

Fig. 1. Geological map of the Fuyun region in Xinjiang, China, showing tectonic units, faults, and ophiolite belts (after *Li et al. 2000*).

The map shows the distribution of various geological units. The Fuyun ophiolite belt is characterized by mafic rocks and is bounded by faults. The Altai ophiolite is also visible, along with the Keketuohai complex and the Kuwei mafic intrusion. The map highlights the complex tectonic history of the region, including the collision of the Siberian and North China cratons.

**2. Results and Discussion**

The study area is characterized by a variety of geological units. The Fuyun ophiolite belt is a prominent feature, consisting of mafic rocks and associated volcanic rocks. The Altai ophiolite is also present, along with the Keketuohai complex and the Kuwei mafic intrusion. The map shows the distribution of these units and their relationships to each other. The tectonic history of the region is complex, involving the collision of the Siberian and North China cratons.

The Fuyun ophiolite belt is a key feature of the region, representing a remnant of an ancient oceanic crust. It is characterized by mafic rocks and associated volcanic rocks. The Altai ophiolite is also present, along with the Keketuohai complex and the Kuwei mafic intrusion. The map shows the distribution of these units and their relationships to each other. The tectonic history of the region is complex, involving the collision of the Siberian and North China cratons.

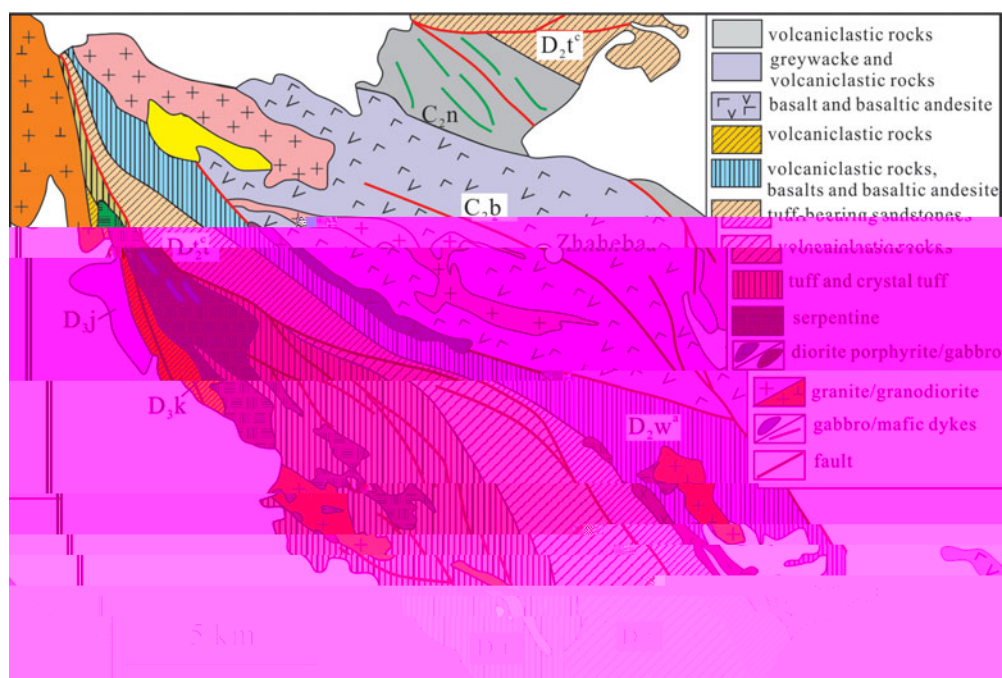


Figure 2. Geological map of the Zhaheba ophiolite (see text for details). Modified from Wang *et al.* (2000, 2001) and Wang *et al.* (2003).

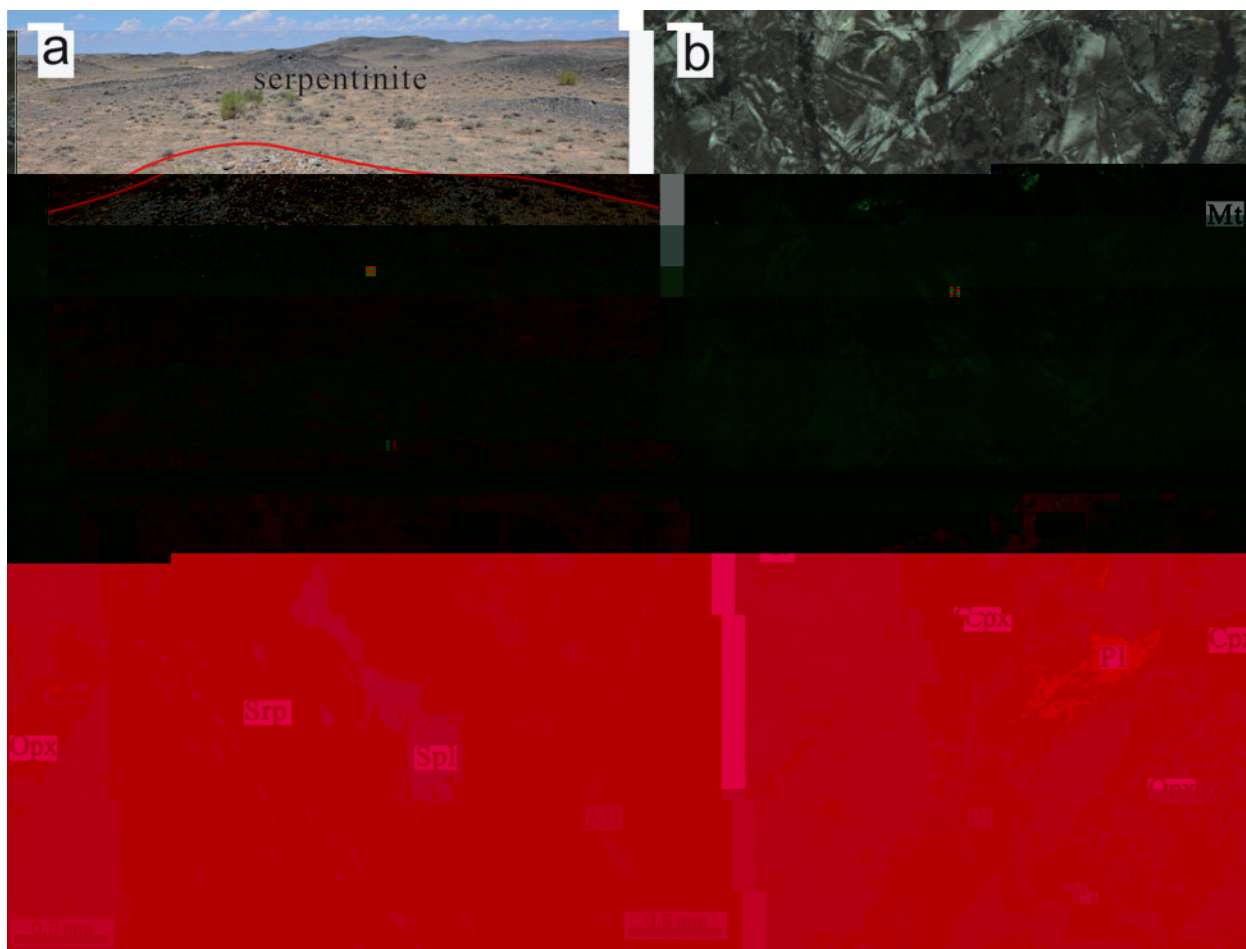


Figure 3. (a) Field photograph of the serpentinite outcrop. (b) Micrograph of the serpentinite texture. The BSE images show the mineral grains in the serpentinite. The labels Opx, Srp, Spl, Pl, and Mt represent the mineral abbreviations. The scale bar is 0.5 mm.



	2013	01-1	2013	01-3	2013	01-4	2013	01-5	2013	01-6	2013	01-	2013	01-	2013	01. 1	2013	01. 2	2013	01. 4
<i>Major elements (%)</i>																				
SiO <sub>2</sub>	3.0	4.20	3.41	3.62	3.22	3.2	3.05	4.22	46.4	51.2										
TiO <sub>2</sub>	0.05	0.20	0.05	0.05	0.04	0.05	0.04	0.14	0.12	0.2										
Al <sub>2</sub> O <sub>3</sub>	0.61	1.6	1.04	0.6	0.0	0.4	0.0	1.2	1.64	1.33										
FeO	.44	4.6	.	.36	.5	.16	.4	3.6	3.24	3.										
MnO	0.0	0.10	0.11	0.11	0.11	0.0	0.11	0.0	0.0	0.0										
MgO	3.21	24.5	3.2	3.3	3.0	3.31	3.44	10.04	.03	5.										

Element

Element	2013 01-1	2013 01-3	2013 01-4	2013 01-5	2013 01-6	2013 01-	2013 01-1	2013 01-2	2013 01-4
	0.005	0.064	0.00	0.005	0.00	0.003	0.003	0.051	0.222
	0.021	0.34	0.044	0.042	0.0 2	0.031	0.033	0.310	1.450
	0.004	0.04	0.00	0.00	0.011	0.005	0.005	0.04	0.21
	0.011	0.232	0.036	0.044	0.012	0.034	0.00	0.123	0. 3
	0.0 0	0.036	0.03	0.03	0.06	0.026	0.025	0.046	0.06
	0.26	1. 10	6.600	1. 0	0. 3	0.233	1.150	1.5 0	0.1 5
	0.406	0.0 2	0.12	0.112	0.0	0.1	0.054	0.16	0.6 5
	0.046	0.034	0.014	0.02	0.050	0.030	0.010	0.050	0.130
	0.1 1	0.144	0.203	0.364	0.042	0.0 4	0.0	0.066	0.0 3

Element	2013 01. 5	2013 01. 6	2013 01. ( 1)	2013 01. ( 1)	2013 01. ( 1)	2013 03. 2 ( 1)	2013 03. 3 ( 1)	2013 03. 4 ( 1)	2013 03. 5 ( 1)	2013 01. 3 ( 2)
	4. 1	45.	4. 1	53.1	51. 1	50.40	50.54	50.52	51.22	52.3
	0.34	0.15	1.40	1.24	1.31	1. 0	1.63	1.31	1.1	0.33
	1. 1	1. 5	16.5	16.1	15. 3	15. 0	16. 6	15.55	15.4	1. 61
	4.52	3.34	. 11	.11	.43	.0	.50	.42	. 2	3.44
	0.0	0.0	0.11	0.10	0.11	0.13	0.11	0.14	0.12	0.0
	6. 1	.42	4. 0	4.2	4.41	5. 1	3.2	6.06	.14	4. 1
	11.03	12.61	6.22	5. 5	6.3	6. 5	4.52	.4	.26	. 0
	4. 6	.3	. 2	.3	.00	4.52	.31	4. 0	4.0	.11
	0.13	0.11	0.3	0.31	0.42	2.04	0.33	1.2	2.03	0.1
	0.04	0.02	0.62	0.62	0.65	0. 4	0.6	0.4	0.44	0.04
	3. 2	3.26	4.24	2.54	2. 3	2.2	5.14	2.65	1. 3	2. 1
	1. 5	1. 2	1. 6	1. 0	1. 4	1.40	1. 1	1. 6	1. 6	1. 1
	4. 1	.4	.11	. 0	.42	6.56	.64	6.0	6.11	.2
#	5	1	55	54	54	56	41	56	64	4

Element	2013 01. 5	2013 01. 6	2013 01. ( 1)	2013 01. ( 1)	2013 01. ( 1)	2013 03. 2 ( 1)	2013 03. 3 ( 1)	2013 03. 4 ( 1)	2013 03. 5 ( 1)	2013 01. 3 ( 2)
	0.0	4. 5	1.16	1.12	1.4	1.0	40.4	5.2	6. 2	5. 1
	0.22	0.135	1.2 4	1.6 3	1.316	1. 53	1.034	1.100	0.5 5	0.62
	25.0	23.	1. 6	1. 5	1. 5	.5	1. 2	25.2	1. 1	1. 0
	11	3.	1. 6	166	1. 2	22	22	254	1	5.
	34.	163	60.5	62.6	64.1	116	1. 1	.0	203	23.
	24.2	21.6	26.	23.6	24.6	2. 1	2. 5	2. 0	2. 0	16.4
	4.	1. 5	63.6	50.	51.4	6.	2. 1	5. 3	132	1.1

Table 1. ...

Sample	2013 01. 5	2013 01. 6	2013 01. 7	2013 01. 8	2013 01. 9	2013 03. 2	2013 03. 3	2013 03. 4	2013 03. 5	2013 01. 3
Age (Ma)	3.60	1.20	3.60	46.0	4.30	23.40	43.00	25.20	32.0	6.56
ε <sub>Sm</sub> (t)	2.6	2.50	2.1	1.0						

Elemente

Element	2013 ( 2)	01. 11 ( 2)	2013 ( 2)	02. 1 ( 2)	2013 ( 2)	02. 2 ( 2)	2013 ( 1)	03. 1 ( 1)	2013 ( 1)	03. 6 ( 1)	2013 ( 2)	01. 10 ( 2)	04 06 ( 1)	04 24 ( 1)	04 2 ( 1)	03 1 ( 1)
<i>Trace elements (ppm)</i>																
	1.4	36.	42.4	26.0	32.4	1.	/	/	/	/	/	/	/	/	/	/
e	0.3 5	0.153	0.35	1.1	0.4	0.46	/	/	/	/	/	/	/	/	/	/
e	32.5	33.2	34.5	25.1	26.3	32.1	13.4	20.5	1.	20.3						
	1.4	203	21	33	341	1.5	144	1.4	214	265						
	56.5	44.2	4.	1.	22.2	53.	15	162	214	265						
	34.	3.5	3.3	23.1	24.	33.	20.6	30.	2.	20.2						
	66.4	4.6	6.4	25.4	2.1	66.6	.1	114	5.5	.02						
	6.4	236.4	256.	205.4	20.	114.20	/	/	/	/						
	4.0	44.1	4.0	4.	103	44.1	/	/	/	/						
	12.0	11.1	11.2	14.	13.6	12.0	/	/	/	/						
	0.5	1.420	1.0 0	3.130	3.2 0	0.5 3	4.	1.1	22.0	1.2						
	.1	1.50	.5	2.0	24.	6.6	.1	31	111	.6						
	13.0	13.0	13.2	21.1	22.	12.5	13.2	13.2	14.	20.1						
	54.	42.3	41.5	144	154	52.	243	133	164	151						
	1.2	0.4	0.55	11.315	11.5	1.25	20.2	12.	21.	12.2						
	0.025	0.030	0.02	0.051	0.052	0.02	/	/	/	/						
	0.3 1	0.2 6	0.32	1.560	1.450	0.360	/	/	/	/						
	0.2	1.20	1.030	0.365	0.406	0.336	/	/	/	/						
	11	3.2	346	25	50	4.3	/	/	/	/						
	10.0	.40	.610	26.40	26.0	10.50	30.6	32.2	40.1	26.4						
e	23.00	1.0	1.40	51.50	54.0	22.30	5.	62.	2.3	52.5						
	2.0	2.520	2.510	5.50	6.1 0	2.6 0	6.	.4	10.5	6.4						
	11.0	11.0	11.60	22.30	24.30	11.60	2.5	31.2	43.1	24.4						
	2.540	2.00	2.6 0	4.4 0	4.00	2.3 0	4.5	5.2	6.	4.5						
	0.6	0.1	0.0	1.163	1.25	0.3	1.45	1.5	2.0	1.03						
	2.4 0	2.13	2.54	4.14	4.46	2.522	3.56	4.01	5.35	4.23						
	0.3 6	0.3	0.3	0.612	0.660	0.3 4	0.4	0.54	0.64	0.63						
%	2.1 0	2.150	2.220	3.420	3.6 0	2.130	2.5	2.	3.24	3.5						
	0.46	0.446	0.444	0.2	0.5	0.46	0.4	0.52	0.5	0.						
	1.350	1.230	1.240	2.120	2.2 0	1.310	1.32	1.3	1.45	2.25						
	0.1 0	0.16	0.1 5	0.304	0.32	0.1 4	0.1	0.2	0.2	0.34						
	1.210	1.050	1.120	1.60	2.110	1.210	1.25	1.23	1.24	2.13						
	0.1 4	0.164	0.165	0.2 1	0.323	0.1 3	0.20	0.1	0.1	0.34						
	1.3 0	0.41	1.040	3.2 0	3.510	1.460	5.3	3.2	4.16	3.2						
	0.0 4	0.062	0.051	0.5	0.644	0.0	1.35	0.6	1.16	0.6						
	0.151	2.0	1.50	2.5	1.	0.33	/	/	/	/						
	0.3 4	0.206	0.200	45.20	35.10	0.41	.13	.0	4.1	21.06						
	1.0	0.61	0.1	.60	.2 0	1.0	4.50	2.63	3.20	.41						
	0.500	0.304	0.302	2.30	3.4 0	0.501	1.	0.6	1.46	2.5						

Elemente / ... et al. (200 a).



Table 2. U-Pb zircon ages and  $\epsilon_{\text{Pb}}(t)$  values for the Zhaheba ophiolite.

Year	Sample No.	Zircon Size ( $\mu\text{m}$ )	Age (Ma)	Age Error (Ma)	$\epsilon_{\text{Pb}}(t)$	Sample No.	Zircon Size ( $\mu\text{m}$ )	Age (Ma)	Age Error (Ma)	$\epsilon_{\text{Pb}}(t)$	Sample No.	Zircon Size ( $\mu\text{m}$ )	Age (Ma)	Age Error (Ma)	$\epsilon_{\text{Pb}}(t)$
2013	01. 3	2	0.36	3.2	0.002	04030(2)	0.04015	2.4	10.	0.134	05123(40)	0.5124	4	6.	
2013	01. 10	2	0.5	6.6	0.0024	04045(23)	0.0445	2.3	11.6	0.1235	05120(43)	0.5124	6	1.	
2013	03. 1	1	3.13	2.0	0.0335	06324(20)	0.06133	4.4	22.3	0.121	0512533(4)	0.5122	14	1.	
2013	03. 2	1	2.	1320	0.0063	042(20)	0.04255	4.5	2.6	0.1046	05121(51)	0.512445	6.3		
2013	03. 3	1	0.6	516	0.0452	0536(43)	0.05111	5.	36.	0.0	05120(30)	0.512450	6.4		
2013	03. 4	1	0.65	140	0.01	0422(51)	0.04120	4.55	24.5	0.1123	051203(53)	0.51250	5		

$\epsilon_{\text{Pb}}(t) = 10000 \left( \left( \frac{^{143}\text{Pb}}{^{144}\text{Pb}} \right)_{\text{sample}} / \left( \frac{^{143}\text{Pb}}{^{144}\text{Pb}} \right)_{\text{standard}} - 1 \right) \times \left( \frac{^{144}\text{Pb}}{^{238}\text{U}} \right)_{\text{sample}}$

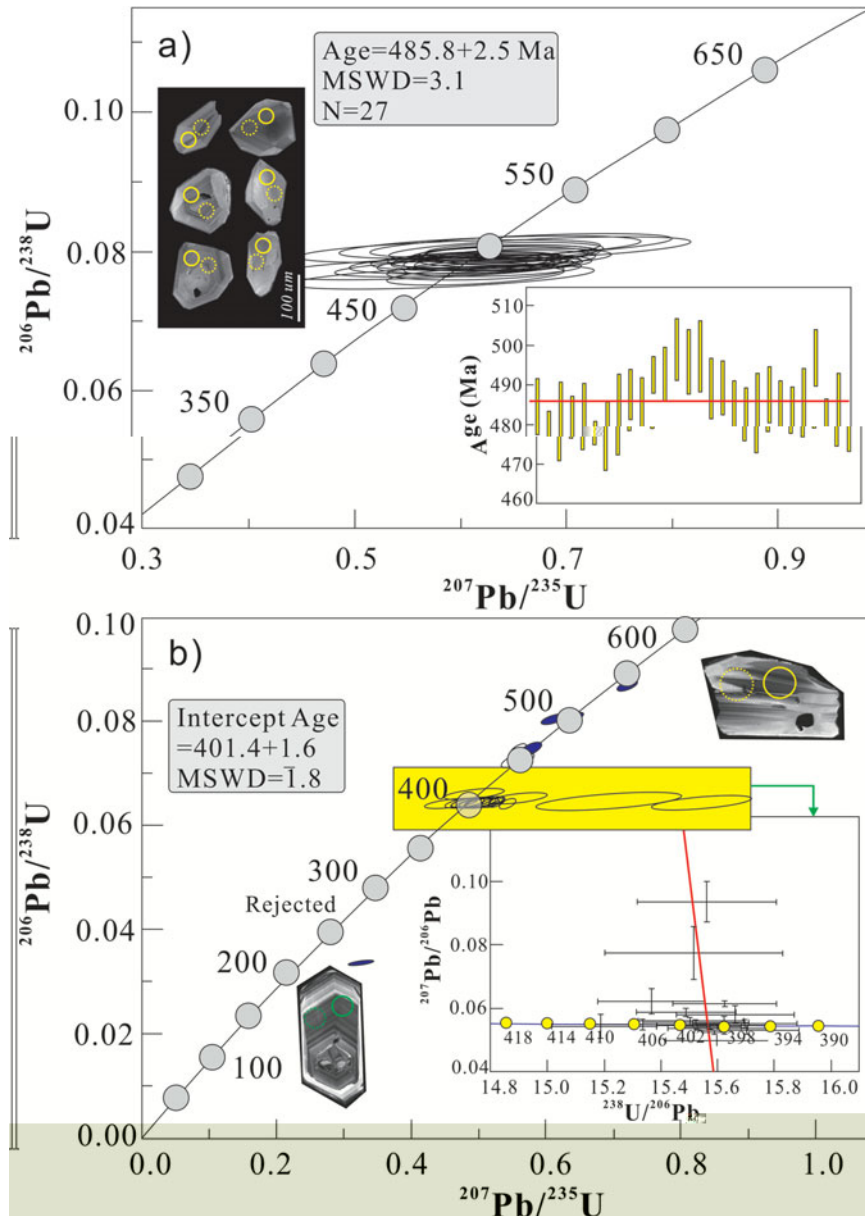


Table 4. U-Pb zircon ages and  $\epsilon_{\text{Pb}}(t)$  values for the Zhaheba ophiolite.

(Table 4). The ages range from 0.36 to 3.13 Ma. The  $\epsilon_{\text{Pb}}(t)$  values range from -0.002 to 0.0335. The MSWD values range from 1.8 to 3.1. The zircon crystals are mostly 1-2  $\mu\text{m}$  in size. The ages are significantly younger than those reported for the Zhaheba ophiolite (e.g., 401 Ma,  $\epsilon_{\text{Pb}}(t) = 0.1123$ ).

...%, ... (2, ... .4).  
 ...% ...  
 ... 1. ... 1 ... 2  
 ...% ... 450. ...  
 500. ...% ...  
 21 ...% ... 1 ...% ...  
 ...<sup>206</sup> ...<sup>23</sup> ...  
 401 ± 2 ... (= 3.3) ...  
 ...<sup>206</sup> ...<sup>23</sup> ...<sup>20</sup> ...<sup>235</sup> ...  
 ...% ...  
 ... 401.4 ± 1.6 ... (= 1.) ...  
 ... .4), ...<sup>206</sup> ...  
 ...<sup>23</sup> ...  
 ... ( ... , 1. 3).

4.b. M a c

4.b.1. Spinel composition

...% ... 1 ...  
 (... .3). ... 100 300 μ ...  
 ...% ... ( ... 11 ...% ...  
 4 ... 1 // ... / e )  
 ... 1 ... 2 3, ... 2 3 ...  
 ...  
 ...% ... 1 ...% 1 ...  
 ... 1 ... (100 / ( + ))  
 ... 44 60 ... (100 / ( + e))  
 ... 25 61. ... 1 ...  
 ... / e ... /  
 1 - ... et al. 2010). ...  
 ... ( ) ... 1 ...  
 ... 1 ... et al. 2013).

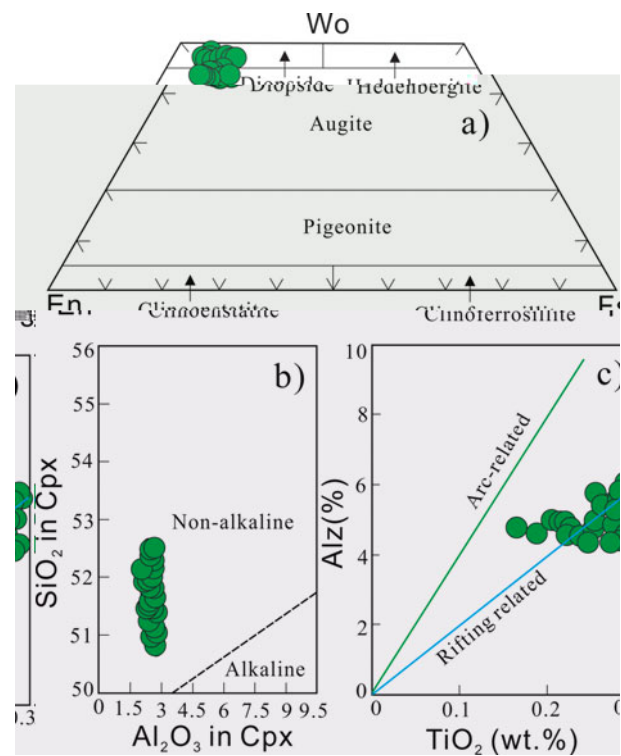
4.b.2. Pyroxene compositions

... 1% ...  
 ... 1 ... (= 4 6). ...  
 ... 1% ... % ...  
 ... ( ... 0.5%) ... 1 -  
 ...% ... 5 ... 1 // ...  
 ... / e ). ... 1% ...  
 ... 41 4 ... 46 55 ... 1  
 (... .5). ...  
 ...<sup>2 3</sup> ...<sup>2</sup> ...<sup>2</sup> ...  
 (... .5, e).

4.c. W a c

4.c.1. Serpentinites and cumulates

...% ... ( )  
 (> 12%, ...  
 ...<sup>2</sup> ( ... 40%), ...<sup>2 3</sup> ( ... %  
 ... 1.0%), ...<sup>2</sup> (0.03 0.06%), ...<sup>2</sup> (0.04  
 0. 2%) ...<sup>2</sup> (0.04 0.05%). ...<sup>2 3</sup> ...



... 5. ( ... ) ( )  
 ... 1 ... 1% ...  
 ... 1 ... ( ) ...  
 (1 ... % ) ... ( % )  
 ... 1% ...

...% ... 1 ( ... e 1) ...  
 ...  
 ... ( ... 6).  
 ...% ... ( 3 103 11 ) ...  
 ... ( 5 11 ) ( ... e 1). ... (> 12%)  
 ...  
 ... 1 ... ( ) (e. ... ,  
 ... ) ...  
 ...<sup>2 3</sup> ...<sup>2 3</sup> ...<sup>2</sup> ...  
 ...% ...  
 ...  
 ...  
 ... ( ) ...  
 ... ( ... e 1). ...  
 ... - 1 ...  
 ( ... ), ...  
 1 ... ( ... 2014 ...  
 ... & e-  
 ... , 1 ... ).

... 45. % ... 51.2 %, ... 1% ...  
 ...<sup>2 3</sup> (3.24 4.6 %), ...<sup>2 3</sup> (1 .3 1 .6%, ...  
 ... 1 ... 2013 ... 01-3), ... (.54 15.42%), ...<sup>2</sup>  
 (0.12 0.34%), ...<sup>2</sup> (2. 1 .3 %, ...  
 2013 ... 01-3) ...<sup>2</sup> (0.11 0.46%) ...  
 ... / e , ... ( ... 1).



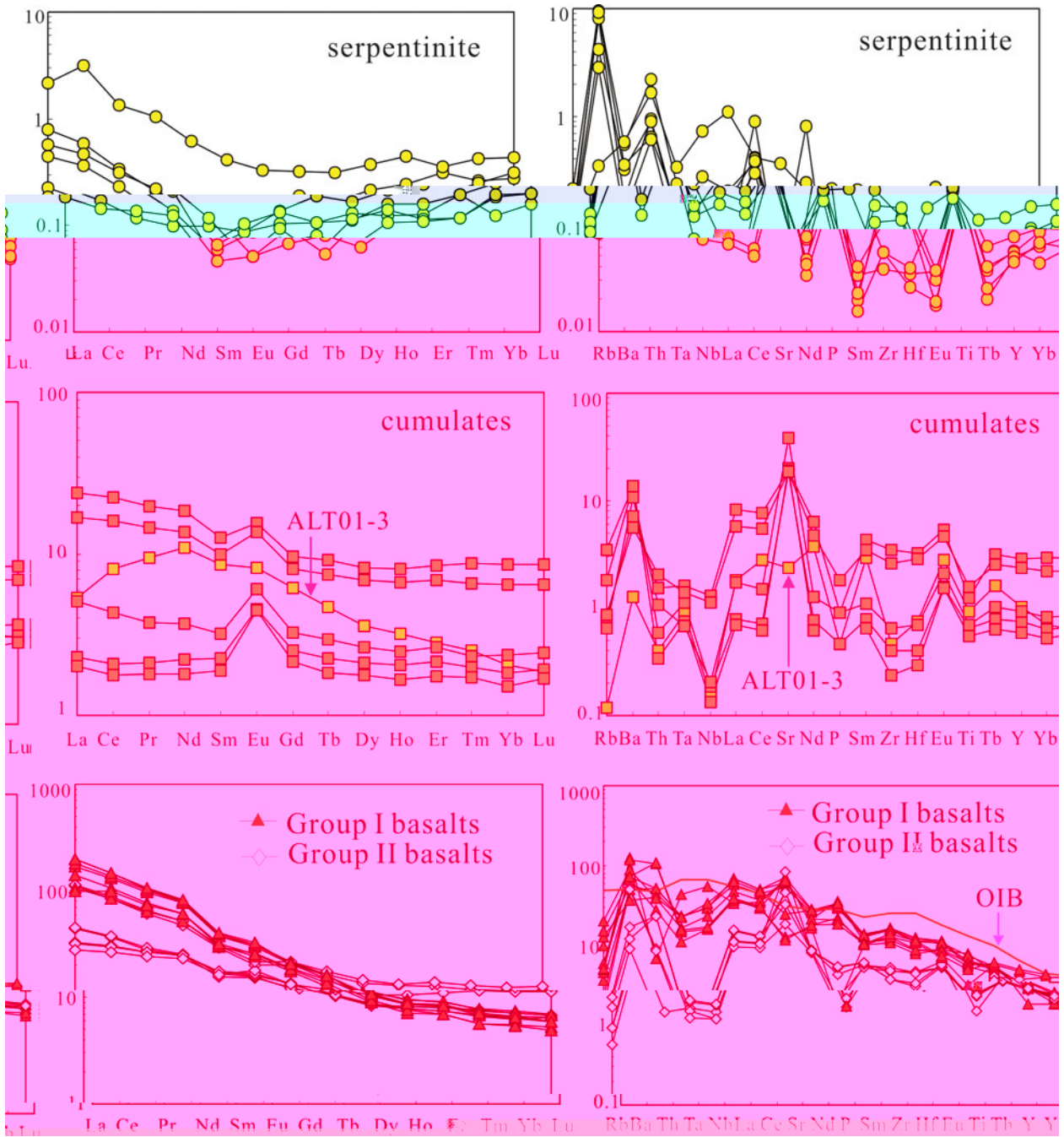


Fig. 1. REE and trace element patterns for serpentinite (top row), cumulates (middle row) and Group I (triangles) and Group II (diamonds) basalts (bottom row). The patterns are normalized to the primitive mantle (PM) composition of Sun & McDonough (1989).

1. The REE patterns for serpentinite (Fig. 1) show a characteristic enrichment in light REE (La, Ce, Pr, Nd) relative to heavy REE (Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu). The patterns for cumulates (Fig. 1) show a characteristic enrichment in heavy REE (Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) relative to light REE (La, Ce, Pr, Nd). The patterns for Group I basalts (triangles) and Group II basalts (diamonds) (Fig. 1) show a characteristic enrichment in light REE (La, Ce, Pr, Nd) relative to heavy REE (Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu). The patterns for Group I basalts (triangles) and Group II basalts (diamonds) (Fig. 1) show a characteristic enrichment in light REE (La, Ce, Pr, Nd) relative to heavy REE (Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu).

4. The W- and S- and Na- and zirconium (Zr) and HfO<sub>2</sub> patterns for serpentinite (Fig. 1) show a characteristic enrichment in W and S relative to Na and Zr and HfO<sub>2</sub>. The patterns for cumulates (Fig. 1) show a characteristic enrichment in Na and Zr and HfO<sub>2</sub> relative to W and S. The patterns for Group I basalts (triangles) and Group II basalts (diamonds) (Fig. 1) show a characteristic enrichment in W and S relative to Na and Zr and HfO<sub>2</sub>. The patterns for Group I basalts (triangles) and Group II basalts (diamonds) (Fig. 1) show a characteristic enrichment in W and S relative to Na and Zr and HfO<sub>2</sub>.

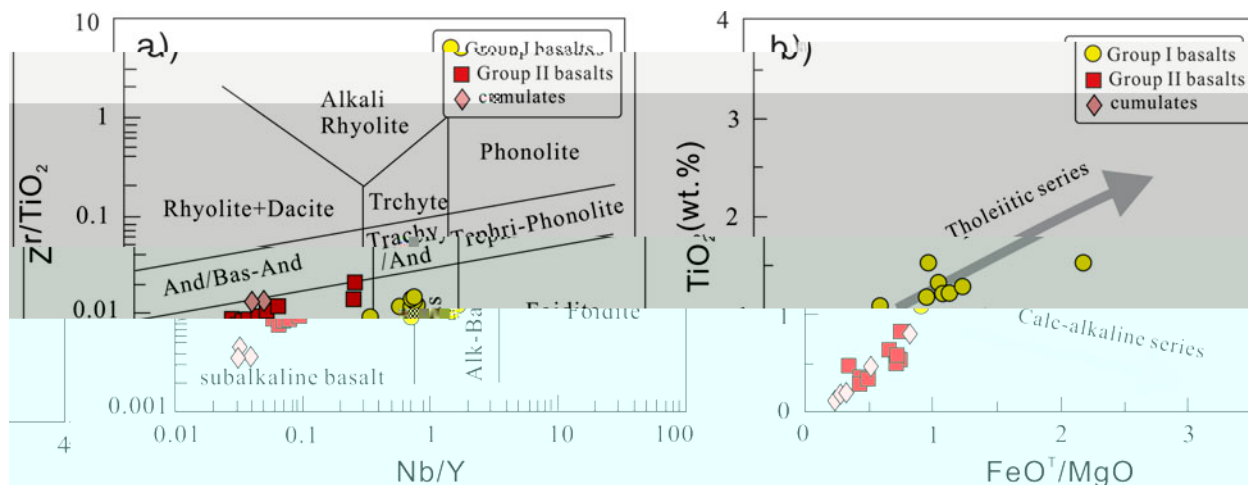


Figure 1. (a) Zr/TiO<sub>2</sub> vs Nb/Y and (b) TiO<sub>2</sub> (wt.%) vs FeO<sup>T</sup>/MgO diagrams for the Zhaheba ophiolite. The symbols represent Group I basalts (yellow circles), Group II basalts (red squares), and cumulates (red diamonds). The fields represent different tectonic settings and rock types.

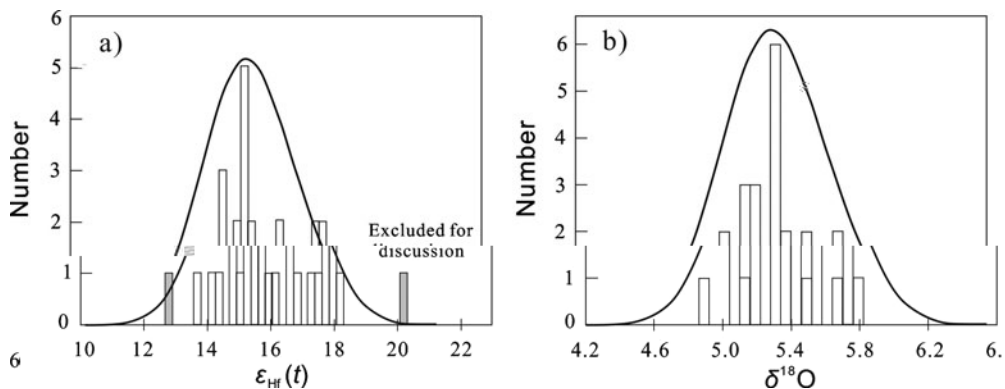


Figure 2. Histograms of (a) ε<sub>Hf</sub>(t) and (b) δ<sup>18</sup>O for the Zhaheba ophiolite. The curves represent normal distributions. The bar labeled 'Excluded for discussion' indicates data points that were not included in the main analysis.

The ε<sub>Hf</sub>(t) values for the Zhaheba ophiolite range from -1.4 to 2.2, with a mean of 1.4 ± 0.2. The δ<sup>18</sup>O values range from 4.1‰ to 5.3‰, with a mean of 5.3 ± 0.23‰. The ε<sub>Hf</sub>(t) values are consistent with a mantle source, and the δ<sup>18</sup>O values are consistent with a mantle source. The ε<sub>Hf</sub>(t) values are consistent with a mantle source, and the δ<sup>18</sup>O values are consistent with a mantle source.

### 5. Discussion

5.1. Tectonic setting. The Zhaheba ophiolite is a typical island arc ophiolite. The geochemical characteristics of the basalts, such as the high TiO<sub>2</sub> content and the high FeO<sup>T</sup>/MgO ratio, are consistent with a tholeiitic series. The ε<sub>Hf</sub>(t) values are consistent with a mantle source, and the δ<sup>18</sup>O values are consistent with a mantle source.

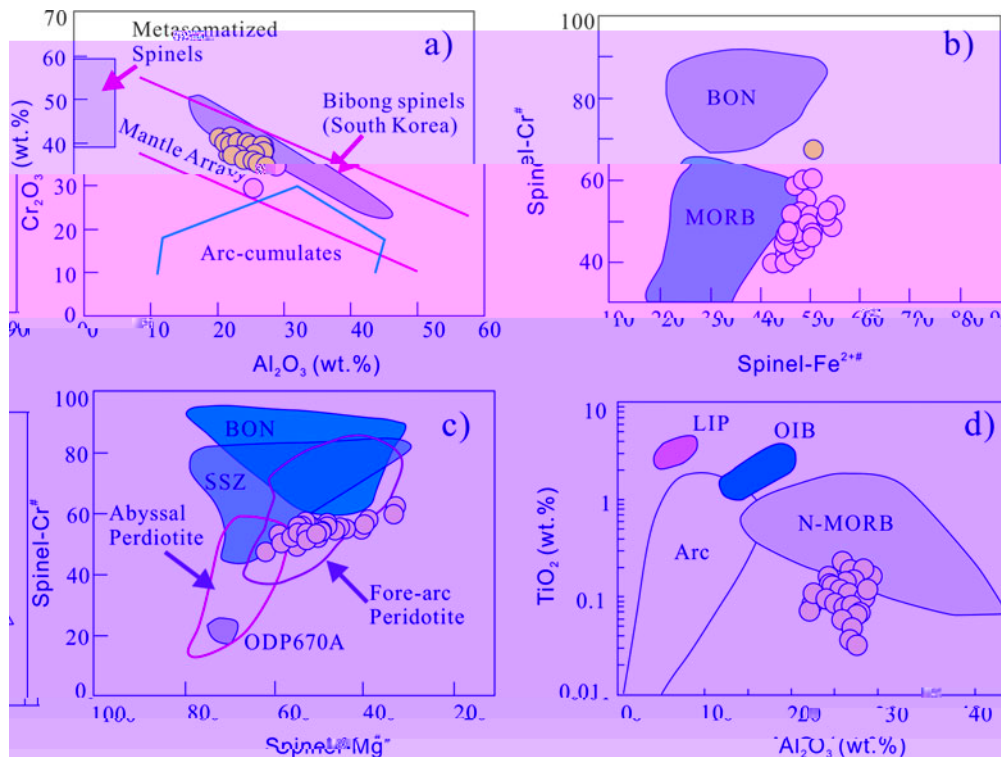


Figure 10. (a)  $Cr_2O_3$  vs  $Al_2O_3$  (wt.%) diagram showing the composition of spinels from various tectonic settings. The Mantle Array is defined by a solid line, and the Arc-cumulates are shown as a shaded region. Bibong spinels (South Korea) are plotted as orange circles. (b)  $Cr\#$  vs  $Fe^{2+}$  diagram showing the composition of spinels from BON (Basaltic Oceanic Nodule) and MORB (Mid-Ocean Ridge Basalt) settings. (c)  $Cr\#$  vs  $Mg\#$  diagram showing the composition of spinels from BON, SSZ (Spinel-Subsaturated Zone), Abyssal Peridotite, Fore-arc Peridotite, and ODP670A settings. (d)  $TiO_2$  vs  $Al_2O_3$  (wt.%) diagram showing the composition of spinels from LIP (Large Igneous Province), OIB (Ocean Island Basalt), N-MORB (Normal Mid-Ocean Ridge Basalt), and Arc settings.

(500–400 ppm) (e.g., *et al.* 2003, *et al.* 2015). The  $Cr_2O_3$  content is generally higher than 1 wt.%, and the  $Al_2O_3$  content is generally higher than 40 wt.%. The  $Cr_2O_3$  content is generally higher than 1 wt.%, and the  $Al_2O_3$  content is generally higher than 30–35 wt.%. (e.g., *et al.* 2003, *et al.* 2006).

5.b. Olivine spinel

The spinel composition is generally similar to that of the mantle spinel, with  $Cr_2O_3$  content of 1–4 wt.%,  $Al_2O_3$  content of 30–40 wt.%, and  $Cr\#$  of 0.4–0.6. The spinel composition is generally similar to that of the mantle spinel, with  $Cr_2O_3$  content of 1–4 wt.%,  $Al_2O_3$  content of 30–40 wt.%, and  $Cr\#$  of 0.4–0.6. (e.g., *et al.*, *et al.*, & *et al.*, 2002, *et al.* 2010).

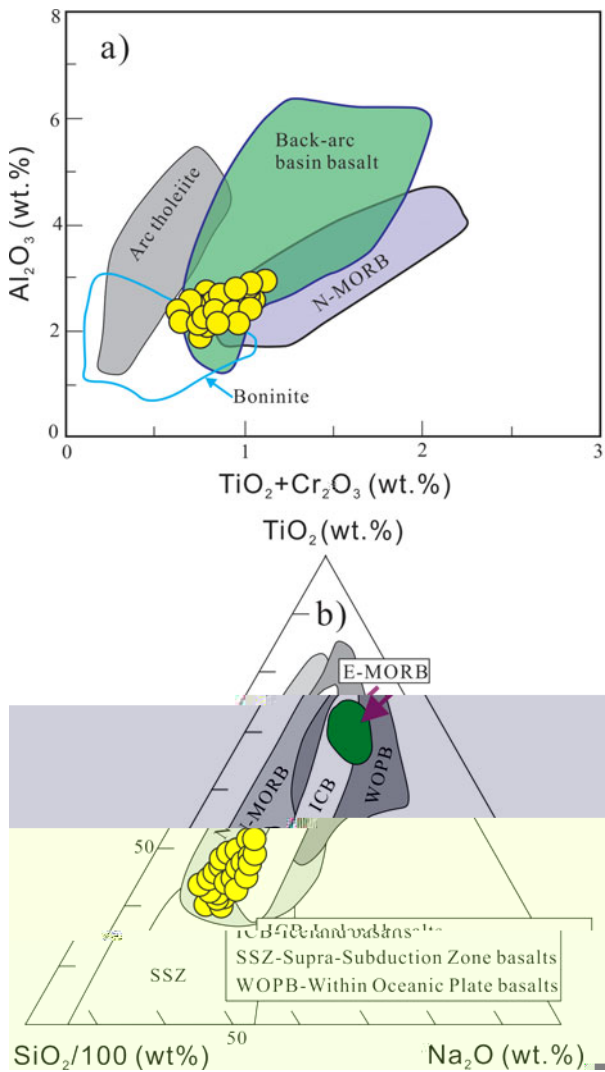


Fig. 11. (a)  $Al_2O_3$  vs  $TiO_2 + Cr_2O_3$  and  $TiO_2$  diagram for the Zhaheba ophiolite. (b)  $SiO_2/100$  vs  $Na_2O$  diagram for the Zhaheba ophiolite. The fields are defined after (1) (11, 24, 11, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100).

The Zhaheba ophiolite is characterized by a range of basaltic rocks. The geochemical data show that the basalts are enriched in light rare earth elements (LREE) and have high  $Al_2O_3$  contents, which are typical of arc tholeiites and back-arc basin basalts. The presence of boninite, a highly magnesian basalt, is also characteristic of back-arc basin settings. The ternary diagram (b) shows that the basalts fall within the fields for MORB, ICB, and WOPB, indicating a tectonic setting related to subduction zones. The SSZ field is also present, suggesting that some of the basalts may have formed in a supra-subduction zone environment.

The geochemical characteristics of the Zhaheba ophiolite basalts are consistent with a back-arc basin setting. The enrichment in LREE and high  $Al_2O_3$  contents are typical of arc tholeiites and back-arc basin basalts. The presence of boninite, a highly magnesian basalt, is also characteristic of back-arc basin settings. The ternary diagram (b) shows that the basalts fall within the fields for MORB, ICB, and WOPB, indicating a tectonic setting related to subduction zones. The SSZ field is also present, suggesting that some of the basalts may have formed in a supra-subduction zone environment.

5.c. P... D... a... b... r...

The geochemical characteristics of the Zhaheba ophiolite basalts are consistent with a back-arc basin setting. The enrichment in LREE and high  $Al_2O_3$  contents are typical of arc tholeiites and back-arc basin basalts. The presence of boninite, a highly magnesian basalt, is also characteristic of back-arc basin settings. The ternary diagram (b) shows that the basalts fall within the fields for MORB, ICB, and WOPB, indicating a tectonic setting related to subduction zones. The SSZ field is also present, suggesting that some of the basalts may have formed in a supra-subduction zone environment.





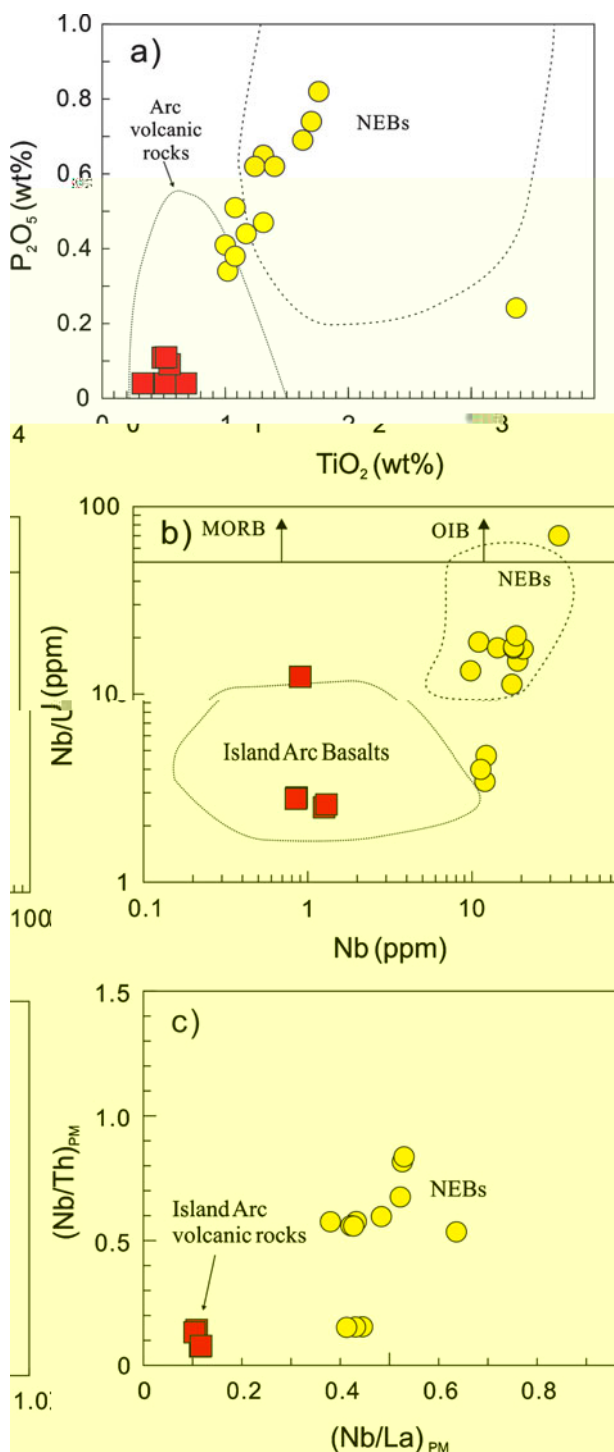


Fig. 14. (a)  $P_2O_5$  (wt%) versus  $TiO_2$  (wt%) diagram for the Zhaheba ophiolite. (b)  $Nb/La$  (ppm) versus  $Nb$  (ppm) diagram for the Zhaheba ophiolite. (c)  $(Nb/Th)_{PM}$  versus  $(Nb/La)_{PM}$  diagram for the Zhaheba ophiolite. MORB = Mid-Ocean Ridge Basalt; OIB = Ocean Island Basalt; NEBs = Nephelinitic Enriched Basalts.

The Zhaheba ophiolite is a typical island arc ophiolite. The basalts are enriched in light REE, Nb, Ta, and Ti, and depleted in heavy REE, Zr, Hf, and Pb. The Nb-Ta concentrations are high, indicating an island arc setting. The  $(Nb/Th)_{PM}$  ratios are also high, consistent with an island arc volcanic rock signature. The Zhaheba ophiolite is similar to other island arc ophiolites, such as the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), and the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015).

The Zhaheba ophiolite is a typical island arc ophiolite. The basalts are enriched in light REE, Nb, Ta, and Ti, and depleted in heavy REE, Zr, Hf, and Pb. The Nb-Ta concentrations are high, indicating an island arc setting. The  $(Nb/Th)_{PM}$  ratios are also high, consistent with an island arc volcanic rock signature. The Zhaheba ophiolite is similar to other island arc ophiolites, such as the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), and the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015).

(1) The Zhaheba ophiolite is a typical island arc ophiolite. The basalts are enriched in light REE, Nb, Ta, and Ti, and depleted in heavy REE, Zr, Hf, and Pb. The Nb-Ta concentrations are high, indicating an island arc setting. The  $(Nb/Th)_{PM}$  ratios are also high, consistent with an island arc volcanic rock signature. The Zhaheba ophiolite is similar to other island arc ophiolites, such as the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), and the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015).

(2) The Zhaheba ophiolite is a typical island arc ophiolite. The basalts are enriched in light REE, Nb, Ta, and Ti, and depleted in heavy REE, Zr, Hf, and Pb. The Nb-Ta concentrations are high, indicating an island arc setting. The  $(Nb/Th)_{PM}$  ratios are also high, consistent with an island arc volcanic rock signature. The Zhaheba ophiolite is similar to other island arc ophiolites, such as the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), and the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015).

(3) The Zhaheba ophiolite is a typical island arc ophiolite. The basalts are enriched in light REE, Nb, Ta, and Ti, and depleted in heavy REE, Zr, Hf, and Pb. The Nb-Ta concentrations are high, indicating an island arc setting. The  $(Nb/Th)_{PM}$  ratios are also high, consistent with an island arc volcanic rock signature. The Zhaheba ophiolite is similar to other island arc ophiolites, such as the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015), and the Zhaheba ophiolite in the Zhaheba area (Li et al., 2015).

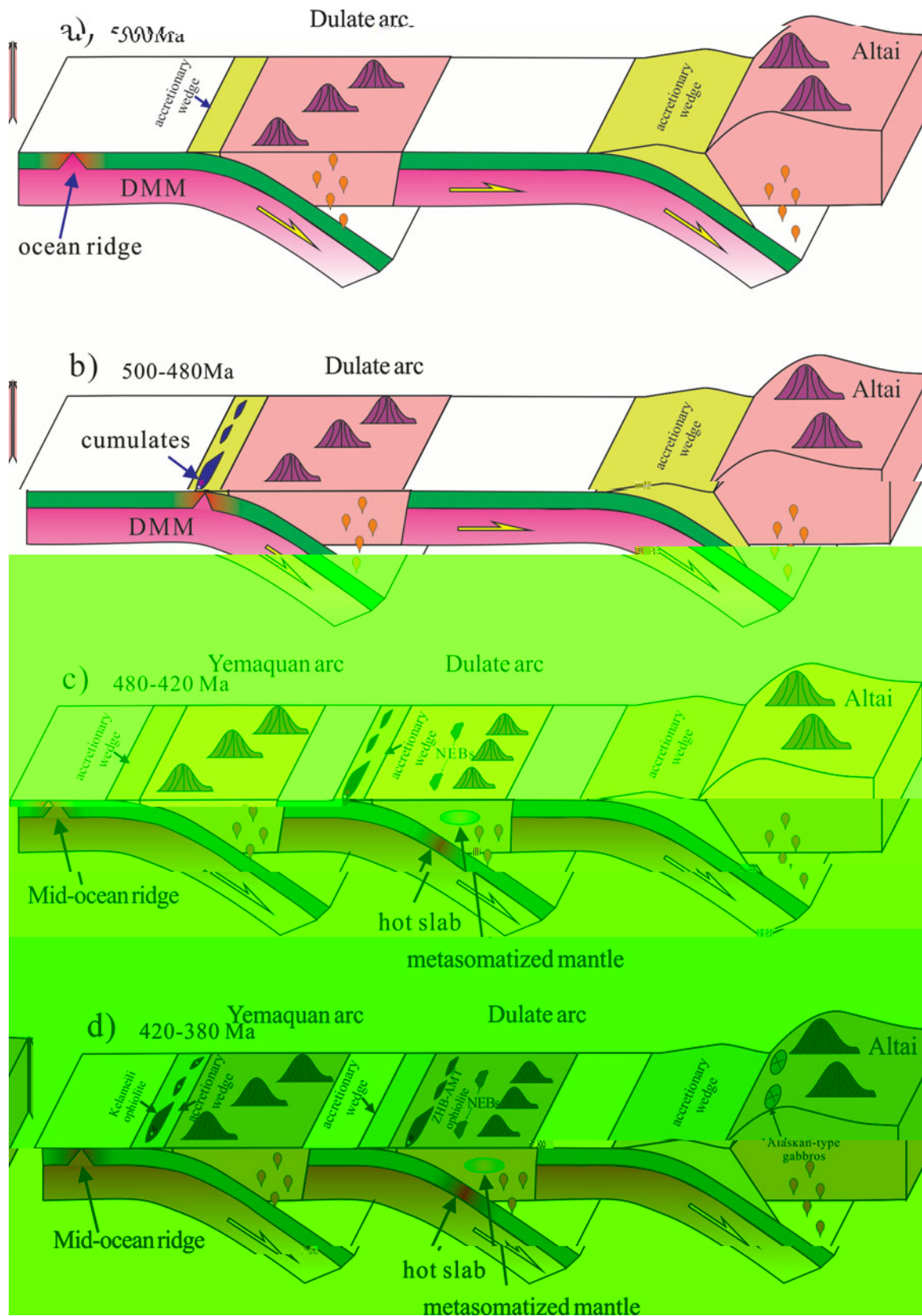


Figure 15. (a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o) (p) (q) (r) (s) (t) (u) (v) (w) (x) (y) (z) (aa) (ab) (ac) (ad) (ae) (af) (ag) (ah) (ai) (aj) (ak) (al) (am) (an) (ao) (ap) (aq) (ar) (as) (at) (au) (av) (aw) (ax) (ay) (az) (ba) (bb) (bc) (bd) (be) (bf) (bg) (bh) (bi) (bj) (bk) (bl) (bm) (bn) (bo) (bp) (bq) (br) (bs) (bt) (bu) (bv) (bw) (bx) (by) (bz) (ca) (cb) (cc) (cd) (ce) (cf) (cg) (ch) (ci) (cj) (ck) (cl) (cm) (cn) (co) (cp) (cq) (cr) (cs) (ct) (cu) (cv) (cw) (cx) (cy) (cz) (da) (db) (dc) (dd) (de) (df) (dg) (dh) (di) (dj) (dk) (dl) (dm) (dn) (do) (dp) (dq) (dr) (ds) (dt) (du) (dv) (dw) (dx) (dy) (dz) (ea) (eb) (ec) (ed) (ee) (ef) (eg) (eh) (ei) (ej) (ek) (el) (em) (en) (eo) (ep) (eq) (er) (es) (et) (eu) (ev) (ew) (ex) (ey) (ez) (fa) (fb) (fc) (fd) (fe) (ff) (fg) (fh) (fi) (fj) (fk) (fl) (fm) (fn) (fo) (fp) (fq) (fr) (fs) (ft) (fu) (fv) (fw) (fx) (fy) (fz) (ga) (gb) (gc) (gd) (ge) (gf) (gg) (gh) (gi) (gj) (gk) (gl) (gm) (gn) (go) (gp) (gq) (gr) (gs) (gt) (gu) (gv) (gw) (gx) (gy) (gz) (ha) (hb) (hc) (hd) (he) (hf) (hg) (hh) (hi) (hj) (hk) (hl) (hm) (hn) (ho) (hp) (hq) (hr) (hs) (ht) (hu) (hv) (hw) (hx) (hy) (hz) (ia) (ib) (ic) (id) (ie) (if) (ig) (ih) (ii) (ij) (ik) (il) (im) (in) (io) (ip) (iq) (ir) (is) (it) (iu) (iv) (iw) (ix) (iy) (iz) (ja) (jb) (jc) (jd) (je) (jf) (jg) (jh) (ji) (jj) (jk) (jl) (jm) (jn) (jo) (jp) (jq) (jr) (js) (jt) (ju) (jv) (jw) (jx) (jy) (jz) (ka) (kb) (kc) (kd) (ke) (kf) (kg) (kh) (ki) (kj) (kk) (kl) (km) (kn) (ko) (kp) (kq) (kr) (ks) (kt) (ku) (kv) (kw) (kx) (ky) (kz) (la) (lb) (lc) (ld) (le) (lf) (lg) (lh) (li) (lj) (lk) (ll) (lm) (ln) (lo) (lp) (lq) (lr) (ls) (lt) (lu) (lv) (lw) (lx) (ly) (lz) (ma) (mb) (mc) (md) (me) (mf) (mg) (mh) (mi) (mj) (mk) (ml) (mm) (mn) (mo) (mp) (mq) (mr) (ms) (mt) (mu) (mv) (mw) (mx) (my) (mz) (na) (nb) (nc) (nd) (ne) (nf) (ng) (nh) (ni) (nj) (nk) (nl) (nm) (nn) (no) (np) (nq) (nr) (ns) (nt) (nu) (nv) (nw) (nx) (ny) (nz) (oa) (ob) (oc) (od) (oe) (of) (og) (oh) (oi) (oj) (ok) (ol) (om) (on) (oo) (op) (oq) (or) (os) (ot) (ou) (ov) (ow) (ox) (oy) (oz) (pa) (pb) (pc) (pd) (pe) (pf) (pg) (ph) (pi) (pj) (pk) (pl) (pm) (pn) (po) (pp) (pq) (pr) (ps) (pt) (pu) (pv) (pw) (px) (py) (pz) (qa) (qb) (qc) (qd) (qe) (qf) (qg) (qh) (qi) (qj) (qk) (ql) (qm) (qn) (qo) (qp) (qq) (qr) (qs) (qt) (qu) (qv) (qw) (qx) (qy) (qz) (ra) (rb) (rc) (rd) (re) (rf) (rg) (rh) (ri) (rj) (rk) (rl) (rm) (rn) (ro) (rp) (rq) (rr) (rs) (rt) (ru) (rv) (rw) (rx) (ry) (rz) (sa) (sb) (sc) (sd) (se) (sf) (sg) (sh) (si) (sj) (sk) (sl) (sm) (sn) (so) (sp) (sq) (sr) (ss) (st) (su) (sv) (sw) (sx) (sy) (sz) (ta) (tb) (tc) (td) (te) (tf) (tg) (th) (ti) (tj) (tk) (tl) (tm) (tn) (to) (tp) (tq) (tr) (ts) (tt) (tu) (tv) (tw) (tx) (ty) (tz) (ua) (ub) (uc) (ud) (ue) (uf) (ug) (uh) (ui) (uj) (uk) (ul) (um) (un) (uo) (up) (uq) (ur) (us) (ut) (uu) (uv) (uw) (ux) (uy) (uz) (va) (vb) (vc) (vd) (ve) (vf) (vg) (vh) (vi) (vj) (vk) (vl) (vm) (vn) (vo) (vp) (vq) (vr) (vs) (vt) (vu) (vv) (vw) (vx) (vy) (vz) (wa) (wb) (wc) (wd) (we) (wf) (wg) (wh) (wi) (wj) (wk) (wl) (wm) (wn) (wo) (wp) (wq) (wr) (ws) (wt) (wu) (wv) (ww) (wx) (wy) (wz) (xa) (xb) (xc) (xd) (xe) (xf) (xg) (xh) (xi) (xj) (xk) (xl) (xm) (xn) (xo) (xp) (xq) (xr) (xs) (xt) (xu) (xv) (xw) (xx) (xy) (xz) (ya) (yb) (yc) (yd) (ye) (yf) (yg) (yh) (yi) (yj) (yk) (yl) (ym) (yn) (yo) (yp) (yq) (yr) (ys) (yt) (yu) (yv) (yw) (yx) (yy) (yz) (za) (zb) (zc) (zd) (ze) (zf) (zg) (zh) (zi) (zj) (zk) (zl) (zm) (zn) (zo) (zp) (zq) (zr) (zs) (zt) (zu) (zv) (zw) (zx) (zy) (zz)



- ... & ... 2011. ...  
*Geological Bulletin of China* **30**, 150–153 ( ... )  
 ... )
- & ... 2011. ... % ...  
*Acta Geochimica et Cosmochimica* **75**, 504–512.
- ... & ... 2001. ...  
*Nature* **410**, 6–11.
- ... & ... 2002. ...  
*Chemical Geology* **182**, 22–35.
- ... & ... 1996. ...  
*Journal of Geophysical Research: Solid Earth* (1978–2012) **101**, 11–31.
- ... & ... 2000. ...  
*Contributions to Mineralogy and Petrology* **139**, 20–26.
- ... & ... 2012. ...  
*Geological Bulletin of China* **31**, 126 ( ... )
- ... & ... 2014. ...  
*Chinese Science Bulletin (Chinese Version)* **59**, 2213–2221.
- ... & ... 2000. ...  
*Transactions of the Royal Society of Edinburgh: Earth Sciences* **91**, 1–13.
- ... & ... 2010. ...  
*Journal of Petrology* **31**, 6–11.
- ... & ... 2003. ...  
*Earth Science Frontier* **10**, 43–56 ( ... )
- ... & ... 2001. ...  
*Journal of Petrology* **42**, 655–671.
- ... & ... 2001. ...  
*Nature* **380**, 23–40.
- ... & ... 2000. ...  
*Tectonophysics* **326**, 255–261.
- ... & ... 2010a. ...  
*Lithos* **114**, 1–15.
- ... & ... 2004. ...  
*Geological Magazine* **141**, 225–231.
- ... & ... 2010b. ...  
*Geostandards and Geoanalytical Research* **34**, 11–34.
- ... & ... 2013. ...  
*Chinese Science Bulletin* **58**, 464–474.
- ... & ... 2000. ...  
*Lithos* **113**, 2–4–1.
- ... & ... 2010. ...  
*Chinese Science Bulletin* **55**, 1535–1546.
- ... 2003. *User's Manual for Isoplot 3.00: A Geochronological Toolkit for Microsoft Excel*. ...  
 4, 3–11.
- ... & ... 2015. ...  
*Gondwana Research*, 1–6. (2015).  
[10.1016/j.gr.2015.04.004](https://doi.org/10.1016/j.gr.2015.04.004).
- ... & ... 2014. ...  
*American Journal of Science* **274**, 32–355.
- ... & ... 1995. ...  
*Geology* **23**, 51–54.
- ... 1991. *Structure of Ophiolites and Dynamics of Oceanic Lithosphere*. ...  
 36–11.
- ... 1991. ...  
*Journal of Petrology* **38**, 104–114.
- ... & ... 2000 a. ...  
*Acta Petrologica Sinica* **25**, 16–24 ( ... )
- ... & ... 2000 b. ...  
*Acta Petrologica Sinica* **25**, 14–21 ( ... )
- ... & ... 2000. ...  
*Acta Petrologica Sinica* **23**, 162–174 ( ... )
- ... & ... 2002. ...  
*Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 176 ( ... )  
 11, 1–60.

2000. *Chinese Science Bulletin* **14**, 21–6.

2010. *Lithos* **117**, 1–20.

2000. *Journal of Asian Earth Sciences* **30**, 666–5.

2011. *Lithos* **100**, 14–4.

2014. *Elements* **10**, 101.

2001. *Contribution to Mineralogy and Petrology* **141**, 36–52.

2013. *Gondwana Research* **24**, 3–2–411.

2011. *Journal of Petrology* **37**, 6–3–26.

2013. *Precambrian Research* **231**, 301–24.

2012. *Precambrian Research* **192–195**, 1–0–20.

2011. *Philosophical Transactions of the Royal Society of London* **335**, 3–2.

2015. *Nature* **377**, 5–5–600.

2014. *Lithos* **206–207**, 234–51.

2002. *Reviews of Geophysics* **40**, 3–1–3–3.

2000. *Journal of Petrology* **37**, 6–3–26.

2000. *Science in China Series D – Earth Sciences* **52**, 1345–5.

2000. *Magmatism in the Ocean Basin* (ed. by ...), 11.52–4.

2000. *Chemical Geology* **247**, 352–3.

2000. *Acta Petrologica Sinica* **23**, 1–33–44.

2006. *Contributions to Mineralogy and Petrology* **133**, 1–11.

2006. *Journal of Geology* **114**, 35–51.

2000. *Lithos* **110**, 35–2.

2012. *Earth-Science Reviews* **113**, 303–41.

2006. *Chemical Geology* **20**, 325–43.

2002. *Journal of Geology* **110**, 1–3.

2006. *Geology in China* **33**, 4–6–6.

2014. *Geoscience Frontiers* **5**, 525–36.

2000. *Journal of Asian Earth Sciences* **32**, 102–1.

2013. *Gondwana Research* **23**, 1316–41.

2004. *Journal of Geological Society, London* **161**, 33–42.

200. a. & . 2006. *Chemical Geology* **242**, 22–31.
- b. & . 2006. *Acta Geologica Sinica* **80**, 254–63 (in Chinese with English abstract).
- c. & . 2003. *Chinese Science Bulletin* **48**, 2231–5.
- d. & . 2013. *Lithos* **179**, 263–4.
- e. & . 2012. *Journal of Asian Earth Sciences* **52**, 11–33.
- f. & . 200. *Acta Petrologica Sinica* **24**, 1054–5 (in Chinese with English abstract).
- g. & . 196. *Annual Review of Earth and Planetary Sciences* **14**, 43–51.
- h. & . 2015. *Journal of Asian Earth Sciences* **113**, 5–10.
- i. & . 2012. *Gondwana Research* **21**, 246–65.
- j. & . 200. *American Journal of Sciences* **309**, 221–30.
- k. & . 1993. *Regional Geology of the Xinjiang Uygur Autonomous Region*. Geological Survey of China, Beijing, 11.2: 145 (in Chinese).
- l. & . 2015. *Journal of Asian Earth Sciences* **113**, 5–10.
- m. & . 2012. *Gondwana Research* **21**, 246–65.
- n. & . 200. *Acta Petrologica Sinica* **24**, 1054–5 (in Chinese with English abstract).
- o. & . 196. *Annual Review of Earth and Planetary Sciences* **14**, 43–51.
- p. & . 2003. *Chinese Science Bulletin* **48**, 2231–5.
- q. & . 2013. *Lithos* **179**, 263–4.
- r. & . 2012. *Journal of Asian Earth Sciences* **52**, 11–33.
- s. & . 200. *Acta Petrologica Sinica* **24**, 1054–5 (in Chinese with English abstract).
- t. & . 196. *Annual Review of Earth and Planetary Sciences* **14**, 43–51.