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叶海敏 叶现韬 张传林

YE HaiMin, YE XianTao and ZHANG ChuanLin

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2013 05 10 2013 08 22

Ye HM Ye XT and Zhang CL. 2013. Geochemistry and geodynamic implications of Nileke Permian volcanic rocks in Western Tianshan NW China. *Acta Petrologica Sinica* 29 10 3389 – 3401

Abstract The terrestrial Nileke Permian volcanic rocks outcrop at the most western section of the Awulale Late Paleozoic volcanic belt. In this contribution we reported petrography elemental and Sr-Nd isotope compositions of the Nileke Permian basaltic rocks in aiming to have a better understanding its geodynamic implications. The Nileke volcanic strata could be divided into two series i. e. the Wulang series lower and the Hamisite seires upper and the diverse rock types include basalts andesites trachytes and rhyolites. In geochemistry the upper Hamisite seires exhibit shoshonitic signatures such as having high K_2O 2.81% ~ 3.91% Sr $> 1000 \times 10^{-6}$ total REE $> 200 \times 10^{-6}$ contents high La/Yb_N 9.7 ~ 11.7 but low Nb/La ratios most < 0.2 and shows. The lower Wulang series could be divided into two sub-groups sub-group one contains the lowest SiO_2 low Sr $< 500 \times 10^{-6}$ total REE $50 \times 10^{-6} < \Sigma REE < 80 \times 10^{-6}$ and low La/Yb_N 1.6 ~ 2.2 but the highest MgO and relatively higher Nb/La ratios > 0.35 . These features are comparable with those of E-MORB suggesting that they could be derived from high-degree partial melting in a decompressing process. Sub-group two has a wide range of geochemical compositions straddling between the Hamisite seires and the sub-group one. The Nileke Permian volcanic rocks have intensive depleted Sr-Nd isotopic compositions similar with those of MORB indicating that they were derived from the time-integrated depleted mantle sources. However their significant depletion in Nb-Ta intensive differentiation and enrichment in LILE argue that the Permian basaltic rocks in Nileke area were derived from a recently metasomatized depleted lithospheric mantle sources. Additionally our study reveals that their chemical signatures were constrained by partial melting degree and crystal fractionation process. In combination with regional geology and previous studies the Nileke Permian volcanic rocks could be genetically related to the Permian Tarim mantle plume.

Key words Nileke Western Tianshan Permian volcanic rocks Geochemistry Tectonic implications

Sr-Nd

 K_2O

2.81% ~ 3.91% Sr $> 1000 \times 10^{-6}$ $\Sigma REE > 200 \times 10^{-6}$ La/Yb_N 9.7 ~ 11.7 Nb/La < 0.2
 SiO_2 MgO Sr $< 500 \times 10^{-6}$ $50 \times 10^{-6} < \Sigma REE < 80 \times 10^{-6}$
 La/Yb_N 1.6 ~ 2.2 Nb/La > 0.35 E-MORB

Sr-Nd

MORB

Nb-Ta

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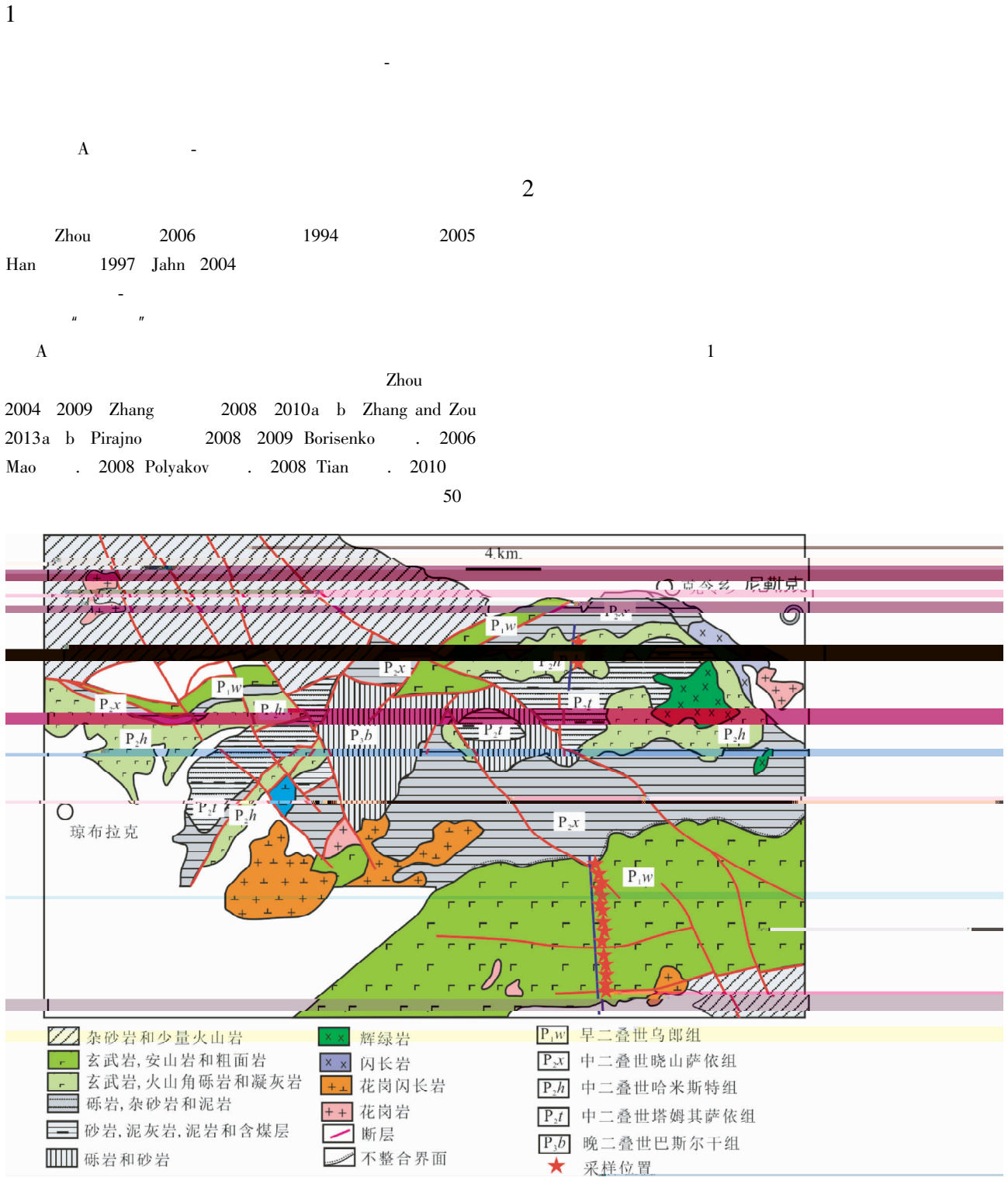
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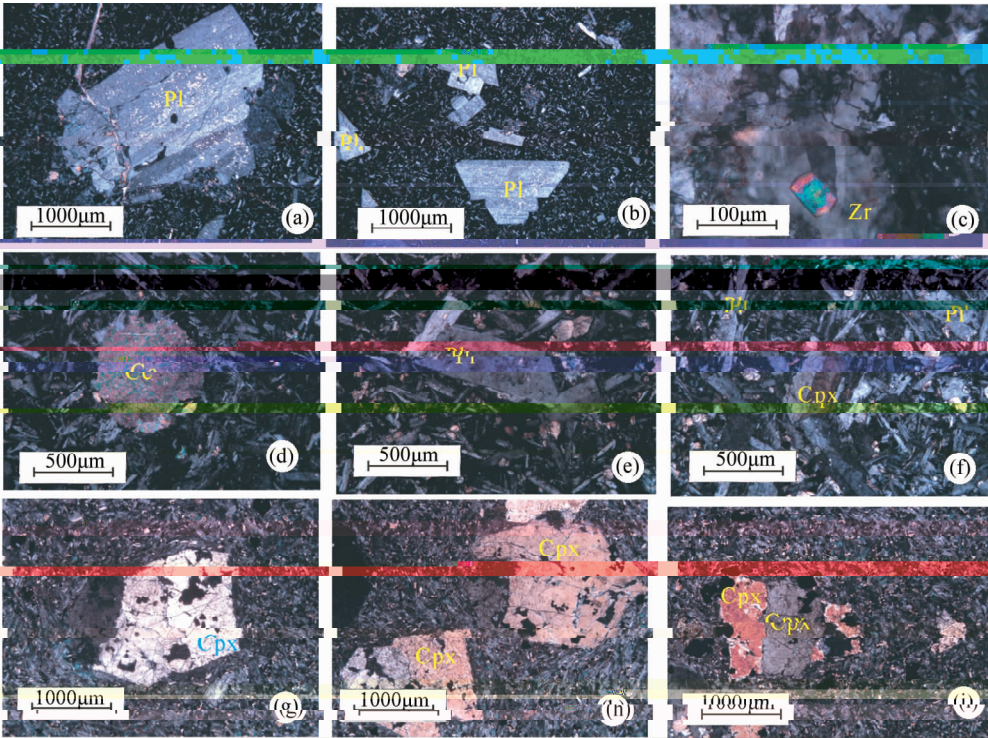
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290Ma 275Ma



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Fig.1 Geological map of Nileke Xinjiang



2
 a b e - Pl c - Zr d - Cc f -
 Cpx g-i -

Fig. 2 Microphotographs showing petrologic characteristics of the Nileke Permian volcanic rocks
 a b e -tabular plagioclase phenocrysts of basalt c -zircon of basalt d -blowhole filled with calcites of basalt f -clinopyroxenes together with plagioclases of basalt g-i -euhedral/semi-euhedral clinopyroxene phenocrysts of basalt

264km²
 2600m

200m

2

1

60% 2 ~

2

12mm
 3%

16%

3

1 Table 1	Major element	wt% and trace element compositions of the Permian Nileke volcanic rocks								
		WT03-1	WT03-2	WT03-3	WT03-4	WT03-5	WT03-6	WT03-7	WT04-2	WT04-5
		$\times 10^{-6}$								
SiO ₂	47.72	51.58	51.71	49.87	51.36	51.56	51.79	62.91	51.11	51.18
TiO ₂	1.48	1.50	1.56	1.51	1.55	1.55	1.55	0.77	1.57	1.53
Al ₂ O ₃	15.56	15.20	15.85	15.63	15.76	15.95	15.72	16.87	15.81	15.66
Fe ₂ O ₃	9.71	10.49	10.41	10.21	10.62	10.75	10.58	5.45	10.70	10.35
MnO	0.21	0.12	0.23	0.22	0.19	0.18	0.15	0.02	0.14	0.14
CaO	9.30	6.89	7.77	8.23	7.61	8.05	7.18	5.25	6.99	7.95
MgO	3.97	4.23	4.05	3.99	4.17	3.88	4.11	1.94	3.91	3.92
K ₂ O	3.21	3.91	3.10	3.11	2.94	2.81	3.39	1.41	3.73	3.48
Na ₂ O	2.97	3.20	3.36	3.49	3.60	3.45	3.45	4.24	3.35	3.22
P ₂ O ₅	0.53	0.60	0.66	0.63	0.65	0.64	0.64	0.33	0.65	0.65
LOI	5.47	2.18	1.15	3.02	1.38	1.02	1.30	0.69	1.88	1.78
Total	100.12	99.90	99.84	99.92	99.83	99.84	99.85	99.87	99.85	99.84
Mg [#]	57	57	56	56	56	54	56	54	55	55
La	30.92	33.71	40.09	39.88	41.09	40.44	40.66	12.97	41.80	40.90
Ce	73.21	80.18	97.81	97.21	99.83	99.24	98.68	31.20	101.2	99.66
Pr	9.93	11.03	13.61	13.53	13.90	13.71	13.75	4.40	14.50	14.24
Nd	41.94	46.49	58.26	57.42	59.07	58.48	58.30	20.06	61.81	61.09
Sm	7.85	8.62	10.57	10.36	10.66	10.58	10.49	4.95	10.92	10.70
Eu	2.35	2.48	3.00	2.87	2.93	2.95	2.95	1.55	3.01	2.95
Gd	6.56	7.09	8.33	8.07	8.45	8.35	8.44	5.08	8.60	8.44
Tb	0.91	0.93	1.13	1.10	1.13	1.11	1.13	0.89	1.13	1.11
Dy	4.75	4.62	5.78	5.44	5.60	5.49	5.60	5.75	5.69	5.47
Ho	0.91	0.85	1.09	1.02	1.04	1.03	1.06	1.25	1.08	1.04
Er	2.50	2.29	3.00	2.81	2.82	2.81	2.90	3.56	2.91	2.80
Tm	0.37	0.34	0.45	0.42	0.43	0.42	0.44	0.53	0.42	0.40
Yb	2.28	2.06	2.79	2.56	2.59	2.56	2.64	3.39	2.69	2.59
Lu	0.34	0.31	0.42	0.38	0.40	0.40	0.39	0.54	0.40	0.39
Rb	116.5	170.6	81.14	58.96	63.49	61.55	89.53	50.35	85.79	79.55
Ga	20.43	20.89	20.72	19.52	20.70	20.12	19.90	17.84	20.27	21.26
V	227.5	230.1	227.0	222.7	222.6	219.1	219.9	28.52	225.9	223.5
Cr	116.2	127.0	78.84	77.63	75.56	62.97	67.76	28.86	69.99	71.20
Ni	66.32	58.77	38.96	33.88	35.99	35.80	37.09	2.62	37.25	36.84
Sc	23.14	22.56	23.06	21.99	22.52	21.69	22.17	17.54	22.15	21.94
Sr	1157	1627	1915	1992	1979	1904	1892	472	2330	1974
Ba	1153	937	1037	1077	977	1010	1115	286	1166	1099
Th	3.29	3.41	4.18	3.96	4.14	3.95	3.99	2.13	4.17	4.19
U	0.76	0.79	0.94	1.01	0.93	0.89	0.93	0.84	0.97	1.08
Ta	0.33	0.31	0.31	0.30	0.30	0.29	0.30	0.27	0.30	0.31
Nb	5.86	5.60	5.32	5.21	5.35	5.18	5.27	3.71	5.40	5.46
Zr	149.4	151.4	183.2	180.2	186.5	177.4	178.7	99.79	184.2	184.1
Hf	3.77	3.87	4.66	4.60	4.77	4.49	4.59	2.94	4.68	4.70
Y	23.73	23.61	29.52	27.46	27.96	27.41	28.07	31.71	27.64	26.58
	WT04-21	WT09-1	WT09-2	WT09-3	WT09-5	WT09-6	WT09-7	WT010-1	WT010-2	WT010-3
	郎									
SiO ₂	51.04	50.89	50.91	49.73	52.48	50.95	53.16	48.09	47.79	48.84
TiO ₂	1.53	1.31	1.29	1.40	1.35	1.25	1.25	1.24	1.27	1.62
Al ₂ O ₃	15.83	16.22	15.95	16.92	15.65	16.53	15.64	17.59	17.99	14.60
Fe ₂ O ₃	10.50	10.38	10.30	12.22	9.97	9.99	10.87	10.21	10.34	10.29
MnO	0.23	0.42	0.39	0.66	0.16	0.16	0.18	0.32	0.50	0.51
CaO	7.40	5.03	5.43	2.83	5.92	9.05	4.62	8.40	6.03	6.60
MgO	4.30	5.70	5.62	5.01	4.88	5.65	4.49	6.63	6.89	4.68
K ₂ O	3.59	1.92	1.70	1.47	0.90	1.26	0.89	1.59	2.43	1.49

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Continued Table 1

	WT04-21	WT09-1	WT09-2	WT09-3	WT09-5	WT09-6	WT09-7	WT010-1	WT010-2	WT010-3
郎										
Na ₂ O	3.14	4.42	4.66	5.43	5.44	2.60	5.90	2.67	3.00	3.39
P ₂ O ₅	0.65	0.56	0.56	0.60	0.60	0.22	0.54	0.21	0.22	0.64
LOI	1.63	3.09	3.11	3.66	2.57	2.21	2.34	2.96	3.48	7.72
Total	99.85	99.92	99.92	99.94	99.90	99.88	99.88	99.91	99.93	100.38
Mg [#]	57	64	64	57	62	65	58	68	69	60
La	41.59	29.80	27.71	27.88	30.58	14.51	31.90	6.94	5.51	32.45
Ce	101.5	65.12	63.25	65.56	69.31	33.35	68.31	17.75	14.24	71.23
Pr	14.48	8.51	8.31	8.65	9.04	4.76	8.77	2.70	2.26	9.45
Nd	61.81	34.04	34.00	35.01	37.26	21.04	34.38	12.94	11.38	38.52
Sm	10.86	6.55	6.52	6.92	7.47	4.98	6.41	3.52	3.36	7.26
Eu	3.02	1.73	1.78	1.72	2.11	1.70	1.78	1.24	1.25	1.99
Gd	8.42	5.94	5.89	6.18	6.74	5.05	5.84	3.66	3.60	6.60
Tb	1.13	0.88	0.88	0.92	0.97	0.88	0.88	0.68	0.68	0.99
Dy	5.65	5.02	4.92	5.25	5.51	5.53	4.94	4.31	4.38	5.54
Ho	1.05	0.99	0.99	1.05	1.10	1.19	0.99	0.91	0.92	1.13
Er	2.86	2.78	2.70	2.86	3.00	3.27	2.74	2.44	2.55	3.06
Tm	0.42	0.40	0.40	0.42	0.44	0.50	0.39	0.38	0.39	0.43
Yb	2.69	2.52	2.47	2.62	2.78	3.17	2.52	2.31	2.42	2.82
Lu	0.39	0.40	0.38	0.40	0.43	0.49	0.37	0.36	0.37	0.42
Rb	75.06	70.66	62.85	53.85	30.22	40.00	28.35	86.44	197.1	72.51
Ga	20.86	18.08	19.20	28.40	18.65	17.53	18.40	17.32	17.11	17.67
V	213.4	221.9	217.5	225.9	228.1	201.3	209.3	253.9	249.2	219.6
Cr	68.33	96.69	91.10	104.3	68.20	110.5	54.85	164.1	169.6	70.99
Ni	34.40	42.38	38.80	43.13	26.22	86.40	31.79	71.56	70.06	18.66
Sc	21.64	27.73	27.23	28.32	27.93	29.30	25.53	34.32	34.30	26.14
Sr	2131	451.7	351.8	252.1	311.3	292.6	232.7	394.4	462.1	96.50
Ba	1173	492.6	496.8	507.9	297.9	271.4	183.1	388.8	599.5	184.7
Th	4.22	2.63	2.57	2.77	3.25	2.75	2.93	0.70	0.70	3.70
U	0.93	0.81	0.78	0.92	1.03	0.85	1.00	0.24	0.27	0.99
Ta	0.31	0.56	0.54	0.59	0.60	0.34	0.55	0.19	0.19	0.58
Nb	5.34	9.40	9.24	10.00	10.13	4.58	9.15	2.44	2.51	9.44
Zr	181.8	211.6	209.2	225.7	231.9	198.2	204.7	96.71	98.82	220.4
Hf	4.65	4.78	4.63	5.05	5.17	4.54	4.52	2.47	2.51	5.15
Y	27.19	25.32	25.01	26.43	28.32	28.90	25.27	23.42	23.87	28.18
郎										
	WT010-6	WT010-7	WT011-1	WT011-2	WT011-3	ZK03	WT012-1	WT012-2-1	WT012-2-2	
SiO ₂	67.42	67.92	54.93	57.67	50.74	54.91	47.45	54.14	56.47	
TiO ₂	0.44	0.43	1.06	1.16	1.18	1.06	1.98	1.20	2.04	
Al ₂ O ₃	15.77	15.55	14.43	14.58	15.83	15.28	18.15	16.63	14.66	
Fe ₂ O ₃	3.75	3.86	10.74	9.87	10.99	9.79	12.17	9.81	8.89	
MnO	0.11	0.09	0.54	0.30	0.63	0.48	1.32	0.70	0.35	
CaO	2.84	1.58	3.63	5.34	4.79	5.32	2.75	3.08	5.89	
MgO	1.02	1.06	4.74	2.81	5.34	3.44	5.97	2.45	3.04	
K ₂ O	3.37	3.45	3.75	3.63	3.57	3.93	0.32	4.93	3.27	
Na ₂ O	3.91	4.67	2.93	2.69	3.25	2.51	5.20	3.57	2.54	
P ₂ O ₅	0.18	0.18	0.37	0.48	0.42	0.37	0.31	0.50	0.92	
LOI	1.08	1.09	2.79	1.33	3.15	2.85	4.32	2.90	1.82	
Total	99.88	99.88	99.91	99.86	99.91	99.95	99.94	99.90	99.89	
Mg [#]	47	47	59	48	62	54	62	45	53	
La	24.72	17.64	12.17	20.79	15.57	16.21	6.96	18.72	21.60	
Ce	49.61	37.15	30.21	49.02	37.79	36.77	20.67	44.21	52.62	
Pr	5.98	4.78	4.31	6.65	5.27	5.01	3.48	5.91	7.67	

1

Continued Table 1

	WT010-6	WT010-7	WT011-1	WT011-2	WT011-3	ZK03	WT012-1	WT012-2-1	WT012-2-2
	郎								
Nd	22.66	19.03	19.26	28.94	23.60	21.73	17.22	25.41	35.25
Sm	4.08	3.85	4.82	6.78	5.77	5.10	5.05	6.11	8.27
Eu	1.17	1.01	1.02	1.55	1.25	1.24	1.33	1.24	4.91
Gd	3.81	3.56	4.83	6.58	5.67	5.01	5.19	6.12	8.31
Tb	0.57	0.56	0.85	1.13	0.98	0.86	1.00	1.10	1.36
Dy	3.30	3.41	5.43	7.07	6.23	5.25	6.39	6.99	8.17
Ho	0.71	0.74	1.17	1.48	1.32	1.12	1.35	1.52	1.72
Er	2.08	2.14	3.35	4.15	3.70	3.09	3.62	4.22	4.65
Tm	0.33	0.34	0.51	0.65	0.59	0.48	0.52	0.67	0.67
Yb	2.25	2.33	3.28	4.07	3.68	3.01	3.22	4.13	4.21
Lu	0.38	0.37	0.50	0.61	0.56	0.47	0.49	0.62	0.64
Rb	103.4	108.4	188.2	188.7	191.4	186.0	13.70	232.8	85.68
Ga	15.24	14.54	14.51	16.68	16.34	16.18	25.28	19.53	17.45
V	42.48	45.59	244.0	203.9	268.1	267.2	234.5	214.8	99.53
Cr	28.37	36.90	74.77	48.06	81.26	86.08	315.70	51.42	24.52
Ni	2.25	2.59	22.00	13.64	25.22	21.60	211.7	12.65	5.09
Sc	10.34	9.97	30.77	29.55	32.97	32.54	36.02	30.07	27.71
Sr	302.6	147.5	234.9	289.4	310.4	285.1	337.7	294.7	365.8
Ba	513.9	498.6	500.8	428.8	499.8	506.8	143.6	1177	1831
Th	6.35	4.74	8.47	11.00	9.66	8.45	0.47	11.51	5.91
U	1.18	1.21	2.47	3.30	3.08	2.66	0.34	3.36	1.80
Ta	0.45	0.42	0.44	0.57	0.49	0.45	0.33	0.60	0.52
Nb	5.35	5.22	6.16	8.06	6.94	6.26	4.32	8.28	6.55
Zr	128.1	127.9	176.0	229.9	200.3	177.4	149.1	242.4	207.5
Hf	3.47	3.48	4.84	6.28	5.41	4.82	3.49	6.47	5.21
Y	19.14	20.05	31.82	39.12	35.30	29.94	36.48	42.73	41.72

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Sm-Nd

Table 2 Sm-Nd isotopic compositions of the Permian Nileke volcanic rocks

	Rb $\times 10^{-6}$	Sr $\times 10^{-6}$	$\frac{87\text{Rb}}{86\text{Sr}}$	$\frac{87\text{Sr}}{86\text{Sr}}$ 2	$\left(\frac{87\text{Sr}}{86\text{Sr}}\right)_i$	Sm $\times 10^{-6}$	Nd $\times 10^{-6}$	$\frac{147\text{Sm}}{144\text{Nd}}$	$\frac{143\text{Nd}}{144\text{Nd}}$ 2	$\left(\frac{143\text{Nd}}{144\text{Nd}}\right)_i$	Nd		
wt03-2	170.6	1627	0.3033	0.70560	5	0.70439	8.62	46.49	0.112097	0.512692	9	0.512487	4.08
wt09-6	40	292.6	0.3954	0.70543	3	0.70385	4.98	21.04	0.142965	0.512846	3	0.512584	5.98
wt10-1	86.44	394.4	0.6341	0.70680	4	0.70427	3.52	12.94	0.164465	0.512893	4	0.512592	6.13
wt10-2	197.1	462.1	1.2343	0.70944	2	0.70452	3.36	11.38	0.17851	0.512888	4	0.512561	5.53
wt10-3	72.51	96.5	2.1751	0.71307	5	0.70440	7.26	38.52	0.113945	0.512681	9	0.512472	3.80
wt10-6	103.4	302.6	0.9887	0.70794	8	0.70400	4.08	22.66	0.108855	0.512725	8	0.512525	4.84
wt11-2	188.7	289.4	1.8873	0.71184	6	0.70432	6.78	28.94	0.141641	0.512805	4	0.512545	5.23
wt11-3	191.4	310.4	1.7834	0.70429	5	0.69718	5.77	23.60	0.147816	0.512813	6	0.512542	5.17
wt12-1	13.7	337.7	0.1173	0.70524	8	0.70477	5.05	17.22	0.177308	0.512951	5	0.512626	6.80

Note Isotopic results normalized to $^{86}\text{Sr}/^{86}\text{Sr} = 0.1194$ and $^{146}\text{Nd}/^{144}\text{Nd} = 0.7219$. NBS 987 average Sr standard = 0.71025 ± 1 and Jndi-1 Nd standard = 0.51212 ± 1.1 in this study. Initial isotope ratios and epsilon values calculated at 280Ma using present day bulk Earth-CHUR values of $^{87}\text{Rb}/^{86}\text{Sr} = 0.07809$ $^{87}\text{Sr}/^{86}\text{Sr} = 0.7045$ $^{147}\text{Sm}/^{144}\text{Nd} = 0.19667$ and $^{143}\text{Nd}/^{144}\text{Nd} = 0.512638$

		Perkin-Elmer Sciex Elan 6000						
		1 ~ 5mm		ICP-MS	40mg	bomb		
5%	5%			HNO ₃	HF	Rh		
		200			USGS	W-2	G-2	GSR-I
				GSR-2	GSR-3			
Rigaku 100e	X	XRF		2% ~ 5%		1996		
1% ~ 5%		Li	2009					

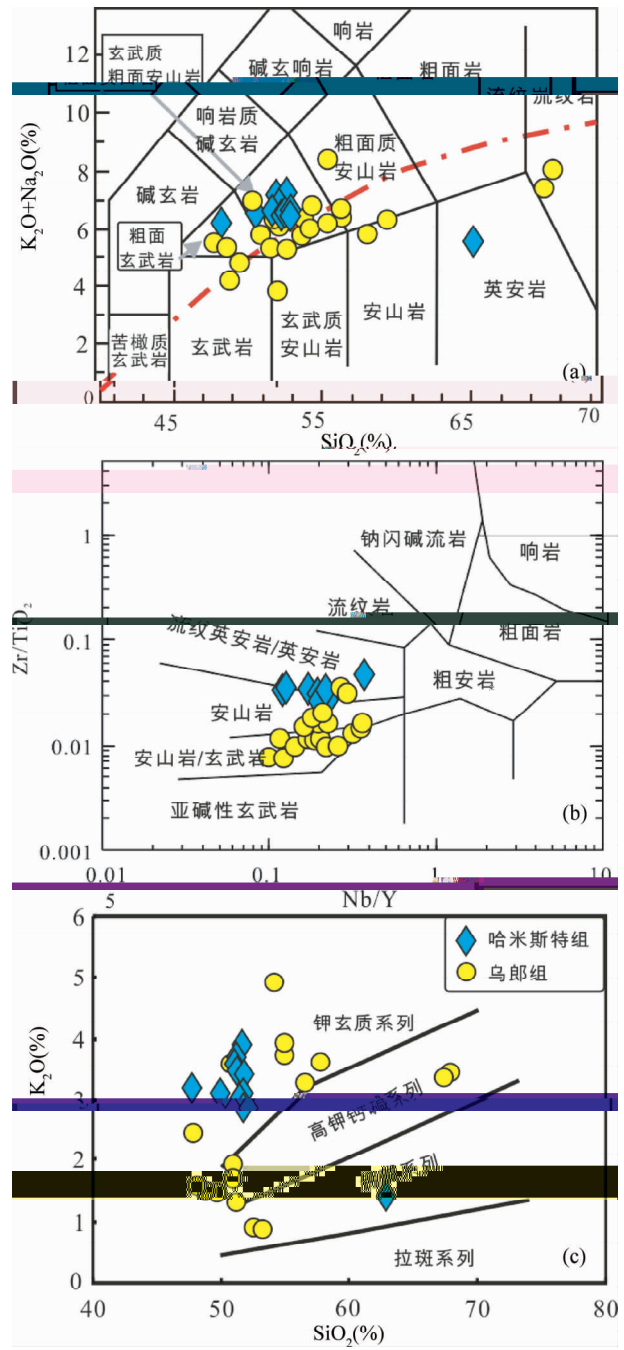
MC-ICPMS Sr NBS987
 Sr-GIG $^{87}\text{Sr}/^{86}\text{Sr}$ $^{86}\text{Sr}/^{88}\text{Sr} = 0.1194$
 2002 Nd
 JNdi-1 Nd-GIG $^{143}\text{Nd}/^{144}\text{Nd}$
 $^{146}\text{Nd}/^{144}\text{Nd} = 0.7219$ 2003
 Sr Nd 0.002%

4
 4.1
 11 18
 1 Sm-Nd
 2
 -SiO₂ TAS 3a
 WT04-2
 TAS K Na
 Ti Zr Y Nb
 Zr/TiO₂-Nb/Y 3b

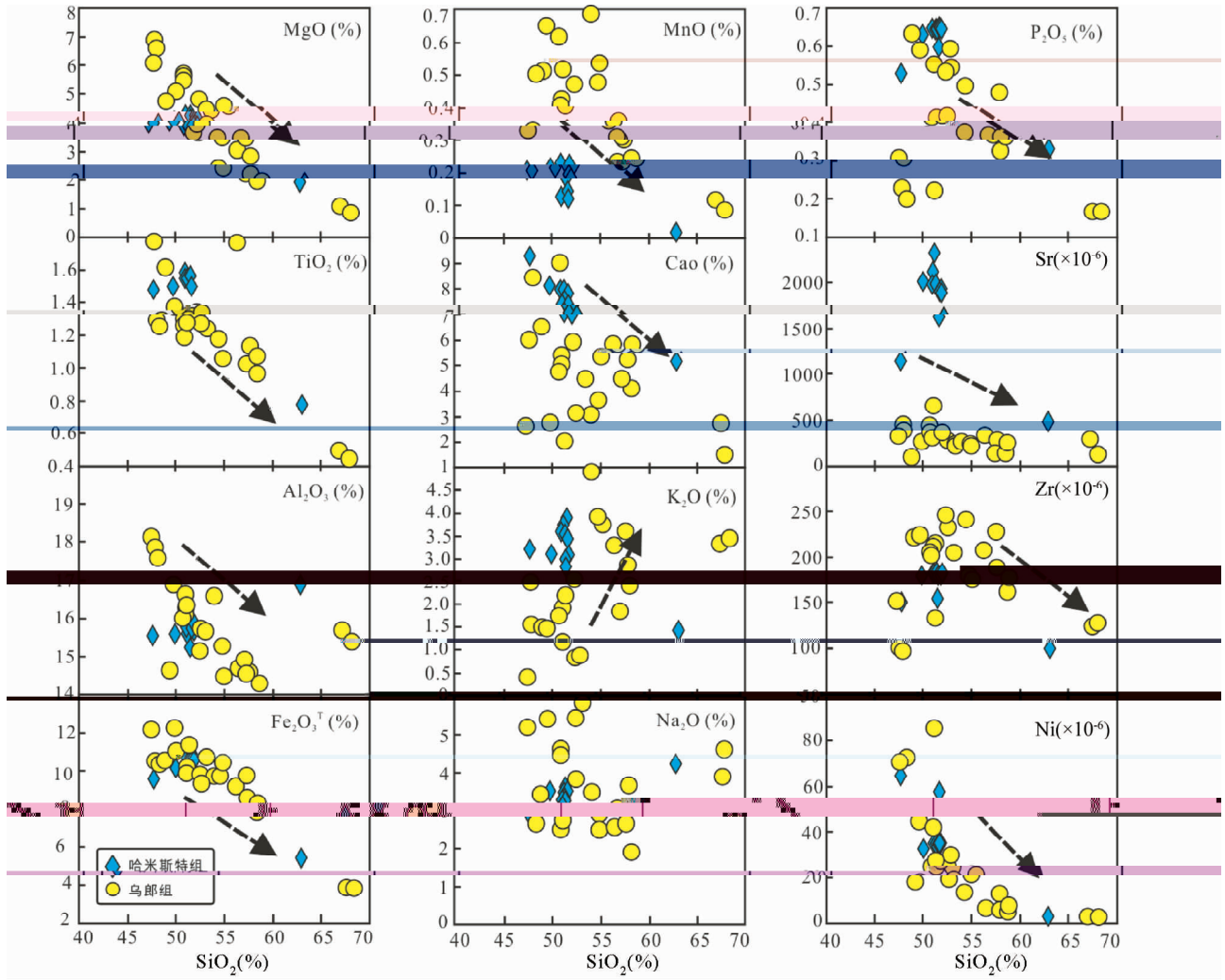
SiO₂ 47.72% ~
 51.71% TiO₂ 1.48% ~ 1.57% K₂O 2.81% ~
 3.91% K₂O/Na₂O 0.81 ~ 1.22 Al₂O₃ 15.20% ~
 15.95% 3a 4 1 K₂O-SiO₂
 3c
 WT04-2
 4 WT04-2
 SiO₂ CaO
 郎
 3a 4 K₂O-SiO₂
 3c

SiO₂ MgO TiO₂
 CaO Al₂O₃ FeO MnO P₂O₅
 >10% SiO₂ 3a
 Al₂O₃ K₂O Na₂O Sr SiO₂ 5a b
 4

4.2
 $184.8 \times 10^{-6} \sim 256.2 \times 10^{-6}$ La/Yb_N
 $= 9.7 \sim 11.7$ WT04-2
 96.1×10^{-6} La/Yb_N 2.7 5a Eu
 $\text{Eu}/\text{Eu}^* = 0.91 \sim 0.97$ $\Sigma\text{REE} = 53.1 \times 10^{-6} \sim$
 181.9×10^{-6} La/Yb_{N} = 1.6 \sim 9.1 Eu Eu}



3
 Fig. 3 Classification of types and series of the Nileke Permian volcanic rocks



4

Fig. 4 Harker diagram of the Nileke Permian volcanic rocks

$Eu/Eu^* = 0.61 \sim 1.79$

5a 5b

WT010-1 WT010-2

4.3 Sr-Nd

WT012-1

Sr-Nd

6

5b

$\Sigma REE = 53.3 \times 10^{-6} \sim$

郎

76.5×10^{-6} $La/Yb_N = 1.6 \sim 2.2$ $Eu/Eu^* = 0.79 \sim$

Sr-Nd

Nd

1.09

E-MORB

Sr

Nd

$= 3.8 \sim 6.8$

$^{87}Sr/^{86}Sr_i = 0.69718 \sim$

5c d

0.70477

OIB

Rb Ba Th K Sr 1157 ×

MORB

Sr-Nd

$10^{-6} \sim 2330 \times 10^{-6}$ WT04-2 = 472×10^{-6} Nb

Ta Zr Hf Ti Nb-Ta La

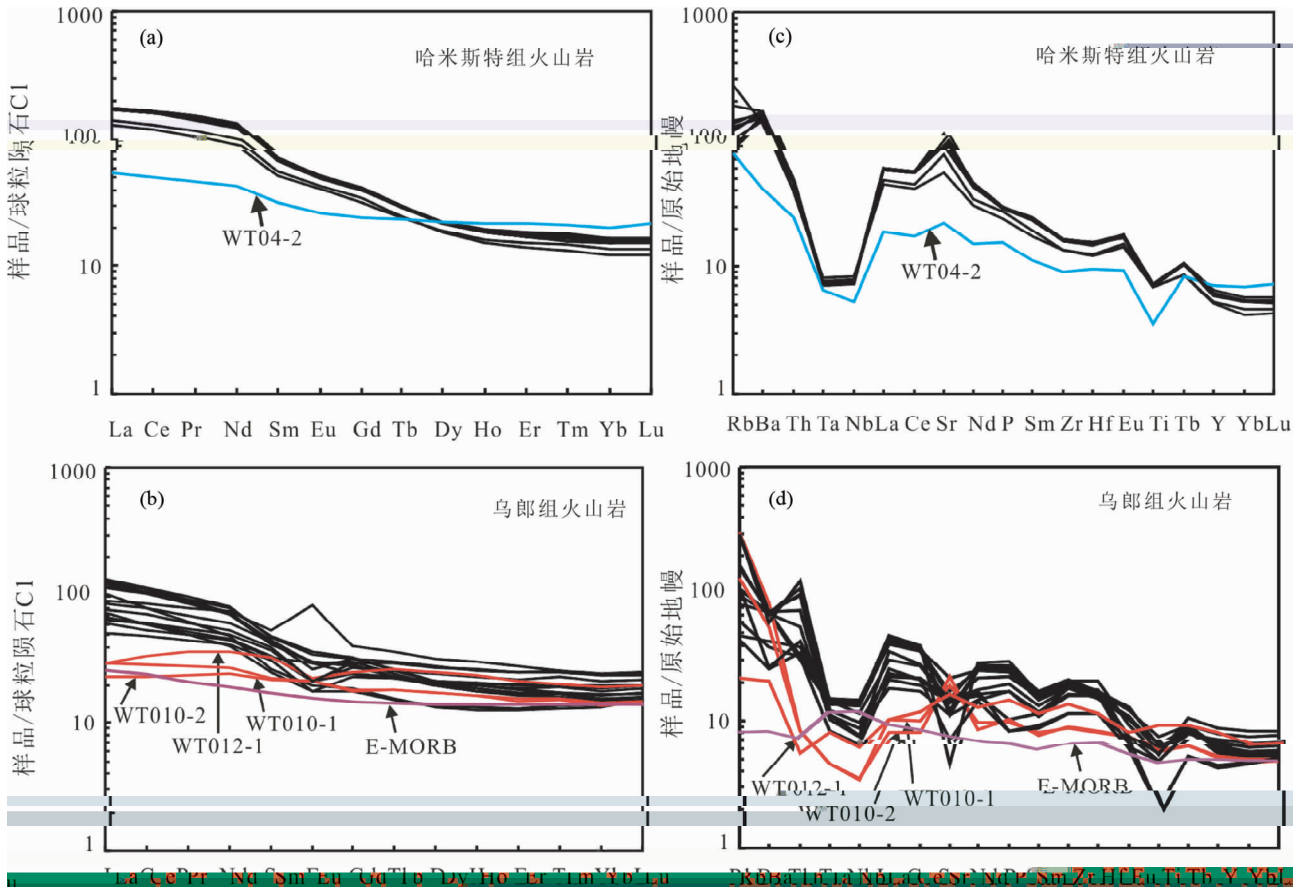
$Nb/La = 0.13 \sim 0.19$ WT04-2 = 0.28

郎

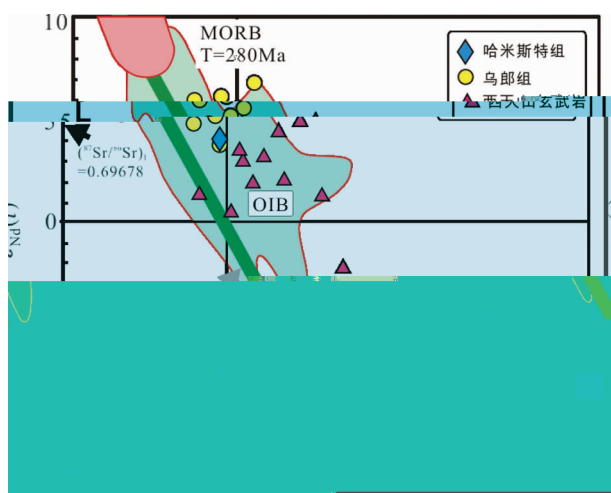
5

Sr $96 \times 10^{-6} \sim 462 \times 10^{-6}$ 5.1

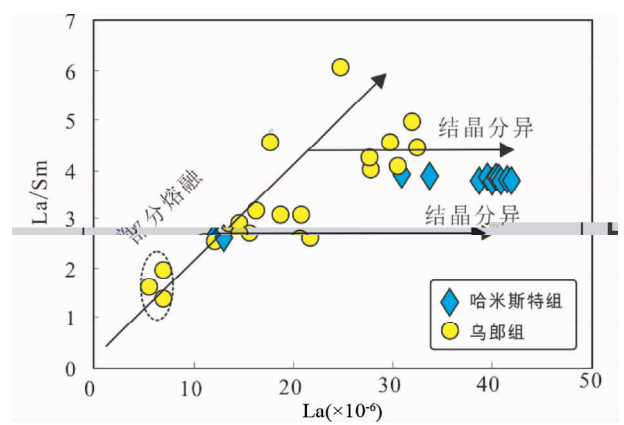
Nb-Ta Nb/La = 0.22 ~ 0.62 郎



5
Fig. 5 REE distribution patterns and trace element spider diagrams of the Nileke Permian volcanic rocks

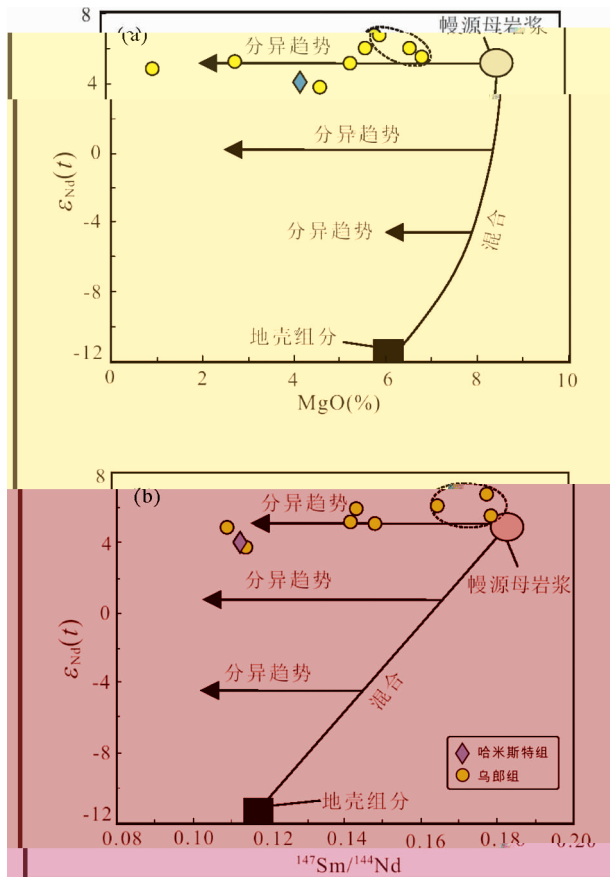


6
Sr-Nd MORB
OIB EMI EMII Zindler and Hart 1986
Fig. 6 Sr-Nd isotopic composition diagram of the Nileke Permian volcanic rocks after Zindler and Hart 1986



7
La La/Sm
E-MORB WT010-1 WT010-2
WT012-1
Fig. 7 La vs. La/Sm of the Nileke Permian volcanic rocks

3a b Eu 5a La/Sm
La 7 OIB Sr-Nd WT010-1 WT010-2



8 MgO ¹⁴⁷Sm/¹⁴⁴Nd

Nd

E-MORB WT010-1 WT010-2

WT012-1

Fig. 8 MgO and ¹⁴⁷Sm/¹⁴⁴Nd vs. ¹⁴⁷Sm/¹⁴⁴Nd diagram of the Nileke Permian volcanic rocks

WT012-1 SiO₂ 47.5% ~ 48.1%

MgO 5.97% ~ 6.89%

50 × 10⁻⁶ < ΣREE < 80 × 10⁻⁶

1.6 ~ 2.2 Nb/La > 0.35

E-MORB Cr

Ni 164.1 × 10⁻⁶ ~ 315.7 × 10⁻⁶ 70.1 × 10⁻⁶

~ 211.7 × 10⁻⁶ ¹⁴⁷Sm/¹⁴⁴Nd Eu

Eu/Eu* = 0.79 ~ 1.09

8

K₂O 2.81% ~ 3.91%

ΣREE > 200 × 10⁻⁶

11.7 La/Yb_N 9.7 ~

9 Arth 1976

Zr/Sm Hf/Sm Nb/

Y Nu9607

1% 5% 10% Zr/Sm

Hf/Sm Nb/Y

E-MORB

> 10%

E-MORB

Dy/Yb

Dy/Yb > 2.5

Dy/Yb < 1.5 Jiang

2009 Dy/Yb 2.07 ~

2.24 WT04-2 = 1.7 1.46 ~

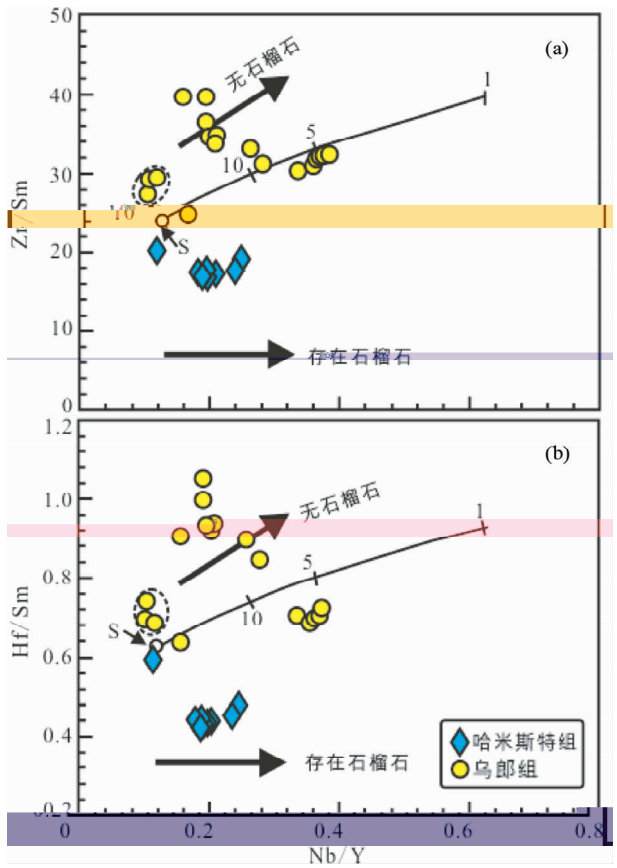
2.0

Nb-Ta 郎

Nb/La 0.22 ~ 0.62 Nb/

La < 0.2 Nb-Ta

MgO ¹⁴⁷Sm/¹⁴⁴Nd



9 Nb/Y-Zr/Sm a Nb/Y-
Hf/Sm b

Arth 1976

Nu9607

S

Nb/La > 0.35

E-MORB

3
MORB

Sr-Nd

Nb-Ta

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