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^{40}Ar-^{39}Ar dating of basalts from Tarim Basin, NW China and its implication to a Permian thermal tectonic event*

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Abstract: This paper reports ^{40}Ar-^{39}Ar ages of northwestern China's Tarim Basin Permian basalts. ^{40}Ar-^{39}Ar age dating for basaltic samples from the Yingan section, Keping area and Damusi section of the southwestern part of Tarim Basin yields plateau ages of (281.8±4.2) Ma and a weighted mean value of (290.1±3.5) Ma respectively. This study combined with previous data indicates that the basaltic rocks from the studied area formed during 282~290 Ma. ^{40}Ar-^{39}Ar age dating from the basalts addresses a tectonothermal event in the Tarim Basin that occurred during the Early Permian of 278~290 Ma.

Key words: ^{40}Ar-^{39}Ar age dating, Basalt, Tectonic setting, Tarim Basin
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INTRODUCTION

Tarim Basin, surrounded by Tianshan, Kunlun and Altun orogenic belts and being the biggest sedimentary basin in China, mainly consists of the Precambrian basement and Phanerozoic stratum, and recorded a well magmatic history at ages of 2500~270 Ma. Some geologists (Chen *et al*., 1997; Yang *et al*., 1997; 2005; Jia, 1997; Jiang *et al*., 2004a; 2004b) conducted Permian tectonics, geochemistry, geophysics and possibly oil-gas geological survey in the Tarim Basin. Two types of the Late Paleozoic volcanic rocks can be divided: the basalt zone in the central and western basin and the intermediate-acidic volcanic rock zone in the northern basin. This intermediate-acid igneous rock zone consists of andesite, rhyolite, granodiorite, granite, granophyre and tuff, with their isotopic ages ranging from 248~288 Ma. Huge volumes of 260~292 Ma Permian basalts and igneous rocks were found that represented a prominent Permian magmatic event, and are widely distributed in the Tarim Basin, Xinjiang, NW China. They are mainly composed of basalts, diabases, basaltic andesites, ultramafic rocks and syenites. Kaipaizileike Formation and Kupukuziman Formation were regarded as formed in the ages of Lower to Middle and Middle Permian respectively. The basalts are component parts of the large Permian volcanic rocks concentration area. Because the previous age data obtained from the Permian basalts and igneous rocks were poor, and precise age dating can provide a good age limit to the tectonothermal event of Tarim Basin, a ^{40}Ar-^{39}Ar dating was carried out on basalts from the northwestern and southwestern parts of Tarim Basin. ^{40}Ar-^{39}Ar stepwise heating age dating of whole-rocks is a little diferent from the methods for those of minerals such as plagioclase, K-feldspar and biotite (Reichow *et al*., 2002; Sun *et al*., 2003; Hickey-Vargas, 2005; Deckart *et al*., 2005); however, the former may also be a good and precise method to

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determine the ages of basic volcanic rocks. This paper will present ^{40}Ar-^{39}Ar ages, and then discuss Permian magmatic thermal event that possibly happened in the Tarim Basin.

SAMPLES, ^{40}AR/^{39}AR STEPWISE INCREMENTAL HEATING METHOD AND RESULTS

The Yingan section is located in the northwestern part of the Tarim Basin (Fig.1) and a field occurrence of 180°∠44° in the surrounding sedimental stratum. The basalt layers had total thickness of ca. 530 m in this section except for small amounts of intercalated Permian sedimental layers composed of mudstones, siltstones, and mud-bearing limestones. The Damusi section occurred in Yecheng County, southwestern part of the Tarim Basin (Fig.1), and massive basalt layers were interlayered in the middle part of Early Permian Qipan Formation with 220°∠50° and were approximately 42 m thickness.

Samples of Yg20-21 and Txn25-21 for the ^{40}Ar-^{39}Ar age dating were from the third basaltic layer among a total of four basaltic layers of the Yingan section, and from the interlayer of the Damusi section (Fig.1). The two samples consist mainly of groundmass of microlites of plagioclase, clinopyroxene and iron oxides with small amounts of olivine. The groundmass had intersertal and crytocrystalline textures, and massive structures. Both of the two samples had no phenocrysts, vesicular and amygdaloidal structures that can be used to measure ^{40}Ar-^{39}Ar ages.

The sample bottle treated was irradiated for 3223 min in the nuclear reactor, Chinese Institute of Atomic Energy of Beijing. The reactor delivers the density of a neutron flow of ~6.0×10^{12} n/(cm^2·s). The integrated neutron flux is about 1.16×10^{18} n/cm^2. The Ar extraction system is composed of an electron bombardment heated furnace in which the samples are heated under vacuum. The released gases are admitted to a purification system. Ar purified was trapped in an activated charcoal finger at liquid-nitrogen temperature, and then released into the MM-1200B Mass Spectrometer to analyze Ar isotope. Measured isotopic ratios were corrected for the mass discrimination, atmospheric Ar component, blanks

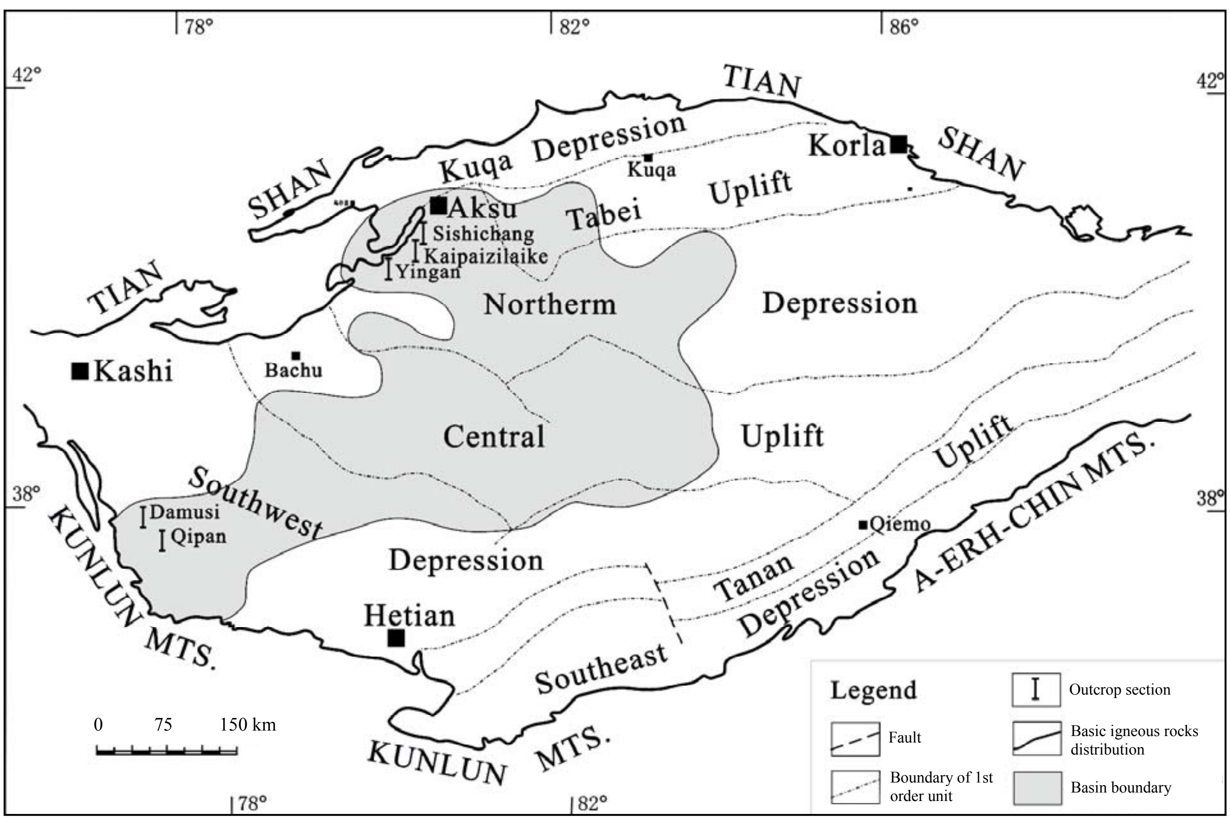

Fig.1 Tectonic sketch map of Tarim Basin and sample locations of Yingan and Damusi sections

and irradiation induced mass interference. The correction factors of interfering isotopes produced during irradiation were determined by analysis of irradiated K_2SO_4 and CaF_4 pure salts with their values being: $(^{36}Ar/^{37}Ar)_{Ca}$=0.000240; $(^{40}Ar/^{39}Ar)_K$=0.004782; and $(^{39}Ar/^{37}Ar)_{Ca}$=0.000806. The blanks of the m/e=40, m/e=39, m/e=37, m/e=36 are less than 6×10^{-15} mol, 4×10^{-16} mol, 8×10^{-17} mol and 2×10^{-17} mol respectively. The decay constant used is $\lambda=5.543\times10^{-10}$ a^{-1} (Steiger and Jager, 1977). All ^{37}Ar were corrected for radiogenic decay (half-life 35.1 d). The monitor used in this work is an internal standard of Fangshan biotite (ZBH-25) with age of 132.7 Ma and potassium content of 7.6%. Detailed analytical techniques can be seen in (Chen *et al*., 2002).

^{40}Ar-^{39}Ar dating conducted on whole-rock basalts from the Yingan section yielded a plateau age of (281.8±4.2) Ma (2σ) including 35.3% of the ^{39}Ar and anti-isochron age of (282.5±4.4) Ma (2σ) with *MSWD*=0.26 for sample Yg20-21, and a weighted mean value of (290.1±3.5) Ma for sample Txn25-21 in the Ar/Ar age diagrams (Fig.2). ^{40}Ar-^{39}Ar stepwise heating data of whole-rocks from the Tarim basalt samples can be seen in Table 1.

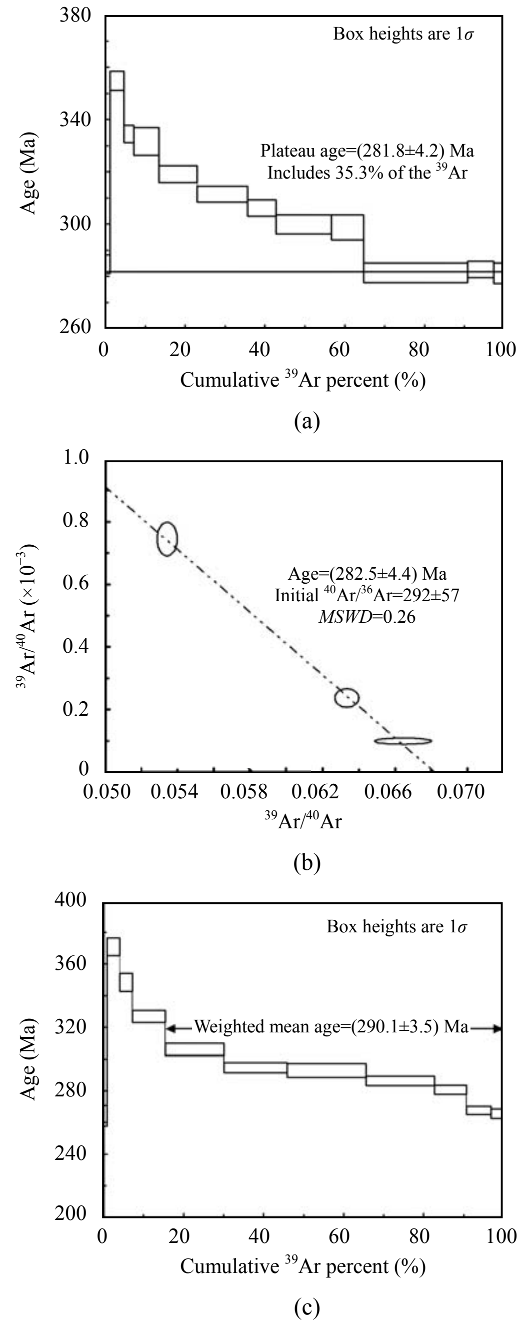

Fig.2 $^{40}Ar/^{39}Ar$ stepwise incremental heating measured results. (a) A plateau age of Yg20-21 from the Yingan section; (b) An isochore age of Yg20-21 from the Yingan section; (c) A weighted mean age of Txn25-21 from the southwestern part of the Tarim Basin

DISCUSSION

The Permian volcanic rock suites have spatial and temporal magmatic association in the Tarim Basin based on previous study of Chen *et al*.(1997) and Yang *et al*.(2005). K-Ar studies of samples of the Yingan section and Damusi section (unpublished data) indicate also presence of Permian thermal disturbance between (287.2±5.6) Ma and (289.6±5.6) Ma, respectively. Some geochronological data for Permian magmatic rocks are shown in Table 2, with some section locations being seen in Fig.1. Yang *et al*.(1996) got a plateau ^{40}Ar-^{39}Ar age of (278±1.4) Ma from the Kupukuziman Formation in the Sishichang section. The syenite has ^{40}Ar-^{39}Ar age of (277.7±1.3) Ma (Yang *et al*., 1996), when it formed under within-plate environment. K-Ar analyses of basaltic rocks from the lower to upper parts of the basalt layers from the Kaipaizileike Formation yielded weighted mean K-Ar ages ranging from 260 Ma to 290 Ma. This is interpreted as the eruption age of the Kaipaizileike volcanic rocks.

The basalts display rich K, Rb, Ba, Th, LILE and LREE, higher LREE/HREE ratios, negative Eu anomalies and flat Nb and Ta pattern in the spider diagram. These geochemical features combined with discriminative tectonic diagrams indicate that the basalts erupted on tectonic setting similar to that of continental within-plate. Geochemical and Nd isotopic

Table 1 ^{40}Ar-^{39}Ar stepwise heating data of whole-rocks from the Tarim basalt samples

T (°C)	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$(^{38}Ar/^{39}Ar)_m$	F	^{39}Ar ($\times10^{-14}$ mol)	^{39}Ar (Cum.) (%)	Age (Ma)	$\pm1\sigma$ (Ma)
500	37.6607	0.0657	0.6128	0.0104	18.2844	3.45	0.06	346.0	16
600	18.6196	0.0133	1.1620	0.0277	14.7924	59.69	1.19	284.6	3.5
700	19.4889	0.0025	0.8019	0.0138	18.8158	184.01	4.65	354.8	3.7
800	18.3428	0.0027	0.9937	0.0164	17.6320	128.93	7.08	334.4	3.3
900	17.7489	0.0013	1.1263	0.0145	17.4688	339.05	13.47	331.6	5.3
950	16.8931	0.0007	0.8518	0.0135	16.7514	508.72	23.04	319.1	3.2
1000	16.4271	0.0006	0.8096	0.0128	16.3094	669.96	35.66	311.4	3.0
1050	16.1896	0.0009	0.9556	0.0132	16.0061	379.07	42.80	306.1	3.1
1100	15.8484	0.0010	1.2463	0.0142	15.6496	735.38	56.64	299.8	3.6
1150	15.8091	0.0012	1.6463	0.0161	15.5855	429.11	64.72	298.7	4.7
1250	14.9724	0.0031	6.6931	0.0157	14.6064	1382.69	90.76	281.3	3.7
1320	15.7009	0.0055	7.2199	0.0161	14.6824	348.34	97.32	282.6	3.2
1400	18.6203	0.0156	7.1004	0.0190	14.6020	142.41	100.00	281.2	3.9

Step heating for Yg20-21; W=120.00 mg; J=0.011552; m: measured isotopic ratios; F=$^{*40}Ar/^{39}Ar$, is the ratio of radiogenic Argon40 and Argon39

T (°C)	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$(^{38}Ar/^{39}Ar)_m$	F	^{39}Ar ($\times10^{-14}$ mol)	^{39}Ar (Cum.) (%)	Age (Ma)	$\pm1\sigma$ (Ma)
500	15.9835	0.0150	0.3008	0.0770	11.5758	8.88	0.13	227.6	4.4
600	19.1498	0.0192	1.3516	0.0236	13.5777	55.20	0.93	264.2	6.5
700	20.3905	0.0029	1.3133	0.0150	19.6450	215.89	4.07	370.9	5.7
800	18.6857	0.0015	1.1296	0.0171	18.3371	218.98	7.25	348.4	5.7
900	17.3840	0.0013	1.0355	0.0130	17.0943	560.95	15.41	326.8	3.8
950	16.0467	0.0009	1.5455	0.0130	15.9106	1015.06	30.17	306.0	3.7
1000	15.3797	0.0009	2.0684	0.0127	15.2702	1081.60	45.90	294.6	3.2
1050	15.2649	0.0007	1.5573	0.0132	15.1700	1358.61	65.65	292.8	4.4
1100	14.9042	0.0007	1.2368	0.0141	14.8051	1171.74	82.69	286.3	3.1
1150	14.7412	0.0013	1.7826	0.0160	14.4965	546.89	90.64	280.8	2.9
1250	14.0176	0.0031	7.9845	0.0186	13.7615	423.87	96.80	267.6	2.7
1400	15.1904	0.0093	14.8159	0.0210	13.6537	219.99	100.00	265.6	3.0

Step heating for Txn25-21; W=120.00 mg; J=0.011618; m: measured isotopic ratios; F=$^{*40}Ar/^{39}Ar$, is the ratio of radiogenic Argon40 and Argon39

Table 2 Some geochronological data of the Permian basalts from Tarim Basin

Sampling sections	Stratum (Formation)	Lithology	Methods	Results (Ma)	References
Yigan (different layers)	Kupukuziman	Basalt	K-Ar	289.0±6.1[a]	[a:] Zhang *et al.*(2003)
				272.9±4.0[a]	
				288.4±4.4[a]	
				248.3±3.8[a]	[b:] Yang *et al.*(unpub. data)
				287.2±5.6[b]	
				289.6±5.6	
Taxinan	Qipan	Basalt	K-Ar	292.4±0.5[c]	[c:] Liu and Li (1991)
Sishichang	Kupukuziman	Basalt	K-Ar[c,d] Ar-Ar[e]	278.5±1.4[d] 278[e]	[d:] Yang *et al.*(1996) [e:] Jia (1992)
Kaipaizileike	Kaipaizileike	Basalt	K-Ar	259.8±0.9[c]	

characteristics suggest that the basalts were probably derived from an enriched lithospheric mantle reservoir subjected to partial melting (Yang *et al*., 1997; Jiang *et al*., 2004b). Chen *et al*.(1997) argued that basalts, diabases and other intrusive rocks are products of Permian rifting based on their chronological ages ((292±0.5) Ma and (259.8±0.9) Ma), field occurrence, geochemistry and Late Paleozoic sedimentary features in the interior of Tarim Basin and surrounding tectonic framework. Zhang *et al*.(2003) argued that Kupukuziman and Kaipaizileike Formations were formed during the Lower to Middle and Middle Permian based on some evidences of paleontology and sediments. Combined with some chronological study (^{40}Ar-^{39}Ar, K-Ar, Sm-Nd) of drilling core basalt samples from the central part of Tarim Basin and other Permian igneous rocks as well as their geochemical characteristics indicate that the timing of this thermal overprinting on the basalts are related to the widespread Early Permian thermo-tectonic event in different part of Tarim Basin under within-plate environments, and are regarded as much earlier than those age data from previous study.

The new ^{40}Ar/^{39}Ar age data gave clearer and more detailed information of temporal variation of volcanism than the preliminary K-Ar results of 248~292 Ma. In addition, the ^{40}Ar-^{39}Ar age data combined with previous isotopic data suggest that the most intensive and extensive tectonothermal event occurred in Early Permian and no subsequent largely thermal disturbance (stable crustal setting) occurred in the interior of Tarim Basin was clarified.

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