	99.28	99.12	99.92	99.82	99.22	99.69	99.08	98.32	99.01
Rb	122.3	117.5	151.6	122.2	201.6	219.7	130.0	174.0	75.37	114.1	79.73	56.80	57.10	131.0	110.0
Sr	694.1	816.7	281.5	614.0	321.5	488.4	490.0	505.2	492.3	476.6	480.9	454.2	456.0	512.0	519.0
Nd	12.22	21.34	18.91	15.10	18.19	16.40	22.21	23.40	24.65	24.27	22.05	19.82	23.71	34.25	34.53
Sm	2.65	4.34	3.94	3.20	3.35	3.40	5.01	5.01	5.38	5.31	4.94	4.62	5.35	6.87	7.26
REE	63.41	109.79	99.33	76.36	98.75	87.59	125.50	125.89	126.36	125.70	116.72	105.81	120.67	164.54	160.03
$(Tb/Yb)_N$	1.24	1.68	1.63	1.41	1.63	1.53	1.47	1.58	1.60	1.73	1.71	1.61	1.41	1.34	1.48
$(La/Lu)_N$	4.29	9.45	11.00	7.61	10.77	8.56	11.22	11.58	6.41	7.80	6.95	8.20	9.84	11.32	10.06
Delta Eu	0.98	0.98	0.80	0.88	0.98	0.99	0.96	0.84	0.83	0.87	0.70	0.73	0.82	1.02	0.91
$^{87}Rb/^{86}Sr$	0.509	0.416	1.557	0.575	1.812	1.300	0.767	0.995	0.442	0.692	0.479	0.361	0.362	0.739	0.613
$^{87}Sr/^{86}Sr$	0.705614	0.705362	0.708540	0.705861	0.709351	0.708032	0.706472	0.707112	0.705402	0.706142	0.705511	0.705180	0.705201	0.706291	0.705901
Error, 2σ	0.000009	0.000009	0.000013	0.000010	0.000016	0.000014	0.000010	0.000013	0.000009	0.000009	0.000008	0.000008	0.000009	0.000011	0.000009
$^{87}Sr/^{86}Sr$, i	0.704166	0.704179	0.704112	0.704226	0.704198	0.704335	0.704291	0.704282	0.704145	0.704174	0.704149	0.704153	0.704171	0.704189	0.704158
$^{147}Sm/^{144}Nd$	0.131	0.123	0.126	0.128	0.111	0.125	0.136	0.129	0.132	0.132	0.135	0.141	0.136	0.121	0.127
$^{143}Nd/^{144}Nd$	0.512789	0.512787	0.512776	0.512794	0.512736	0.512758	0.512729	0.512714	0.512789	0.512790	0.512784	0.512791	0.512784	0.512771	0.512781
Error, 2σ	0.000014	0.000012	0.000010	0.000013	0.000014	0.000012	0.000013	0.000009	0.000010	0.000014	0.000015	0.000015	0.000011	0.000009	0.000010
$\varepsilon_{Nd}(T)$	4.62	4.79	4.50	4.80	4.10	4.17	3.32	3.21	4.60	4.62	4.42	4.41	4.40	4.53	4.57
TDM, Ga	0.67	0.61	0.65	0.64	0.62	0.68	0.83	0.79	0.68	0.67	0.71	0.76	0.72	0.63	0.65

* Major elements are analyzed using XRF (in wt %), trace elements using ICP-MS (in ppm)

swarms.

The enclaves consist of euhedral to subhedral clinopyroxene, amphibole and plagioclase, and of trace amount of quartz and K-feldspar, with porphyritic texture. Phenocrysts are euhedral clinopyroxene and plagioclase. Amphibole usually mantles around clinopyroxene phenocrysts, and is partially replaced by chlorite and epidote. Magnetite, ilmenite and apatite occur as fine-grained inclusions in clinopyroxene, amphibole and plagioclase.

The host rocks of enclaves consist of subhedral amphibole, plagioclase, K-feldspar and quartz. Magnetite and apatite occur as fine-grained inclusions in amphibole and plagioclase. Amphiboles have been partially replaced by chlorite and epidote along the margin.

3. Analytical Techniques

All equipments used in the present study for qualitative analyses are installed at the Research Center for Mineral Resources Exploration, Chinese Academy of Sciences. Mineral analyses were carried out by wavelength-dispersion X-ray spectrometry on a Shimadzu-1500 electron microprobe. The operation condition was set to 15 kV and 20 nA using a beam defocused to approximately 10µm diameter. Counting time was 10 seconds per element. Synthetic pure oxides and natural minerals were used as standards. Pyroxene nomenclature and site assignments follow IMA guidelines (Morimoto, 1989). The amphibole results were recalculated on an anhydrous basis to a total of 13 cations, excluding Ca, Na and K, per 23 atoms of oxygen; the cations assigned to each site according to IMA guidelines (Robinson et al., 1982; Leake et al., 1997).

Whole-rock samples were ground in an agate mill, after careful washing in distilled water, then analyzed for the major element compositions by XRF spectrometry on glass disks made by fusion of the whole rock powder with lithium tetraborate. Trace elements were analyzed by inductively coupled plasma-mass spectrometry (ICP-MS). Whole rock samples were analyzed for Sr and Nd isotopic compositions. Strontium and neodymium were extracted by conventional ion exchange chromatographic techniques, after dissolution with a HF-HNO_3-HCl mixture. Sr and Nd isotopic ratios were measured using a Finnigan MAT 262 multiple collector, thermal ionization mass spectrometer running in dynamic mode. Replicate analyses of the NBS-987 reference standard gave an average value of 0.710287±0.000010 (n=14). $^{87}Sr/^{86}Sr$ was normalized within-run to $^{86}Sr/^{88}Sr=0.1194$. The $^{143}Nd/^{144}Nd$ ratio was normalized within-run to $^{146}Nd/^{144}Nd= 0.7219$.

The Nd standard La Jolla yielded an average ratio of $^{143}Nd/^{144}Nd=0.511942\pm0.000012$ (n=12). All errors and standard deviations are given at the 2σ confidence level. Chemical and isotopic compositions of the Biliutai pluton are listed in Table 1.

4. Mineral Chemistry

4.1. Pyroxene

Pyroxene only occurs as phenocryst in the enclaves from the Biliutai pluton. Green pleochroic clinopyroxene is subhedral, with prismatic sections up to 3 mm in length. Most pyroxenes are mantled by amphibole. Magnetite, apatite and ilmenite may occur as inclusions in pyroxene. Compositions of representative pyroxenes are measured, which range from augite (core) to subcalcic augite (rim, Fig. 2a). Clinopyroxene cores in the enclaves have higher Ca and Mg contents than their rims, although Mg content varies slightly from core to rim (see Fig. 2a). The mg# (= 100Mg/(Mg+Mn+Fe)) values range from 74.57 to 86.15, and cores have relatively high mg# values than rims.

4.2. Amphibole

Amphibole is abundant both in enclaves and host rocks of the Biliutai pluton. In host rocks, green amphibole occurs as subhedral crystal. In enclaves, yellowish brown to green amphiboles mantle pyroxene phenocrysts. Representative compositions of amphibole are determined, which are highly variable (Fig. 2b-c). Amphiboles from the enclaves are less variable in composition than those in the host rocks. Amphiboles from the enclaves have lower Si (<6.65 p.f.u.) and mg# (=(Mg/(Mg+Fe^{2+})) values (<0.50) than amphiboles from the host rocks, which have high and largely variable Si contents (>6.65 p.f.u.) and high mg# values (>0.5). All amphiboles from the enclaves have Na+K values in site A higher than 0.5, which belong to ferro-edenitic hornblende – pargasite (Fig. 2b). Some amphiboles from the host rocks have Na+K values in A site higher than 0.5, and belong to silicic edenite – edenitic hornblende (Fig. 2b); others belong to actinolite – magnesio-hornblende because of low Na+K values in A site (Fig. 2c).

4.3. Feldspar

Subhedral plagioclase is a common mineral both in host rocks and enclaves with An contents ranging from 1.3 to 54 (Fig. 2d). Plagioclase phenocrysts in the enclaves generally have high An values (49-54 in cores and 23-50 in rims). Plagioclase in the groundmass from the enclaves has relatively homogeneous composition with much lower An compo-

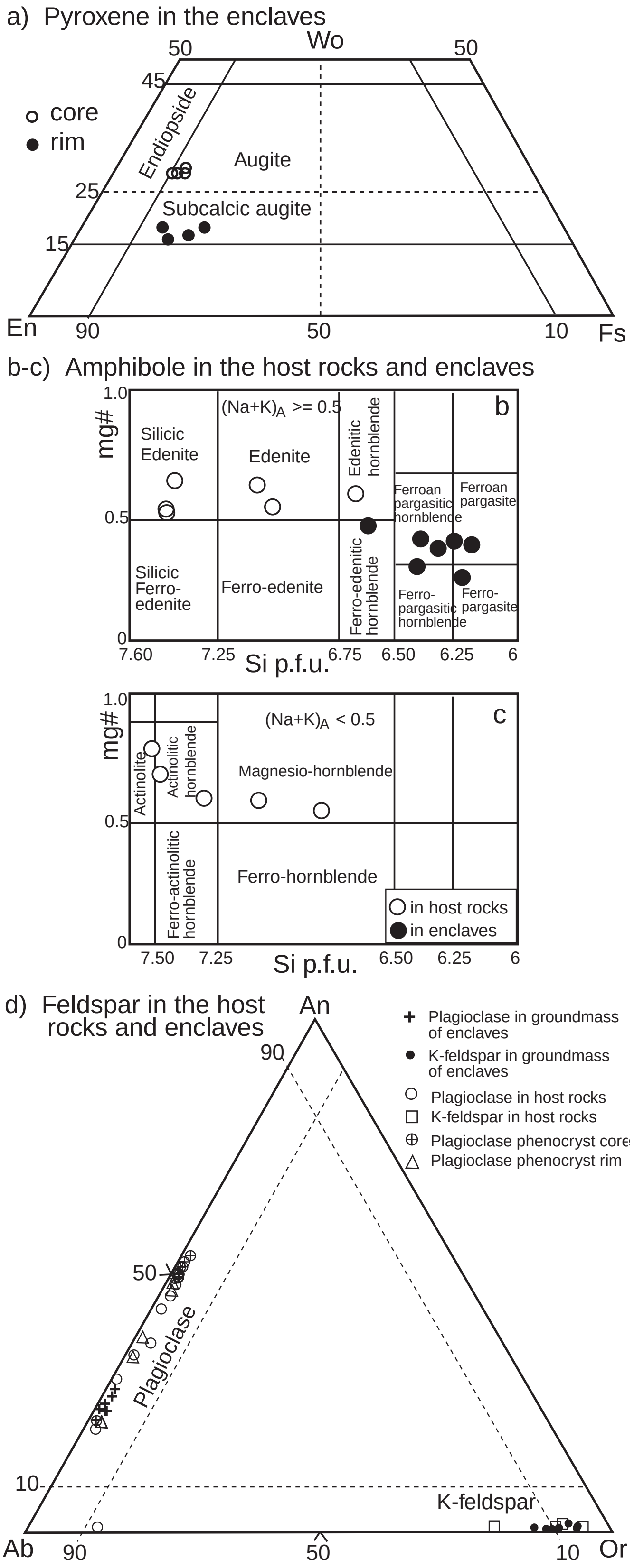

Fig. 2 Quadrilateral diagram of pyroxenes (a), classification diagrams for amphiboles (b, c), and Ab-An-Or diagram for feldspar (d) from the Biliutai pluton.

nents of 22-28. Plagioclase in the host rocks varies largely in composition (An 1.3-52.5). K-feldspar occurs both in the host rocks and enclaves, and coexists with quartz and small plagioclase. The composition is not highly variable (Fig. 2d). K-feldspar in the enclaves occurs only in groundmass.

5. Geochemistry

5.1. *Major and trace element geochemistry*

Both the host rocks and enclaves belong to syeno-diorite based on alkali-SiO_2 diagram except one enclave sample, which falls in the region of gabbro (Fig. 3a). The enclaves and host rocks fall in the shoshonitic space with one exception, which falls in the high-K calc-alkaline space, in the plot of SiO_2 vs K_2O (Fig. 3b). Four samples of enclaves have obviously high TiO_2 concentrations (Fig. 4a), which probably is due to the concentration of ilmenite. Enclaves have relatively higher Fe_2O_3, CaO and MgO contents than their host rocks (Fig. 4a-d). P_2O_5 and Na_2O contents are not different obviously between enclaves and host rocks (Fig. 4e-f). Al_2O_3 concentration is lower in the enclaves than that in host rocks (Fig. 4g). Enclaves have relatively high concentrations of Cr, V and Ni compared to the host rocks (Fig. 4h-j). Absence of apparent continuous correlation from enclaves to host rocks in these diagrams rules out the possibility of magma differentiation from enclaves to host rocks.

The concentrations of rare earth elements (REE) in the Biliutai pluton are largely variable (Table 1). Enclaves have higher REE concentrations (106-165 ppm) than host rocks (66-110 ppm). REE differentiation can be estimated by chondrite-normalized ratios of $(La/Lu)_N$, with $(La/Lu)_N$ >1 meaning that light REE (LREE) were enriched and heavy REE (HREE) were depleted relatively. $(La/Lu)_N$ values are high and vary largely both for enclaves (6.4~11.3) and host rocks (4.3~11.6), indicating high enrichment of LREE. Similarly, small variance of $(Tb/Yb)_N$ values (1.2~1.7) indicates weak HREE differentiation. Enclaves and host rocks have similar REE patterns with LREE enrichment. The host rocks are enriched in LREE without apparent Eu anomalies (Fig. 5a). The enclaves are strongly enriched in LREE with negative Eu anomalies (Fig. 5b).

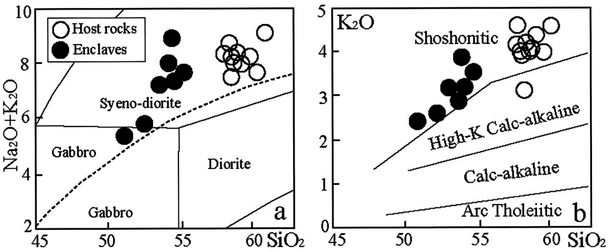

Fig. 3 a) Total alkali vs silica classification diagram, the curved dashed line subdivides the alkalic from subalkalic rocks, and b) K_2O vs SiO_2 diagram, for the Biliutai pluto.

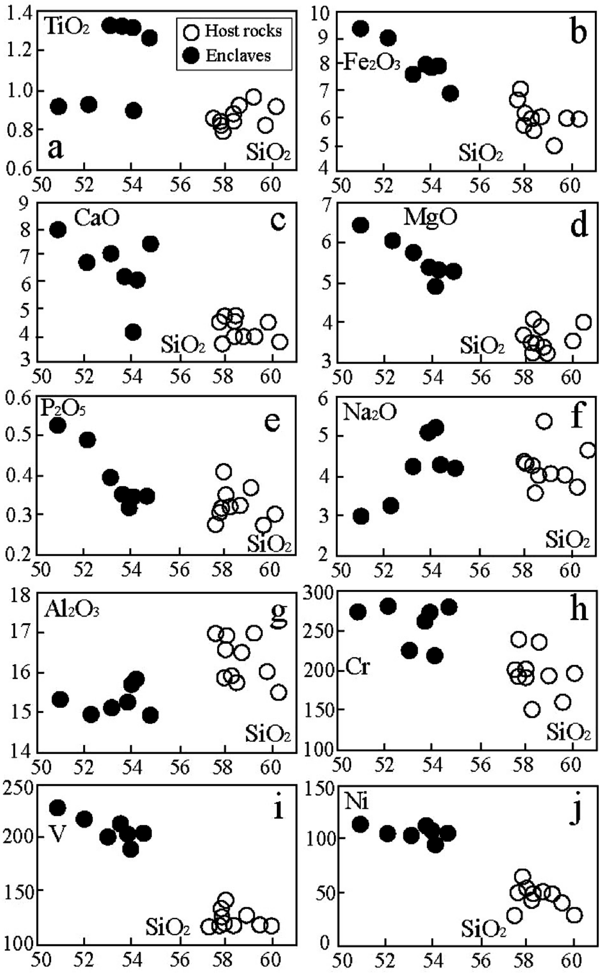

Fig. 4 Harker diagrams for selected major and trace elements of the Biliutai pluton.

Large ion lithosphere elements (LILE, i.e. Cs, Rb, K, Sr, Eu, Ba) are relatively mobile in fluid. On the other hand, the high field strength elements (HFSE, i.e. Y, Zr, Ti, Nb, Ta) are immobile in fluid, and their behaviors are controlled by source chemistry and crystal/melt process during magma evolution (Pearce and Norry, 1979; Sun and McDonough, 1989). In MORB-normalized multi-element diagrams, the host rocks are enriched in LILE, Th, U and LREE, and are depleted in HFSE and HREE (Fig. 5c). Similar to the host rocks, the enclaves are enriched in LILE, Th, U and LREE, and are depleted in HFSE (Fig. 5d). All samples from the Biliutai pluton are enriched in LILE and LREE, and show Nb-Ta troughs in the multi-element diagrams. However, the host rocks differ from enclaves by their apparent Sr enrichment and relative strong HFSE depletion.

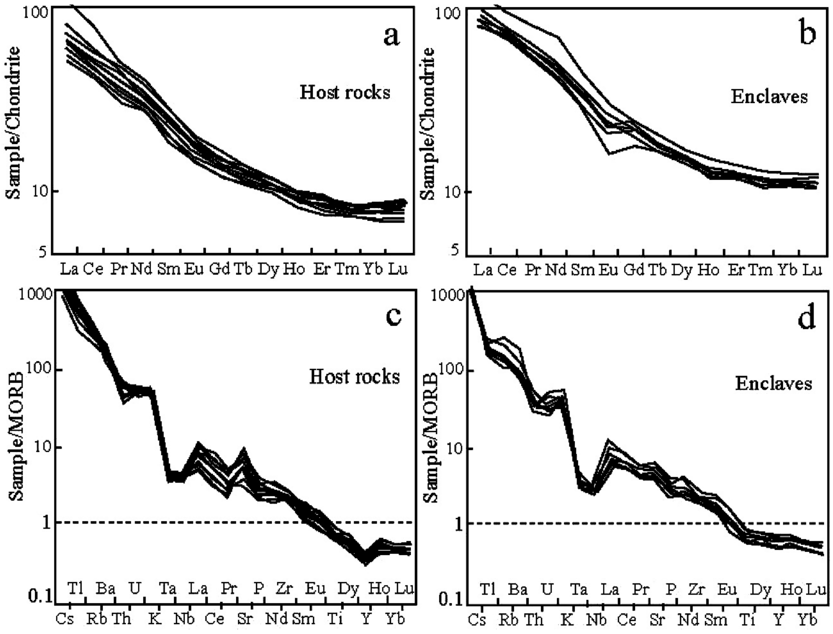

Fig. 5 a-b) Chondrite-normalized REE distribution patterns for host rocks (a) and enclaves (b). c-d) MORB-normalized (by Sun and McDonough, 1989) multi-element diagram for host rocks (c) and enclaves (d).

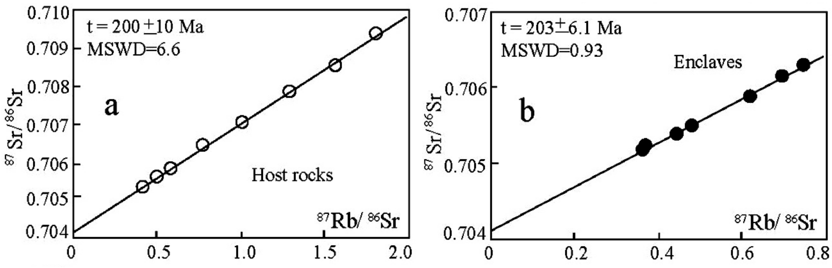

Fig. 6 a) Host rocks (except sample HR2 and H33) form a Rb-Sr isochron giving an age of 200±10 Ma with initial $^{87}Sr/^{86}Sr$ of 0.704220±0.000140 (MSWD=6.6). b) All enclave samples form one Rb-Sr isochron giving an age of 203±6.1 Ma with initial $^{87}Sr/^{86}Sr$ of 0.704140±0.000041 (MSWD=0.93).

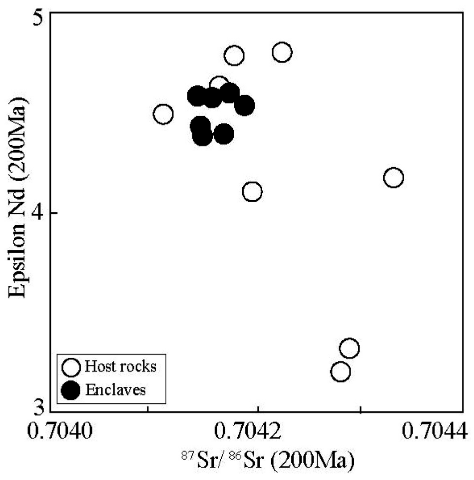

Fig. 7 Plots of initial $^{87}Sr/^{86}Sr$ vs ε_{Nd} values for the enclaves and host rocks in the Biliutai pluton.

5.2. *Sr-Nd isotopic compositions*

Samples of host rocks form a Rb-Sr isochron giving an age of 200±10 Ma with initial $^{87}Sr/^{86}Sr$ =0.704220 ±0.000150 (MSWD=6.6; Fig. 6a). Samples of enclaves form an isochron yielding an age of 203±6.1 Ma with initial $^{87}Sr/^{86}Sr$= 0.704140± 0.000041 (MSWD=0.93; Fig. 6b). If combined the enclaves and host rocks together to form one isochron, it will give an age of 203.7±5.9 Ma with initial $^{87}Sr/^{86}Sr$= 0.704155± 0.000067 (MSWD=4.4). These results are almost the same within their error ranges. Therefore, the host rocks and enclaves have probably the same age, and have same initial $^{87}Sr/^{86}Sr$ ratios. Such equality indicates a similarity in their petrogenesis. We therefore use 200 Ma to calculate ε_{Nd} and initial $^{87}Sr/^{86}Sr$ values. The initial $^{87}Sr/^{86}Sr$ ratios range from 0.704112 to 0.704335. ε_{Nd} values vary between +3.21 and +4.80 (Table 1, Fig. 7).

6. Discussion

6.1. *Enclaves: results of magma differentiation or representative of different magma sources?*

Mafic enclaves in granitoids have been intensively studied all over the world (Chappell et al., 1987; Didier and Barbarin, 1991; Zhu, 1994; Maas et al., 1997). There are three main theories for the petrogenesis of microgranular enclaves: 1) fragments of wall rock facies closely related to the host magma or of cognate fragments of cumulates (Chappell et al., 1987); 2) globules of mafic magma, commingled with more felsic host rocks (Didier and Barbarin, 1991); and 3) fragments of recrystallized, refractory metamorphic rocks and fragments of melt residues from the granite source (Maas et al., 1997). The third possibility can be ruled out immediately as the enclaves in the Biliutai pluton have magmatic texture and crystallized mineral assemblages. As the enclaves and host rocks have almost similar Sr-Nd isotopic characteristics and the same age of 200 Ma (Fig. 6), the enclaves should not be the result of assimilation of basalt or gabbro by the host magma in the lower crust.

The enclaves in the Biliutai pluton are generally round and elliptical with gradational contacts with the host rocks. The most obvious characteristic for the enclaves is the occurrence of pyroxene as a phenocryst, which is completely absent in the host rocks. The mineralogical difference between enclaves and their host rocks is also presented in the chemical compositions of amphiboles. Amphiboles from the enclaves have very limited compositional variation, and are generally Fe-rich and Si-poor (Fig. 2b), whereas amphiboles from the host rocks are Mg-rich and highly variable in Si contents (Fig. 2b-c). Chemically, the enclaves have relatively lower concentrations of SiO_2 and Al_2O_3, and higher concentrations of Fe_2O_3, MgO, CaO, Cr, Ni and V (Fig. 4). As these and other elements are largely scattered on various diagrams with no apparent correlation, no differentiation trends can be identified. This eliminates the possibility of the enclaves as the parental magma for host rocks, and therefore rules out the possibility of fractional crystallization from enclaves to host rocks. This implies that there is no fractional crystallization relationship between enclaves and host rocks, each of them has their own parental magma or similar original magmas, but experienced different magma processes such as the contamination by the continental crust with different degrees.

6.2. Continental crust contamination

Th is highly enriched in pelagic sediments and both Th and Nb are considered to be immobile elements in fluids (Plank, 1996). These two elements are highly incompatible and their ratio should therefore be unaffected by magmatic differentiation, and it will not change greatly during partial melting (Hofmann, 1988). Thus, the Th/Nb ratio can be taken as an indicator of the relative contribution of continental material, with low Th/Nb ratios reflecting a relatively small contribution of continental crust. The variable Th/Nb ratios of the Biliutai pluton (0.36-0.84, much higher than MORB value of 0.05 (Sun and McDonough, 1989)) imply different percentages of crustal contamination. Samples from the Biliutai pluton have very high Ba/Nb ratios (54-133), which are even higher than that of the average continental crust (about 54). This suggests other mechanisms for Ba enrichment and/or Nb depletion except contamination by continental crust. Fluid probably was important for Ba enrichment. A fluid-modified source can generate a melt with high Ba/Nb ratio. As U is mobile in a fluid relative to Nb, Th and Sm (Brenan et al., 1995), its enrichment by fluid can be a plausible explanation for high U/Nb, U/Th and U/Sm ratios in the Biliutai pluton. These observations suggest that fluid played an important role during the contamination by the continental crust.

Enclaves have very limited variation both in initial $^{87}Sr/^{86}Sr$ ratios and ε_{Nd} values relative to their host rocks (Fig. 7). This probably suggests that the enclaves were relatively little contaminated by continental materials, i.e., the host rocks have experienced more contamination than enclaves, and therefore implies that the magma source for enclaves is different from the magma source for host rocks. Nd and Sr isotope data (Fig. 7), as well as the differences of the other geochemical data (Figs. 3-6), therefore, demonstrate that the enclaves and their host rocks have similar but different magma sources.

6.3. Magma generation

Generation of potassium-rich magmas generally takes place during late- to post-orogenic extension and crustal uplift. Two current models explain the generation of potassium-rich magma. The lithosphere thinning model (Turner, 1996) assumes that prior to convective thinning of mantle lithosphere, maximum elevation of the orogenic plateau is determined by the balance between driving and buoyancy forces. Heating of the lithospheric mantle following thinning causes partial melting of enriched lithospheric mantle to produce shoshonite melts. Tectonic erosion model (Flower et al., 1998) emphasizes tectonic erosion of contaminated lithospheric mantle by the asthenosphere, which yields a refractory, K-rich source, diapirism induced by gravity and viscosity destabilisation resulting from lithosphere extension and generation of K-rich, HFSE-depleted melt.

The Biliutai pluton is a typical alkaline magmatic body (Fig. 4b), and is largely different from the Mesozoic calc-alkaline magmatic rocks due to its high potassium concentrations. The enclaves and host rocks show incompatible trace element patterns enriched in LILE and LREE with troughs of Nb-Ta in the MORB-normalized spidergram (Fig. 5c-d). Most samples of host rocks are enriched in Sr and Zr, and depleted in Th, Y and HREE (Fig. 5). This is a distinctive feature considered typical of subduction-related magmas (Pearce and Norry, 1979). The geochemical arc-type signature may therefore suggest derivation of the magma for the Biliutai pluton from subduction-modified mantle sources. The geochemical characteristics of the Biliutai pluton suggest that the likely origin of the mantle source enrichment could be related to a subduction component similar to that of the Permian volcanic rocks. The age of this incompatible element enrichment can be evaluated using depleted mantle Nd model ages as 0.6~0.8 Ga (Table 1). The subduction and collision processes caused the fluid contamination of the mantle. During the extensional period, this mantle partially melted and formed the Permian volcanic rocks (Zhu et al., 2001). Afterwards, the Biliutai pluton formed at about 200Ma during the extensional processes. As the calc-alkaline Jurassic volcanic and intrusive activities are related to the subduction of Pacific oceanic lithosphere (Zhao et al., 1989), the Biliutai pluton, therefore, probably records the last magmatic event related to the continental collision in the Mongolia orogenic zone.

7. Conclusions and Metallogenic Significance

The Biliutai pluton records a 200 Ma old alkaline magmatic activity in the Mongolia orogenic zone, and this magmatic activity represents the last magma process related to the collision event in the Mongolia orogenic zone. The enclaves and their host rocks have different magma sources. The magma for the enclaves is depleted relative to the magma from which the host rocks formed. The magma for the host rocks has been strongly contaminated by continental materials. Although the gold deposit in the Biliutai alkaline pluton occurs as quartz veins and obviously was controlled by small faults inside this pluton (Zhu et al., 1998), it is clear that the gold is from magma or the source region from which the alkaline magma generated. This implies that gold and other ore-forming elements come from lithospheric mantle similar to the alkaline magma. Therefore, the magma formed at 200Ma in this region could be gold-bearing, and the magmatic bodies formed at this period have high potentiality for gold mineralization. This is a new idea for gold exploration in this region, and it needs more detail work in future.

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