*

叶海敏　叶现韬　张传林
YE HaiMin, YE XianTao and ZHANG ChuanLin

210016
Nanjing Institute of Geology and Mineral Resources　Nanjing 210016　*China*
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 [illegible] 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　50×10^{-6}

P588.14

1 引言

-

A -

Zhou *et al.* 2006 1994 2005
Han *et al.* 1997 Jahn 2004

-

" "

A

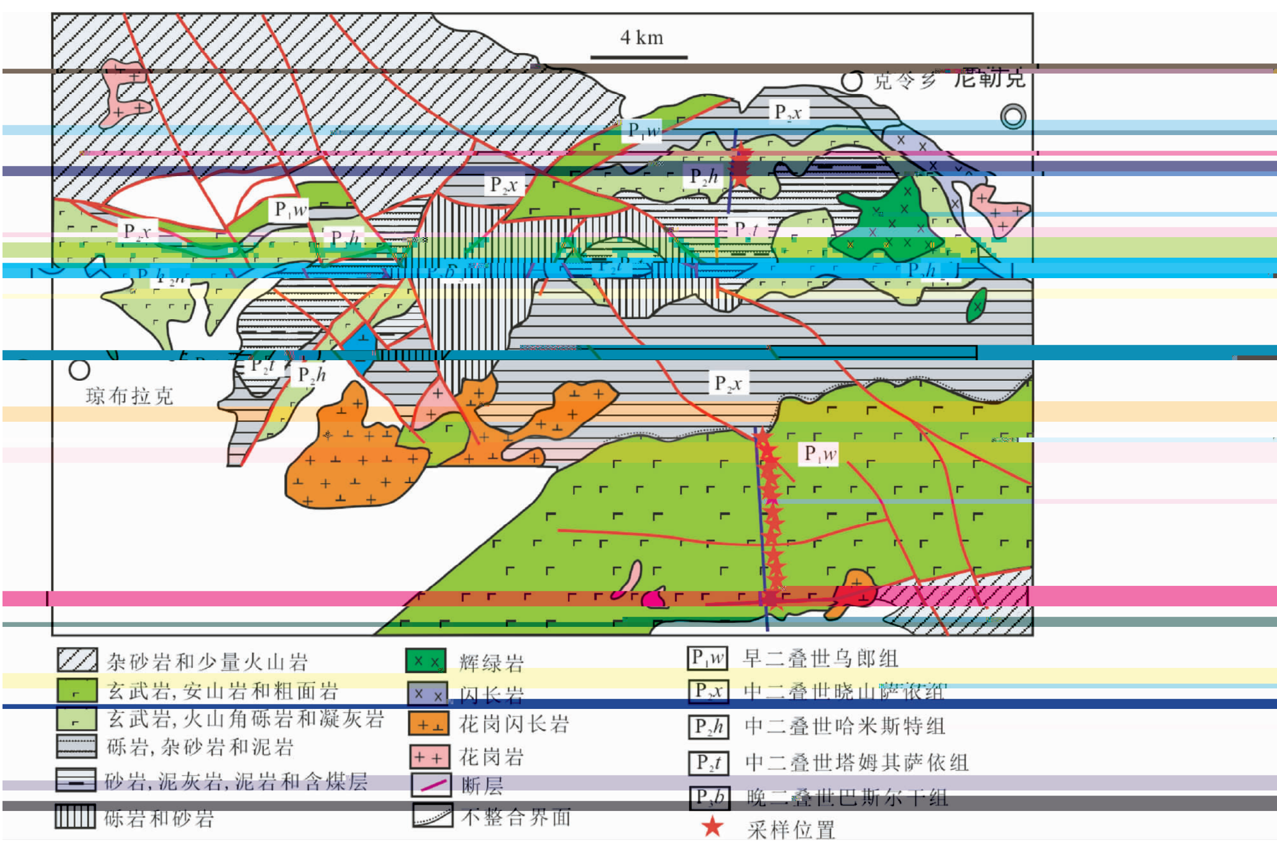
Zhou *et al.*
2004 2009 Zhang *et al.* 2008 2010a b Zhang and Zou
2013a b Pirajno *et al.* 2008 2009 Borisenko *et al.* 2006
Mao *et al.* 2008 Polyakov *et al.* 2008 Tian *et al.* 2010

50

290Ma 275Ma

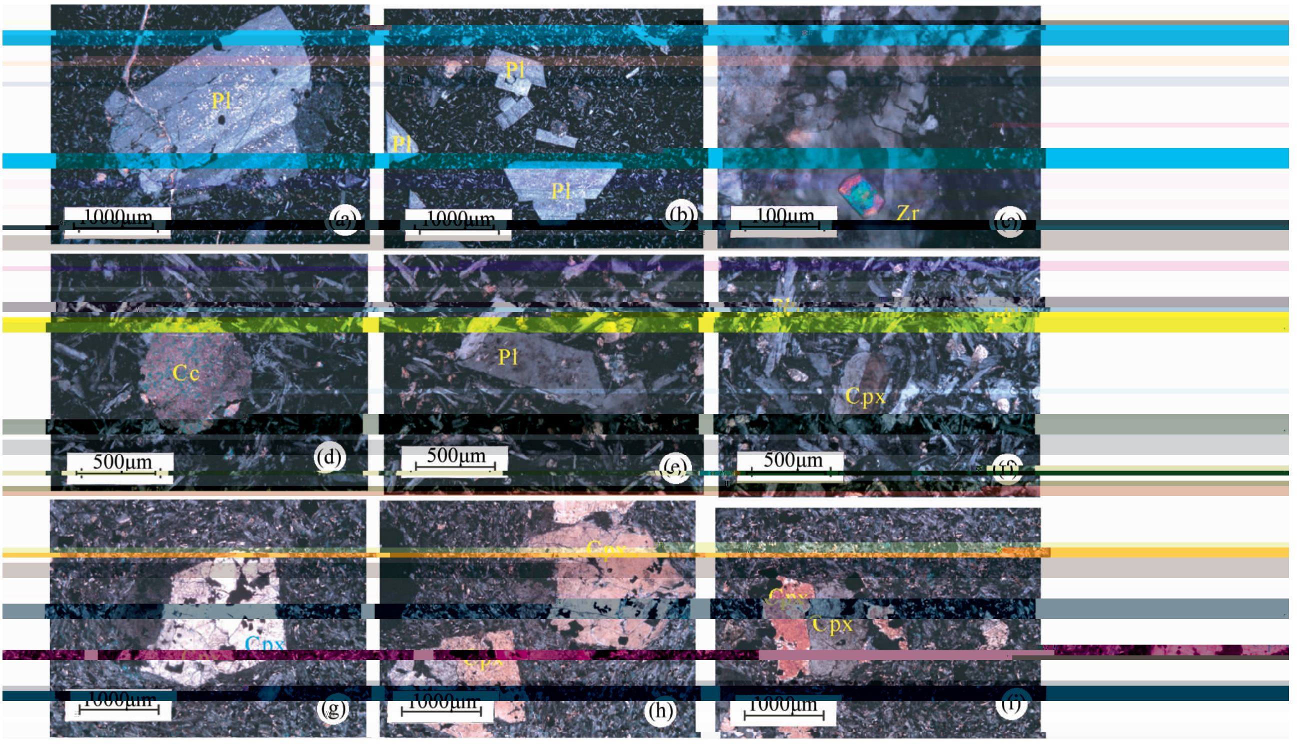
2 区域地质概况

1



1

Fig. 1 Geological map of Nileke Xinjiang



Pl
1000μm
(a)
Pl
Pl
Pl
1000μm
(b)
100μm
Zr
(c)
Cc
500μm
(d)
Pl
500μm
(e)
Cpx
500μm
(f)
Cpx
1000μm
(g)
1000μm
(h)
Cpx
1000μm
(i)

2

a b e - Pl é

1 wt% ×10^{-6}

Table 1 Major element wt% and trace element ×10^{-6} 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	WT04-7
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_2O_3	15.56	15.20	15.85	15.63	15.76	15.95	15.72	16.87	15.81	15.66
Fe_2O_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_2O	3.21	3.91	3.10	3.11	2.94	2.81	3.39	1.41	3.73	3.48
Na_2O	2.97	3.20	3.36	3.49	3.60	3.45	3.45	4.24	3.35	3.22
P_2O_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_2O_3	15.83	16.22	15.95	16.92	15.65	16.53	15.64	17.59	17.99	14.60
Fe_2O_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_2O	3.59	1.92	1.70	1.47	0.90	1.26	0.89	1.59	2.43	1.49

1

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_2O	3. 14	4. 42	4. 66	5. 43	5. 44	2. 60	5. 90	2. 67	3. 00	3. 39
P_2O_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
S44.	47	. 32 0	2. 40	4. 61	23. 3	18. 02	17 0			

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

2 Sm-Nd

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

	Rb $\times10^{-6}$	Sr $\times10^{-6}$	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	2σ	$(^{87}Sr/^{86}Sr)_i$	Sm $\times10^{-6}$	Nd $\times10^{-6}$	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	2σ	$(^{143}Nd/^{144}Nd)_i$	ε_{Nd} t
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 $^{86}Sr/^{86}Sr = 0.1194$ and $^{146}Nd/^{144}Nd = 0.7219$. 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 $^{87}Rb/^{86}Sr$ = 0.07809 $^{87}Sr/^{86}Sr$ = 0.7045 $^{147}Sm/^{144}Nd$ = 0.19667 and $^{143}Nd/^{144}Nd$ = 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 *et al.* 2009

MC-ICPMS Sr NBS987

Sr-GIG $^{87}Sr/^{86}Sr$ $^{86}Sr/^{88}Sr = 0.1194$

2002 Nd

JNdi-1 Nd-GIG $^{143}Nd/^{144}Nd$

$^{146}Nd/^{144}Nd = 0.7219$ 2003

Sr Nd 0.002%

4 地球化学特征

4.1

11 18

1 Sm-Nd

2

-SiO_2 TAS 3a

WT04-2

K Na

TAS

Ti Zr Y Nb

Zr/TiO_2-Nb/Y 3b

SiO_2 47.72% ~

51.71% TiO_2 1.48% ~1.57% K_2O 2.81% ~

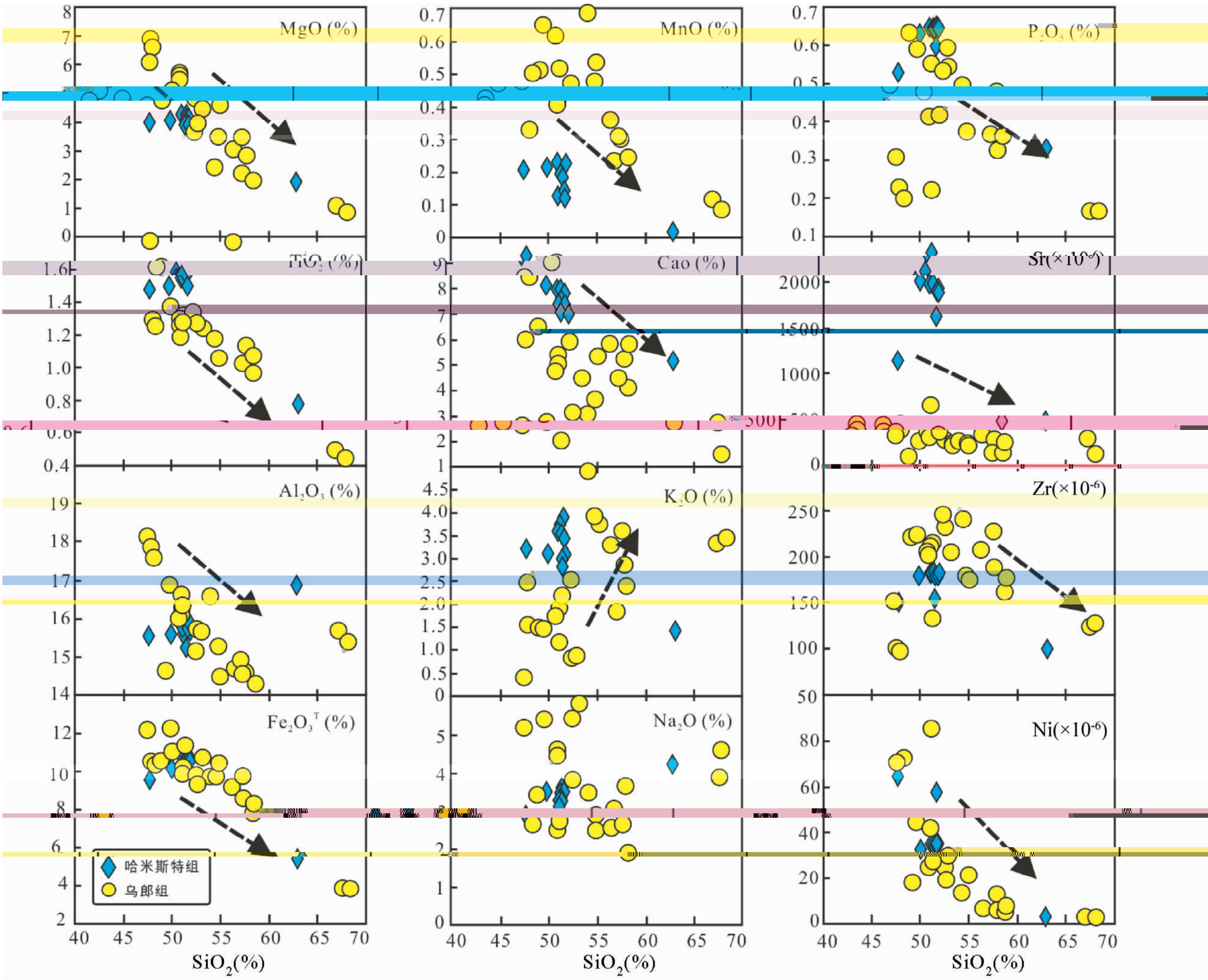
3.91% K_2O/Na_2O 0.81 ~1.22 Al_2O_3 15.20% ~

15.95% 3a 4 1 K_2O-SiO_2

3c

WT04-2

4 WT04-2



4

Fig. 4 Harker diagram o f the Nileke Permian volcanic rocks

Eu/Eu* =0. 61 ~ 1. 79

5a 5b WT010-1 WT010-2

WT012-1

5b $\Sigma REE = 53.3\times10^{-6}\sim76.5\times10^{-6}$ La/Yb $_N$ = 1. 6 ~ 2. 2 Eu/Eu* = 0. 79 ~ 1. 09 E-MORB

5c d

Rb Ba Th K Sr 1157 × $10^{-6}\sim2330\times10^{-6}$ WT04-2 = 472×10^{-6} Nb Ta Zr Hf Ti Nb-Ta La Nb/La = 0. 13 ~ 0. 19 WT04-2 = 0. 28

郎

Sr $96\times10^{-6}\sim462\times10^{-6}$

Nb-Ta Nb/La = 0. 22 ~ 0. 62

4. 3 Sr-Nd

Sr-Nd 6

郎

Sr-Nd Nd

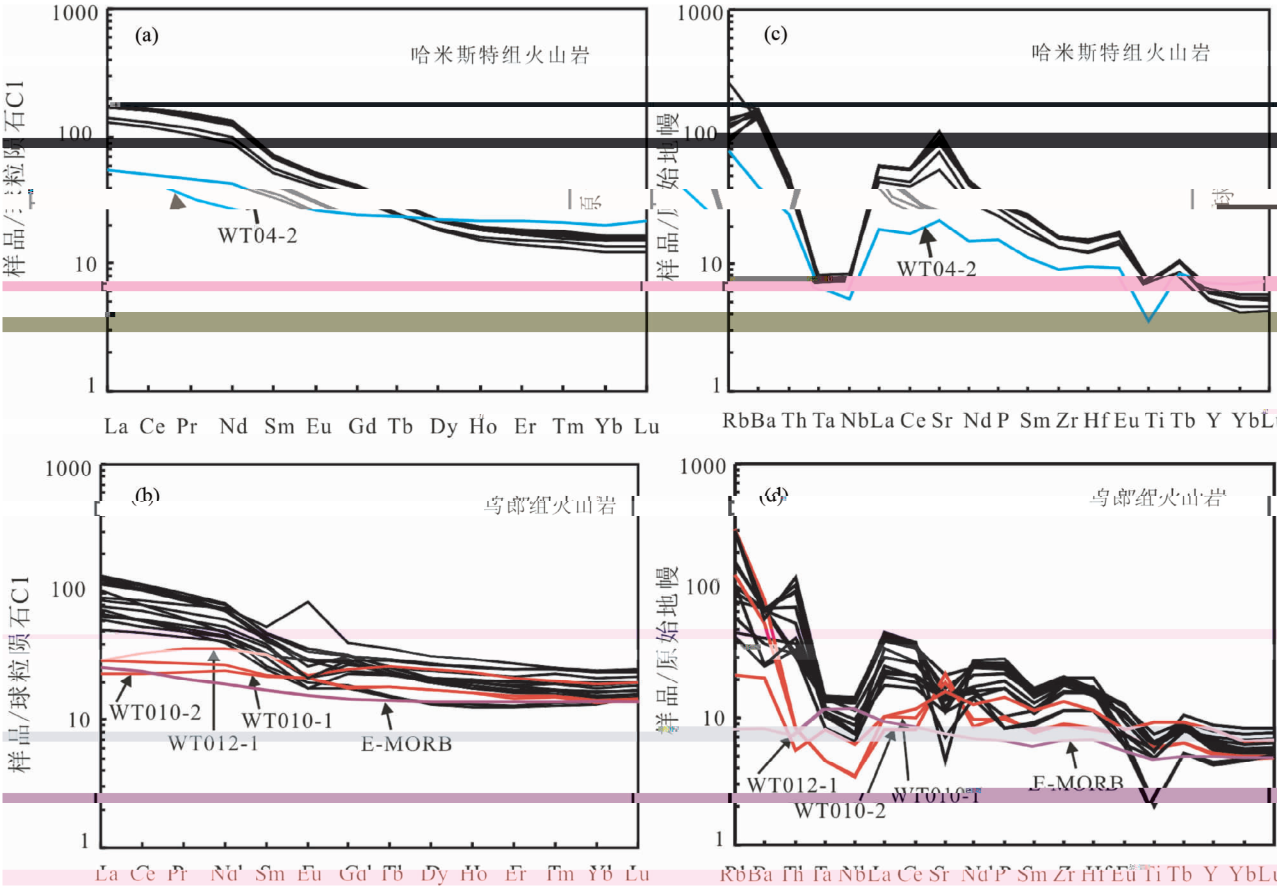
Sr ε_{Nd} t = 3. 8 ~ 6. 8 $^{87}Sr/^{86}Sr$ $_i$ = 0. 69718 ~ 0. 70477 OIB

MORB Sr-Nd

5 讨论

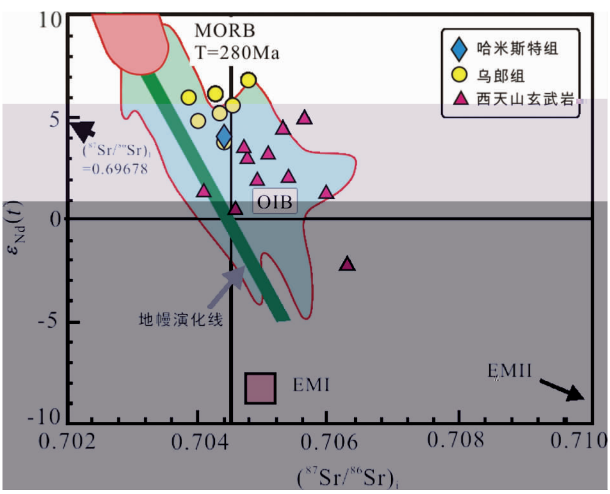
5. 1

郎



5

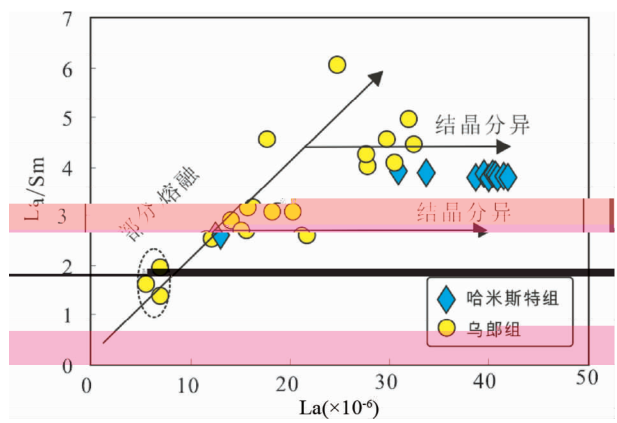
Fig. 5 REE distribution patterns and trace element spider diagrams of the Nileke Permian volcanic rocks



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

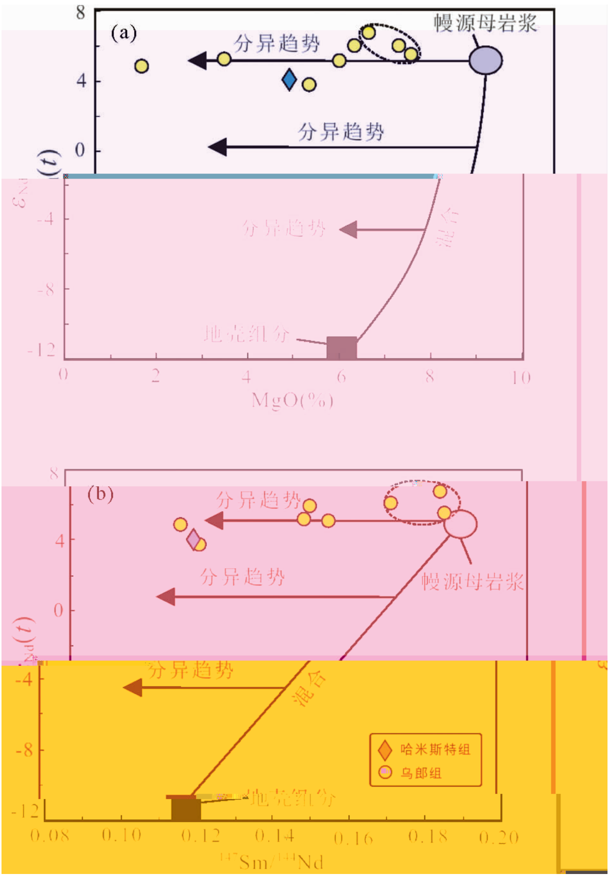
E-MORB WT010-1 WT010-2

WT012-1

Fig. 7 La vs. La/Sm of the Nileke Permian volcanic rocks

3a b Eu 5a La/Sm OIB Sr-Nd

La 7 WT010-1 WT010-2



8 MgO $^{147}Sm/^{144}Nd$

ε_{Nd} t

E-MORB WT010-1 WT010-2

WT012-1

Fig. 8 MgO and $^{147}Sm/^{144}Nd$ vs. ε_{Nd} t diagram of the Nileke Permian volcanic rocks

WT012-1 SiO_2 47.5% ~ 48.1% MgO 5.97% ~ 6.89% Sr < 500 × 10^{-6} 50 × 10^{-6} < ΣREE < 80 × 10^{-6} La/Yb $_N$ 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} $^{147}Sm/^{144}Nd$ Eu

Eu/Eu* = 0.79 ~ 1.09

8

K_2O 2.81% ~ 3.91% Sr > 1000 × 10^{-6} ΣREE > 200 × 10^{-6} La/Yb $_N$ 9.7 ~ 11.7

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 *et al.*

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 $^{147}Sm/^{144}Nd$

ε_{Nd} t 8

Nb-Ta

LILE

Sr-Nd

Sr-Nd

5.2

2005

Ti/V 20

10

MORB BAB

Xu 2001 Xu *et al.* 2004 2007

2008 E-MORB

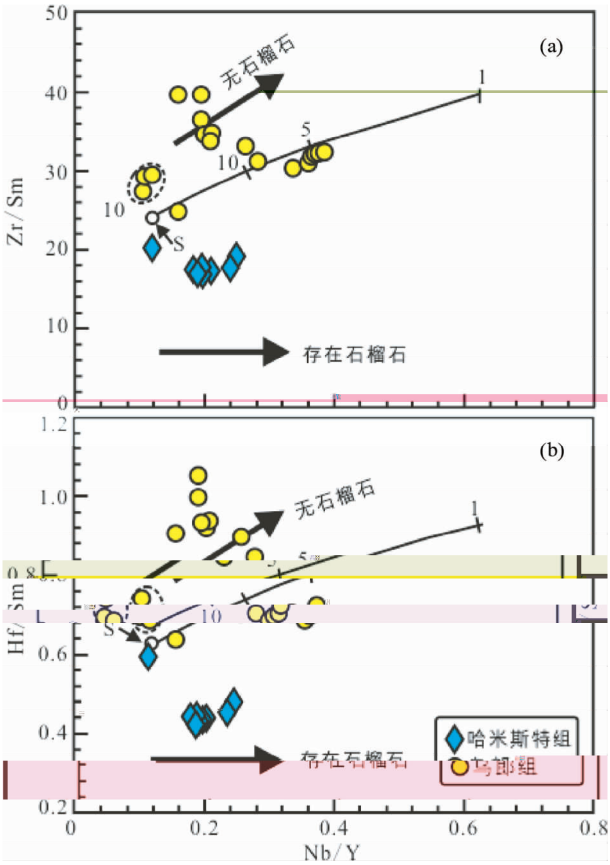
E-MORB

P-MORB "plume-ridge" E-MORB

Schilling 1973

E-MORB

Schilling *et al.* 1985



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

Arth 1976

Nu9607

S 1% 5% 10%

E-MORB WT010-1 WT010-2 WT012-1

Fig. 9 Nb/Y-Zr/Sm a and Nb/Y-Hf/Sm b diagram of the Nileke Permian volcanic rocks

-

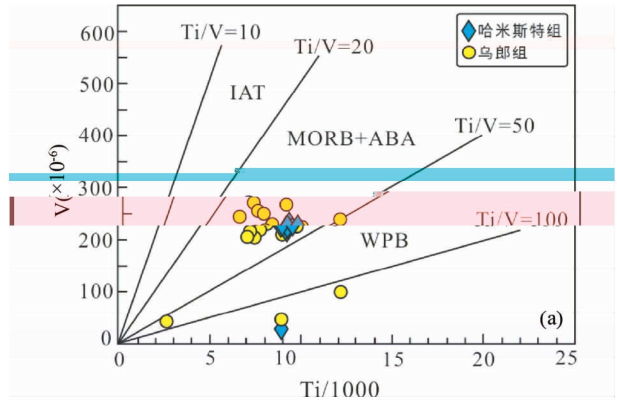
Xiao *et al.* 2003 2006 Tang *et al.* 2010 2012 Zhang *et al.* 2007

220Ma Zhang *et al.* 2007 220Ma

320Ma

Gao *et al.* 2009

-



10 Ti/1000-V

Fig. 10 Ti/1000 vs. V diagram of the Nileke Permian volcanic rocks

320 ~ 290Ma

1994 2005 Han *et al.* 1997 Jahn 2004

Zhang *et al.* 2010a

Nb/La >0.35 E-MORB

3 Sr-Nd

MORB

Nb-Ta

References

Arth JG. 1976. Behavior of trace elements during magmatic processes A summary of theoretical models and their applications. Journal of Research of the US Geological Survey 4 1 41 – 47

Borisenko AS Sotnikov VI Izokh AE Polyakov GV and Obolensky AA. 2006. Permo-Triassic mineralization in Asia and its relation to plume magmatism. Russian Geology and Geophysics 47 166 – 182

Gao J Long LL Klemd R Qian Q Liu DY Xiong XM Su W Liu W Wang YT and Yang FQ. 2009. Tectonic evolution of the South Tianshan Orogen and adjacent regions NW China Geochemical and age constraints of granitoid rocks. International Journal of Earth Sciences 98 6 1221 – 1238

Han BF Wang SG Jahn BM Hong DW Kagami H and Sun YL. 1997. Depleted-mantle source for the Ulungur River A-type granites from north Xinjiang China Geochemistry and Nd-Sr isotopic evidence and implications for Phanerozoic crustal growth. Chemical Geology 138 3 – 4 135 – 159

Jahn BM. 2004. Phanerozoic continental growth in Central Asia. Journal of Asian Earth Sciences 23 5 599 – 603

Jiang YH Jiang SY Dai BZ Liao SY Zhao KD and Ling HF. 2009. Middle to Late Jurassic felsic and mafic magmatism in southern Hunan Province Southeast China Implications for a continental arc to rifting. Lithos 107 3 – 4 185 – 204

Li JY Song B Wang KZ Li YP Sun GH and Qi DY. 2006. Permian mafic-ultramafic complexes on the southern margin of the Tu-Ha Basin East Tianshan Mountains Geological records of vertical crustal growth in Central Asia. Acta Geoscientia Sinica 27 5 424 – 446 in Chinese with English abstract

Li XH Liu Y Li QL Guo CH and Chamberlain KR. 2009. Precise determination of Phanerozoic zircon Pb/Pb age by multicollector SIMS without external standardization. Geochemistry Geophysics Geosystems 10 4 1525 – 2027

Liang XR Wei GJ Li XH and Liu Y. 2003. Precise measurement of $^{143}Nd/^{144}Nd$ and Sm/Nd ratios using multiple collectors inductively coupled plasma mass spectrometer MC-ICPMS . Geochimica 32 1 91 – 96 in Chinese with English abstract

Liu Y Liu HC and Li XH. 1996. Simultaneous and precise determination of 40 trace elements in rock samples using ICP-MS. Geochimica 25 6 552 – 558 in Chinese with English abstract

Mao JW Pirajno F Zhang ZH Chai FM Wu H Chen SP Cheng LS Yang MJ and Zhang CQ. 2008. A review of the Cu-Ni sulphide deposits in the Chinese Tianshan and Altay orogens Xinjiang Autonomous Region NW China Principal characteristics and ore-forming processes. Journal of Asian Earth Sciences 32 2 – 4 184 – 203

Pirajno F Mao JW Zhang ZC Zhang ZH and Chai FM. 2008. The association of mafic-ultramafic intrusions and A-type magmatism in the Tian Shan and Altay orogens NW China Implications for geodynamic evolution and potential for the discovery of new ore deposits. Journal of Asian Earth Sciences 32 2 – 4 165 – 183

Pirajno F Ernst RE Borisenko AS Fedoseev G and Naumov EA. 2009. Intraplate magmatism in Central Asia and China and associated metallogeny. Ore Geology Reviews 35 2 114 – 136

Polyakov GV Izokh AE and Borisenko AS. 2008. Permian ultramafic-mafic magmatism and accompanying Cu-Ni mineralization in the Gobi-Tien Shan belt as a result of the Tarim plume activity. Russian Geology and Geophysics 49 7 455 – 467

Schilling JG. 1973. Iceland mantle plume Geochemical study of Reykjanes Ridge. Nature 242 5400 565 – 571

Schilling JG Thompson G Kingsley R and Humphris S. 1985. Hotspot-migrating ridge interaction in the South Atlantic. Nature 313 5999 187 – 191

Song ZR Xiao XL Luo CL Wu MR Ling LH and Cheng CH. 2005. New advances in the study of Permian stratigraphy at Nileke in the Yinin Basin Xinjiang. Xinjiang Geology 23 4 334 – 338 in Chinese with English abstract

Tang GJ Wang Q Wyman DA Li ZX Zhao ZH Jia XH and Jiang ZQ. 2010. Ridge subduction and crustal growth in the Central Asian Orogenic Belt Evidence from Late Carboniferous adakites and high-Mg diorites in the western Junggar region northern Xinjiang West China . Chemical Geology 277 3 – 4 281 – 300

Tang GJ Wang Q Wyman DA Li ZX Xu YG and Zhao ZH. 2012. Recycling oceanic crust for continental crustal growth Sr-Nd-Hf isotope evidence from granitoids in the western Junggar region NW China. Lithos 128 – 131 73 – 83

Tian W Campbell IH Allen CM Guan P Pan WQ Chen MM Yu HJ and Zhu WP. 2010. The Tarim picrite-basalt-rhyolite suite a Permian flood basalt from northwest China with contrasting rhyolites produced by fractional crystallization and anatexis. Contributions to Mineralogy and Petrology 160 3 407 – 425

Wang SG Han BF Hong DW Xu BL and Sun YY. 1994. Geochemistry and tectonic significance of alkali granites along Ulungur River Xinjiang. Chinese Journal of Geology 28 4 373 – 382 in Chinese with English abstract

Wei GJ Liang XR Li XH and Liu Y. 2002. Precise measurement of Sr isotopic composition of liquid and solid base using LP MC-ICPMS. Geochimica 31 3 295 – 299 in Chinese with English abstract

Wu H Li HQ Mo XH Chen FW Lu YF Mei YP and Deng G. 2005. Age of the Baishiqun mafic-ultramafic complex Hami Xinjiang and its geological significance. Acta Geologica Sinica 79 4 498 – 502 in Chinese with English abstract

Xia ZC Xu XY Xia LQ Li XM Ma ZP and Wang LS. 2005. Geochemistry of the Carboniferous-Permian post-collisional granitic rocks from Tianshan. Northwestern Geology 38 1 1 – 14 in Chinese with English abstract

Xiao WJ Windley BF Hao J and Zhai MG. 2003. Accretion leading to collision and the Permian Solonker suture Inner Mongolia China Termination of the Central Asian Orogenic Belt. Tectonics 22 6 1069 – 1088

Xiao WJ Windley BF Yan QR Qin KZ Chen HL Yuan C Sun M Li JL and Sun S. 2006. SHRIMP zircon age of the Aermantai ophiolite in the North Xinjiang Area China and its tectonic implications. Acta Geologica Sinica 80 1 32 – 37 in Chinese with English abstract

Xu YG. 2001. Thermo-tectonic destruction of the Archaean lithospheric keel beneath the Sino-Korean craton in China Evidence timing and mechanism. Physics and Chemistry of the Earth Part A Solid Earth and Geodesy 26 9 747 – 757

Xu YG He B Ch 9 m

igneous province southwestern China Evidence for crustal growth