Geol. Mag. **154** (3), 2017, pp. 419–440. © Cambridge University Press 2016
10.101 / 0016 56 16000042

[illegible]

[illegible] ‡, [illegible] ‡†, [illegible] ‡
& [illegible] ‡
[illegible] 10003 [illegible]
‡ [illegible] 210016, [illegible]
[illegible] 36 4 -5305 [illegible]

(*Received* [illegible] 2015; *accepted* [illegible] 2016; *first published online* [illegible] 2016)

Abstract [illegible] ~4 5 [illegible] ~400 [illegible] ε(*t*) (13 20) [illegible] δ[1] (+5.3 ‰) [illegible] 1% [illegible]

1. Introduction

[illegible] (e.g. [illegible] *et al.* 200 [illegible], 200 [illegible] *et al.* 2012 [illegible] *et al.* 2012, 2013 [illegible] *et al.* 2013) [illegible] *et al.* 200 [illegible] *et al.* 200 a) [illegible] *et al.* 2000 [illegible] 2003 [illegible] *et al.* 200 [illegible] 2014) [illegible] (2011) [illegible] (2014) [illegible]

[illegible] 2000 [illegible] *et al.* 2002 [illegible] *et al.* 2004, 200 a) [illegible] *et al.* 200 a,b [illegible] 2012) [illegible] *et al.* 2003 [illegible] *et al.* 2003 [illegible] *et al.* 200 a) [illegible]

† [illegible]

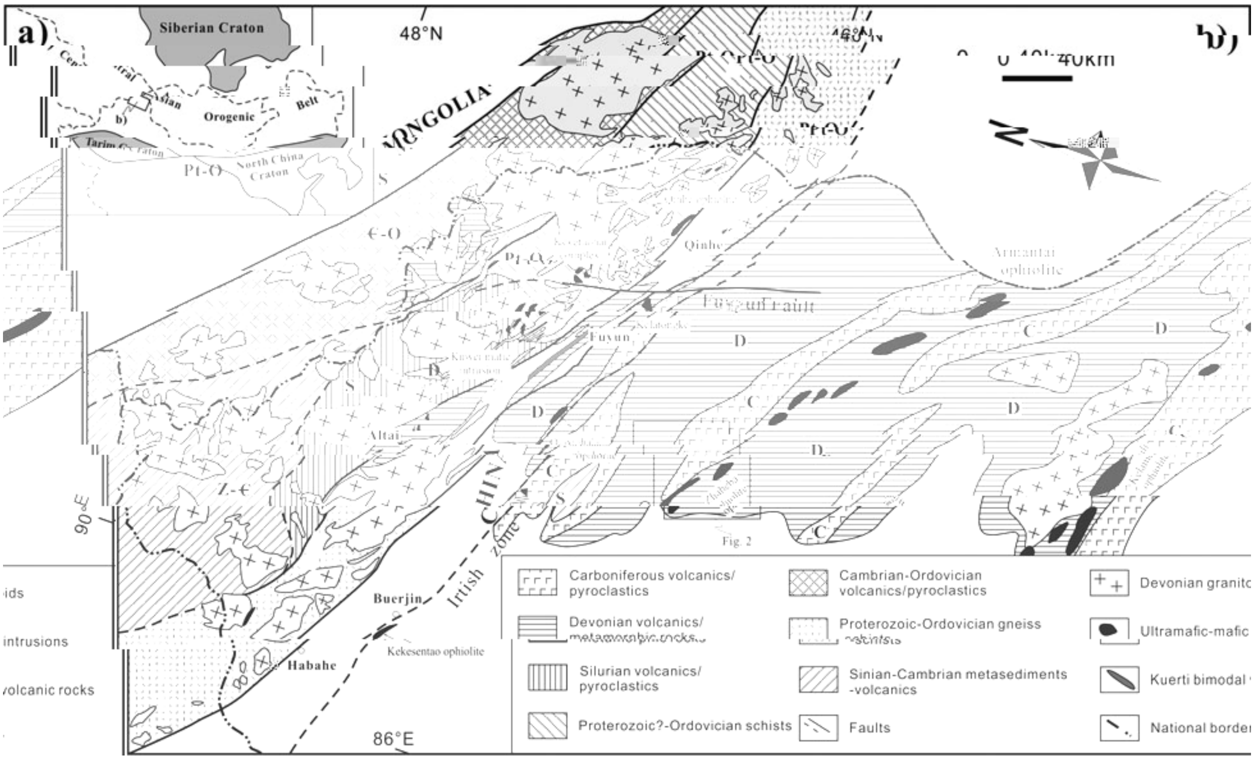


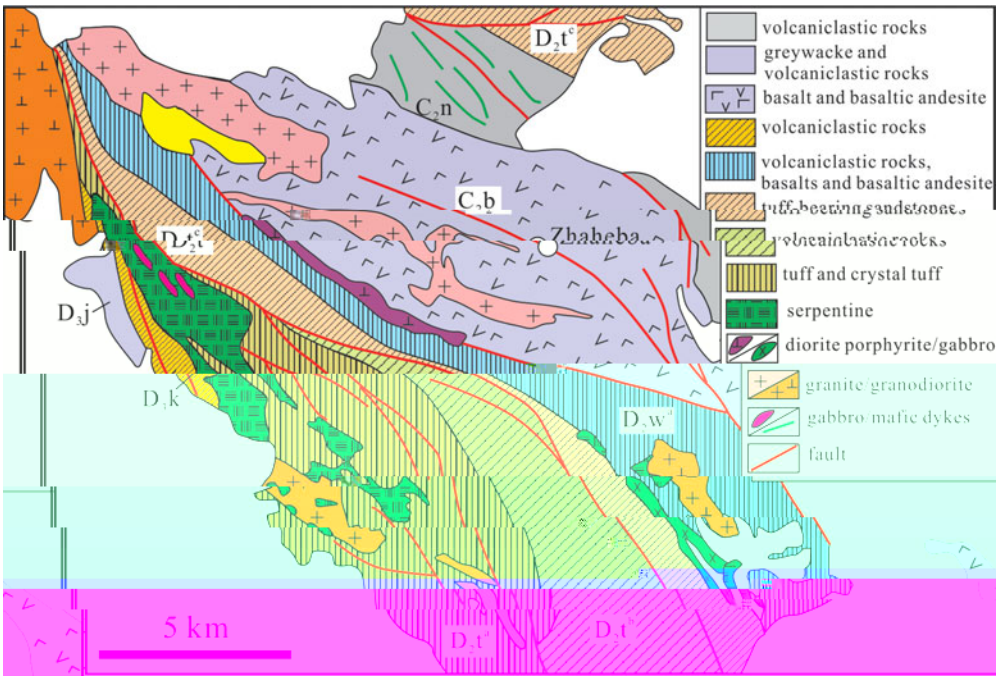
Figure 1. (a) ... (b) ... *et al.* 200).

... (1) ... (2) ...

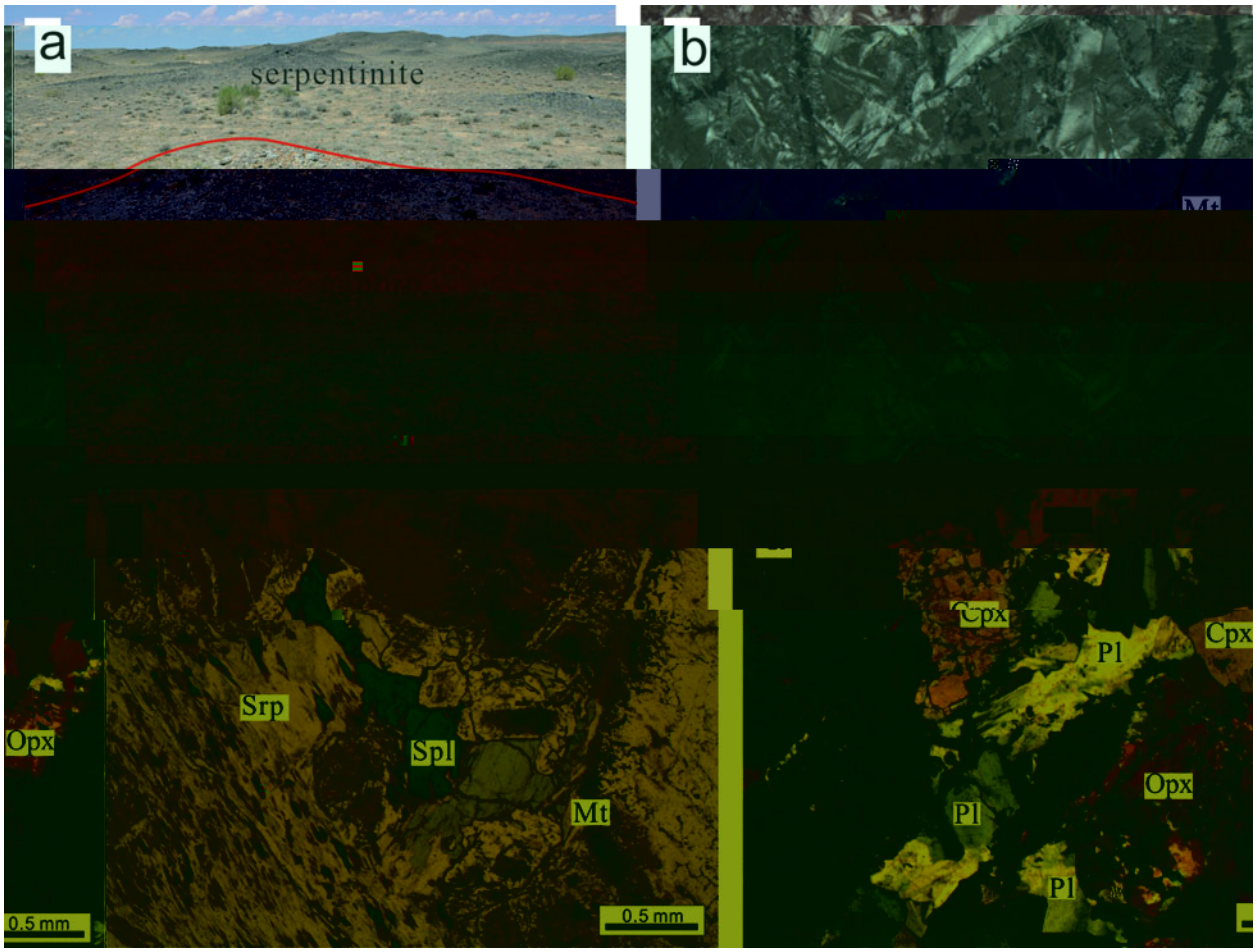
2. R [redacted] a [redacted] a

... (Figure 1, 2) ... (Fig. 3) ... 15 ... (Fig. 2, ...) ... 5 ...

... > 0% ... (Fig. 3) ... *et al.* 2013) ... (40 0%) ... 1% ... (30 50%) ... 1% ... (5 10%) ... (Fig. 3) ... 1% ... *et al.* 2006) ... (Fig. 2) ... 1 (... , 1 3).



e 2. (, , e) e 1 e (e et al. 200 , 200 a , 1 3).



e 3. (, , e) e 1 e 1 e 1 e. ( ) e > 0% e 1e e 1 e. ( ) e % e 1 e 1 e, e 1% e e 1% e e. 1 e 1% e e 1% e e 1 e, 1 e 1e e.

3. A a ca c [redacted]

3.a. Z c U–Pb a a H–[redacted] a [redacted]

[illegible] (2013 01, 46° 32′ 51 , °2′ 4) [illegible] (2013 02, 46° 33′ 2 , °2′ 36) [illegible] et al. (2011). [illegible] et al. 2010) [illegible] 2003). [illegible] 5 % [illegible] 2, [illegible] 12 0 [illegible] et al. (2010a). [illegible] = 0.0020052), [illegible] δ[1] [illegible] 5.31 ‰ (et al. 2010b). [illegible] δ[1] 5.44 ± 0.21 ‰ (2), [illegible] 5.4 ± 0.2 ‰ (et al. 2013). [illegible] 3 [illegible]

3.b. M a a [redacted]

[illegible] 00 [illegible] 15 [illegible] 15 [illegible] 20 [illegible] 1- [illegible] 4 [illegible] 5 [illegible]

3.c. W - c a [redacted]

[illegible] 100 [illegible] et al. (2004). [illegible] 2 %. [illegible] 6000 [illegible] et al. (2004). [illegible] 50 [illegible] $_3$ [illegible] -1, -2 [illegible] -2, [illegible] -1 [illegible] 3, [illegible] 3 5 %. [illegible] 1.

[illegible] $_3$ [illegible] et al. (2004). [illegible] ^{143}/^{144} [illegible] = 0.11 4 [illegible] ^{146}/^{144} = 0. 21 [illegible] 0. 102 [illegible] 0. 0506 [illegible] -1, [illegible] ^{143}/^{144} [illegible] 0.512104 [illegible] 0.5126 1 [illegible] -1. [illegible] 2.

4. A a ca [redacted]

4.a. Z c U–Pb a [redacted]

[illegible] 100 150 μ [illegible] 1 1 2 1. [illegible] 1 % [illegible] 4). [illegible] (22 123 11) [illegible] (5 11) [illegible] 0.4 0. [illegible] 30 [illegible] 4 5. ± 2.5 [illegible]

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

2 0 141.306 .201 ( ) 1( ) 4 5(02 (30. (4 .20)-. (6-.501-)-60203(0. 0)-5)-60202.11)-602 .

	0.005	0.064	0.00	0.005	0.00	0.003	0.003	0.051	0.044	0.222
	0.021	0.34	0.044	0.042	0.0 2	0.031	0.033	0.310	0.25	1.450
	0.004	0.04	0.00	0.00	0.011	0.005	0.005	0.04	0.043	0.21
	0.011	0.232	0.036	0.044	0.012	0.034	0.00	0.123	0.0 0	0. 3
	0.0 0	0.036	0.03	0.03	0.06	0.026	0.025	0.046	0.031	0.06
	0.26	1. 10	6.600	1. 0	0. 3	0.233	1.150	1.5 0	0.516	0.1 5
	0.406	0.0 2	0.12	0.112	0.0	0.1	0.054	0.16	0.1 1	0.6 5
	0.046	0.034	0.014	0.02	0.050	0.030	0.010	0.050	0.02	0.130
	0.1 1	0.144	0.203	0.364	0.042	0.0 4	0.0	0.066	0.042	0.0 3

	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)
					Major elements (%)					
2	4 .1	45.	4 .	53.1	51. 1	50.40	50.54	50.52	51.22	52.3
2	0.34	0.15	1.40	1.24	1.31	1. 0	1.63	1.31	1.1	0.33
2 3	1 .	1 .5	16.5	16.1	15. 3	15.	16. 6	15.55	15.4	1 .61
e2 3	4.52	3.34	.	.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.	.42	4. 0	4.2	4.41	5.	3.2	6.06	.14	4.
	11.03	12.61	6.22	5. 5	6.3	6. 5	4.52	.4	.26	. 0
2	4. 6	.3	. 2	.3	.00	4.52	.31	4. 0	4.0	.11
2	0.13	0.11	0.3	0.31	0.42	2.04	0.33	1.2	2.03	0.1
2 5	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.
	. 5	. 2	. 6	. 0	.4	.40	. 1	.6	.6	. 1
	4.	.4	.11	. 0	.42	6.56	.64	6.0	6.11	.2
#	5	1	55	54	54	56	41	56	64	4
					Trace elements (ppm)					
	.0	4. 5	1.16	1.12	1.4	.0	40.4	5.2	6. 2	5. 1
e	0.22	0.135	1.2 4	1.6 3	1.316	1. 53	1.034	1.100	0.5 5	0.62
e	25.0	23.	1 .6	1 .5	1 .5	.5	1 .2	25.2	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 .	0.	203	23.
	24.2	21.6	26.	23.6	24.6	2 .	2 .5	2 .0	2 .0	16.4
	4.	1 5	63.6	50.	51.4	6.	2 .	5 .3	132	1.1

Table 1. [illegible]

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

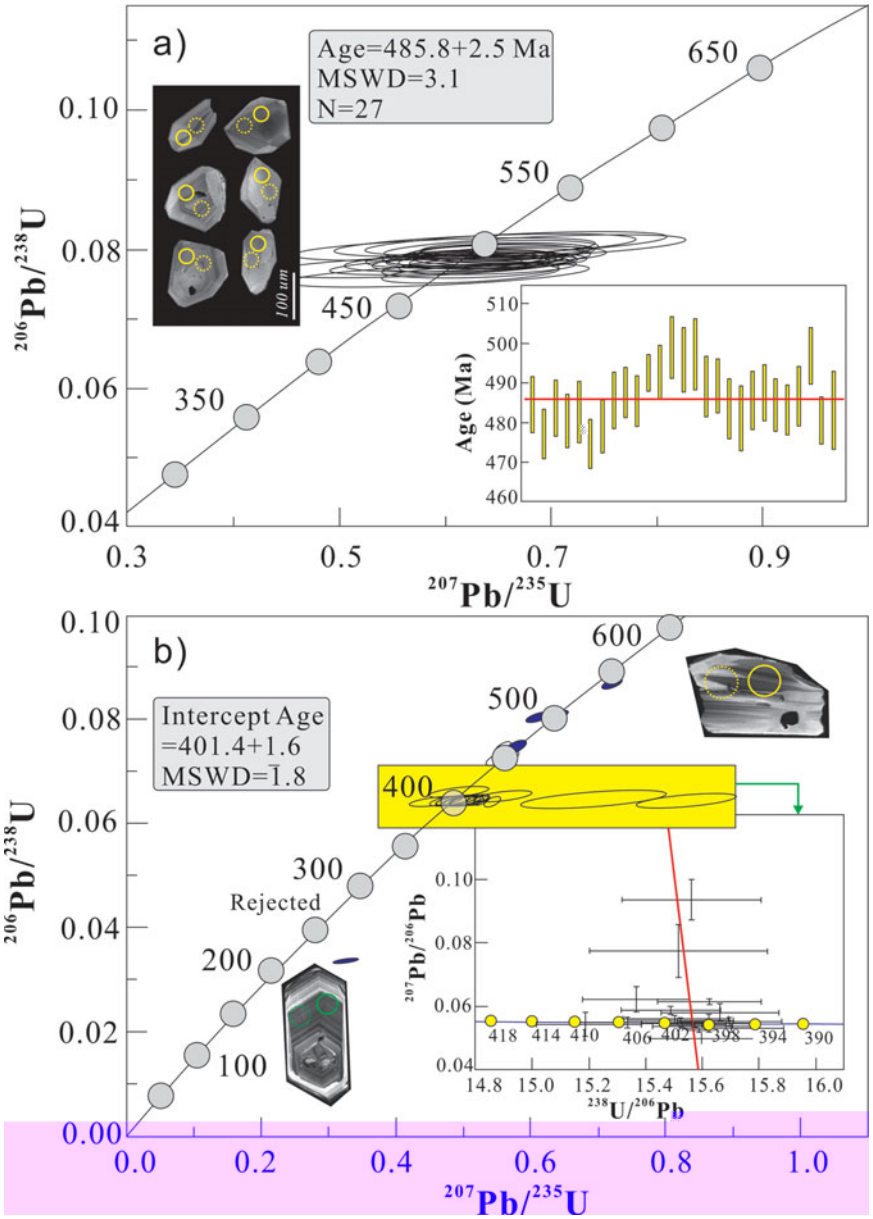
	2013 01. 11 (2)	2013 02. 1 (2)	2013 02. 2 (2)	2013 03. 1 (1)	2013 03. 6 (1)	2013 01. 10 (2)	04 06 (1)	04 24 (1)	04 2 (1)	03 1 (1)
				Trace elements (ppm)						
	1 .4	36.	42.4	26.0	32.4	1 .	/	/	/	/
e	0.3 5	0.153	0.35	1.1	0. 4	0.46	/	/	/	/
e	32.5	33.2	34.5	25.1	26.3	32.1	13.4	20.5	1 .	20.3
	1 4	203	21	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

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

e 2. 1 e e 1 e e e e

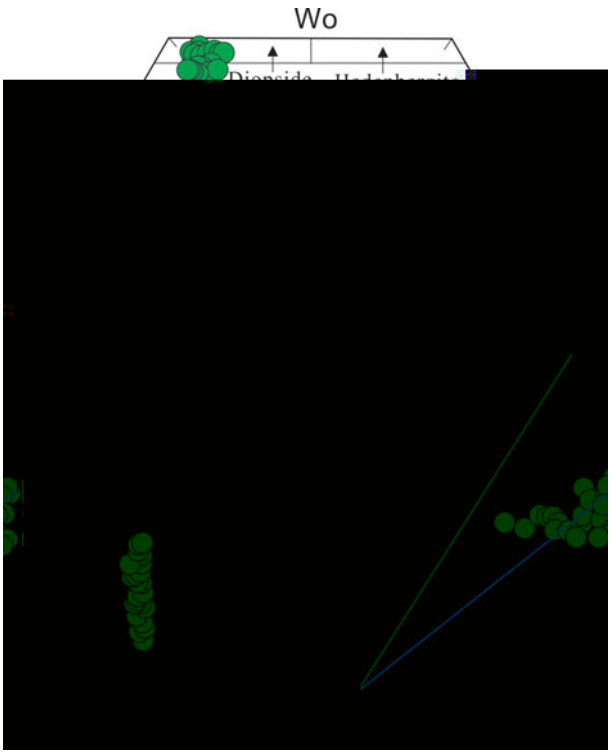
1 e	e %de	(11)	(11)	6 / 6 (1σ)	(6)	(11)	(11)	14 144 / 143 144 (1σ)	(143 144 /)	ε (*t*)
2013 01 3 (2)	0.36	3 2	0.002	0. 04030(2)	0. 04015	2.4	10.	0.13 4	0.512 3 (40)	0.5124 4	6.
2013 01 10 (2)	0.5	6 6	0.0024	0. 04 5 (23)	0. 04 45	2.3	11.6	0.1235	0.512 0 (43)	0.5124 6	.1
2013 03 1 (1)	3.13	2 0	0.0335	0. 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*)(/ 6) e e e e e e e e e 401 .



e 4. (e) e 1 e e e e 1 e e e e 1σ e e % e 2σ ( ) e e.

(.4 = 2 , = 3.1). e e - e 1 e , % e1 e 4 ± 4 e e e e e% e e e 1 e (*et al.* 2003). e e , e , 1 e e e 1 e e 100 200 μ e e / 1 3. ee e e - e , e e e e e , 1 . , 11(1) e , ee , 0% e 1 e % 1 e , e e e e% e e - e , e e 1(2) e e , e .



4.b. M a c

4.b.1. Spinel composition

4.c. W - c a c

4.c.1. Serpentinites and cumulates

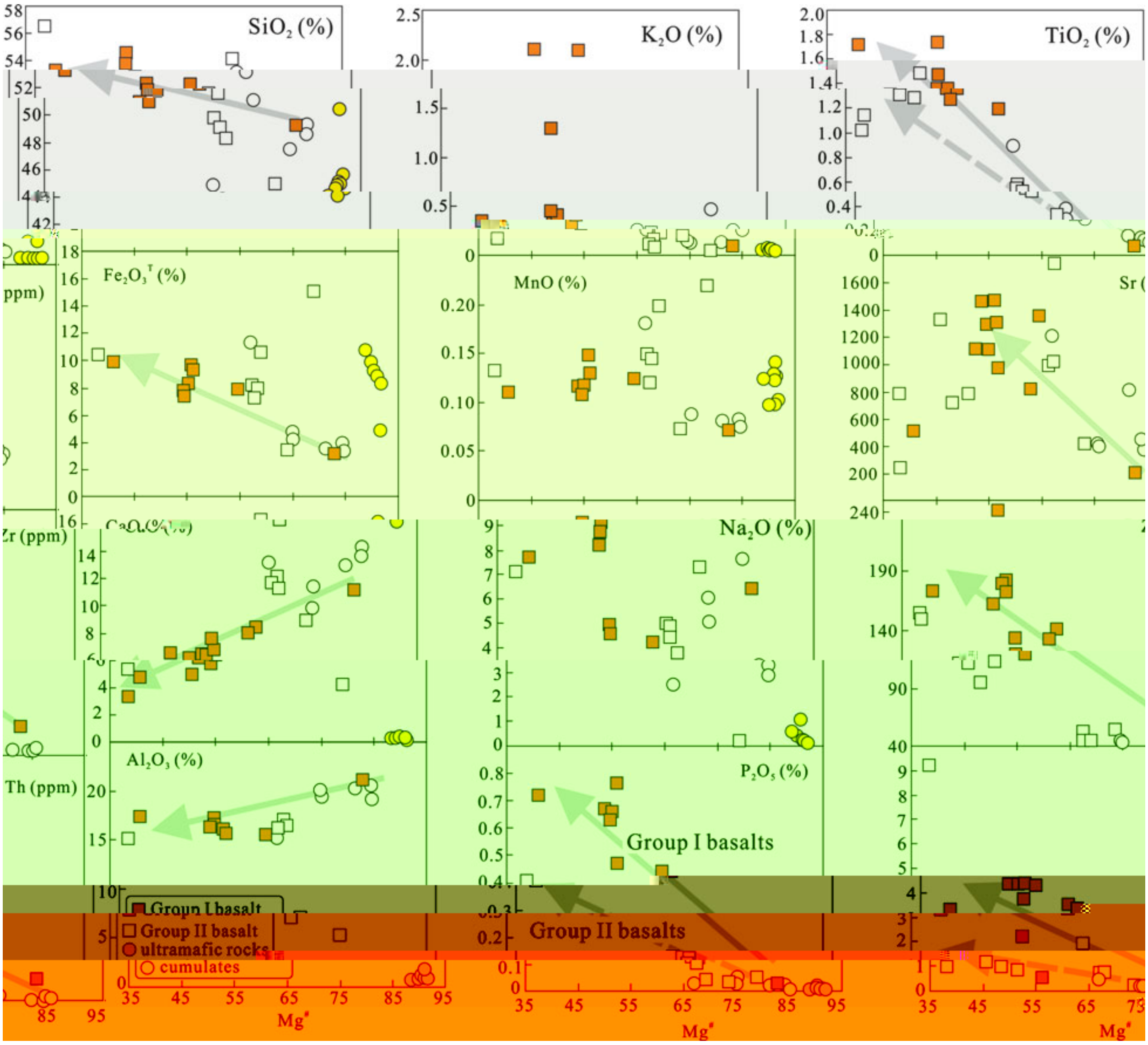
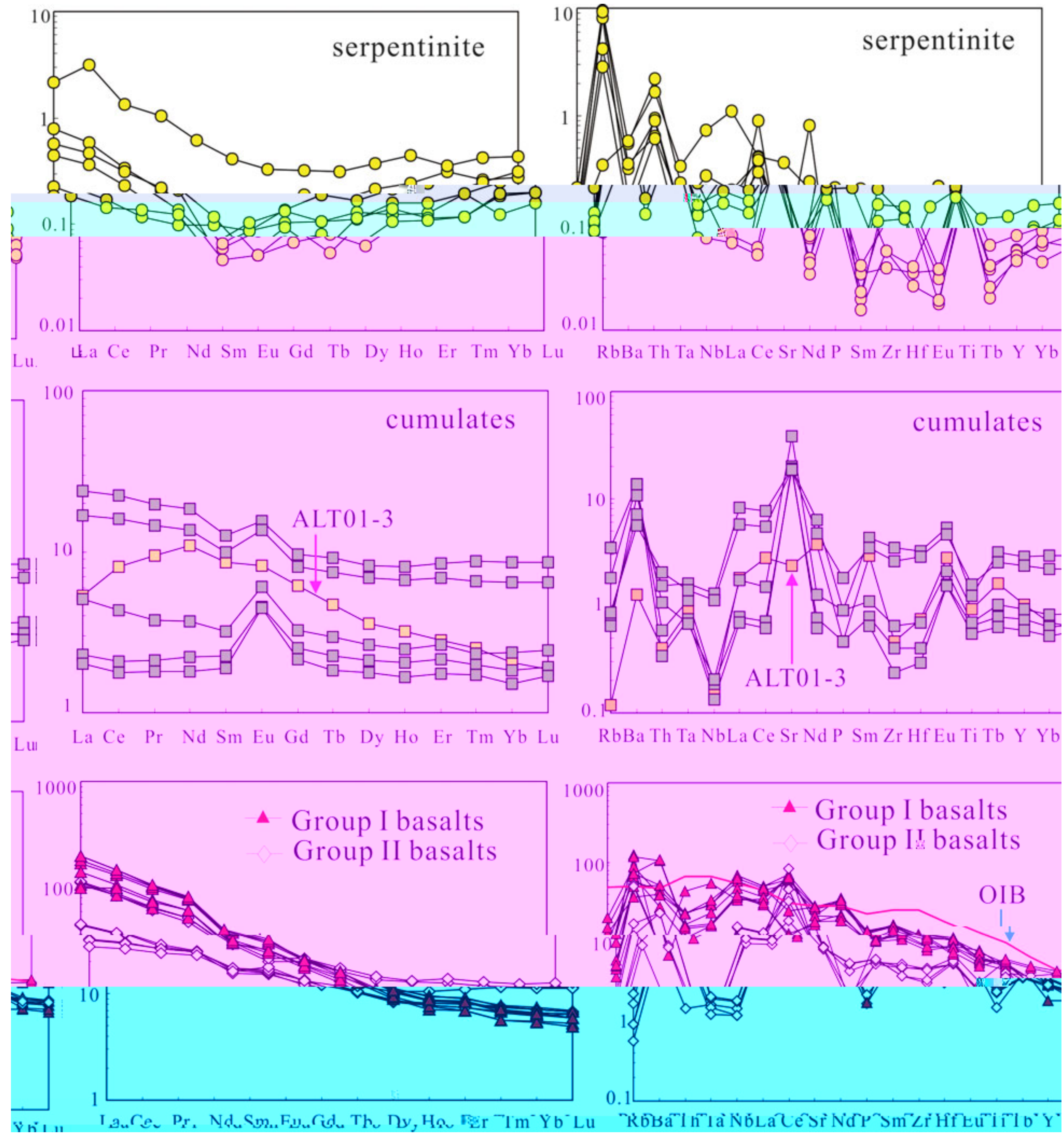


Figure 6. … *et al.* 200 …

4.c.2. Basalts

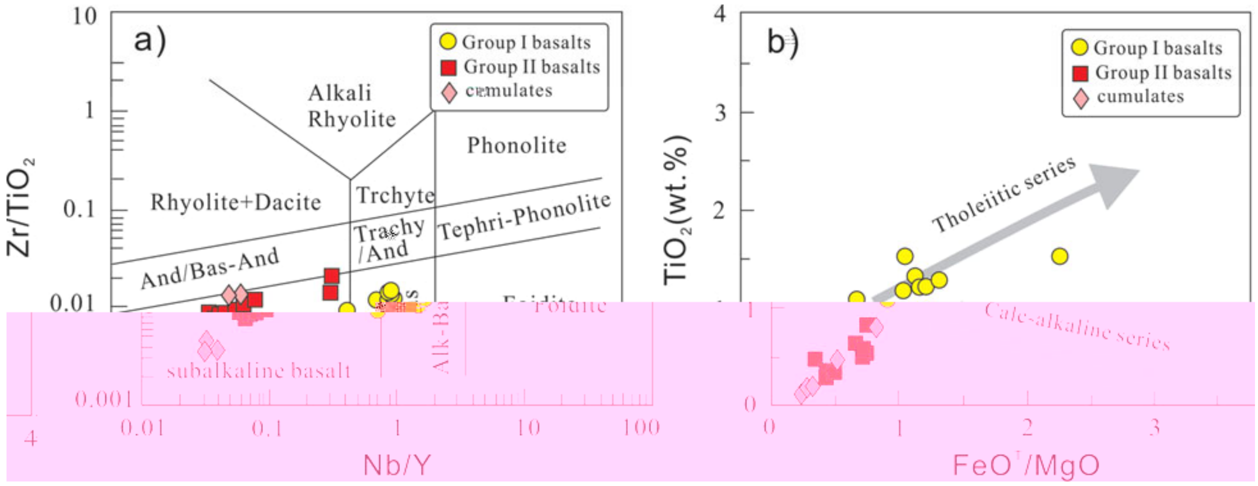


(1).

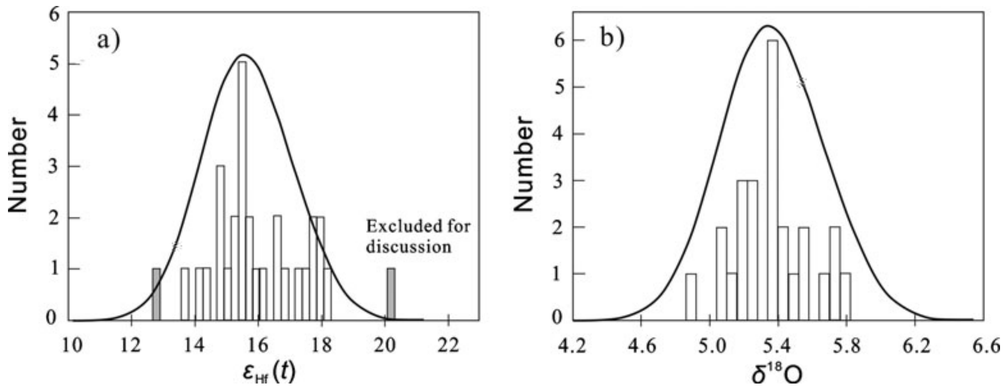
1 = 0. 0 1.14) ( ). 2 ( ) 4 6 1 = 1.02 1.21) ( ). 1 0.44 0. 1 2 1 (~0.11). ( ).

4. . W - c S –N a z c H–O[redacted]

1 1 2. 1 2 1 1 (0.0024 0.0452) (0. 04030 0. 0536), 1 (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.).



. , e . (. . , . . . e) (a) . e 1 . e e e e (/ . 2 . . /) e e . . (. e e e & . %, 1). ( ) . e- e 2 . e / . 1 . . . e . . e ee e e . e e . e e e . %. . (1 4).



. , e . . (a) . e . ε (t) . ( ). . . 1e 1e . . e . . e . e . 1 . . e.

. e . . . . . 1e e 1 . . . . e e , e 1 e (2013 01) . e . e e , (. - e , 11 e e %. e e 2 e 1 //. , . . . e. / e, . .), ε (= 4 5) 13 20. e . e e e . 2 5. 5 . e 1 %e ε (t) (> 16) e e e %, e e e % . e . , e e 1 e e e , e . . , e . . e ε (t), e %e % . 1e 15. e - , e δ1 , e e 4. 1 ‰ 5. 3 ‰, . (. . .). , e e e e e e , %e 1 e 1 - δ1 . e 5.3 ± 0.23 ‰ (. . .).

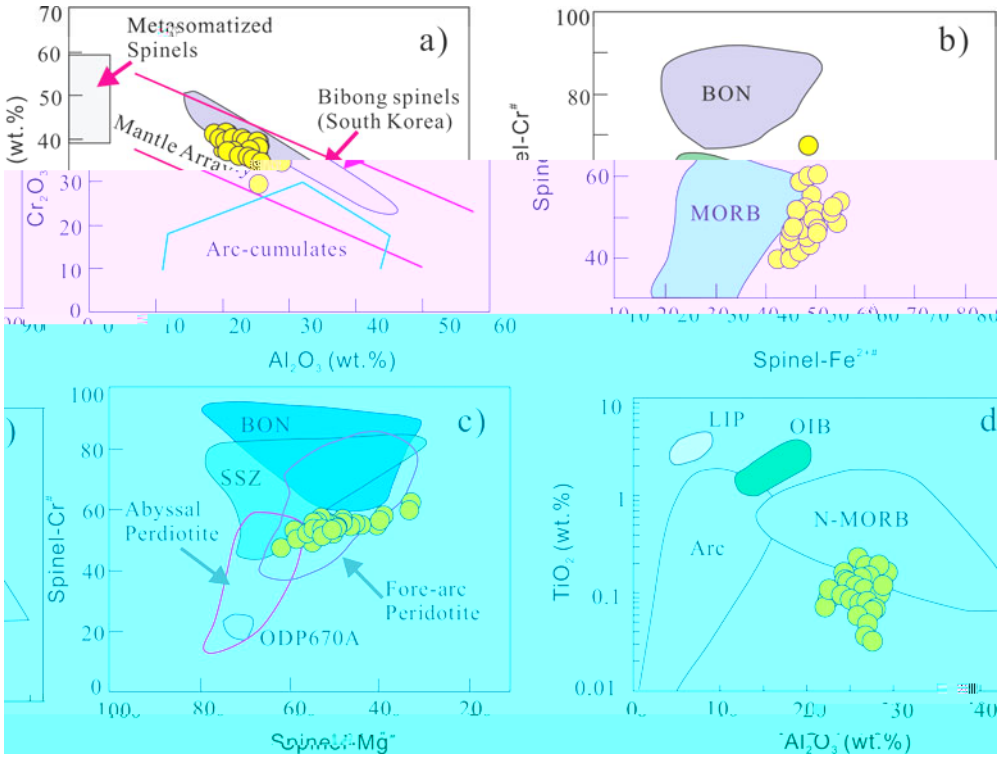
. e . ~400 e , 1 e e e e ε (t) , e e ee 1.4 .2 e- e. . e e 6 0 20 . e e %e e e e . - 1e 1 e , e e e , . . e (, *et al.* 200).

5. [redacted]

5.a. T a [redacted] Z a ba

ee . , e e e e , e - e e , e e e e e . - e e e 1 ee e , 1 e *c*. 4 6 401 , e 1ee e % e e . e e , e . % e e 1 e , % e1 e e (503 ±) e 1 e e , - e ee e e 1 e e (416 ± 3). e e e 1 e , e e 1 e e 1 e (. , *et al.* 2012 *et al.* 200 *b*, . 1). e e e- , e ee (401) ee , e (4 6) (, - e e 1e e) e e % % , . , e , e e e e , e ee e e - e e e 1 e. e e e e e e e e e , e ee (, 1 3).

ee e e e 1 e e e. , e , e e e e e (. 1), e 1 e e , . e . ee e , .e. e e 1 e

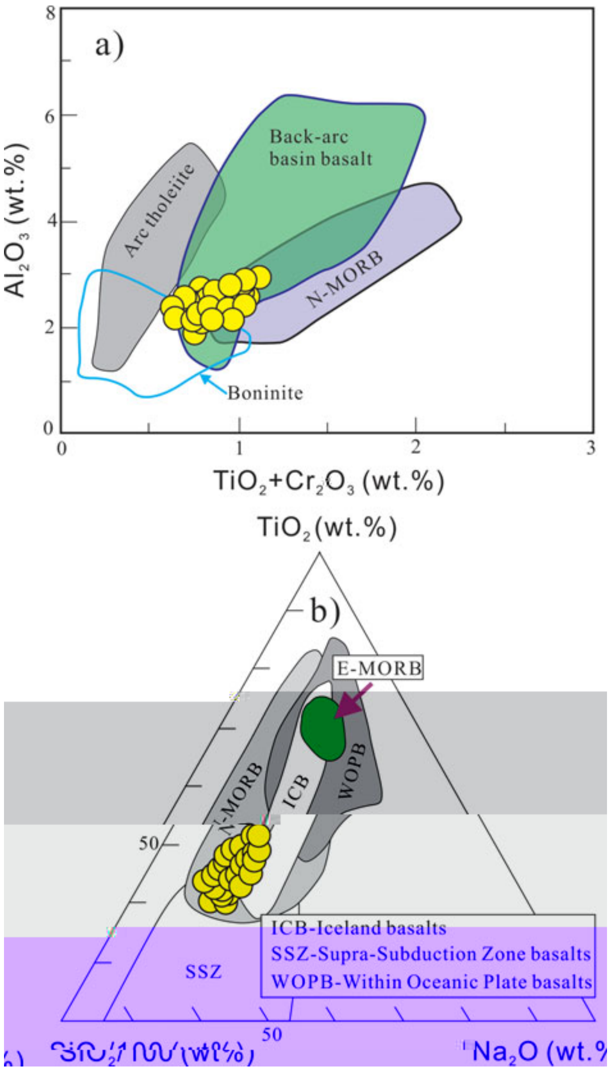


e 10. (, , e) e 1 e e . (a) 2 3 e , 2 3 (%) (e & , 2000). ( ) . (100 /(+)) e , e^{2+} . (100 e^{2+}/(e^{2+} +)) 1 e e 1 e (e , 1 4 e & e e , 2001). (e) . (100 /(+)) e , . (100 /(+ e)) 1 e e 1 e (e e *et al.* 1 5). ( ) 2 e , 2 3 e 1 e 1 1 e e 1 e (e e e % & e, e, 2001). e, - e e , 1 - , , e e .

e (500 4 0) (*et al.* 2003 , *et al.* 2015 , %), e e e 1 e e (430 400) (*et al.* 200 *b*, 2014 e e e e e)e e , e , e e - 1 e (3 0 350) (*et al.* 2003 , *et al.* 2006).

5.b. O a c a

, e , e e e e e - 1 e e e 1 e 1e e e e e e e % , e , e e (e , & e, 2002 . *et al.* 2010



e 11. (... e) (a) $_2$ $_3$ $_2$ + $_2$ $_3$ ... ( ) $_2$ $_2$/100 ... 1% ... e 11 ...

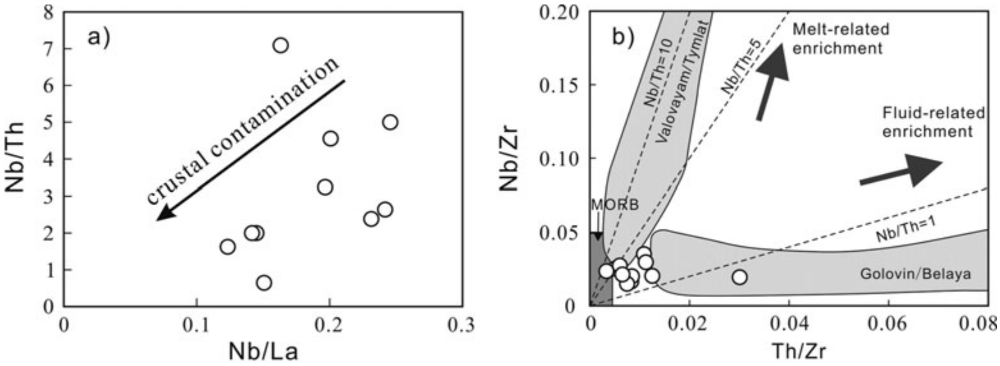
... % ... (- %de). ... 1% ... $_2$ $_3$ $_2$ + $_2$ $_3$ ... 1% ... (. 11). ... $_2$/100 $_2$ ... 11 ... (. 11). ... (.). ...

... (. 12), ... % ... 1 ... % ... (. 12). ... 1% ... *et al.* (2002) ... 1 ... % ... 1 ... (...). ...

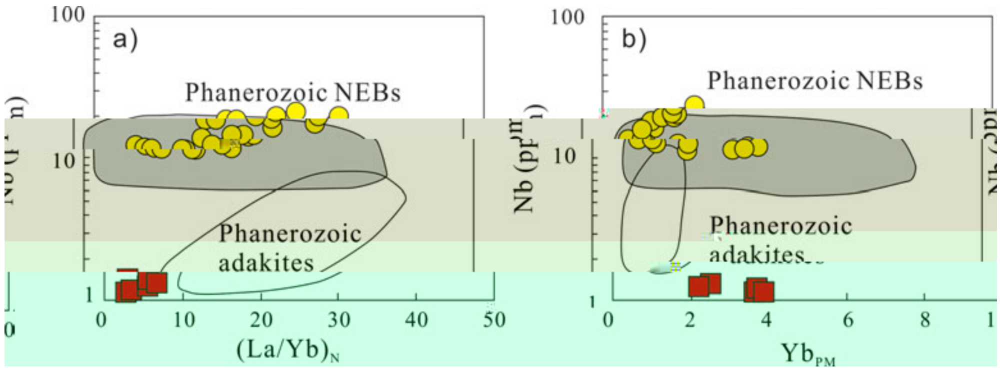
5.c. P [redacted] D a [redacted]

... % ... 2. ... (11 24 11 , ... e 15 11), $_2$ $_5$ (0.4 0.6 %) ... (11 15, ... 1 60) ... (...) (... & ... , 1 2 ... & ... , 2001) (. 13). ... (1) ... (e. ... & ... , 2002) (2) ... (... & ... , 1 2 ... & ... , 1 3 ... *et al.* 1 6). ... 1 ...

... 1 ... , 200 ... *et al.* 2011). ... / [6] ... (0. 04120 0. 06133) ... ε (*t*) ... (+1. + .5). ... (3.44 20.4) ... (1.51 2.54) ... (e. ... & ... , 1 6). ... *et al.* 1 6 ... e11 e, 1 6). ... % ... & ... , 2000). ... %(... & ... , 1 2 ... *et al.* 1 6). ... *et al.* (200) ...



e 12. (a) . / . . / ... (.) 1 ... / ... / ...
e ... 1 ... e.



e 13. (... e) (a) (/) ( ) ... 1 ...
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... e ... 1 ... e %
ε (t) (1. .5) (/ ^{6}) (0. 04120 0. 06133)
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(. 14). ... , e 2 ... e e ... 1
e ... e ... e 1 e , % e ... e
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e 1 ... 2 ... e ... e e ... e ... e .
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1e , e e .

5. . I ca[redacted] Pa a z c acc [redacted] J a

e e ... e ee . 1 ... e e ... e ... e ... ,
.e. e e ... e 1 ... e (416 ... et al. 2014
et al. 2015), ... e ... 1 ... e (503
4 5 ... et al. 2003 ... et al. 2015 ... %)
... e % . 1 ... e (400) (. 1). ee
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e e ... e ... - e ... e ... e ... e ... -
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e e e e ... % ... e ... e ... e
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e e ee ... e ... e ... e1 e e -
e e ee ... e e ..., e ... - e ... e ... e,
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ee1- ... % (et al. 200 , 200 a,b ... et al.
200 a). e ... e ... e ee ... e e
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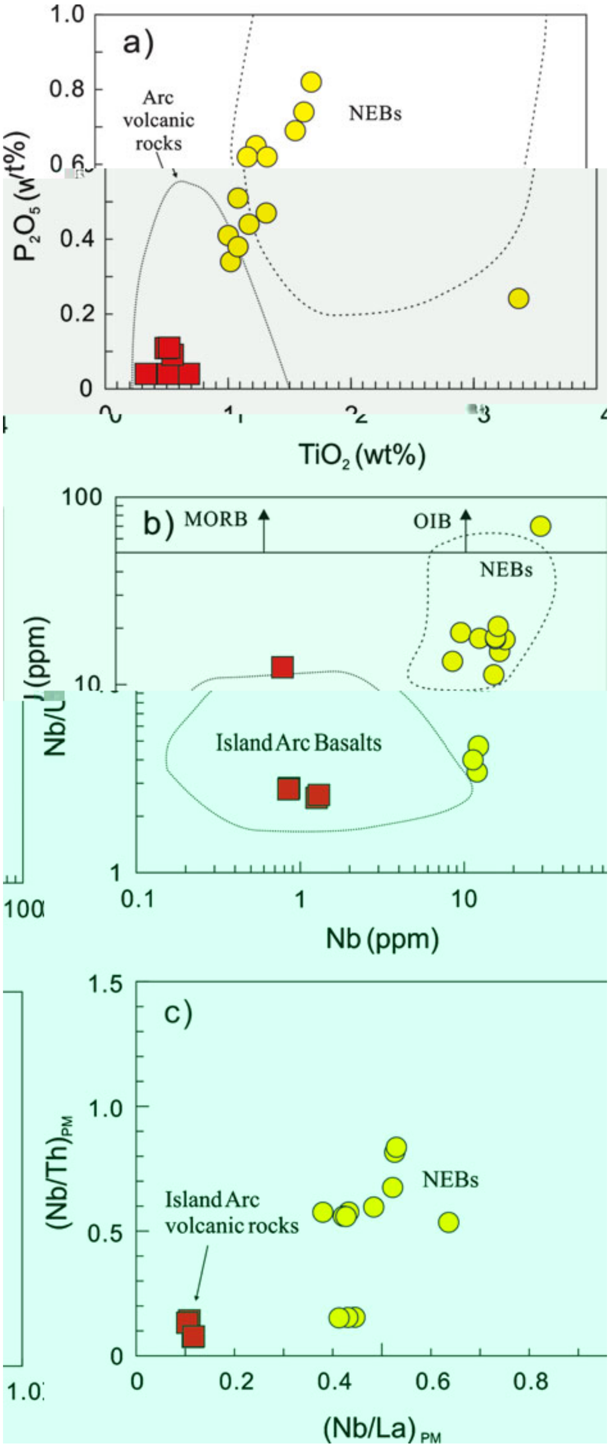
(et al. 200 b). ee ... e e e e



14. ( ) ( ) ( ) ( ) (/) (/) ( ) *et al.* (1 5)

[illegible]

et al. (2015) [illegible] 400 3 0 [illegible]

[illegible] 460 3 5 [illegible] *c.* 400 [illegible] *et al.* 2006, 200 [illegible] *et al.* 200 [illegible] *et al.* 200 [illegible] *et al.* 200 , 200 [illegible] *et al.* 2012 [illegible] *et al.* 2015). [illegible] 2002 [illegible] *et al.* 200). [illegible] *et al.* 2015).

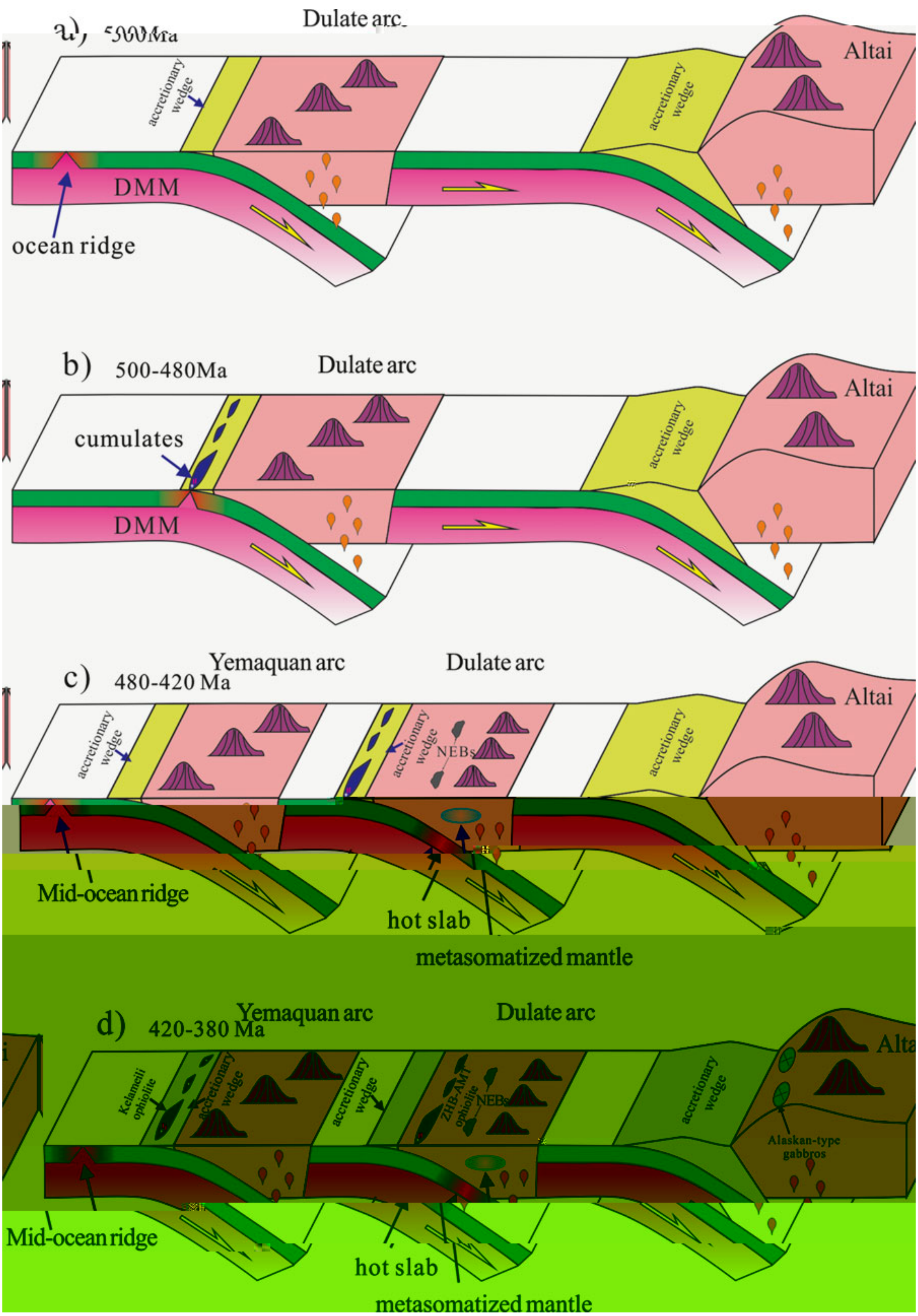
[illegible] 5.) [illegible] 2 [illegible] (1 , 15). [illegible] *et al.* (200 , 200 *b*) [illegible] *et al.* 200). [illegible] 200 [illegible] *et al.* 2013).

[illegible] . 15).

(1) [illegible] (*c.* 500 [illegible] . 15). [illegible]

(2) [illegible] (500 4 0 [illegible] . 15). [illegible]

(3) [illegible] (4 0 420 [illegible] (45 [illegible] *et al.* 2015) [illegible] (440 [illegible] *et al.* 2014) [illegible] . 15). [illegible]


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

(4) … (420 3 0 …) (… *et al.* 2014; … *et al.* 2015). … 2 … 15 … (400 3 0 …). …

6. C[redacted]

(1) … ~4 5 …, … *c.* 400 …
(2) …
(3) …

Ac[redacted]. … 305 … (2011 … 06 03-01).

S a a a

… 11 … /10.101 / 0016 56 16000042.

R[redacted]

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… & … 1 3. … *Geology* **21**, 54 50.

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