The Island Arc (2003) **12,** 13–21

Research Article

Absence of Archean basement in the South Kunlun Block: Nd-Sr-O isotopic evidence from granitoids

CHAO YUAN,[1,2,†] MIN SUN,[1,*] MEI-FU ZHOU,[1] HUI ZHOU,[3] WENJIAO XIAO[4] AND JILIANG LI[4]

[1]*Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China (email: minsun@hkucc.hku.hk),* [2]*Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China,* [3]*Department of Geology, Peking University, Beijing, 100871, China and* [4]*Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, 100029, China*

Abstract The West Kunlun mountain range along the northwestern margin of the Tibetan Plateau is crucial in understanding the early tectonic history of the region. It can be divided into the North and South Kunlun Blocks, of which the former is considered to be part of the Tarim Craton, whereas consensus was not reached on the nature and origin of the South Kunlun Block. Samples were collected from the 471 Ma Yirba Pluton, the 405 Ma North Kudi Pluton and the 214 Ma Arkarz Shan Intrusive Complex. These granitoids cover approximately 60% of the Kudi area in the South Kunlun Block. Sr, Nd, and O isotope compositions preclude significant involvement of mantle-derived magma in the genesis of these granitoids; therefore, they can be used to decipher the nature of lower–mid crust in the area. All samples give Mesoproterozoic Nd model ages (1.1–1.5 Ga) similar to those of the exposed metamorphic complex of this block but significantly different from those of the basement of the North Kunlun Block (2.8 Ga). This indicates that the South Kunlun Block does not have an Archean basement, and, thus, does not support the microcontinent model that suggests the South Kunlun Block was a microcontinent once separated from and later collided back with the North Kunlun Block.

Key words: granitoids, Nd-Sr-O isotopes, Tibetan Plateau, West Kunlun.

INTRODUCTION

The West Kunlun mountain range along the northwestern margin of the Tibetan Plateau is one of the most poorly understood orogenic belts in China. It consists of the North and South Kunlun Blocks (Fig. 1), welded together during the Paleozoic (Pan 1996). Because of the existence of a Paleoproterozoic or earlier basement, the North Kunlun Block is generally considered to be part of the Tarim Craton (Ding 1996; Matte *et al.* 1996; Mattern *et al.* 1996; Pan 1996; Mattern & Schneider 2000), whereas there is considerable debate concerning the nature and origin of the South Kunlun Block. Several tectonic models have been proposed to explain the geological evolution of the area, such as the microcontinent model (Jiang 1992; Pan *et al.* 1994; Li *et al.* 1995; Mattern *et al.* 1996; Pan 1996; Mattern & Schneider 2000), the subduction–accretion model (Chang *et al.* 1989; Sengör 1990; Sengör & Okurogullari 1991) and the archipelago model (Yao & Hsü 1994; Hsü *et al.* 1995). One of the key points for the validity of any of these models is whether the South Kunlun Block shares a common basement with the North Kunlun Block and the Tarim Craton.

Crust-derived granitoids can be used to probe the nature of their crustal sources (Miller *et al.* 1990; Farmer 1992; Johannes & Holtz 1996); in particular, the isotopic composition of granitoids might reflect the tectonic setting and crustal struc-

*Correspondence.

†Present address: Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China.

Received 26 February 2002; accepted for publication 3 September 2002.

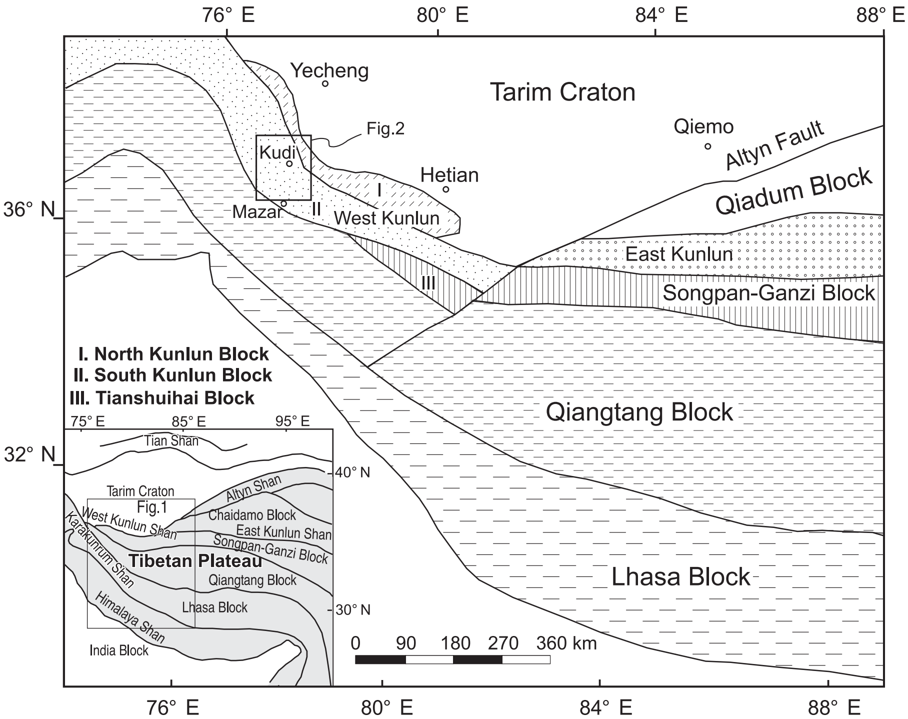

Fig. 1 Tectonic framework of the Tibetan Plateau and adjacent areas.

ture (Borg *et al.* 1990). Large amounts of granitoids are exposed in the West Kunlun mountain range, but systematic isotopic data are rare for these intrusions. This study provides Nd-Sr-O isotopic data for some selected granitic samples from the Kudi area, which allow us to constrain the nature of the basement of the South Kunlun Block.

REGIONAL GEOLOGY

The Tibetan Plateau is composed of several continental and arc terranes, successively accreted from Gondwanaland to Laurasia (Chang *et al.* 1986; Dewey *et al.* 1988). The Kunlun mountain range in the northern margin of the plateau records the earliest history of the plateau (Pan *et al.* 1994). This mountain range is divided by the Altyn Fault into the west and east segments (Fig. 1). The West Kunlun is further subdivided into the North and South Kunlun Blocks by the mid-Kunlun Suture marked by the Kudi–Subashi Ophiolitic Belt, which indicates the existence of an important ocean in the past, the Proto-Tethys (Deng 1989; Pan 1996; Yang *et al.* 1996) (Figs 1,2). Collision of the two blocks is considered to have resulted in the closure of this ocean and, consequently, a significant orogenic event in the early Paleozoic (Matte *et al.* 1996; Mattern *et al.* 1996; Pan 1996).

The basement of the North Kunlun Block is dominated by Paleoproterozoic–Archean gneiss and migmatite, which are intruded by 2.2 Ga granites (Xu *et al.* 1994; Pan 1996). Isotope analyses yielded a depleted mantle Nd model age of 2.8 Ga (Arnaud & Vidal 1990), indicating that the North Kunlun Block shares an Archean basement with the Tarim Craton (Matte *et al.* 1996). The overlying sedimentary rocks include clastic rocks and carbonate; that is, the Sinian (Neoproterozoic)–Ordovician Kilian Group (Chang *et al.* 1989), the Devonian Tisnab Group (Wen *et al.* 2000) and the late Paleozoic–Cenozoic strata (Mattern *et al.* 1996; Pan & Bian 1996). The existence of a basement older than the Paleoproterozoic supports the idea that the North Kunlun Block is the southern continuation of the Tarim Craton (Matte *et al.* 1996; Mattern *et al.* 1996; Pan 1996).

A metamorphic complex also exists in the South Kunlun Block, which primarily consists of schist and gneiss with local, lens-shaped ultramafic rocks, and underlies late Paleozoic to Mesozoic clastic rocks, carbonate and volcanic rocks (Geological Investigation Team Two 1985; Deng 1989; Gaetani *et al.* 1990; Mattern *et al.* 1996). Although this complex is lithologically similar to its counterpart of the North Kunlun Block, its age has not been well constrained. Pan and Bian (1996) and Matte *et al.* (1996) surmised an age of Paleo–Mesoproterozoic, whereas Sengör and Okurog-

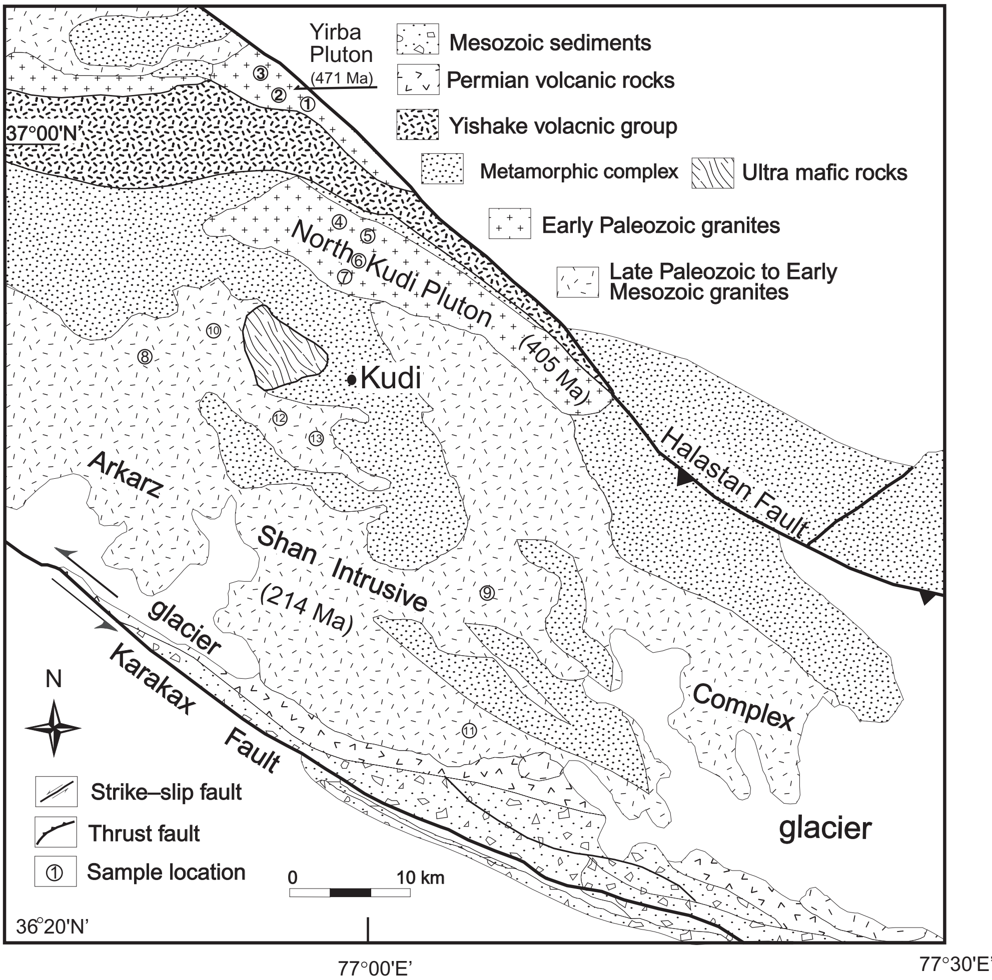

Fig. 2 Geological map of the Kudi area, South Kunlun Block. Sample locations: (1) 96KL45; (2) 96KL48; (3) 96KL159, 160, 162, 163; (4) 96KL176, 177; (5) 96KL179; (6) 96KL188; (7) 96KL193, 196; (8) 96KL209, 210, 211; (9) 96KL241, 243; (10) 96KL264, 268; (11) 96KL245; (12) 96KL257, 260; (13) 96KL262, 263.

ullari (1991) and Sengör and Natal'in (1996) assigned it to the Neoproterozoic–early Paleozoic. Zhou (1998) obtained 1.1–1.4 Ga Nd model ages for gneissic rocks of this complex. Recently obtained $^{40}Ar/^{39}Ar$ ages for biotite and K-feldspar separates from the complex range from 452 Ma to 350 Ma (Matte *et al.* 1996; Li *et al.* 2000; Zhou *et al.* 2000), which are interpreted to reflect an early Paleozoic collisional event (Pan *et al.* 1994; Matte *et al.* 1996; Xiao *et al.* 2002; Yuan *et al.* 2002).

GRANITIC PLUTONS IN THE KUDI AREA

Granitic plutons are widely distributed in the West Kunlun range (Fig. 2), with ages mainly in two populations: an older suite (518–384 Ma) and a younger suite (290–180 Ma) (Cowgill *et al.* 2002). Samples for this study were collected from the Yirba Pluton, the North Kudi Pluton (NKP) and the Arkarz Shan Intrusive Complex (ASIC). These intrusions occupy approximately 60% of the Kudi area in the South Kunlun Block. The Yirba Pluton and NKP have an early Paleozoic age and are considered to be products of the closure of Proto-Tethys (Pan *et al.* 1994; Matte *et al.* 1996; Mattern *et al.* 1996; Pan 1996). The ASIC, covering an area of > 2800 km^2, has a Triassic age (Fig. 2), and consequently it is interpreted to be genetically related to the closure of the Paleo-Tethys, a late Paleozoic ocean that existed to the south of the study area (Pan *et al.* 1994; Matte *et al.* 1996; Mattern *et al.* 1996; Pan 1996).

YIRBA PLUTON

The Yirba Pluton is located approximately 30 km north of Kudi (Fig. 2). It intrudes the metamorphic complex of the South Kunlun Block and is intruded by a late Paleozoic–early Mesozoic granitic pluton in the north, while its southern margin is in fault contact with the volcanic sequence of the Kudi ophiolite (i.e. the Yishake Group) (Xiao *et al.* 2002). To the east, the Yirba Pluton is truncated by the

Halastan fault. This pluton is a medium–coarse-grained granodiorite composed of plagioclase (55%), K-feldspar (15%), quartz (20%) and subordinate ferromagnesian minerals, including hornblende and biotite. Accessory minerals include magnetite, titanite, zircon and apatite. The pluton is deformed, with lineation and foliation defined by hornblende and biotite consistent with northwest–southeast shearing in the country rocks (Mattern *et al.* 1996). Samples from this pluton are generally fresh, with local sericitization and kaolinization of feldspar and chloritization of biotite. Chemical analyses show characteristics of volcanic arc granites, and zircon U-Pb analyses give 471 ± 5 Ma concordant age (Yuan *et al.* 2002), prior to the Silurian collision between the North and South Kunlun Blocks (Matte *et al.* 1996). Accordingly, this pluton was considered to be generated in an active continental margin during consumption of the Proto-Tethys (Xiao *et al.* 2002; Yuan *et al.* 2002).

NORTH KUDI PLUTON

The North Kudi Pluton intrudes the metamorphic complex of the South Kunlun Block (Fig. 2). This pluton is undeformed and predominantly medium-grained monzogranitic in composition. It consists of K-feldspar (30–45%), plagioclase (30–40%), quartz (approximately 28%), biotite (approximately 10%) and accessory minerals, including titanite, apatite, zircon, monazite and magnetite (Zhang *et al.* 2000). This pluton is relatively enriched in K_2O and high-field-strength elements, manifesting A-type granite characteristics, and is regarded as a post-kinematic granite (Matte *et al.* 1996; Jiang *et al.* 2002; Yuan *et al.* 2002). It has a concordant U-Pb zircon age of 405 ± 2 Ma (Yuan *et al.* 2002).

ARKARZ SHAN INTRUSIVE COMPLEX

The voluminous ASIC is exposed mainly along the crest of the West Kunlun. It is composed of fine–medium-grained granodiorite and biotite monzogranite, intruding both the metamorphic complex and the lower Permian volcanic rocks of the South Kunlun Block. The Permian volcanic rocks possess an arc signature and are related to the consumption of the Paleo-Tethys (Wang 1996). Samples from the ASIC all have similar mineral assemblages, although in various proportions, including plagioclase (30–35%), K-feldspar (15–35%), quartz (25–40%), biotite (approximately 15%) and minor hornblende. Accessory minerals include zircon, apatite, titanite, allanite, monazite and magnetite. Rocks of this complex are generally undeformed and fresh, although low-grade hydrothermal alteration of K-feldspar and plagioclase can be observed. The ASIC is calc-alkaline in composition and has a U-Pb zircon age of 214 ± 1 Ma, equivalent to the final stage of the closure of the Paleo-Tethys (Yuan *et al.* 2002).

ANALYTICAL METHODS

Representative samples were analyzed for Nd-Sr-O isotope compositions. Nd and Sr isotopic analyses were conducted following the procedure described by Jahn *et al.* (1990). The Sr and Nd ratios were measured on a VG-354 mass spectrometer (VG Micromass, Manchester, UK) at the Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing. Sr and Nd blanks were 0.2–0.5 ng and approximately 0.05 ng, respectively. Mass fractionations for Sr and Nd isotopes were corrected by normalizing to $^{86}Sr/^{88}Sr = 0.1194$ and $^{146}Nd/^{144}Nd = 0.7219$, respectively. Repeat analyses gave a mean $^{87}Sr/^{86}Sr$ value of 0.710237 ± 0.000014 for NBS-987 and a mean $^{143}Nd/^{144}Nd$ value of 0.512635 ± 0.000008 for BCR-1 (all at 2σ). The whole-rock oxygen isotope analyses were carried out in the Institute of Mineral Resources, Chinese Academy of Geosciences, following the method of Taylor and Epstein (1962). These measurements were accomplished using a MAT 251 (Finnigan MAT, Egelsbach, Germany), and the analytical precision was approximately 0.2‰.

RESULTS

All granitic samples in this study showed typical crustal $^{147}Sm/^{144}Nd$ ratios (0.083–0.120) and did not exhibit significant Sm-Nd differentiation. Their initial Nd and Sr isotope compositions were calculated based on their zircon U-Pb ages. The Yirba Pluton was characterized by relatively high εNd_t values (from − 1.09 to + 0.66), and its initial $^{87}Sr/^{86}Sr$ ratios ranged from 0.7075 to 0.7091. The $\delta^{18}O$ values of this pluton were relatively low, between 5.7‰ and 7.4‰. The NKP had εNd_t values between − 2.5 and − 4.0, and its initial $^{87}Sr/^{86}Sr$ ratios were between 0.7076 and 0.7098. Of the three plutons, the NKP had the most enriched oxygen isotope compositions, with $\delta^{18}O$ values between 7.2‰ and 10.3‰. The ASIC granodiorite and monzogranite had a wide range of Nd and Sr

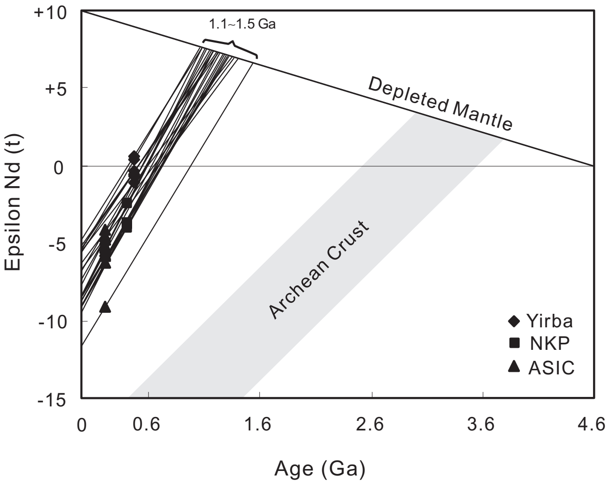

Fig. 3 Initial Nd isotope composition and T_{DM} ages of granitoids from the Kudi area. Depleted mantle line follows Jahn *et al.* (1990). ASIC, Arkarz Shan Intrusive Complex; NKP, North Kudi Pluton.

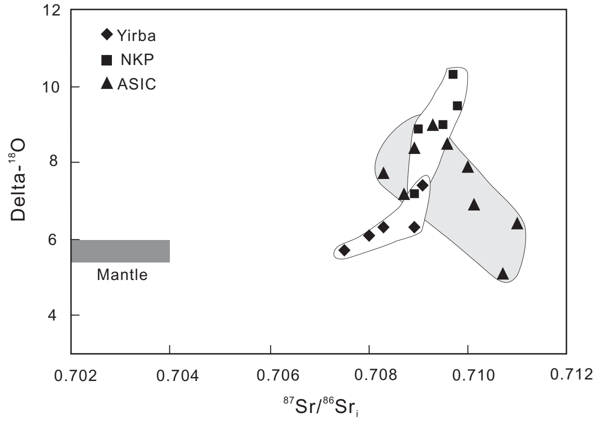

Fig. 4 Sr-O isotope correlations of granitoids from the Kudi area, South Kunlun Block. ASIC, Arkarz Shan Intrusive Complex; NKP, North Kudi Pluton. Mantle component data ($\delta^{18}O = +5.7 \pm 0.3$; $^{87}Sr/^{86}Sr = 0.703 \pm 0.001$) from Taylor (1980).

isotopic compositions (from $\varepsilon Nd_t = -4.5$ to $\varepsilon Nd_t = -9.1$ and initial $^{87}Sr/^{86}Sr = 0.7083$–0.7110 for granodiorite, and $\varepsilon Nd_t = -4.1$ to $\varepsilon Nd_t = -6.2$ and initial $^{87}Sr/^{86}Sr = 0.7087$–0.7109 for monzogranite, respectively). The oxygen isotope compositions of the ASIC samples were also variable, with $\delta^{18}O$ values between + 5.1‰ and + 8.5‰ (Table 1).

The depleted mantle Nd model ages (mean crustal residence ages) of a rock suite can be used to estimate the average time since the precursor magma was extracted from a hypothetical depleted mantle reservoir and became a part of the continental crust (Jahn *et al.* 1990). Because all samples in the present study had a narrow Sm/Nd range (from $f_{Sm/Nd} = -0.39$ to $f_{Sm/Nd} = -0.57$) and crustal signature, their T_{DM} ages were calculated assuming a single-stage linear evolution model (Jahn *et al.* 1990). All samples in the present study had similar depleted mantle Nd model ages, with T_{DM} values between 1.06 and 1.53 Ga (Table 1; Fig. 3).

DISCUSSION

PETROGENESIS AND SOURCE OF THE GRANITOIDS IN THE KUDI AREA

The granitic samples in the present study had εNd_t and $^{87}Sr/^{86}Sr$ ratios similar to those of the I-type granites of the Lachlan Fold Belt, Australia (Collins 1998) (Table 1). Most of the samples had $\delta^{18}O$ values between 6.4‰ and 10.3‰, similar to those of typical I-type granites (O'Neil & Chappell 1977). These samples neither contained mafic microgranular enclaves (Barbarin & Didier 1991), nor showed any microstructural evidence of magma mixing, such as mantled quartz xenocrysts, existence of K-feldspar megacrysts or discontinued zoning in plagioclase (Vernon 1991). In addition, there was no coeval mafic magmatic activity in the area. Therefore, the direct involvement of mantle-derived magma in the genesis of these granitoids was not significant and, accordingly, their isotopic compositions might reflect the nature of the lower–mid crust of their source region.

In a $\delta^{18}O$–$^{87}Sr/^{86}Sr$ diagram (Fig. 4), data showed different trends. The Yirba Pluton and the NKP both had positively correlated Sr-O isotopic relations (Fig. 4), which might have resulted from the partial melting of a mixed source containing both felsic and mafic materials (Taylor 1980; Haack *et al.* 1982). Some samples from the 471 Ma Yirba Pluton had $\delta^{18}O$ data similar to the mantle value (5.7 ± 0.3‰; cf. Taylor 1980), but they possessed relatively high initial $^{87}Sr/^{86}Sr$ ratios (0.7075–0.7091). This might be the manifestation of the involvement of a significant amount of mafic material in their magma source. In contrast, the 405 Ma post-kinematic NKP had both higher $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ ratios, implying a predominant amount of felsic material in the magma source. Samples from the third intrusion, the 214 Ma ASIC, showed a negative $\delta^{18}O$ and initial $^{87}Sr/^{86}Sr$ correlation (Fig. 4), which could imply the involvement of material with low ^{18}O and high $^{87}Sr/^{86}Sr$ values, such as hydrothermally altered rocks (Taylor 1980).

Table 1 Nd-Sr-O isotope compositions of representative granitic plutons of the Kudi area

Sample no.[†]	Sm (p.p.m.)	Nd (p.p.m.)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$ (±2σ)	$^{143}Nd/^{144}Nd_i$[‡]	$f^{§}_{Sm/Nd}$	$\varepsilon Nd_{(t)}$	T_{DM}[¶] (Ga)	Rb (p.p.m.)	Sr (p.p.m.)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ (±2σ)	$^{87}Sr/^{86}Sr_i$[††]	$\delta^{18}O$ (‰) (SMOW)
Yirba Pluton														
96KL45	14.7	90.1	0.0989	0.512346 ± 0.000007	0.51204	–0.50	0.66	1.07	135.4	749.2	0.522	0.710986 ± 0.000015	0.7075	5.7
96KL48	6.64	36.0	0.112	0.512333 ± 0.000011	0.51199	–0.43	–0.35	1.22	103.5	519.6	0.575	0.712959 ± 0.000017	0.7091	7.4
96KL159	11.1	56.0	0.120	0.512322 ± 0.000014	0.51195	–0.39	–1.09	1.35	139.2	721.8	0.557	0.711712 ± 0.000016	0.7080	6.1
96KL160	9.33	59.2	0.0952	0.512323 ± 0.000010	0.51203	–0.51	0.44	1.06	147.2	879.7	0.483	0.711552 ± 0.000014	0.7083	6.3
96KL162	12.5	69.3	0.109	0.512311 ± 0.000007	0.51198	–0.45	–0.60	1.21	147.4	872.8	0.487	0.711663 ± 0.000011	0.7084	—
96KL163	8.21	48.0	0.104	0.512293 ± 0.000013	0.51197	–0.47	–0.65	1.18	128.2	858.2	0.431	0.711764 ± 0.000012	0.7089	6.3
North Kudi Pluton														
96KL176	12.8	74.9	0.103	0.512193 ± 0.000007	0.51192	–0.48	–3.83	1.32	225.7	151.7	4.307	0.734100 ± 0.000018	0.7093	—
96KL177	15.9	99.3	0.0966	0.512179 ± 0.000007	0.51192	–0.51	–3.77	1.26	224.8	187.0	3.477	0.727660 ± 0.000017	0.7076	—
96KL179	15.8	97.7	0.0974	0.512169 ± 0.000023	0.51191	–0.50	–4.01	1.28	270.9	209.0	3.751	0.730469 ± 0.000035	0.7089	7.2
96KL182	11.4	76.1	0.0908	0.512166 ± 0.000007	0.51193	–0.54	–3.73	1.22	253.1	144.6	5.069	0.738184 ± 0.000015	0.7090	8.9
96KL188	8.94	44.8	0.120	0.512310 ± 0.000013	0.51199	–0.39	–2.46	1.37	39.83	120.6	0.584	0.711408 ± 0.000015	0.7080	—
96KL193	13.9	87.7	0.0958	0.512176 ± 0.000014	0.51192	–0.51	–3.79	1.26	232.0	221.7	3.027	0.727258 ± 0.000011	0.7098	9.5
96KL196	11.5	72.5	0.0960	0.512179 ± 0.000006	0.51192	–0.51	–3.74	1.26	231.8	215.7	3.110	0.727577 ± 0.000012	0.7097	10.3
Arkarz Shan Intrusive Complex[‡‡]														
96KL209	4.88	35.9	0.0840	0.512213 ± 0.000014	0.51209	–0.57	–5.21	1.10	151.5	168.8	2.592	0.717842 ± 0.000019	0.7100	7.9
96KL210	4.33	30.4	0.0859	0.512209 ± 0.000014	0.51209	–0.56	–5.34	1.12	124.9	209.5	1.722	0.714739 ± 0.000019	0.7095	—
96KL211	3.41	24.6	0.0837	0.512233 ± 0.000008	0.51212	–0.57	–4.82	1.07	150.1	161.3	2.687	0.717795 ± 0.000018	0.7096	8.5
96KL241	3.92	23.7	0.100	0.512289 ± 0.000011	0.51215	–0.49	–4.12	1.15	190.1	140.1	3.918	0.720605 ± 0.000012	0.7087	7.2
96KL243	4.37	27.4	0.0964	0.512253 ± 0.000012	0.51212	–0.51	–4.73	1.16	165.2	164.8	2.894	0.717675 ± 0.000013	0.7089	8.4
96KL264	3.84	23.2	0.0998	0.512185 ± 0.000013	0.51204	–0.49	–6.20	1.29	180.5	180.7	2.885	0.719636 ± 0.000015	0.7109	—
96KL268	3.34	21.7	0.0930	0.512213 ± 0.000008	0.51208	–0.53	–5.46	1.18	150.0	161.8	2.677	0.717455 ± 0.000012	0.7093	—
96KL245	6.19	30.6	0.120	0.512297 ± 0.000007	0.51213	–0.39	–4.51	1.39	107.8	337.5	0.922	0.711123 ± 0.000014	0.7083	7.7
96KL257	4.29	25.2	0.103	0.512041 ± 0.000015	0.51190	–0.48	–9.10	1.53	146.4	433.5	0.975	0.713124 ± 0.000015	0.7101	6.9
96KL260	5.45	38.0	0.0867	0.512163 ± 0.000015	0.51204	–0.56	–6.27	1.18	145.5	272.0	1.544	0.715738 ± 0.000014	0.7110	6.4
96KL262	4.61	28.9	0.0960	0.512200 ± 0.000004	0.51206	–0.51	–5.80	1.23	159.7	442.4	1.042	0.713467 ± 0.000015	0.7103	—
96KL263	5.47	31.3	0.106	0.512220 ± 0.000018	0.51207	–0.46	–5.67	1.31	163.4	359.5	1.312	0.714662 ± 0.000013	0.7107	5.1

[†]Yirba Pluton: 96KL45–163; North Kudi Pluton: 96KL176–196; Arkarz Shan Intrusive Complex: 96KL209–268 (monzogranite), 96KL245–263 (granodiorite).
[‡]Initial Nd isotope ratio, calculated using $\lambda_{Sm} = 6.54 \times 10^{-12}$/year.
[§]$f_{Sm/Nd} = [(^{147}Sm/^{144}Nd)s/(^{147}Sm/^{144}Nd)_{CHUR}] - 1$, calculated relative to chondrite uniform reservoir (CHUR) with present-day values of $^{143}Nd/^{144}Nd = 0.512638$ and $^{147}Sm/^{144}Nd = 0.1967$.
[¶]T_{DM} is single-stage Nd model-age, calculated with depleted mantle (DM) present-day values of $^{143}Nd/^{144}Nd = 0.51315$ and $^{147}Sm/^{144}Nd = 0.2137$.
[††]Initial Sr isotope ratio, calculated using $\lambda_{Rb} = 1.42 \times 10^{-11}$/year.
[‡‡]Initial Nd and Sr isotope compositions were calculated at an age of 214 Ma.
SMOW, Standard mean ocean water.

IMPLICATIONS FOR THE TECTONIC EVOLUTION OF THE WEST KUNLUN

The microcontinent model regards both the North and South Kunlun Blocks as parts of the Tarim Craton, and argues that southward rifting of the South Kunlun Block and its later collision back with the Tarim Craton resulted in the opening and closure of the Proto-Tethys (Jiang 1992; Pan *et al.* 1994; Li *et al.* 1995; Mattern *et al.* 1996; Pan 1996; Mattern & Schneider 2000). In contrast, the subduction–accretion model envisages the South Kunlun Block as an accretionary product of the northward subduction of the Tethys Plate along the south margin of Laurasia (Chang *et al.* 1989; Sengör 1990; Sengör & Okurogullari 1991). Similar to the subduction–accretion model, the archipelago model considers the South Kunlun Block to be a volcanic arc built on an accretionary prism (Yao & Hsü 1994; Hsü *et al.* 1995; Li *et al.* 1999).

Regardless of age and tectonic setting, all granitic samples in this study exhibit consistent Mesoproterozoic Nd model ages (1.1–1.5 Ga) (Table 1; Fig. 3) similar to those of the metamorphic complex of the South Kunlun Block (1.1–1.4 Ga) (Zhou 1998), but significantly different from those of the North Kunlun Block (2.8 Ga) (Arnaud & Vidal 1990). Therefore, this study indicates that the South Kunlun Block does not have Archean basement, which makes it distinct from the Tarim Craton and the North Kunlun Block. Accordingly, the South Kunlun Block is unlikely to be a microcontinent once rifted from the North Kunlun Block.

SUMMARY

Three granitic intrusions, Yirba, NKP and ASIC, covering approximately 60% of the Kudi area in the South Kunlun Block, have been analyzed for their Sr-Nd-O isotopic compositions. These granitoids were emplaced in different tectonic settings in the Paleozoic or Mesozoic as a result of the closure of two oceans (i.e. Proto-Tethys and Paleo-Tethys) between Gondwanaland and Laurasia. Regardless of the differences in their tectonic setting and age, all samples from these granitoids have Mesoproterozoic Nd model ages (1.1–1.5 Ga) that are much younger than those of the North Kunlun Block/Tarim Craton. Therefore, Archean basement is absent in the South Kunlun Block, and this block cannot be a microcontinent once separated from the North Kunlun Block/Tarim Craton, as suggested by the microcontinent model.

ACKNOWLEDGEMENTS

We thank Professors Zhang Yuquan, Pan Yusheng and Xu Ronghua for valuable discussions, and are grateful to Doctors An Yin, Paul Kapp and Eric Cowgill for their comments on an earlier draft. Constructive reviews by Professor Simon Wilde and Alfred Kröner greatly improved this manuscript.

This research was cosupported by a Knowledge Innovation Program of the Chinese Academy of Sciences (KZCX2-SW-119), a research award from the University of Hong Kong, the Natural Science Foundation of China project (40003005), and grants from the Ministry of Education of China and the Chinese Academy of Sciences. A University of Hong Kong postgraduate studentship to Chao Yuan is gratefully acknowledged.

REFERENCES

ARNAUD N. & VIDAL P. 1990. *Geochronology and Geochemistry of the Magmatic Rocks from the Kunlun–Karakorum Geotraverse*, Colloque of Kunlun-Karakorum, Proceedings of the International Symposium on the Kunlun-Karakorum area, 52. I.P.G., Paris.

BARBARIN B. & DIDIER J. 1991. Microscopic features of mafic microgranular enclaves. *In* J. Didier & B. Barbarin (eds). *Enclaves and Granite Petrology*, pp. 253–62. Elsevier, Amsterdam.

BORG S. G., DEPAOLO D. J. & SMITH B. M. 1990. Isotopic structure and tectonics of the Central Transantarctic Mountains. *Journal of Geophysical Research* **95**, 6647–67.

CHANG C., CHEN N., COWARD M. P. *et al.* 1986. Preliminary conclusions of the Royal Society and Academia Sinica 1985 geotraverse of Tibet. *Nature* **323**, 501–7.

CHANG C. F., PAN Y. S. & SUN Y. Y. 1989. The tectonic evolution of the Qinghai–Tibet plateau. A Review. *In* Sengör A. M. C. (ed.). *Tectonic Evolution of the Tethyan Regions*, pp. 415–76. Reidel, Dordrecht.

COLLINS W. J. 1998. Evaluation of petrogenetic models for Lachlan Fold Belt granitoids: implications for crustal architecture and tectonic models. *Australian Journal of Earth Sciences* **45**, 483–500.

COWGILL E., YIN A. & HARRISON T. M. 2002. Reconstruction of the Altyn Tagh fault based on U-Pb geochronology: the role of backthrusts, mantle sutures, and heterogeneous crustal strength in forming the Tibetan Plateau. *Journal of Geophysical Research. B. Solid Earth*, in press.

DENG W. 1989. A preliminary study on the basic and ultrabasic rocks of the Karakorum–western Kunlun

Mts. *Journal of Natural Resources* **4**, 204–11 (in Chinese with English abstract).

DEWEY J. F., SHACKLETON R. M., CHANG C. F. & SUN Y. Y. 1988. The tectonic evolution of Tibetan Plateau. *Philosophical Transactions of the Royal Society of London* **327**, 379–413.

DING D. G. 1996. Formation and Evolution of southern Tarim Basin and western Kunlun orogenic belt. *In* Ding D., Wang D., Liu W. & Sun S. (eds). *The Western Kunlun Orogenic Belt and Basin*, pp. 201–7. Geological Publishing House, Beijing (in Chinese with English summary).

FARMER G. L. 1992. Magmas as tracers of lower crustal composition: an isotopic approach. *In* Fountain D. M., Arculus R. & Key R. W. (eds). *Continental Lower Crust*, Developments in Geotectonics 23, pp. 363–90. Elsevier, Amsterdam.

GAETANI M., GOSSO G. & POGNANTE U. 1990. A geological transect from Kunlun to Karakorum (Sinkiang, China): the western termination of the Tibetan Plateau. Preliminary note. *Terra Nova* **2**, 23–30.

GEOLOGICAL INVESTIGATION TEAM TWO, BUREAU OF GEOLOGY AND MINERAL RESOURCE OF XINJIANG UYGUR AUTONOMOUS REGION (GITT). 1985. *Geological Map of Southwest Xinjiang (1:500 000) and Explanation.* Geological Press, Beijing.

HAACK U., HOEFS J. & GOHN E. 1982. Constraints on the origin of Daramaran granites by Rb/Sr and $\delta^{18}O$ data. *Contributions to Mineralogy and Petrology* **79**, 279–89.

HSÜ K. J., PAN G., SENGÖR A. M. C. *et al.* 1995. Tectonic evolution of the Tibetan Plateau: a working hypothesis based on the archipelago model of orogenesis. *International Geology Review* **37**, 473–508.

JAHN B. M., ZHOU X. H. & LI J. L. 1990. Formation and tectonic evolution of southeastern China and Taiwan: Isotopic and geochemical constrains. *Tectonophysics* **183**, 145–60.

JIANG C. F. 1992. Opening–closing evolution of the Kunlun Mountains. *In* Jiang C., Yang J., Feng B. *et al.* (eds). *Opening Closing Tectonics of Kunlun Shan*, Geological Memoirs, Series 5, Number 12, pp. 205–17. Geological Publishing House, Beijing.

JIANG Y. H., JIANG S. Y., LIN H. F., ZHOU X. R., RUI X. J. & YANG W. Z. 2002. Petrology and geochemistry of shoshonitic plutons from the western Kunlun orogenic belt, Xinjiang, northwestern China: implications for granitoid geneses. *Lithos* **63**, 165–87.

JOHANNES W. & HOLTZ F. 1996. *Petrogenesis and Experimental Petrology of Granitic Rocks*. Springer, Berlin.

LI Y., LI X., SUN D. & HAN Y. 1995. Tectonic evolution of Qiangtang block and Kangxiwar structure zone in Kara-Kunlun Mountains southwest of Xinjiang, China. Xinjiang Science & Tectonology & Hygiene Publishing House (K), Urumuqi, China (in Chinese with English abstract).

LI J. Y., NIU B. G., LIU Z. G. & QU G. S. 2000. Structure deformation and main tectonothermal events of the Central Orogenic Belt. *In* Jiang C., Wang Z. & Li J. (eds). *Open and Closure Tectonics of the Central Orogenic Belt*, pp. 104–36. The Publishing House of Geology, Beijing (in Chinese with English abstract).

LI J., SUN S., HAO J., CHEN H., HOU Q. & XIAO W. 1999. On the classification of collision orogenic belts. *Scientia Geologica Sinica* **34**, 129–38 (in Chinese with English abstract).

MATTE P., TAPPONNIER P., ARNAUD N. *et al.* 1996. Tectonics of Western Tibet, between the Tarim and the Indus. *Earth and Planetary Science Letters* **142**, 311–30.

MATTERN F. & SCHNEIDER W. 2000. Suturing of the Proto- and Paleo-Tethys oceans in the western Kunlun (Xinjiang, China). *Journal of Asian Earth Sciences* **18**, 637–50.

MATTERN F., SCHNEIDER W., LI Y. & LI X. 1996. A traverse through the western Kunlun (Xinjiang, China): tentative geodynamic implications for the Paleozoic and Mesozoic. *Geologische Rundschau* **85**, 705–22.

MILLER C. F., WOODEN J. L., BENNETT V. C., WRIGHT J. E., SOLOMON G. C. & HURST R. W. 1990. Petrogenesis of the composite peraluminous–metaluminous Old Woman–Piute Range batholith, southeastern California; isotopic constraints. *In* Anderson J. L. (ed.). The Nature and Origin of Cordilleran Magmatism, Boulder, Colorado. *Geological Society of America Memoir* 174, pp. 99–109.

O'NEIL J. R. & CHAPPELL B. W. 1977. Oxygen and hydrogen isotope relations in the Berridale Batholith. *Journal of the Geological Society of London* **133**, 559–71.

PAN Y. S. 1996. Regional geological evolution and conclusion. *In* Pan Y. S. (ed.). *Geological Evolution of the Karakorum and Kunlun Shan*, pp. 230–62. Seismological Press, Beijing.

PAN Y. S. & BIAN Q. 1996. Tectonics. *In* Pan Y. S. (ed.). *Geological Evolution of the Karakorum and Kunlun Shan*, pp. 187–229. Seismological Press, Beijing.

PAN Y. S., WANG Y., MATTE P. & TAPPONNIER P. 1994. Tectonic evolution along the geotraverse from Yecheng to Shiquanhe. *Acta Geologica Sinica* **68**, 295–307.

SENGÖR A. M. C. 1990. Plate tectonics and orogenic research after 25 years: a Tethyan perspective. *Earth Science Reviews* **27**, 1–201.

SENGÖR A. M. C. & NATAL'IN B. A. 1996. Paleotectonics of Asia: fragments of a synthesis. *In* Yin A. & Harrison T. M. (eds). *The Tectonic Evolution of Asia*, pp. 486–640. Cambridge University Press, Cambridge.

SENGÖR A. M. C. & OKUROGULLARI A. H. 1991. The role of accretionary wedges in the growth of continents: Asiatic examples from Argand to Plate Tectonics. *Eclogae Geologicae Helvetiae* **84**, 535–97.

TAYLOR H. P. Jr. 1980. The effects of assimilation of country rocks by magmas on $^{18}O/^{16}O$ and $^{87}Sr/^{86}Sr$ systematics in igneous rocks. *Earth and Planetary Science Letters* **47**, 243–54.

TAYLOR H. P. Jr & EPSTEIN S. 1962. Relation between $^{18}O/^{16}O$ ratios in coexisting minerals of igneous and metamorphic rocks, I. Principles and experimental results. *Geological Society of American Bulletin* **73**, 461–80.

VERNON R. H. 1991. Interpretation of microstructures of microgranitoid enclaves. *In* Didier J. & Barbarin B. (eds). *Enclaves and Granite Petrology*, pp. 277–92. Elsevier, Amsterdam.

WANG D. 1996. Characteristics of sedimentary rocks and environmental evolution. *In* Pan Y. S. (ed.). *Geological Evolution of the Karakorum and Kunlun Shan*, pp. 22–50. Seismological Press, Beijing.

WEN S. X., SUN D. L., YIN J. X., CHEN T. E. & LUO H. 2000. [The stratigraphy and paleontology of the Karakorum and Kunlun area]. *In* Pan Y. S. (ed.). [*Geological Evolution of the Karakorum and Kunlun Shan*], pp. 6–92. Science Press, Beijing (in Chinese).

XIAO W., WINDLEY B. F., HAO J. & LI J. 2002. Arc-ophiolite obduction in the western Kunlun range (China): implications for the Paleozoic evolution of central Asia. *Journal of the Geological Society of London* **159**, 1–12.

XU R., ZHANG Y., XIE Y *et al.* 1994. A discovery of an early Palaeozoic tectono-magmatic belt in the Northern part of west Kunlun Shan. *Scientia Geologica Sinica* **29**, 313–28.

YANG J. S., ROBINSON R. T., JIANG C. F. & XU Z. Q. 1996. Ophiolites of the Kunlun Shan, China and their tectonic implications. *Tectonophysics* **258**, 215–31.

YAO Y. & HSÜ K. J. 1994. Origin of the Kunlun Shan by arc–arc and arc–continent collisions. *The Island Arc* **3**, 75–89.

YUAN C., SUN M., ZHOU M. F., ZHOU H., XIAO W. J. & LI J. L. 2002. Tectonic evolution of the West Kunlun: Geochronologic and geochemical constraints from Kudi granitoids. *International Geology Review* **44**, 653–69.

ZHANG Y., XIE Y., XU R., VIDAL P. & ARNAUD N. 2000. [Geochemistry of granitoid rocks]. *In* Pan Y. S. (ed.). [*Geological Evolution of the Karakorum and Kunlun Shan*], pp. 209–58. Science Press, Beijing (in Chinese).

ZHOU H. 1998. The main ductile shear zone and the lithosphere effective elastic thickness of west Kunlun orogenic belt. PhD Thesis, Institute of Geology, Chinese Academy of Sciences, Beijing, China (in Chinese with English abstract).

ZHOU H., CHU Z., LI J., HOU Q., WANG Z. & FANG A. 2000. $^{40}Ar/^{39}Ar$ dating of the ductile shear zone in Kuda, West Kunlun, Xinjiang. *Scientia Geologica Sinica* **35**, 233–9 (in Chinese with English abstract).