Geol. Mag. **154** (3), 2017, pp. 419–440. © Cambridge University Press 2016
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(*Received* 1 2015 *accepted* 2016 *first published online* 1 2016)

Ab ac

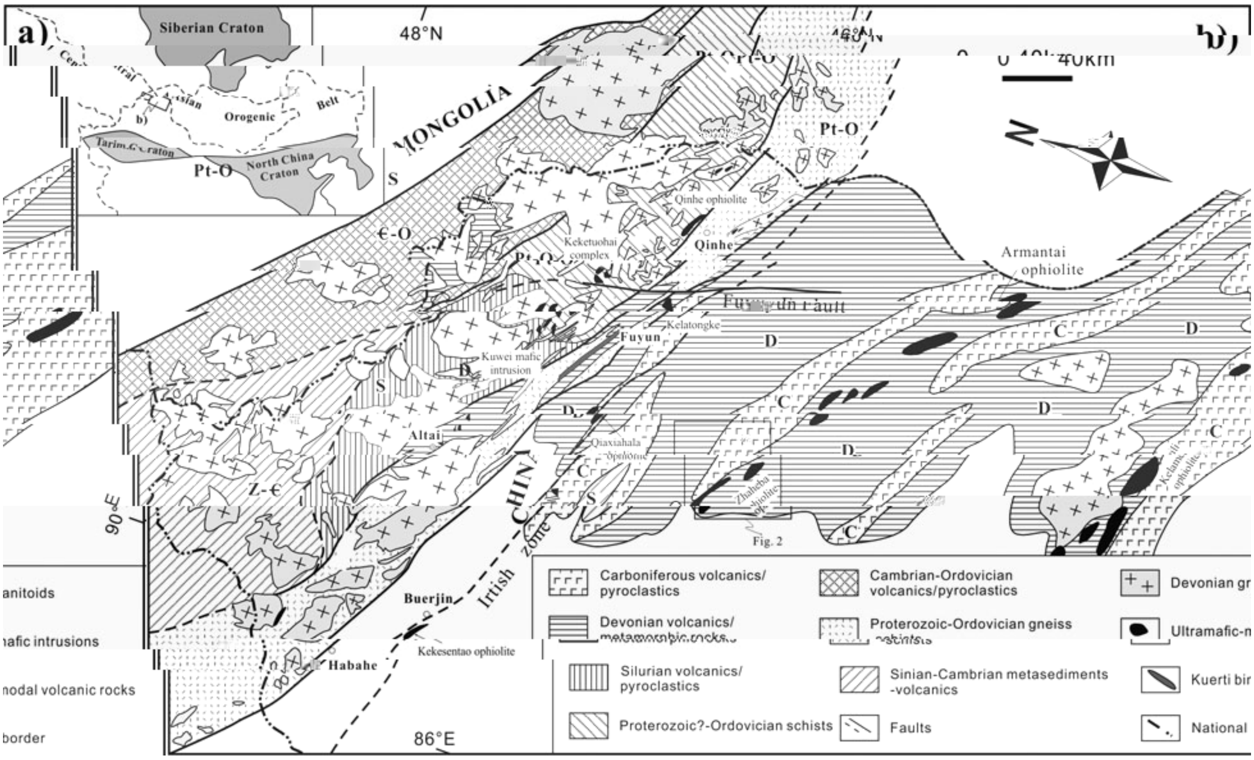
~4 5 ~400 ε (*t*) (13 20) δ (+5.3 ‰)

1. I c

et al. 200 & 200 et al. 2012 et al. 2012, 2013 et al. 2013), et al. 200 et al. 200 a). 1 , 1 3 et al. 2000 & , 2003 et al. 200 , 2014). & (2011) (2014)

1 6

& , 2000 et al. 2002 1 3 et al. 2004, 200 a) et al. 200 d,b & , 2012). et al. 2003 et al. 2003 et al. 200 a)


a)
Siberian Craton
Central Asian Orogenic Belt
Tarim Craton
North China Craton
Pt-O
48°N
b)
0 40km
MONGOLIA
S
€-O
Pt-O
Qinhe ophiolite
Qinhe
Keketuohai complex
Armantai ophiolite
Fuyun fault
Kelatongke
Fuyun
Kuwei mafic intrusion
D
C
Altai
Z-€
90°E
Qiaxiahala ophiolite
Zhaheba ophiolite
Fig. 2
Kelameili ophiolite
CHINA
Irtish zone
Buerjin
Kekesentao ophiolite
Habahe
86°E
Carboniferous volcanics/pyroclastics
Cambrian-Ordovician volcanics/pyroclastics
Devonian volcanics/metamorphic rocks
Proterozoic-Ordovician gneiss schists
Silurian volcanics/pyroclastics
Sinian-Cambrian metasediments -volcanics
Proterozoic?-Ordovician schists
Faults
Kuerti bir
National
Ultramafic-m
Devonian gr
anitoids
nafic intrusions
nodal volcanic rocks
border

1. (a) ... et al. 200).

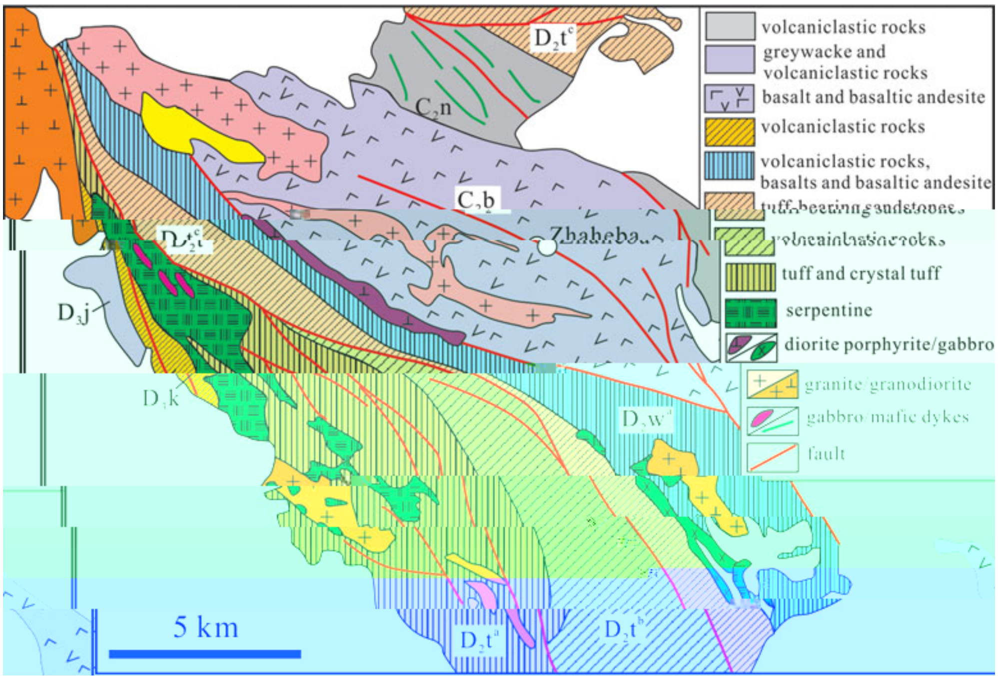


Fig. 2. ([illegible]) [illegible] et al. 200 , 200 [illegible] , 1 [illegible] 3).

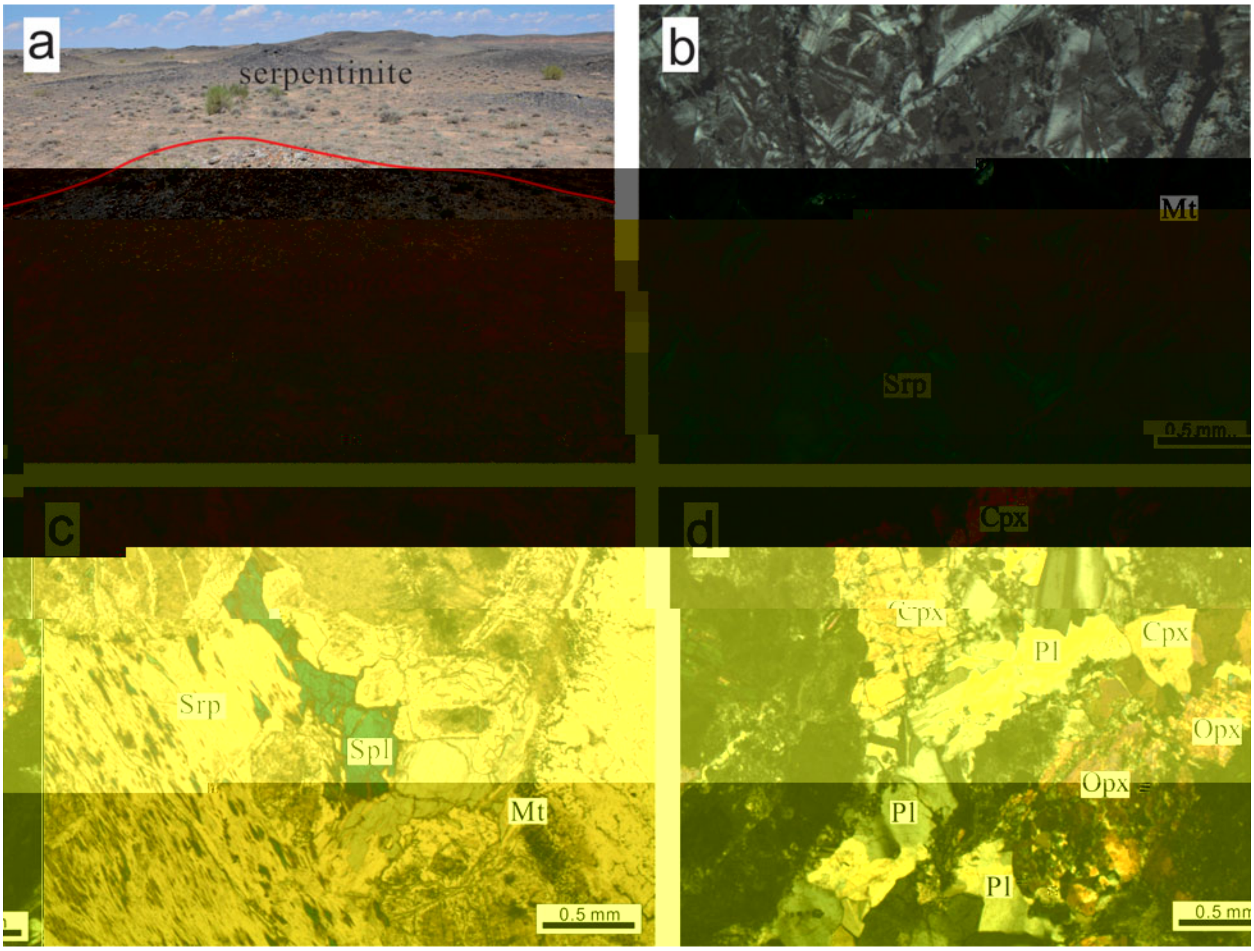


Fig. 3. ([illegible]) [illegible] 0 % [illegible]

3. A a ca c

3.a. Z c U Pb a a H O a a

(2013 01, 46° 32′ 51 ° 2′ 4) (2013 02, 46° 33′ 2 ° 2′ 36)

et al. (2011) *et al.* 2010) (2003). 5 % 1 2 12 0 *et al.* (2010*a*). = 0.0020052), δ 5.31 ‰ *et al.* 2010*b*). δ 5.44 ± 0.21 ‰ (2), 5.4 ± 0.2 ‰ *et al.* 2013). 3

3.b. M a a a

00 15 15

20 4 5

3.c. W - c a a

100 *et al.* (2004). 2 %. 6000 *et al.* (2004) 50 3 -1, -2 -2, -1 3, 3 5%. 1. 3 *et al.* (2004). 143 /144 = 0.11 4 146 /144 = 0. 21 0. 102 143 /144 0. 0506 -1, 0.512104 0.5126 -1. 2.

4. A a ca

4.a. Z c U Pb a

100 150 μ 1 1 2 1. . 4). (22 123) 5) 0.4 0. 30 4 5. ± 2.5

Table 1. [illegible]

[illegible]	2013[illegible]01-1 [illegible]	2013[illegible]01-3	20132[illegible]01-4 [illegible]	2013[illegible]01-5 [illegible]	2013[illegible]01-6 [illegible]	2013[illegible]01- [illegible]	2013[illegible]01- [illegible]	2013[illegible]01[illegible] 1	2013[illegible]01[illegible] 2	2013[illegible]01[illegible] 4
					Major elements (%)					
[illegible]$_2$	3 . 0	4 .20	3 .41	3 .62	3 .22	3 . 2	3 .05	4 .22	46.4	51.2
[illegible]$_2$	0.05	0.20	0.05	0.05	0.04	0.05	0.04	0.14	0.12	0.2
[illegible]$_3$	0.61	1, 6	1.04	0.6	0, 0	0. 4	0, 0	1 .2	1 .64	1 .33
[illegible]$_3$	.44	4.6	.	.36	.5	.16	. 4	3.6	3.24	3.
[illegible]	0.0	0.10	0.11	0.11	0.11	0.0	0.11	0.0	0.0	0.0
[illegible]	3 .21	24.5	3 . 2	3 .	3 .0	3 .31	3 .44	10.04	.03	5.

[illegible] 1. [illegible]

[illegible]	2013 [illegible] 01-1	2013 [illegible] 01-3	2013 [illegible] 01-4	2013 [illegible] 01-5	2013 [illegible] 01-6	2013 [illegible] 01-	2013 [illegible] 01-	2013 [illegible] 01 1	2013 [illegible] 01 2	2013 [illegible] 01 4
[illegible]	0.005	0.064	0.00	0.005	0.00	0.003	0.003	0.051	0.044	0.222
[illegible]	0.021	0.34	0.044	0.042	0.0 2	0.031	0.033	0.310	0.25	1.450
[illegible]	0.004	0.04	0.00	0.00	0.011	0.005	0.005	0.04	0.043	0.21
[illegible]	0.011	0.232	0.036	0.044	0.012	0.034	0.00	0.123	0.0 0	0. 3
[illegible]	0.0 0	0.036	0.03	0.03	0.06	0.026	0.025	0.046	0.031	0.06
[illegible]	0.26	1. 10	6.600	1. 0	0. 3	0.233	1.150	1.5 0	0.516	0.1 5
[illegible]	0.406	0.0 2	0.12	0.112	0.0	0.1	0.054	0.16	0.1 1	0.6 5
[illegible]	0.046	0.034	0.014	0.02	0.050	0.030	0.010	0.050	0.02	0.130
[illegible]	0.1 1	0.144	0.203	0.364	0.042	0.0 4	0.0	0.066	0.042	0.0 3
[illegible]	2013 [illegible] 01 5	2013 [illegible] 01 6	2013 [illegible] 01 (1)	2013 [illegible] 01 (1)	2013 [illegible] 01 (1)	2013 [illegible] 03 2 (1)	2013 [illegible] 03 3 (1)	2013 [illegible] 03 4 (1)	2013 [illegible] 03 5 (1)	2013 [illegible] 01 3 (2)
Major elements (%)										
[illegible] 2	4 .1	45.	4 .	53.1	51. 1	50.40	50.54	50.52	51.22	52.3
[illegible] 2	0.34	0.15	1.40	1.24	1.31	1. 0	1.63	1.31	1.1	0.33
[illegible] 3	1	1 .5	16.5	16.1	15. 3	15.	16. 6	15.55	15.4	1 .61
[illegible] 3	4.52	3.34	.	.11	.43	.0	.50	.42	. 2	3.44
[illegible]	0.0	0.0	0.11	0.10	0.11	0.13	0.11	0.14	0.12	0.0
[illegible]	6.	.42	4. 0	4.2	4.41	5.	3.2	6.06	.14	4.
[illegible]	11.03	12.61	6.22	5. 5	6.3	6. 5	4.52	.4	.26	0
[illegible]	4. 6	.3	. 2	.3	.00	4.52	.31	4. 0	4.0	.11
[illegible]	0.13	0.11	0.3	0.31	0.42	2.04	0.33	1.2	2.03	0.1
[illegible] 5	0.04	0.02	0.62	0.62	0.65	0. 4	0.6	0.4	0.44	0.04
[illegible]	3. 2	3.26	4.24	2.54	2. 3	2.2	5.14	2.65	1. 3	2.
[illegible]	. 5	. 2	. 6	. 0	.4	.40	. 1	.6	.6	. 1
[illegible]	4.	.4	.11	. 0	.42	6.56	.64	6.0	6.11	.2
[illegible] #	5	1	55	54	54	56	41	56	64	4
Trace elements (ppm)										
[illegible]	.0	4. 5	1.16	1.12	1.4	.0	40.4	5.2	6. 2	5. 1
[illegible]	0.22	0.135	1.2 4	1.6 3	1.316	1. 53	1.034	1.100	0.5 5	0.62
[illegible]	25.0	23.	1 .6	1 .5	1 .5	.5	1 .2	25.2	1	1 .0
[illegible]	11	3.	1 6	166	1 2	22	22	254	1	5.
[illegible]	34.	163	60.5	62.6	64.1	116	1	0.	203	23.
[illegible]	24.2	21.6	26.	23.6	24.6	2 .	2 .5	2 .0	2 .0	16.4
[illegible]	4.	1 5	63.6	50.	51.4	6.	2 .	5 .3	132	1.1
[illegible]	52. 4	55.5	[illegible]							

-61212121. (23.) 5.3(21.6)-6 .2(0.34)-61 240. 34.2(254)-643122.1(-612 - .46 2 0 30 . 5 6.26.22)-6240 .2 (15.55)-56 .4(3. 4)-56 4 1 53601 -1.0555( )-

[illegible] 1. [illegible]

[illegible]	2013[illegible]01 5	2013[illegible]01 6	2013[illegible]01 (1)	2013[illegible]01 (1)	2013[illegible]01 (1)	2013[illegible]03 2 (1)	2013[illegible]03 3 (1)	2013[illegible]03 4 (1)	2013[illegible]03 5 (1)	2013[illegible]01 3 (2)
[illegible]	3[illegible]	1.20	3[illegible].60	46.[illegible]0	4[illegible].30	23.40	43.00	25.20	32[illegible]0	6.56

1.

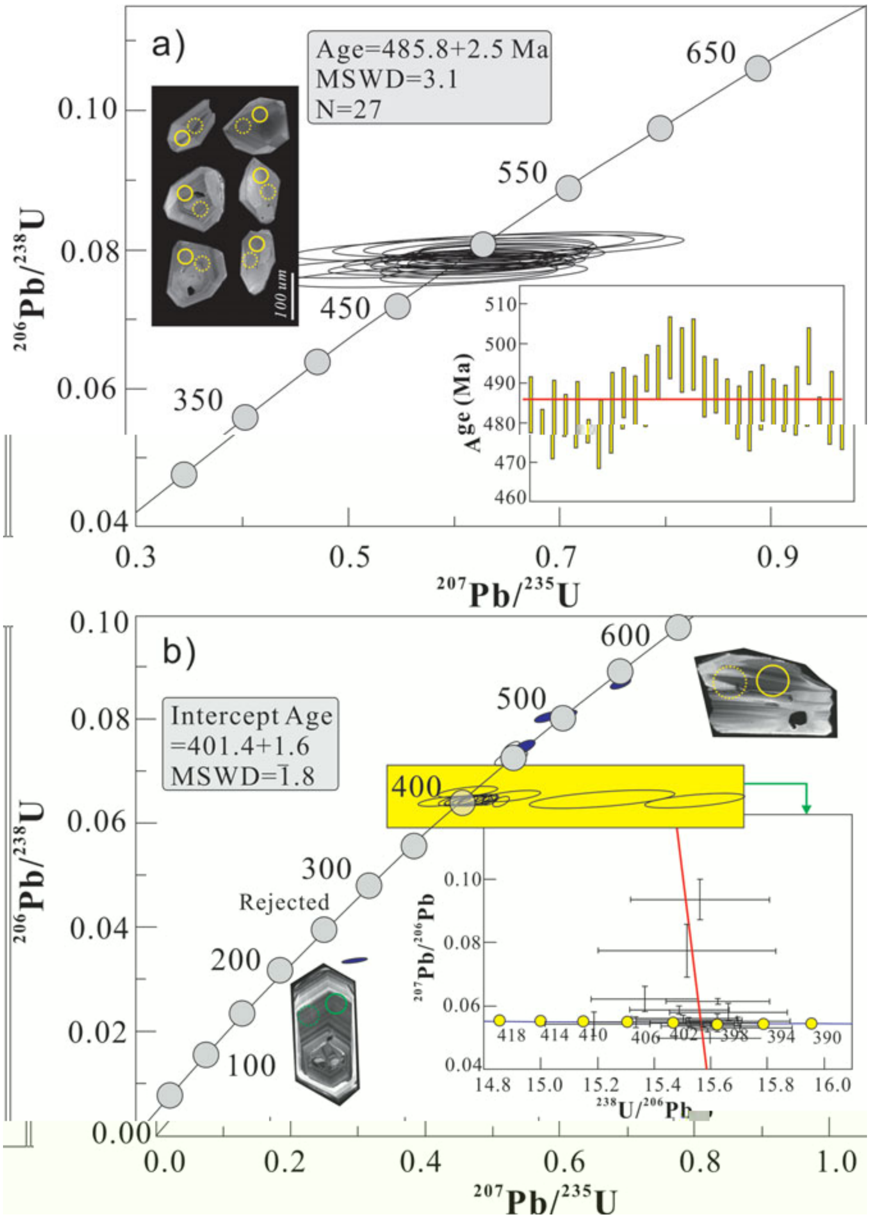
[illegible]	2013 01 11 (2)	2013 02 1 (2)	2013 02 2 (2)	2013 03 1 (1)	2013 03 6 (1)	2013 01 10 (2)	04 06 (1)	04 24 (1)	04 2 (1)	03 1 (1)
Trace elements (ppm)										
[illegible]	1 .4	36,	42.4	26.0	32.4	1 ,	/	/	/	/
[illegible]	0.3 5	0.153	0.35	1.1	0, 4	0.46	/	/	/	/
[illegible]	32.5	33.2	34.5	25.1	26.3	32.1	13.4	20.5	1 .	20.3
[illegible]	1 4	203	21	33	341	1 5	144	1 4	214	265
[illegible]	56.5	44.2	4 .	1 .	22.2	53.	15	162	214	265
[illegible]	34.	3 .5	3 .3	23.1	24.	33.	20.6	30,	2 ,	20.2
[illegible]	66.4	4.6	6.4	25.4	2 .1	66.6	.1	114	5.5	.02
[illegible]	6.4	236.4	256.	205.4	20 ,	114.20	/	/	/	/
[illegible]	4 .0	44.1	4 .0	4,	103	44.1	/	/	/	/
[illegible]	12.0	11.1	11.2	14.	13.6	12.0	/	/	/	/
[illegible]	0.5	1.420	1.0 0	3.130	3.2 0	0.5 3	4,	1 .1	22.0	1 .2
[illegible]	1	1 50	5	2 0	24	6 6	1	31	111	6
[illegible]	13.0	13.0	13.2	21.1	22,	12.5	13.2	13.2	14.	20.1
[illegible]	54,	42.3	41.5	144	154	52.	243	133	164	151
[illegible]	1.2	0. 4	0. 55	11.315	11, 5	1.25	20.2	12.	21,	12.2
[illegible]	0.025	0.030	0.02	0.051	0.052	0.02	/	/	/	/
[illegible]	0.3 1	0.2 6	0.32	1.560	1.450	0.360	/	/	/	/
[illegible]	0.2	1. 20	1.030	0.365	0.406	0.336	/	/	/	/
[illegible]	11	3 2	346	25	50	4.3	/	/	/	/
[illegible]	10. 0	. 40	.610	26.40	26. 0	10.50	30.6	32.2	40.1	26.4
[illegible]	23.00	1 , 0	1 .40	51.50	54. 0	22.30	5 .	62,	2.3	52.5
[illegible]	2. 0	2.520	2.510	5. 50	6.1 0	2.6 0	6,	. 4	10.5	6.4
[illegible]	11. 0	11. 0	11.60	22.30	24.30	11.60	2 .5	31.2	43.1	24.4
[illegible]	2.540	2. 00	2.6 0	4.4 0	4. 00	2.3 0	4.5	5.2	6.	4. 5
[illegible]	0. 6	0, 1	0, 0	1.163	1.25	0. 3	1.45	1.5	2.0	1.03
[illegible]	2.4 0	2. 13	2. 54	4.14	4.46	2.522	3.56	4.01	5.35	4.23
[illegible]	0.3 6	0.3	0.3	0.612	0.660	0.3 4	0.4	0.54	0.64	0.63
[illegible]	2.1 0	2.150	2.220	3.420	3.6 0	2.130	2.5	2.	3.24	3. 5
[illegible]	0.46	0.446	0.444	0. 2	0. 5	0.46	0.4	0.52	0.5	0.
[illegible]	1.350	1.230	1.240	2.120	2.2 0	1.310	1.32	1.3	1.45	2.25
[illegible]	0.1 0	0.16	0.1 5	0.304	0.32	0.1 4	0.1	0.2	0.2	0.34
[illegible]	1.210	1.050	1.120	1, 60	2.110	1.210	1.25	1.23	1.24	2.13
[illegible]	0.1 4	0.164	0.165	0.2 1	0.323	0.1 3	0.20	0.1	0.1	0.34
[illegible]	1.3 0	0, 41	1.040	3.2 0	3.510	1.460	5.3	3.2	4.16	3. 2
[illegible]	0.0 4	0.062	0.051	0.5	0.644	0.0	1.35	0.6	1.16	0.6
[illegible]	0.151	2.0	1.50	2. 5	1.	0.33	/	/	/	/
[illegible]	0.3 4	0.206	0.200	45.20	35.10	0.41	.13	.0	4.1	21.06
[illegible]	1, 0	0. 61	0. 1	. 60	.2 0	1, 0	4.50	2.63	3.20	.41
[illegible]	0.500	0.304	0.302	2. 30	3.4 0	0.501	1.	0.6	1.46	2.5

04 06, 04 26, 04 2 04 1 *et al.* (200 a).

2. [illegible]

[illegible]		( )	( )	/	/ (1σ)	(/)	( )	( )	14 / 144	143 / 144 (1σ)	(143 / 144)	ε (t)
2013 01 3	(2)	0.36	3 2	0.002	0. 04030(2)	0. 04015	2.4	10.	0.13 4	0.512 3 (40)	0.5124 4	6.
2013 01 10	(2)	0.5	6 6	0.0024	0. 04 5 (23)	0. 04 45	2.3	11.6	0.1235	0.512 0 (43)	0.5124 6	.1
2013 03 1	(1)	3.13	2 0	0.0335	0. 06324(20)	0. 06133	4.4	22.3	0.121	0.512533(4)	0.512214	1.
2013 03 2	(1)	2.	1320	0.0063	0. 042 (20)	0. 04255	4. 5	2 .6	0.1046	0.512 1 (51)	0.512445	6.3
2013 03 3	(1)	.06	516	0.0452	0. 0536 (43)	0. 05111	5.	36.	0.0	0.512 0 (30)	0.512450	6.4
2013 03 4	(1)	.65	14 0	0.01	0. 0422 (51)	0. 04120	4.55	24.5	0.1123	0.512 03(53)	0.51250	.5

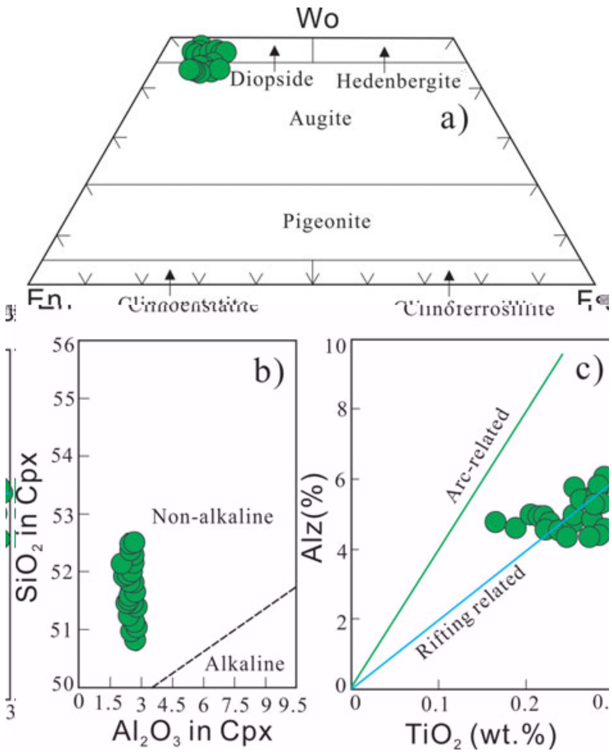
ε (*t*) = 10 000((143 /144) (*t*)/(143 /144) (*t*) − 1) ε (*t*) (/) [illegible] 401 [illegible]



4. ( ) [illegible] 1σ [illegible] 2σ ( ) [illegible]

(. 4 = 2 , / = 3.1). [illegible] 4 ± 4 [illegible] (*et al.* 2003). [illegible] 100 200 μ [illegible]

/ [illegible] 1 3. [illegible] 1 (1) [illegible] 0 % [illegible] (2) [illegible]



5.

4.b. M a c

4.b.1. Spinel composition

4.b.2. Pyroxene compositions

4.c. W - c a c

4.c.1. Serpentinites and cumulates

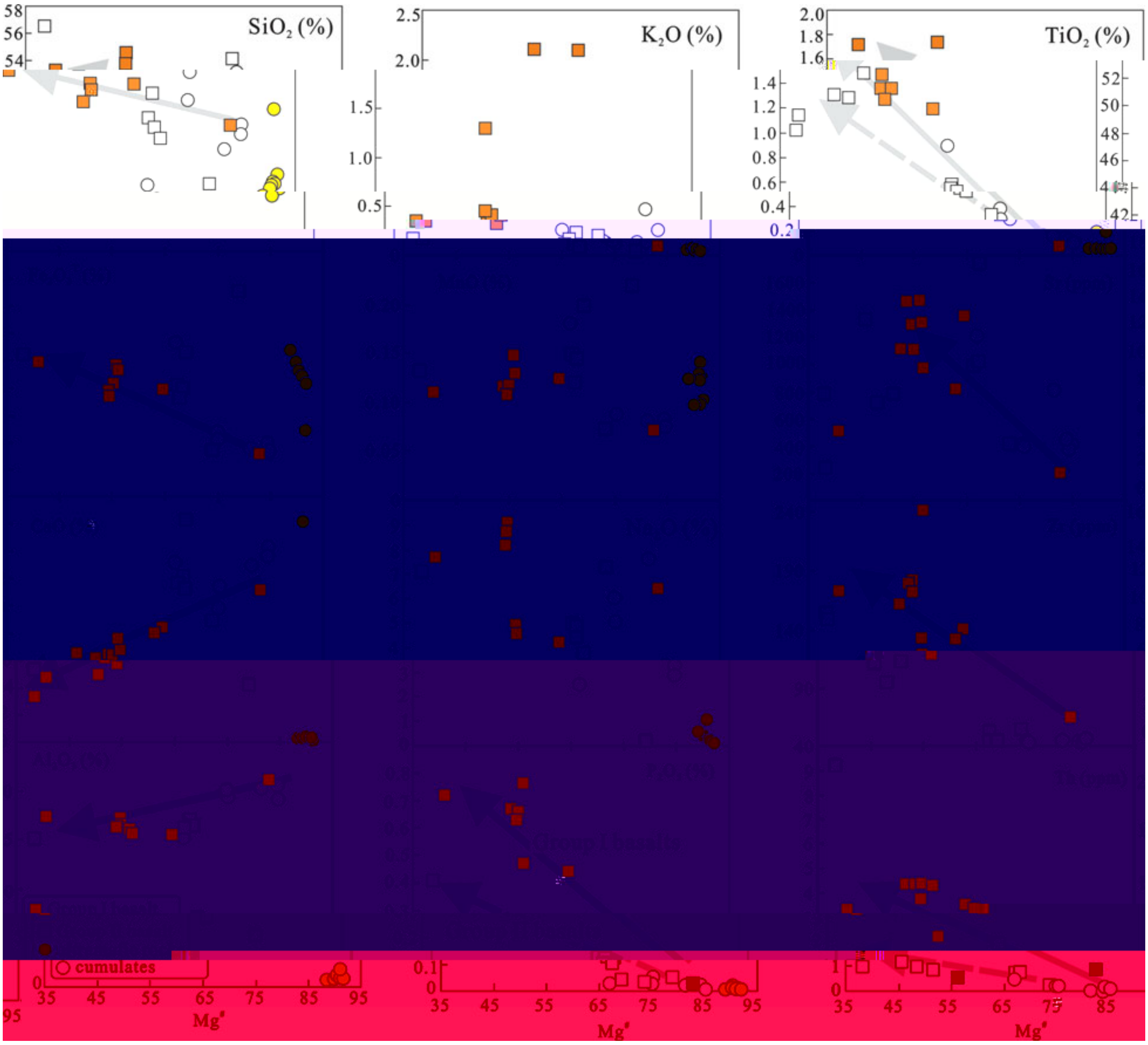


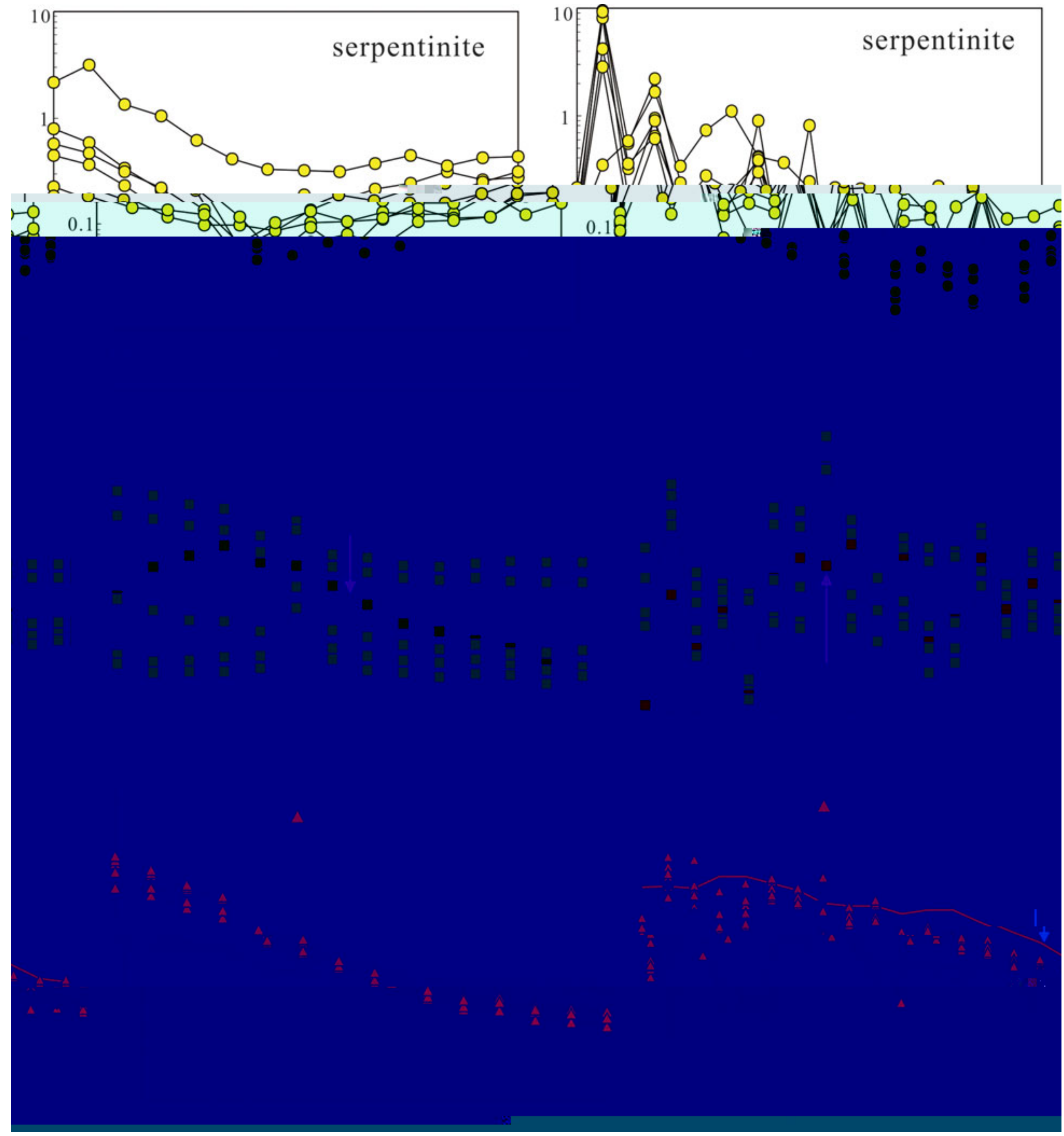
Fig. 6. [illegible] *et al.* 200[illegible] [illegible]).

[illegible] (Fig. 6). [illegible] 5[illegible] 41 [illegible] = 1.3 [illegible] 2.[illegible] [illegible] = 1.1 [illegible] 2.2). [illegible] 2013 [illegible] 01-3 [illegible] (Fig. [illegible]) [illegible] = 0.2 [illegible] 0.4) [illegible]

4.c.2. Basalts

[illegible] 43.15 % [illegible] 5[illegible].65 % [illegible] 52 %, [illegible]

[illegible] 1) [illegible] 1 (1) [illegible] 2 (2). [illegible] 2 [illegible] 1 [illegible] 2 [illegible] (Fig. 6). [illegible] 1. [illegible] 124 [illegible] 205 [illegible] 2 [illegible] 50 [illegible] 60 [illegible] 1. [illegible] 10 [illegible] 30 ([illegible] 20) [illegible]

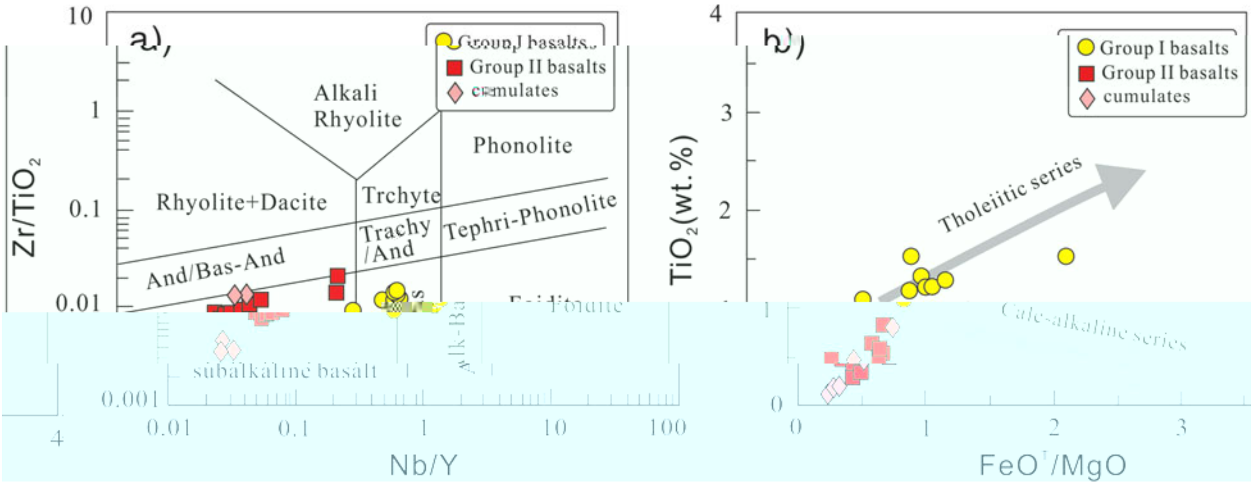


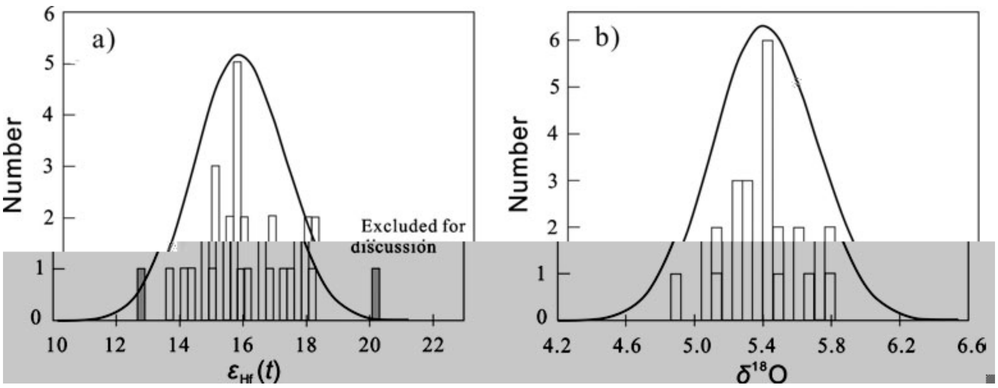
( ) ... & ... (1).

... (/ = 0. 0 1.14) ( ). ... 2. ... (/) ... 4 ... 6 ... (/ = 1.02 1.21) ( ). ... 1. ... 0.44 ... 0. ... 2. ... 1. ... (~0.11). ... ( ).

4. . W - c S N a c H O

... 2. 1. ... 2. ... (0.0024 0.0452) ... (0. 04030 0. 0536), ... (0. 04015 0. 05111, 2013 03 1). ... 0.0 ... 0.13 4 ... 0.512 0 ... 0.512 3 ... ε (*t*) ... +6.3 ... + .5 (2013 03 1 ... +1.).





(2013 ... 01) ... ε(t) (> 16) ... 15. ... 4. 1‰ ... 5. 3‰ ... 5.3 ± 0.23‰

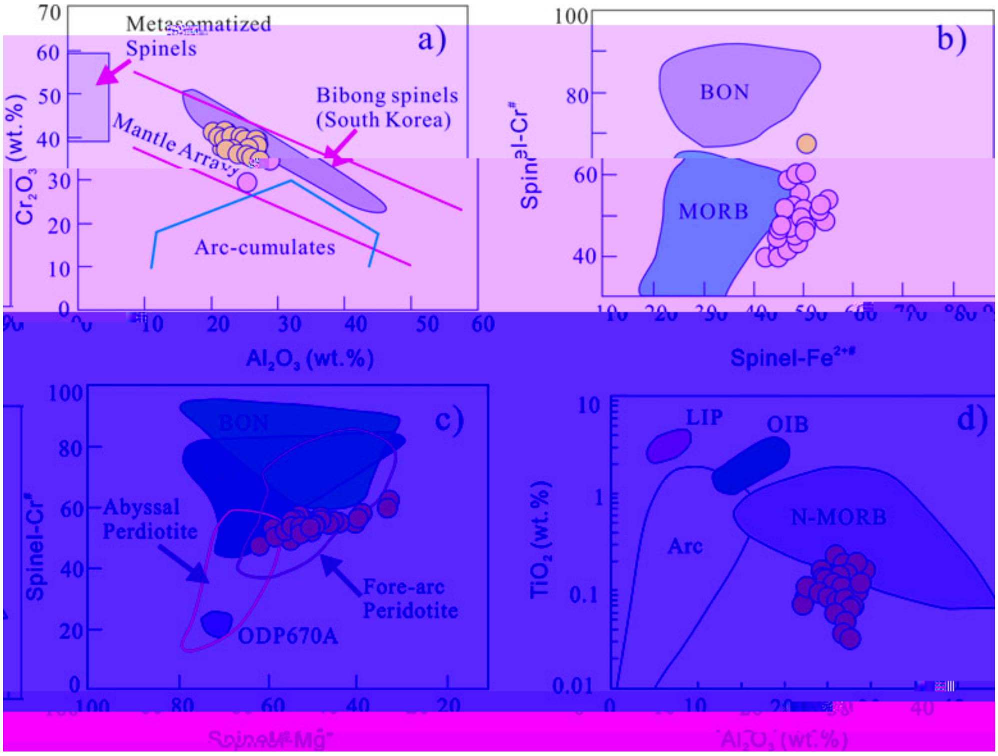
~400 ... ε(t) ... 1.4 ... 2 ... 6 0 ... 20 ... *et al.* 200).

5. D c

5.a. T a b Z a ba

... *c*. 4 6 ... 401 ... (503 ± ... (416 ± 3 ... *et al.* 2012 ... *et al.* 200 *b*, ... 1). ... (401 ... (4 6 ... 1 3).

... 1).

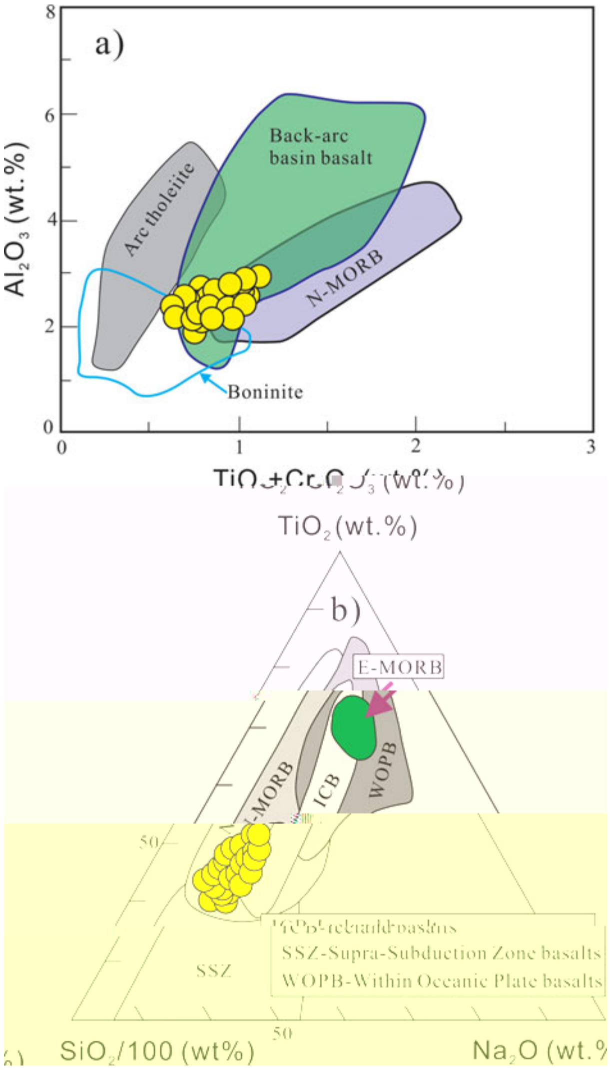


10. (...) ... (a) ... 3 ... 3 (%) ... & ... 2000). ( ) ... (100 ... /(...)) ... 2+ ... (100 ... 2+/(... 2+ + ...)) ... 1 4 ... & ... 2001). ( ) ... (100 ... /(... + ...)) ... (100 ... /(... + ...)) ... *et al.* 1 5). ( ) ... 2 ... 3 ... & ... 2001). ...

... (500 4 0 ...) (... *et al.* 2003 ... *et al.* 2015 ...), ... (430 400 ...) (... *et al.* 200 b, 2014 ...) ... (3 0 350 ...) (... *et al.* 2003 ... *et al.* 2006).

5.b. O ... a c a

... & ... 2002 ... *et al.* 2010 ...



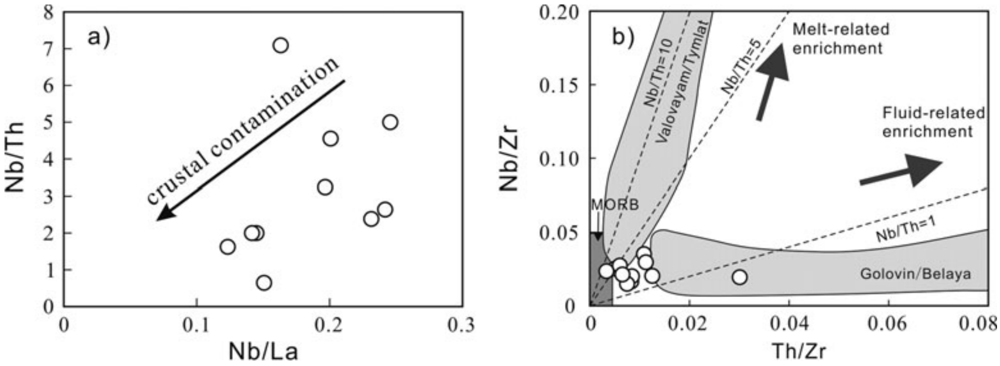
11. ( ) ( ) 3 2+ 3 ( ) 2 2/100

(. 11) 2/100 2 (. 11).

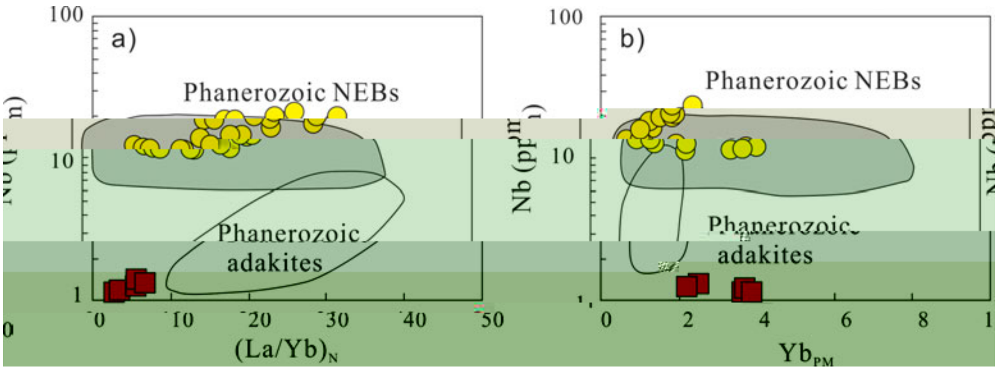
(. 12). (. 12). *et al.* (2002)

5.c. P D a ba a

2. 1. (11 24 15 5 (0.4 0.6 %) (11 15, 60) & 1 2 & J , 2001) (. 13). (1) & , 2002) (2) & 1 2 & , 1 3 *et al.* 1 6). 1. & , 200 *et al.* 2011) 1 (0. 04120 0. 06133) ε (t) (+1. + .5). (3.44 20.4) (1.51 2.54) & , 1 6). *et al.* 1 6 J , 1 6). & J , 2000). & 1 2 *et al.* 1 6). *et al.* (200



12. [illegible]



13. [illegible]

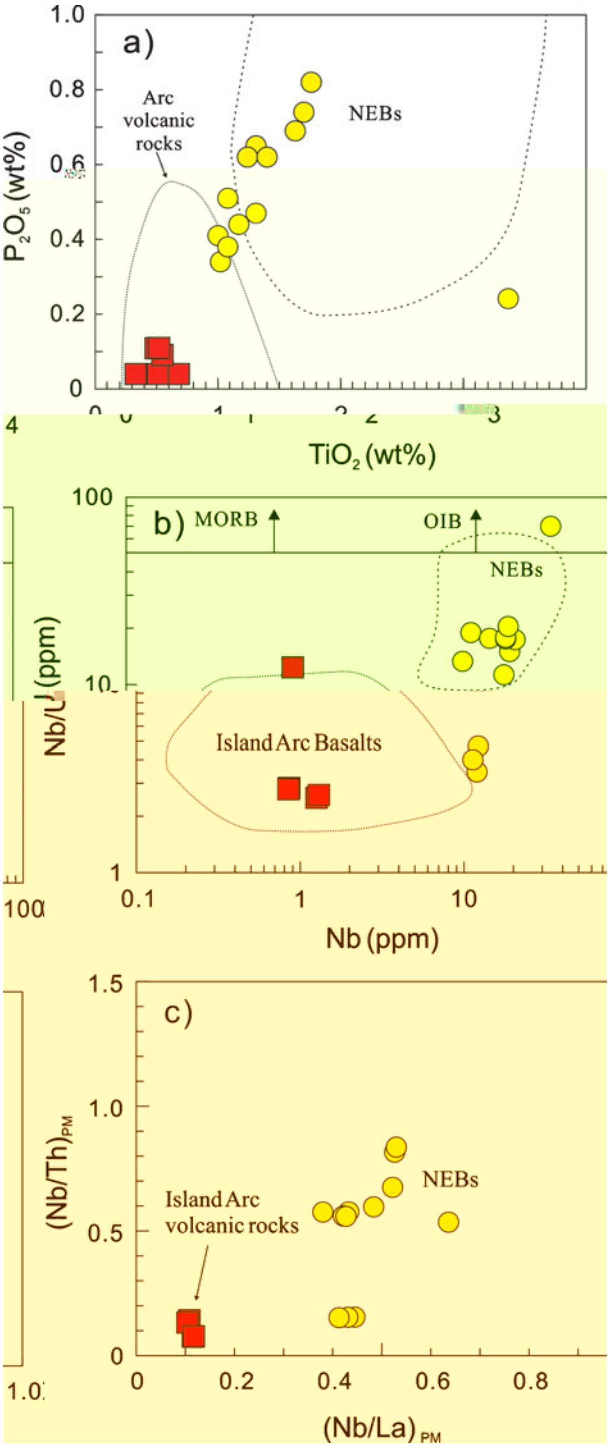
[illegible] ε(t) (1. [illegible] .5) [illegible] (0. 04120 0. 06133) [illegible] 2). [illegible] ε(t) [illegible] (< 0.3), [illegible] 2002). [illegible] (0. [illegible] 1.0), [illegible] (0.1 0.2) [illegible] (0.6 1.0) [illegible] 6). [illegible] 14). [illegible]

[illegible] 14). [illegible]

5. [illegible]

[illegible] (416 [illegible] et al. 2014 [illegible] et al. 2015), [illegible] (503 [illegible] et al. 2003 [illegible] et al. 2015 [illegible] (400 [illegible] et al. 2014), [illegible]

[illegible] et al. 200 [illegible], 200 [illegible] a,b [illegible] et al. 200 [illegible] a). [illegible] et al. 200 [illegible] b). [illegible]



14. ... *et al.* (... 5), ...

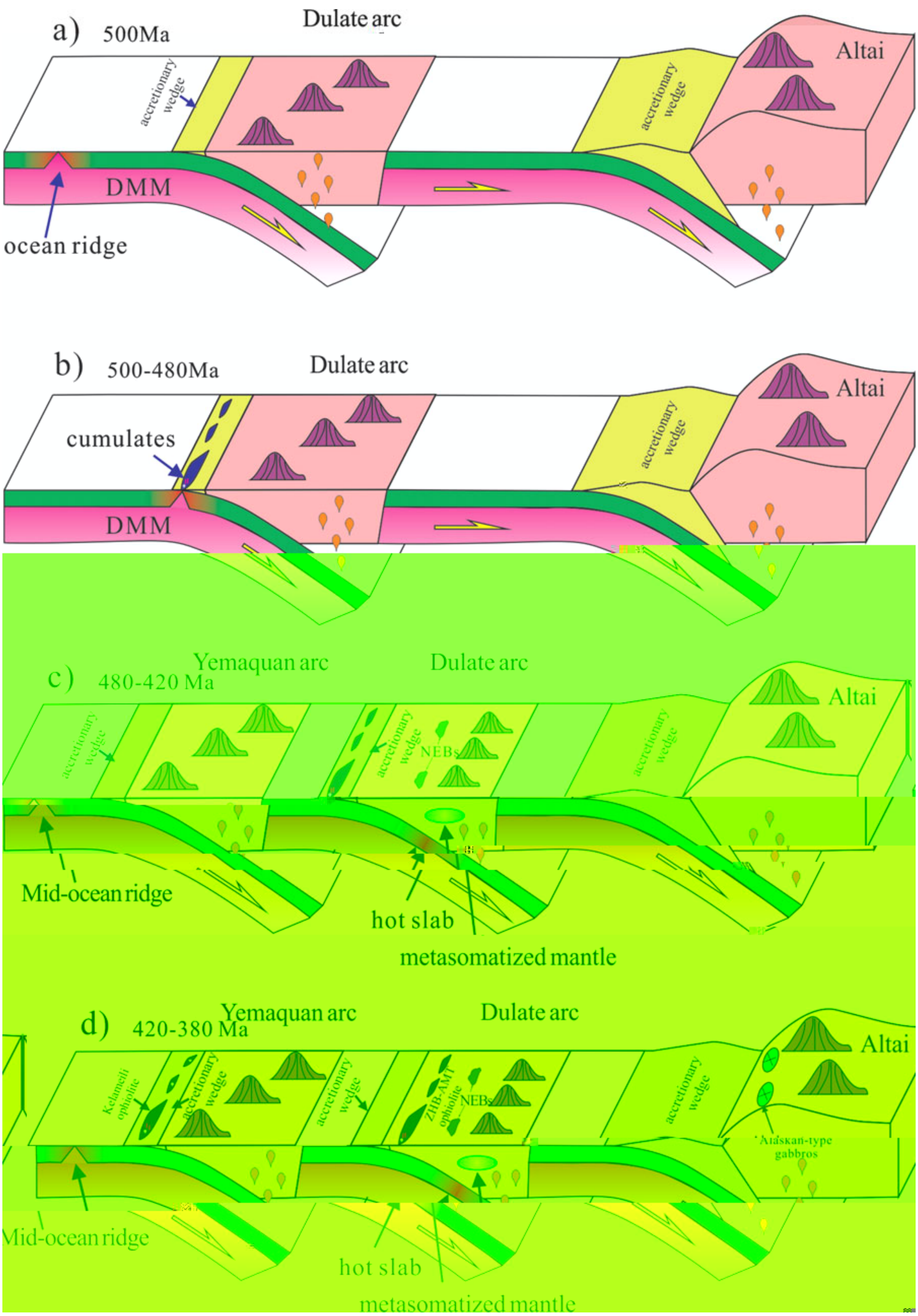
... *et al.* (2015) ... 400 ...

... 460 ... *c.* 400 ... *et al.* 2006, 200 ... *et al.* 200 ... *et al.* 200 ... *et al.* 200 , 200 ... *et al.* 2012 ... *et al.* 2015). ... 2002 ... *et al.* 200). ... *et al.* 2015). ... 15). ... *et al.* (200 , 200 *b*) ... *et al.* 200). ... 200 ... *et al.* 2013). ... 15).

(1) ... (*c.* 500 ... 15) ...

(2) ... (500 ... 15) ...

(3) ... (4 ... 420 ... (45 ... *et al.* 2015) ... (440 ... *et al.* 2014) ... 15) ...


a) 500Ma
Dulate arc
Altai
accretionary wedge
accretionary wedge
DMM
ocean ridge
b) 500-480Ma
Dulate arc
Altai
cumulates
accretionary wedge
DMM
c) 480-420 Ma
Yemaquan arc
Dulate arc
Altai
accretionary wedge
accretionary wedge
NEBs
accretionary wedge
Mid-ocean ridge
hot slab
metasomatized mantle
d) 420-380 Ma
Yemaquan arc
Dulate arc
Altai
Kelameili ophiolite
accretionary wedge
accretionary wedge
ZHB-AMT ophiolite
NEBs
accretionary wedge
Alaskan-type gabbros
Mid-ocean ridge
hot slab
metasomatized mantle

[illegible] 15. ([illegible]) [illegible]

(4) [illegible] (420 [illegible] 3 [illegible] 0 [illegible]) [illegible] *et al.* 2014 [illegible] *et al.* 2015). [illegible] 1. [illegible] 2. [illegible] [illegible] 15). [illegible] (400 [illegible] 3 [illegible] 0 [illegible]). [illegible]

6. C[illegible]

(1) [illegible] ~4[illegible]5 [illegible] *c.* 400 [illegible]

(2) [illegible]

(3) [illegible]

Ac[illegible]

[illegible] 305 [illegible] (2011 [illegible] 06 [illegible] 03-01).

S[illegible]

[illegible] /10.101[illegible] 0016 [illegible] 56 [illegible] 16000042.

R[illegible]

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