Geol. Mag. **154** (3), 2017, pp. 419–440. © Cambridge University Press 2016
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[illegible]

[illegible]*, [illegible]†, [illegible]‡, [illegible]§ & [illegible]‡

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Abstract

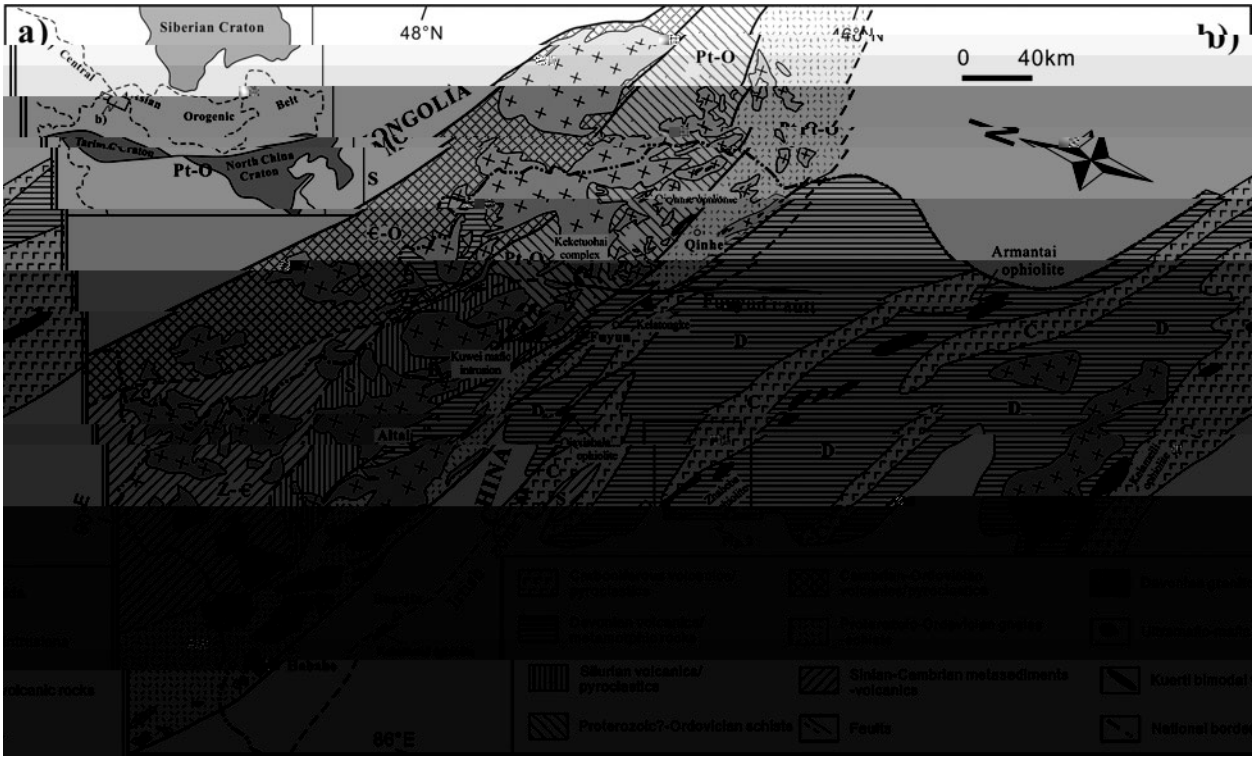
[illegible] ~400 [illegible] ~4.5 [illegible] εNd(*t*) (−13.20) [illegible] δ18O (+5.3 ‰) [illegible] [illegible].

1. Introduction

[illegible] (Wang *et al.* 2007; Wang & Li, 2009; Li *et al.* 2012; Wang *et al.* 2012, 2013; Li *et al.* 2013), [illegible] (Wang *et al.* 2007, 2009; Wang *et al.* 2009, *a*). [illegible] (Wang *et al.* 2000; Wang & Li, 2003; Wang *et al.* 2009; [illegible], 2014). Wang & Li (2011) [illegible] (Fig. 1), [illegible] (2014).

[illegible] (Wang *et al.* 2000; Wang & Li, 2003; Wang *et al.* 2002; Wang *et al.* 2004, 2009, *a*) (Fig. 1). [illegible] (Wang *et al.* 2009, *a*,*b*; [illegible], 2012). [illegible] (Wang *et al.* 2003; Wang *et al.* 2003; Wang *et al.* 2009, *a*) (Fig. 1). [illegible]

[illegible]



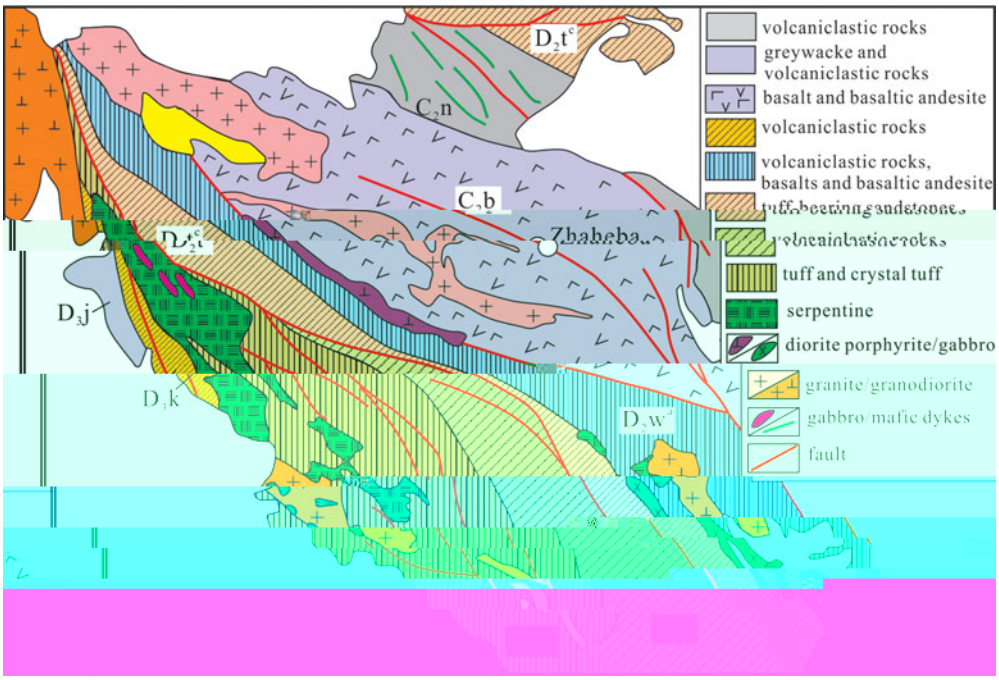
1. ( )
( ) ( )
( )
et al. 200).

(1)
(2)

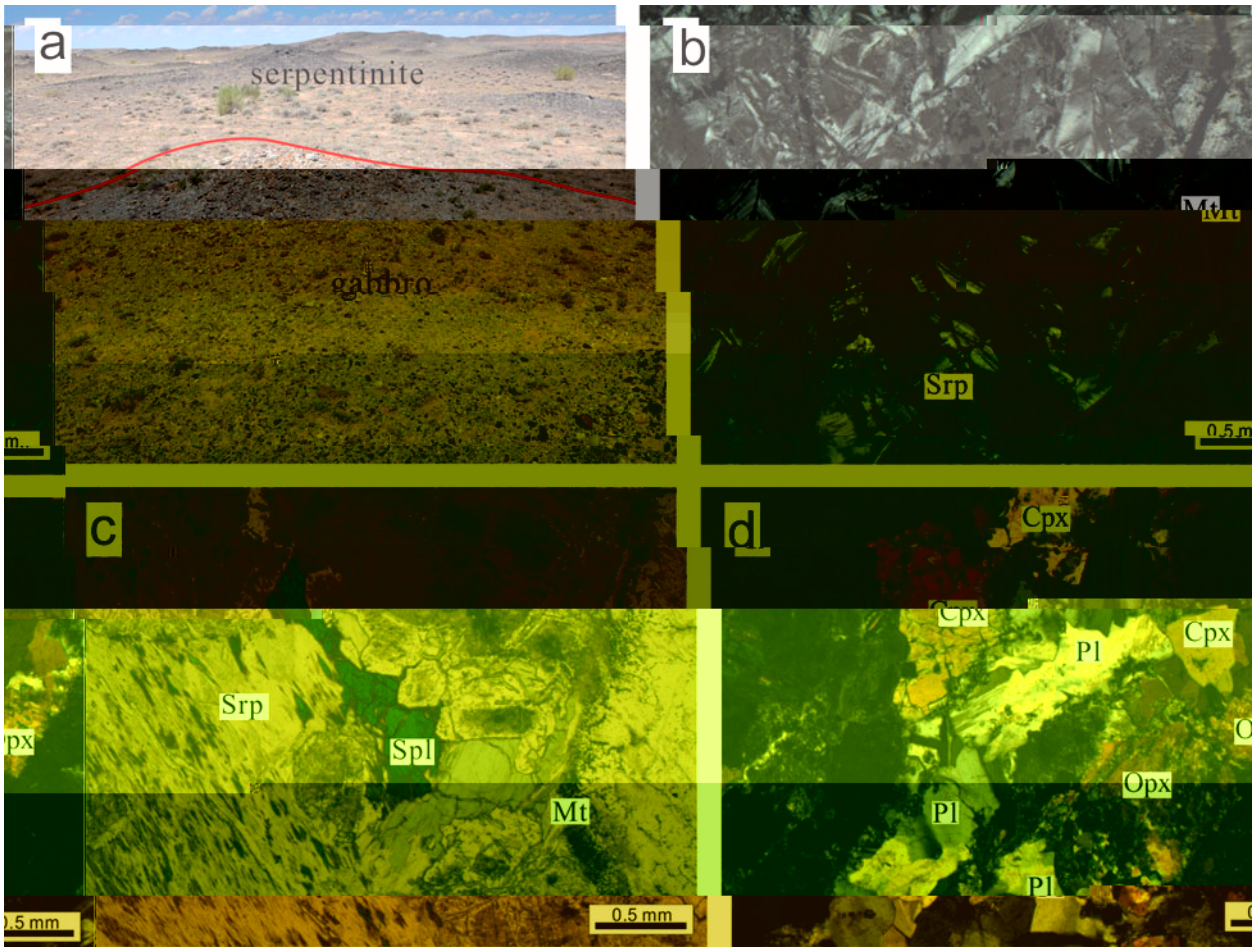
2. Reg onal geology, fiel observat ons an petrography

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

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



2. ( ) *et al.* 200 , 200, *a* , 1, ; 3).



3. ( ) . ( ) > 0% ( ) % % %

3. Analytical procedures

3.a. Zircon U–Pb dating and Hf–O isotope analysis

(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), ( ) δ1 5.31 ‰ (et al. 2010*b*). δ1 5.44 ± 0.21 ‰ (2), 5.4 ± 0.2 ‰ (et al. 2013). 3 / .

3.b. Mineral analysis

00 15 15

20 4 5 / .

3.c. Whole-rock analysis

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 0. 0506, -1, 143 /144 0.512104 0.5126 1 -1. 2.

4. Analytical results

4.a. Zircon U–Pb ages

100 150 μ 1 1 2 1. , % (. 4). % % (22 123 1) (5 11) / 0.4 0. % % 30 % 4 5. ± 2.5

Table 1. [illegible]

[illegible]	2013 [illegible] 01-1	2013 [illegible] 01-3	20132 [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
					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] 2 3	0.61	1., 6	1.04	0.6	0., 0	0. 4	0., 0	1 .2	1, .64	1, .33
[illegible] 2 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,	, .31	3 .44	10.04	, .03	5. ,

Table 1.

	2013 [illegible] 01-1	2013 [illegible] 01-3	20132 [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
	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 [illegible] 01 5	2013 [illegible] 01 6	2013 [illegible] 01	2013 [illegible] 01	2013 [illegible] 01	2013 [illegible] 03 2	2013 [illegible] 03 3	2013 [illegible] 03 4	2013 [illegible] 03 5	2013 [illegible] 01 3
			(1)	(1)	(1)	(1)	(1)	(1)	(1)	(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
2 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
	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
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
	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 .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

1.

	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
			(1)	(1)	(1)	(1)	(1)	(1)	(1)	(2)
	3	1.20	3 .60	46. 0	4 .30	23.40	43.00	25.20	32 0	6.56

Table 1.

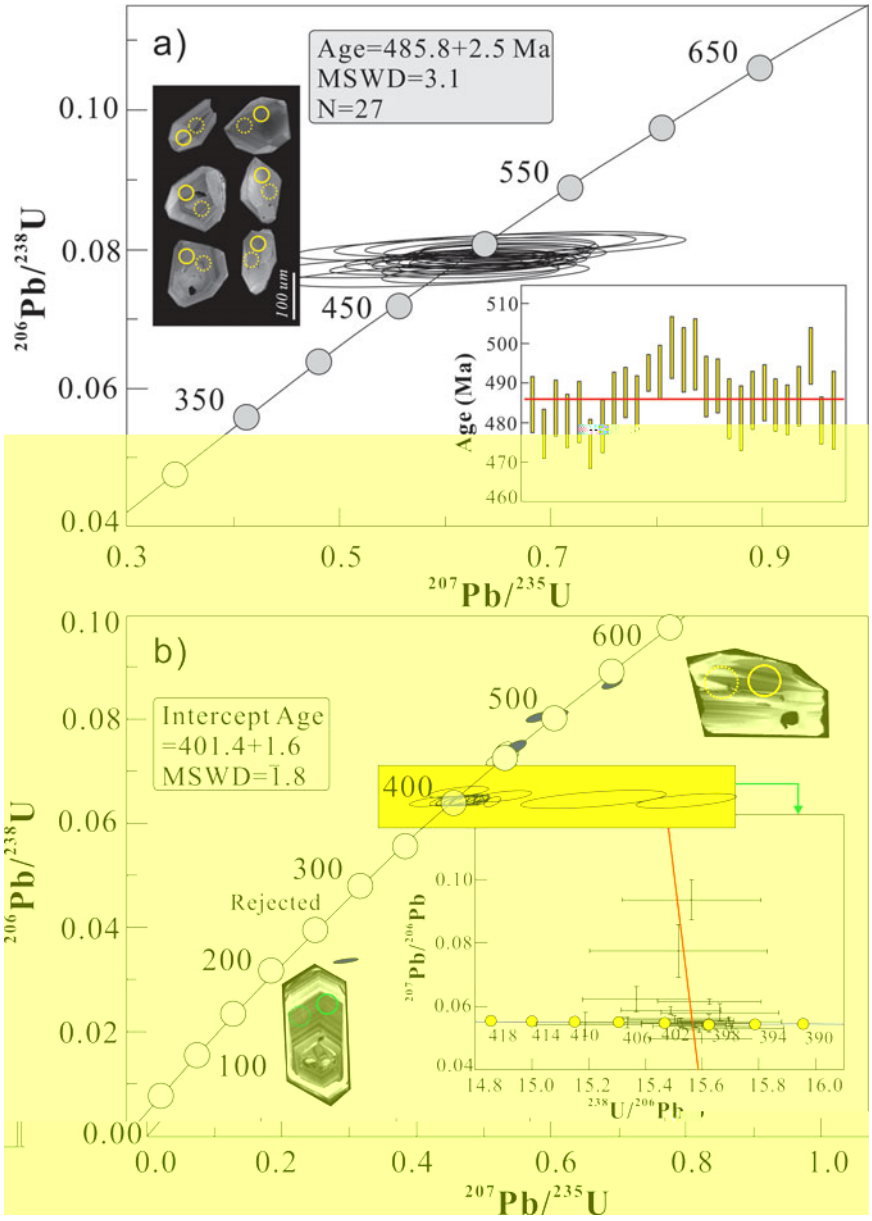
	2013 [illegible] 01_11 [illegible] (r 2)	2013 [illegible] 02_1 [illegible] (r 2)	2013 [illegible] 02_2 [illegible] (r 2)	2013 [illegible] 03_1 [illegible] (r 1)	2013 [illegible] 03_6 [illegible] (r 1)	2013 [illegible] 01_10 [illegible] (r 2)	04/06 [illegible] (r 1)	04/24 [illegible] (r 1)	04/2, [illegible] (r 1)	03/1 [illegible] (r 1)
				Trace elements (ppm)						
	1, .4	36.,	42.4	26.0	32.4	1 .,	/	/	/	/
	0.3, 5	0.153	0.35	1.1,	0., 4	0.46	/	/	/	/
	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
	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,

[illegible] 1 / 04/06, 04/26, 04/2, [illegible] 04/1 [illegible] / [illegible] *et al.* (200, *a*).

2.

2013 01 3 (r 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 (r 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 (r 1)	3.13	2 0	0.0335	0. 06324(20)	0. 06133	4.4,	22.3	0.121	0.51253 3(4)	0.512214	1.
2013 03 2 (r 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 (r 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 (r 1)	.65	14 0	0.01 ,	0. 0422 (51)	0. 04120	4.55	24.5	0.1123	0.512 03(53)	0.51250,	.5

401



4. ( ) 1σ % 2σ ( ),

(. 4 = 2 , = 3.1). - % 1 4 ± 4 % *et al.* 2003).

100 200 μ

/ 1 3. - 1 (r 1) , 0 % % % 1 (r 2)

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

4.b. M neral compos t ons

4.b.1. Spinel composition

(. 3) 100 300 μ 4 (100 / (+)) 44 60 (100 / (+)) 25 61. (et al. 2010). (et al. 2013).

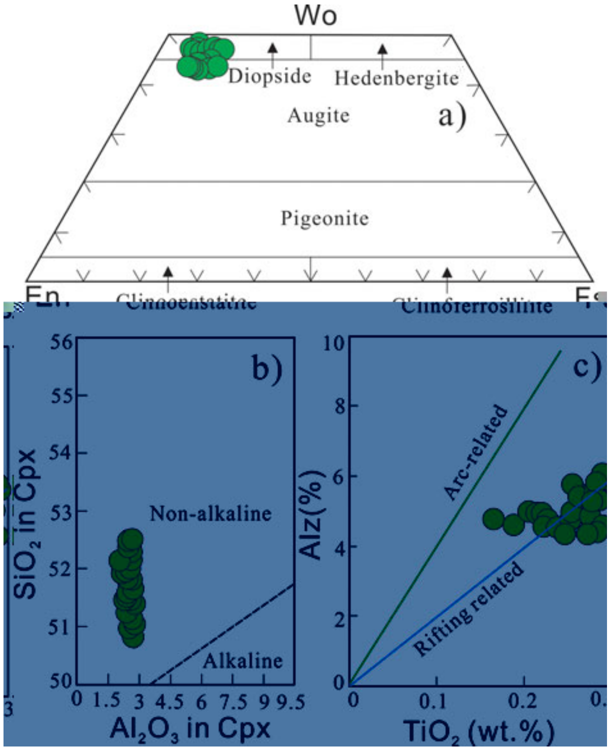
4.b.2. Pyroxene compositions

(= 4 6). 2 (0.5 %) 5 /). 41 4, 46 55 (. 5). 2 3, 2 2 (. 5 ,).

4.c. Whole-rock elemental geochem stry

4.c.1. Serpentinites and cumulates

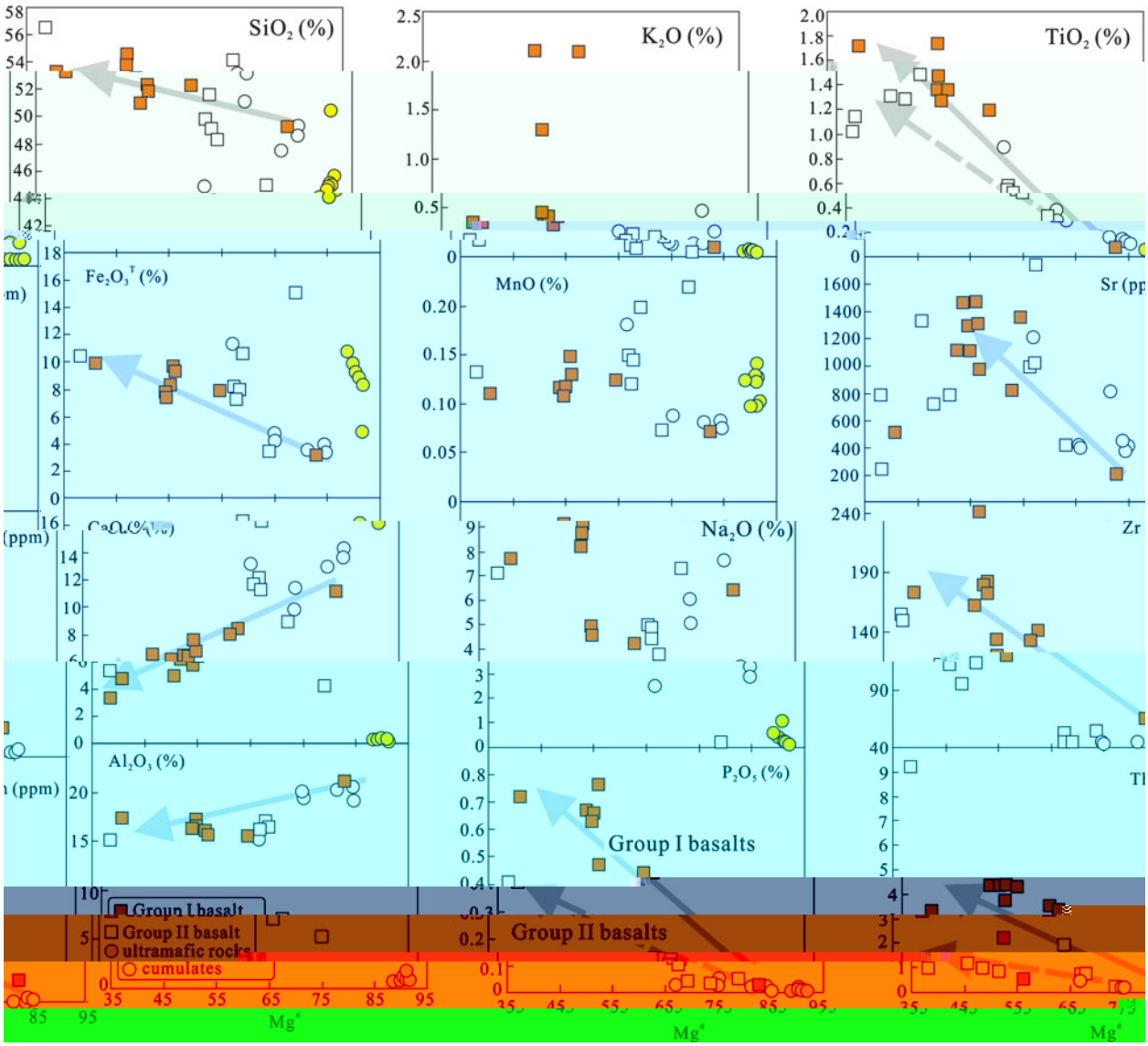
(> 12 %, 2 (40 %), 3 (% 1.0 %), (0.03 0.06 %), (0.04 0. 2 %) 2 (0.04 0.05 %). 3



5. ( ) ( ) 2 (%) 3 (%) ( ) 2 (%)

1 (1) (. 6). (3 103) (5) (1). (> 12 %) 2 3 2, (1) (.), , 2014 & (, 1,).

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



6. ( )) (% *et al.* 200, *a*).

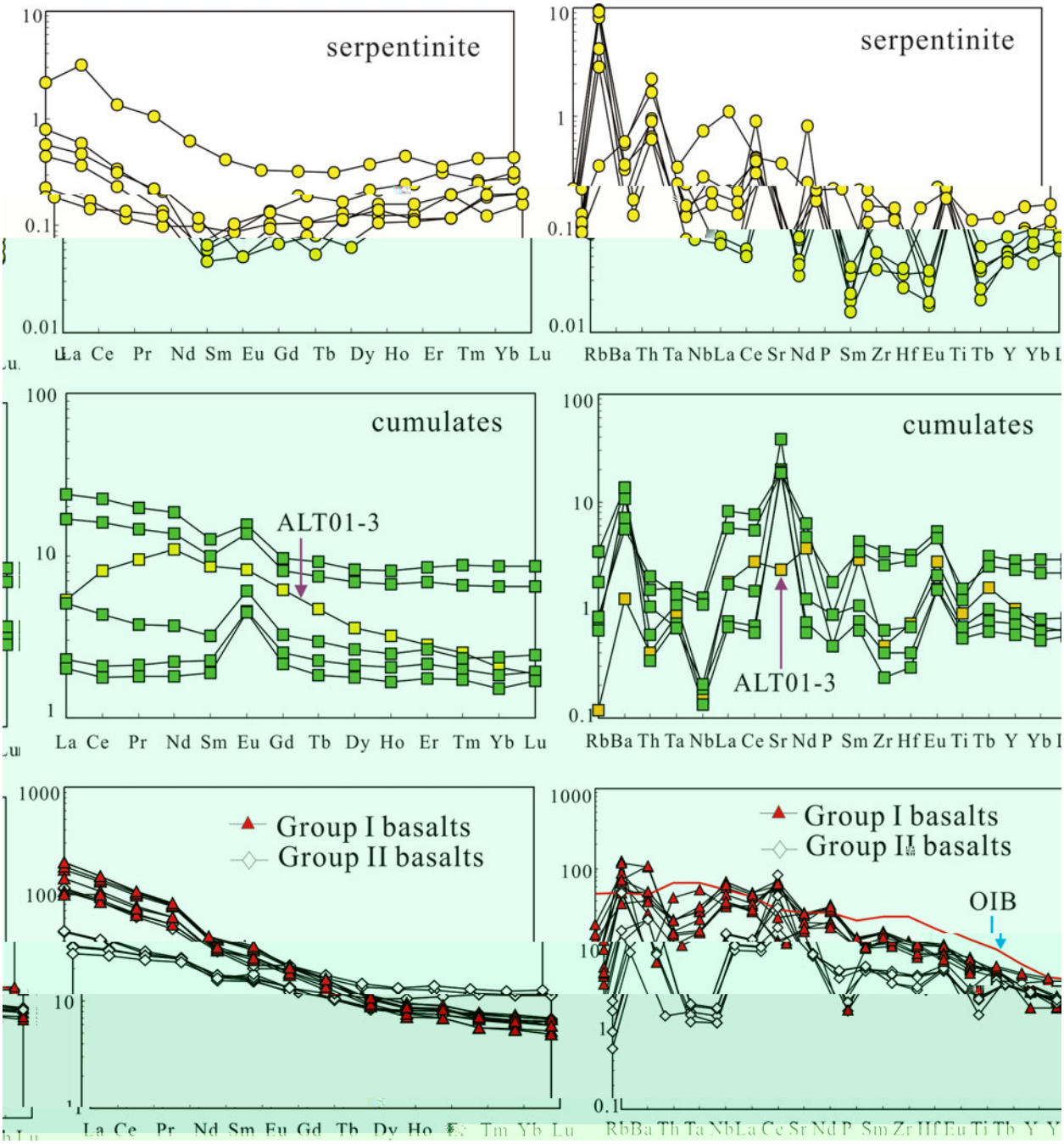
(. 6). 5 11 41 11 , ( ) (( ) = 1.3 2.) (/ = 1.1 2.2). 2013 01-3 1 , 1 % ( ) ( ), % (/ = 0.2 0.4) 1 .

4.c.2. Basalts

43.15 % 5 .65 % (% 52 %,

1) % , 1 / / 2 , 1 1 (1) 1 2 (2). 2 1 , 1 % ( ). 1 2 ( ), 2 2 3 , 5, 2, , 2 3 1 2 2, 5, 2, . (. 6).

1 % 124 11 205 2 50 11 60 11 . 1 (/) 10 30 (% 20)

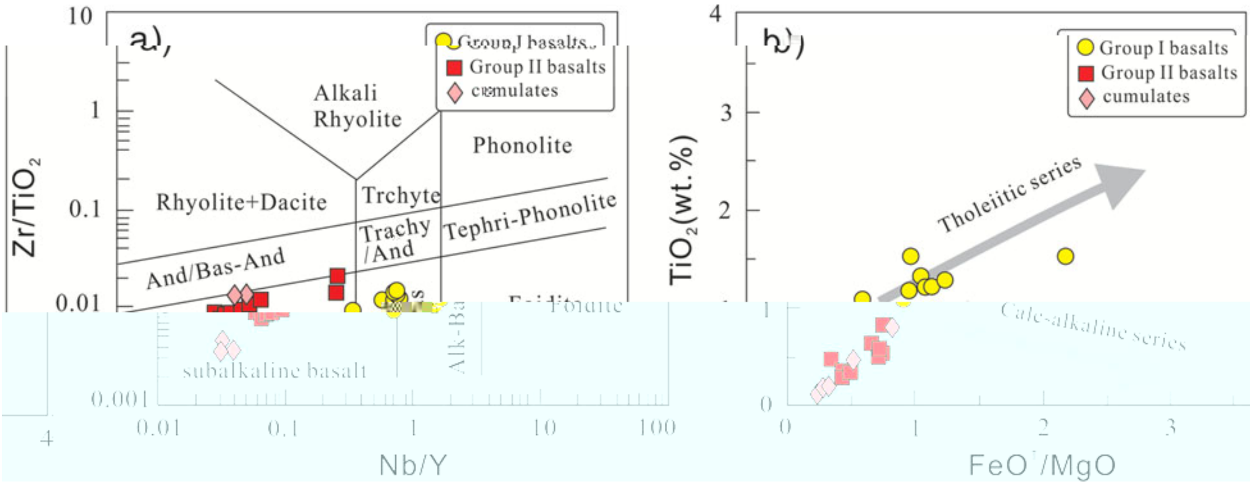


( ) 1 & (1).

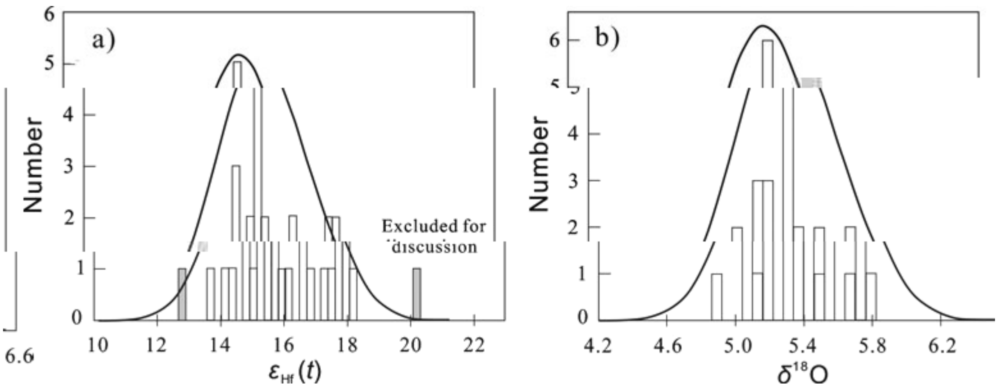
1 (/ = 0. 0 1.14) (.). 2. % 1 - (/) 4 6 1 (/ = 1.02 1.21) (.). 1. 1 0.44 0. 2. 1. 1 % (~0.11). % 1 (.).

4. . Whole-rock Sr–N an z rcon Hf–O sotopes

% 1 1 2. 1. 2. % / - (0.0024 0.0452) / (0. 04030 0. 0536), 1 % / (0. 04015 0. 05171, 1 2013 03 1). % 14 /144 0.0, 0.13, 4 143 /144 0.512 0 0.512 3, % ε (*t*) +6.3 + .5 (1 2013 03 1 +1.).



(1, 4).



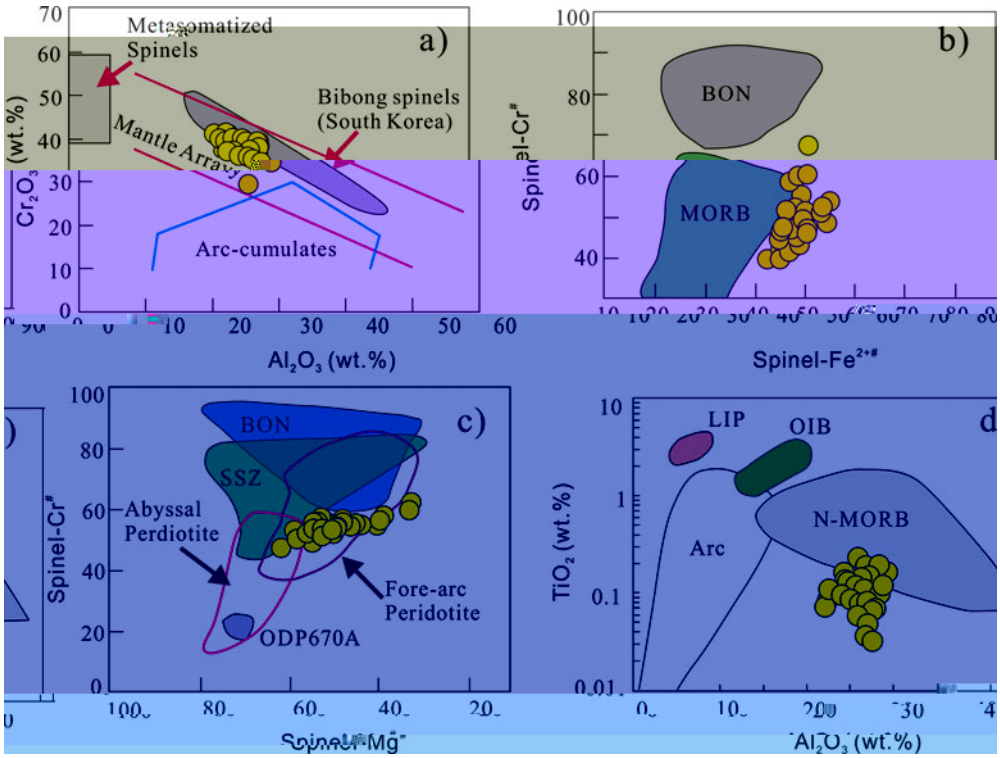
(2013, 01)), εHf (t = 4 5) 13 20. 2 5 5 εHf(t) (> 16) εHf(t), 15. δ18O 4. 1 ‰ 5. 3 ‰,). δ18O 5.3 ± 0.23 ‰ ( ).

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

5. Discussion

5.a. The individual members of the Zhaheba ophiolite

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

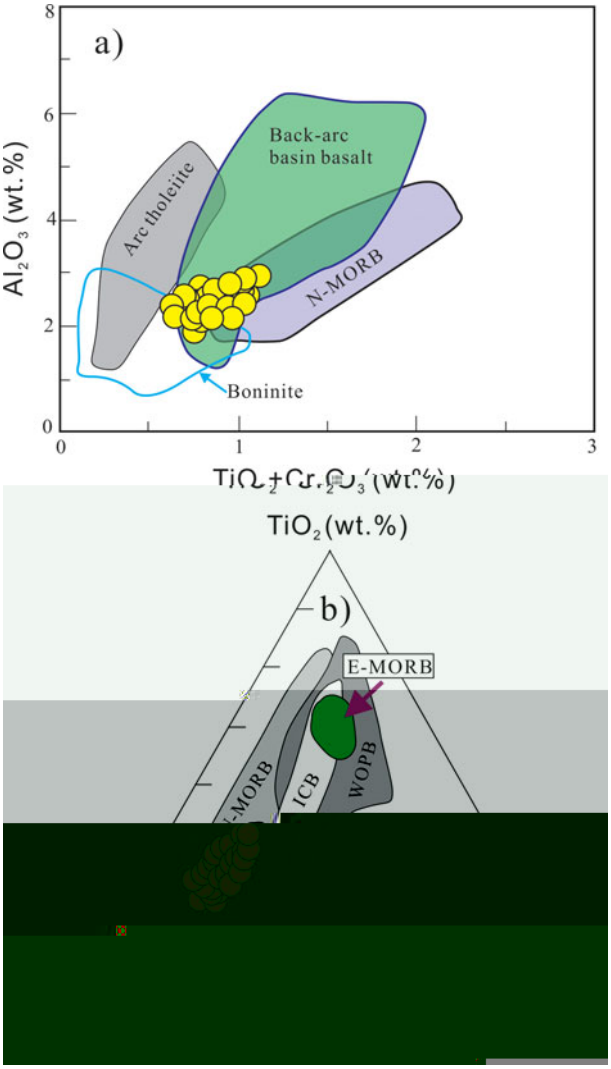


10. ( ) & , 2000). ( ) . (100 /(+)) . (100 2+/(2+ +)) (1, 4 & , 2001). ( ) . (100 /(+)) . (100 /(+)) (et al. 1, 5). ( ) 2 3 1 1 (%) & , 2001). 4

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

5.b. Or g n of the serpent n te an cumulates

%, & , 2002 et al. 2010



11. ( ) ( ) $_2$ $_2$/100 %

( ) (%1). %

5 % $_2$/100 $_2$ $_2$ %1 %

. 11) %

.).

. /

(. 12),

%

/ /

(. 12).

%

et al. (2002)

% %

( ).

5.c. Petrogenes s of the Devon an basalts

%

1

2. 1 (11 24 11

% 15 11), 5 (0.4 0.6 %)

(11 15, 60) (/)

% ( ) (& 1 2

& , 2001) (. 13).

(1)

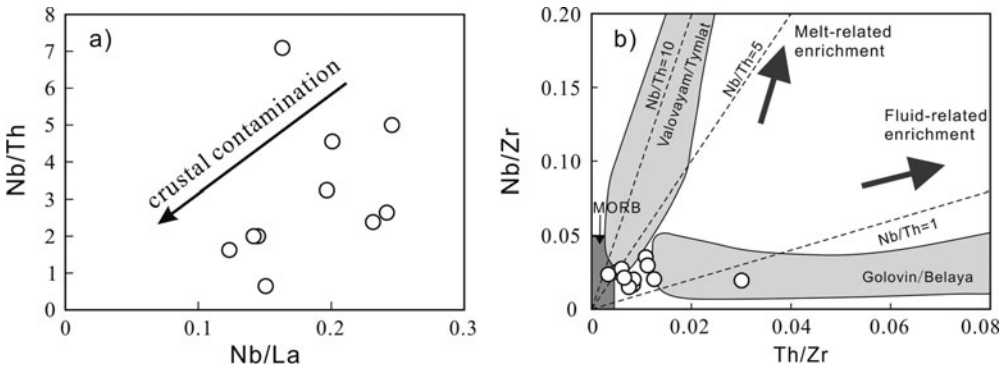
(& %

, 2002) (2)

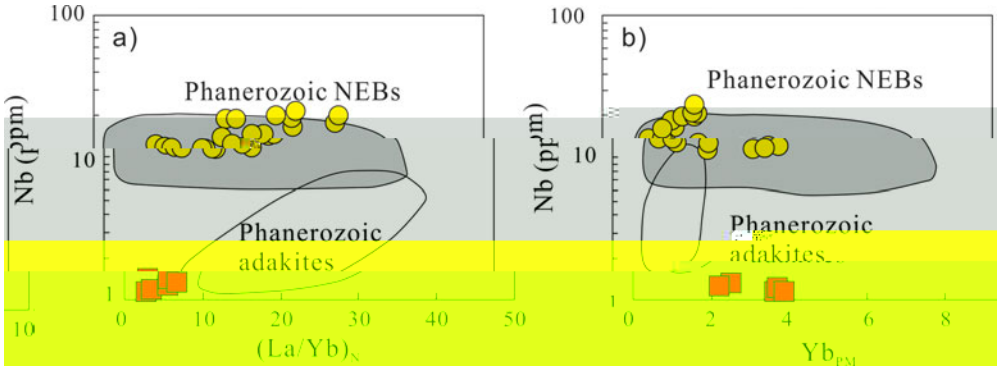
% (& 1 2 & 1 3 *et al.* 1 6).

%

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



12. ( ) / / ( ) 1 / / .

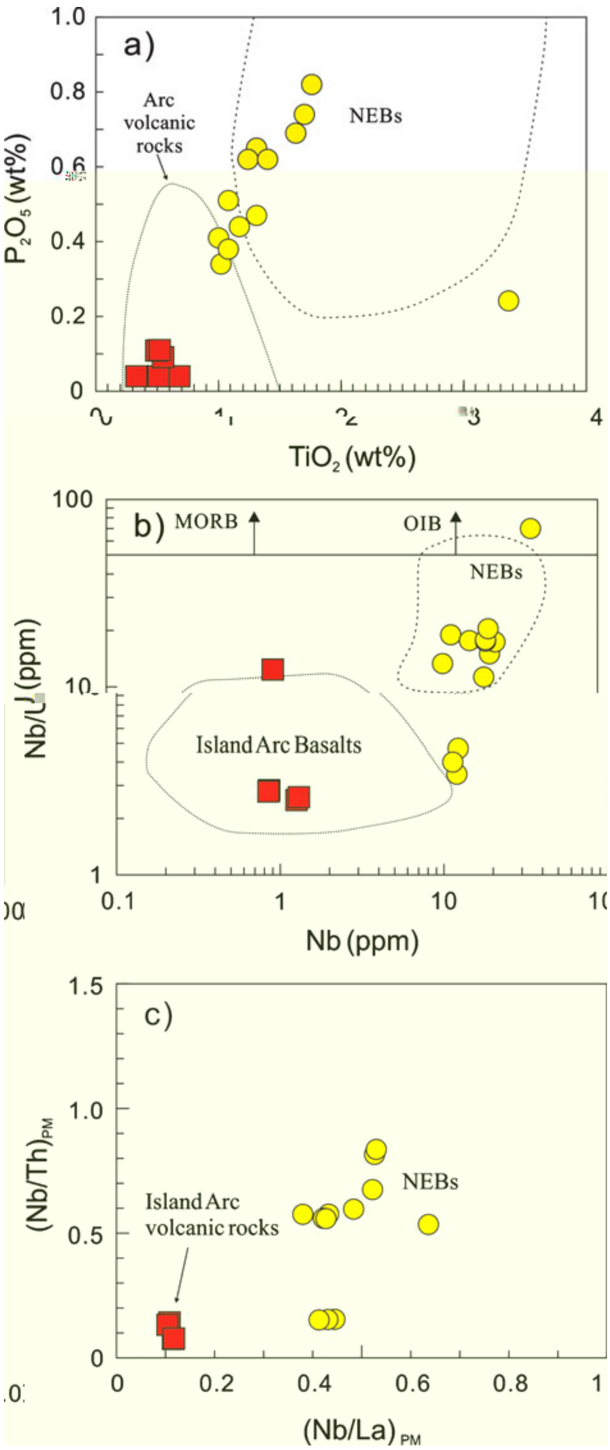


13. ( ) ( ) (/) ( ) 1).

ε (*t*) (1. .5) (/), (0. 04120 0. 06133) % (2). % ε (*t*) (/), % 1 % % % % 2 % (< 0.3) / / (.), % % & % 1 1 , 2002). 2 ( ), (0. 1.0), (/) (0.1 0.2) / (0.6 1.0) 2 % % (& , 1 6). 1 2 5 (/) (. 1 . 14). % % (. 14). 2 % % 1 2 % .

5. . Impl cat ons for the Palaeozo c accret on process n eastern Junggar

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



14. ... *et al.* ...

... *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). ...

... *et al.* (200 ... 200 b) ...

... *et al.* 200). ... 200 ... *et al.* 2013). ...

(1) ... (*c.* 500 ...), ...

(2) ... (500 ...), ...

(3) ... 420 ...), ... (45 ... *et al.* 2015) ...

... (440 ... *et al.* 2014) ...

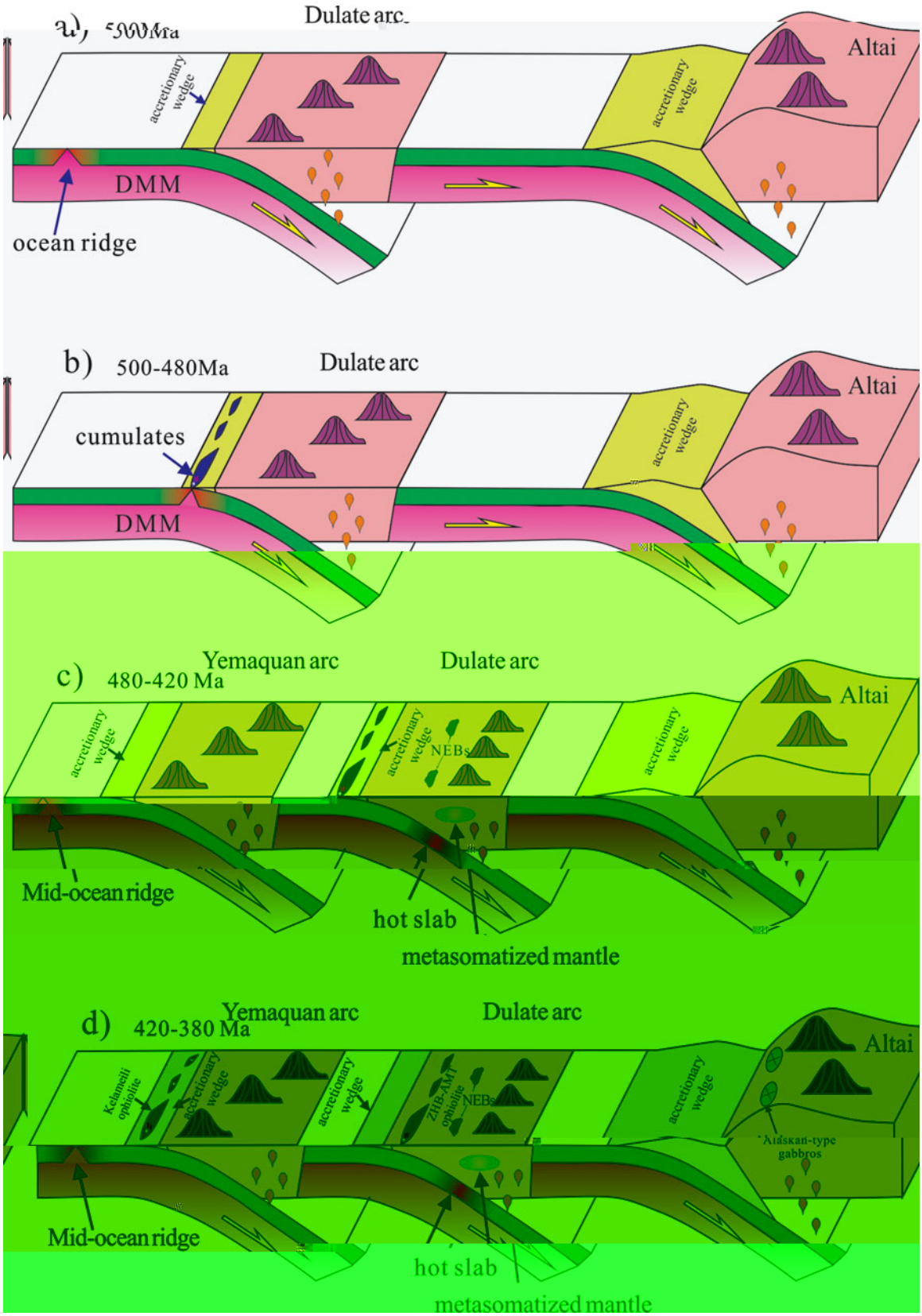

a) 500Ma
Dulate arc
Altai
accretionary wedge
accretionary wedge
DMM
ocean ridge
b) 500-480Ma
Dulate arc
Altai
cumulates
accretionary wedge
DMM
Yemaquan arc
Dulate arc
c) 480-420 Ma
Altai
accretionary wedge
accretionary wedge
NEBs
accretionary wedge
Mid-ocean ridge
hot slab
metasomatized mantle
Yemaquan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

Fig. 15. (

(4)

(420 3 0) (*et al.* 2014 *et al.* 2015).

1. ( ) 2.

(400 3 0).

6. Conclus ons

(1) ~4 5 *c.* 400

(2)

(3)

Acknowle gements. 305 (2011 06 03-01).

Supplementary mater al

11 % 1 /10.101 0016 56 16000042.

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