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

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

[illegible]

[illegible]
, 10003 [illegible]
210016, [illegible]
, 36[illegible]4[illegible]-5305, [illegible]

(*Received* 1[illegible] 2015; *accepted* [illegible] 2016; *first published online* 1[illegible] 2016)

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

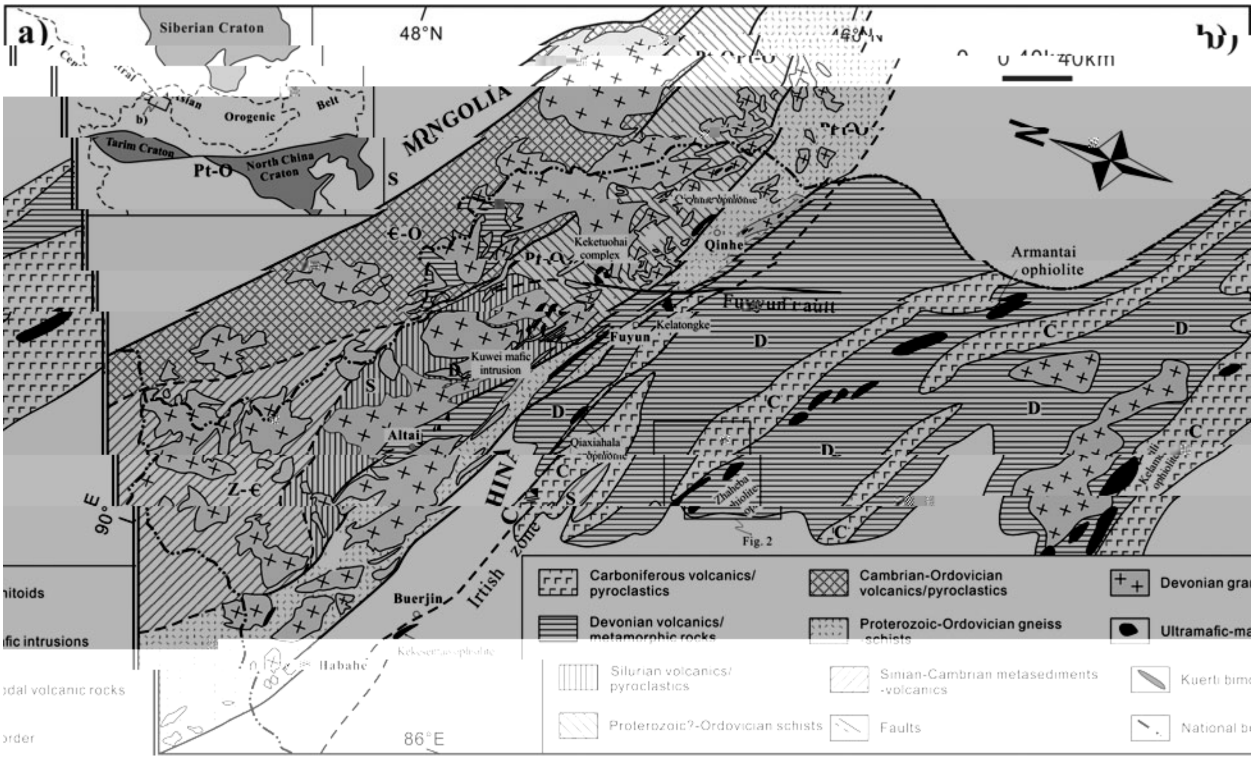
[illegible] ([illegible]), [illegible]

1. Introduction

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

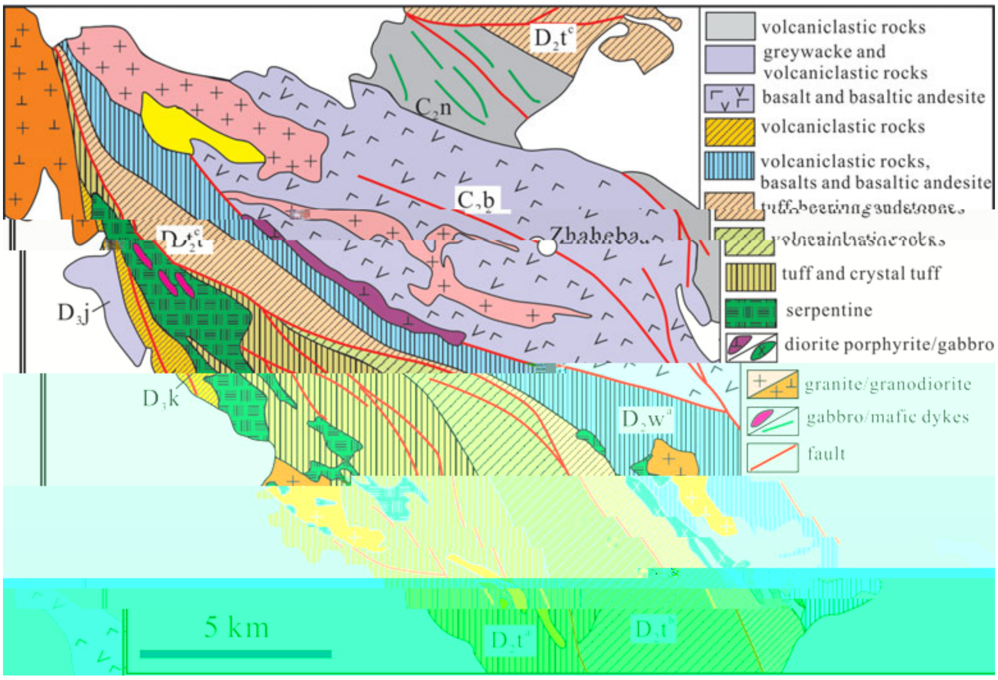
[illegible] 1[illegible]6 [illegible]

[illegible] ([illegible]), [illegible] ([illegible], 2000 [illegible] & [illegible] 1[illegible] 3 [illegible] & [illegible], 2000 [illegible] *et al.* 2002 [illegible] *et al.* 2004, 200[illegible]*a*) ([illegible] 1[illegible]). [illegible] (*et al.* 200[illegible]*d*,*b* [illegible] & [illegible], 2012). [illegible] ([illegible] 1[illegible] 3 [illegible] *et al.* 2003 [illegible] *et al.* 2003 [illegible] *et al.* 200[illegible]*a*) ([illegible] 1[illegible]). [illegible]

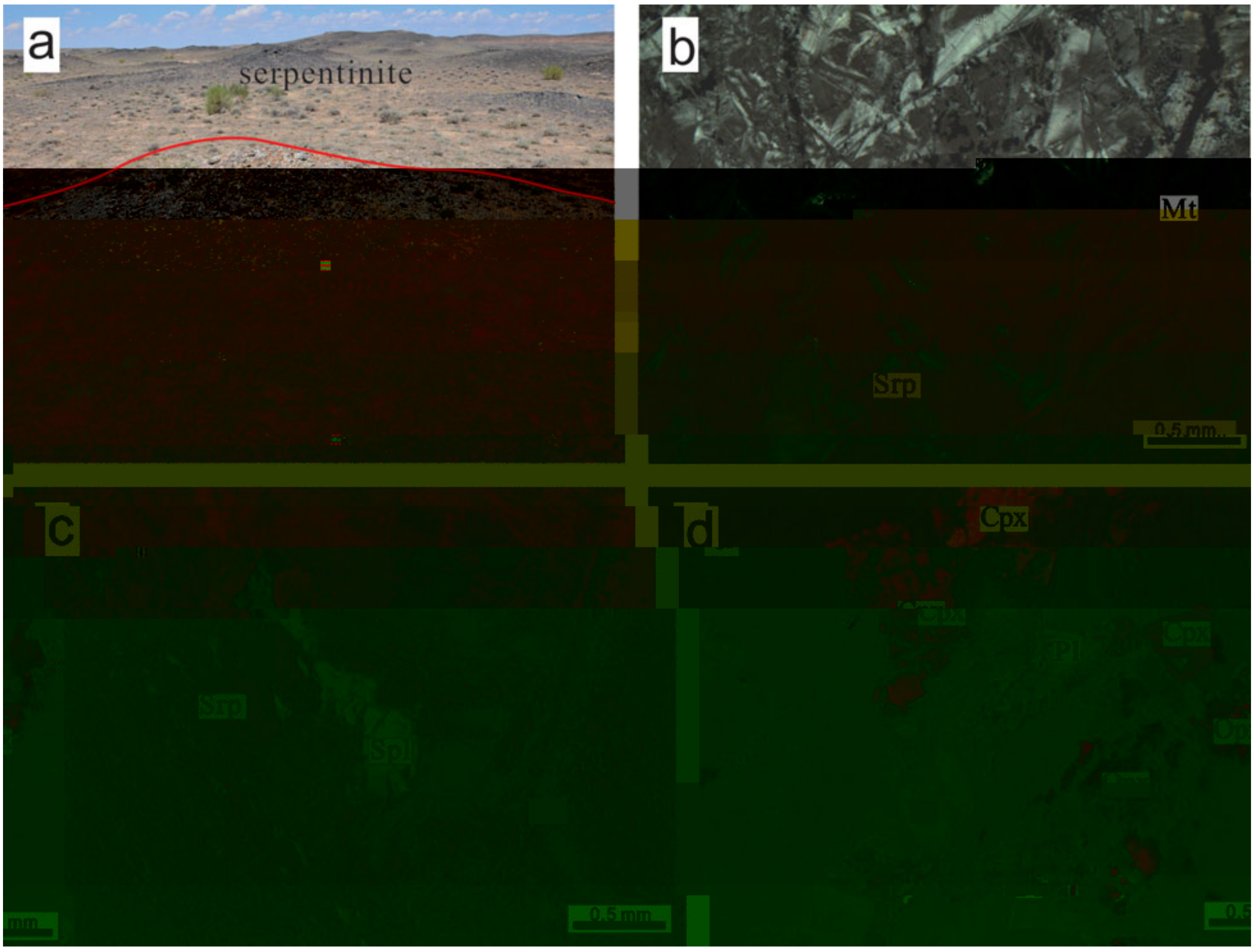


1. (a) ... *et al.* 200).

2. Regional geology, field observations and petrography



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



3. [illegible] 0% [illegible]

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 % ...

... 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.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 ... 2.

4. Analytical results

4.a. Zircon U–Pb ages

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

[illegible] 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 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]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]	0.12	15.42	0.15	0.14	0.2	0.10	0.14.5(01-)-2. (10 324. (1 .64)-5 0 5(.0[illegible] 3)-4([illegible])-([illegible] .4 5 -5.4 [illegible] 0 142.5 5 [illegible]			

[illegible] 1. [illegible]

[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
[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 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 (%)										
[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] 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

[illegible] 1. [illegible]

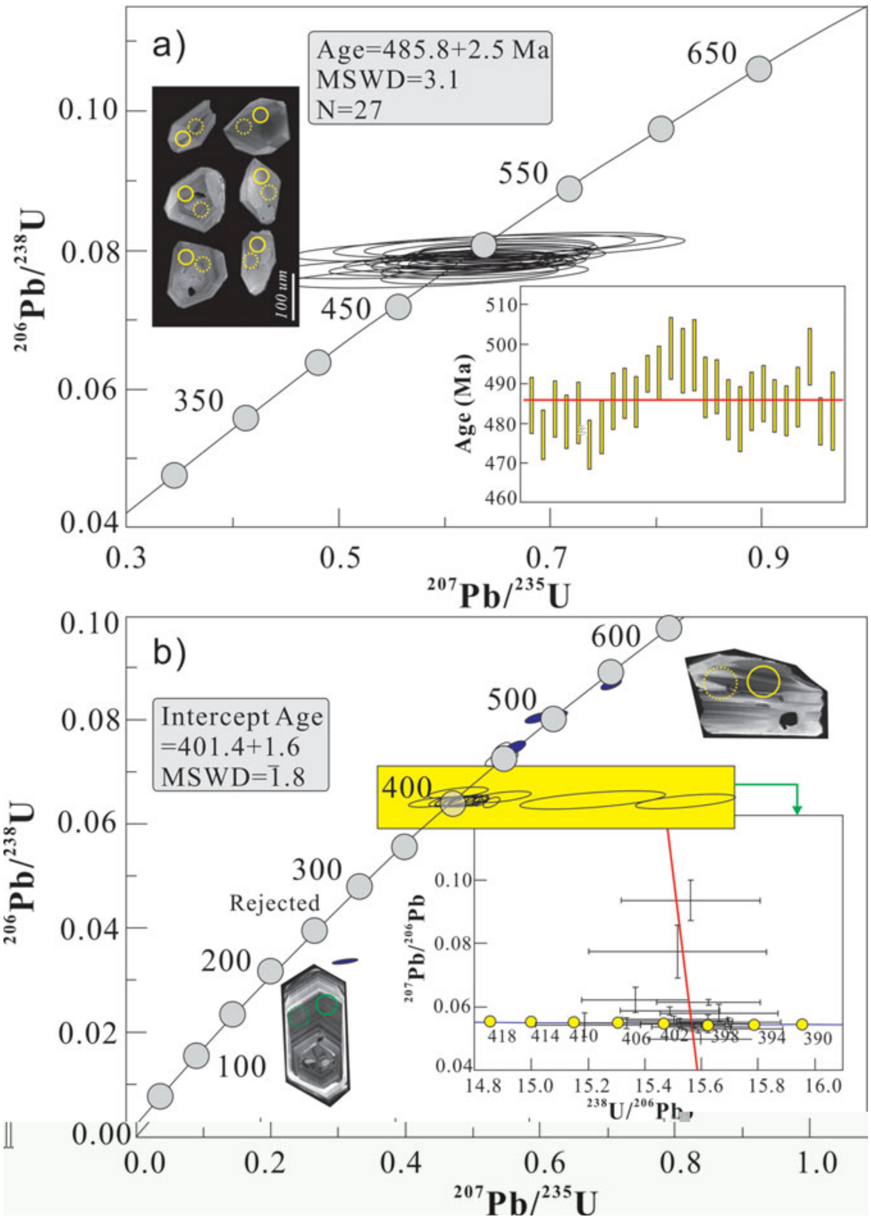
[illegible]	2013 01 11 (2)	2013 02 1 (2)	2013 02 2 (2)	2013 03 1 (1)	2013 03 6 (1)	2013 01 10 (2)	04 06 (1)	04 24 (1)	04 2 (1)	03 1 (1)
					Trace elements (ppm)					
[illegible]	1 .4	36,	42.4	26.0	32.4	1 ,	/	/	/	/
[illegible]	0.3 5	0.153	0.35	1.1	0, 4	0.46	/	/	/	/
[illegible]	32.5	33.2	34.5	25.1	26.3	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

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

[illegible] 2. [illegible]

[illegible]	[illegible]	[illegible] ( )	[illegible] ( )	[illegible] / [illegible]	[illegible] / [illegible] (1σ)	([illegible] / [illegible])t	[illegible] ( )	[illegible] ( )	14? [illegible] / 144 [illegible]	143 [illegible] / 144 [illegible] (1σ)	(143 [illegible] / 144 [illegible])t	ε [illegible] (t)
2013 [illegible] 01 3	[illegible] (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 [illegible] 01 10	[illegible] (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 [illegible] 03 1	[illegible] (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 [illegible] 03 2	[illegible] (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 [illegible] 03 3	[illegible] (1)	.06	516	0.0452	0. 0536 (43)	0. 05111	5.	36.	0.0	0.512 0 (30)	0.512450	6.4
2013 [illegible] 03 4	[illegible] (1)	.65	14 0	0.01	0. 0422 (51)	0. 04120	4.55	24.5	0.1123	0.512 03(53)	0.51250	.5

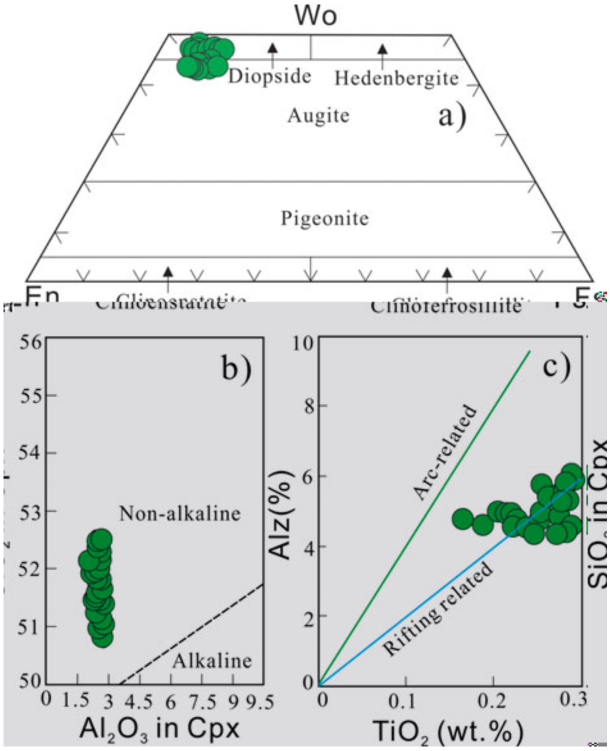
ε (t) = 10 000((143 /144)t/(143 /144) (t)−1) ε (t) [illegible] ([illegible] / [illegible])t [illegible] 401 [illegible]



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

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

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



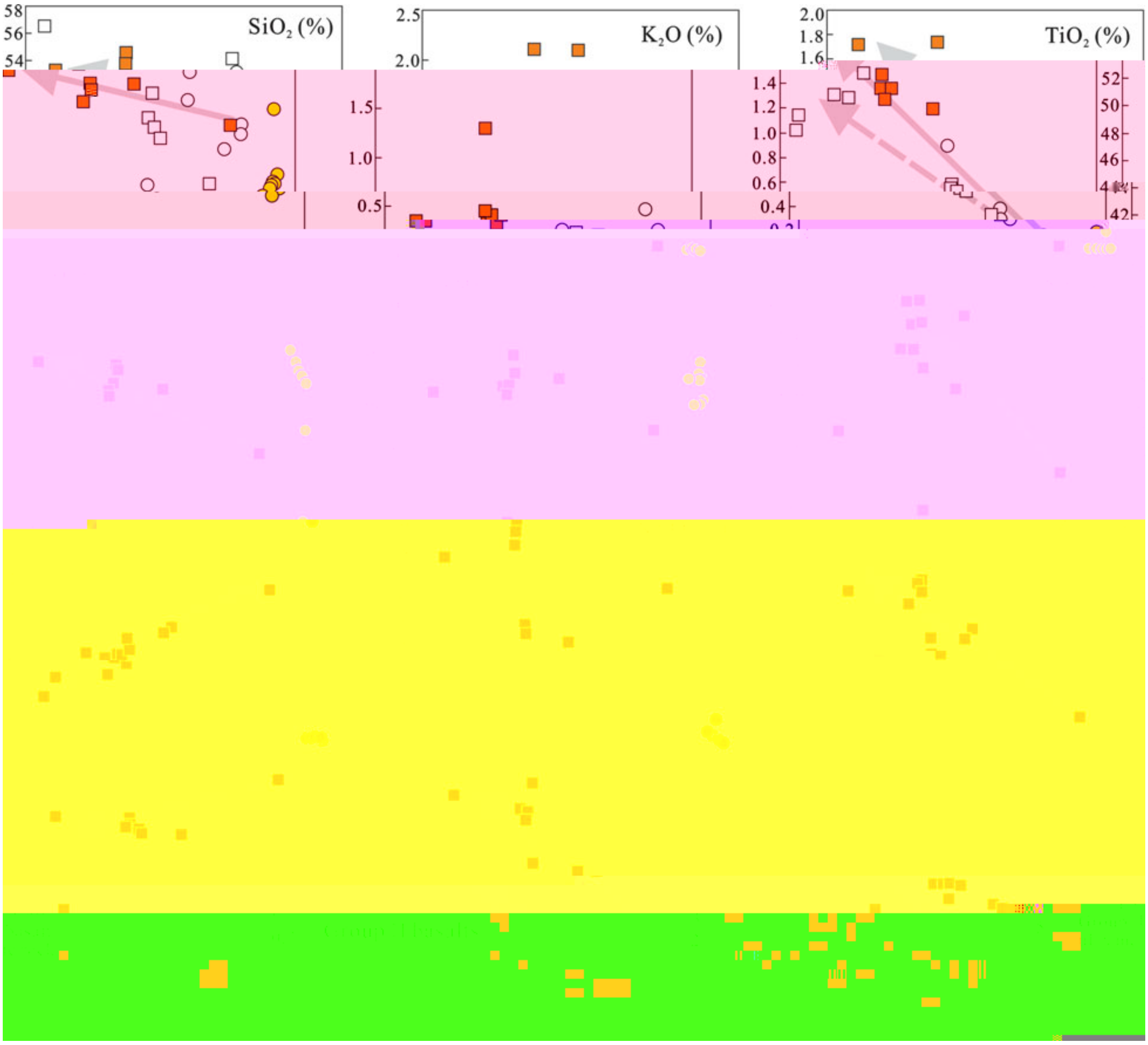
4.b. Mineral compositions

4.b.1. Spinel composition

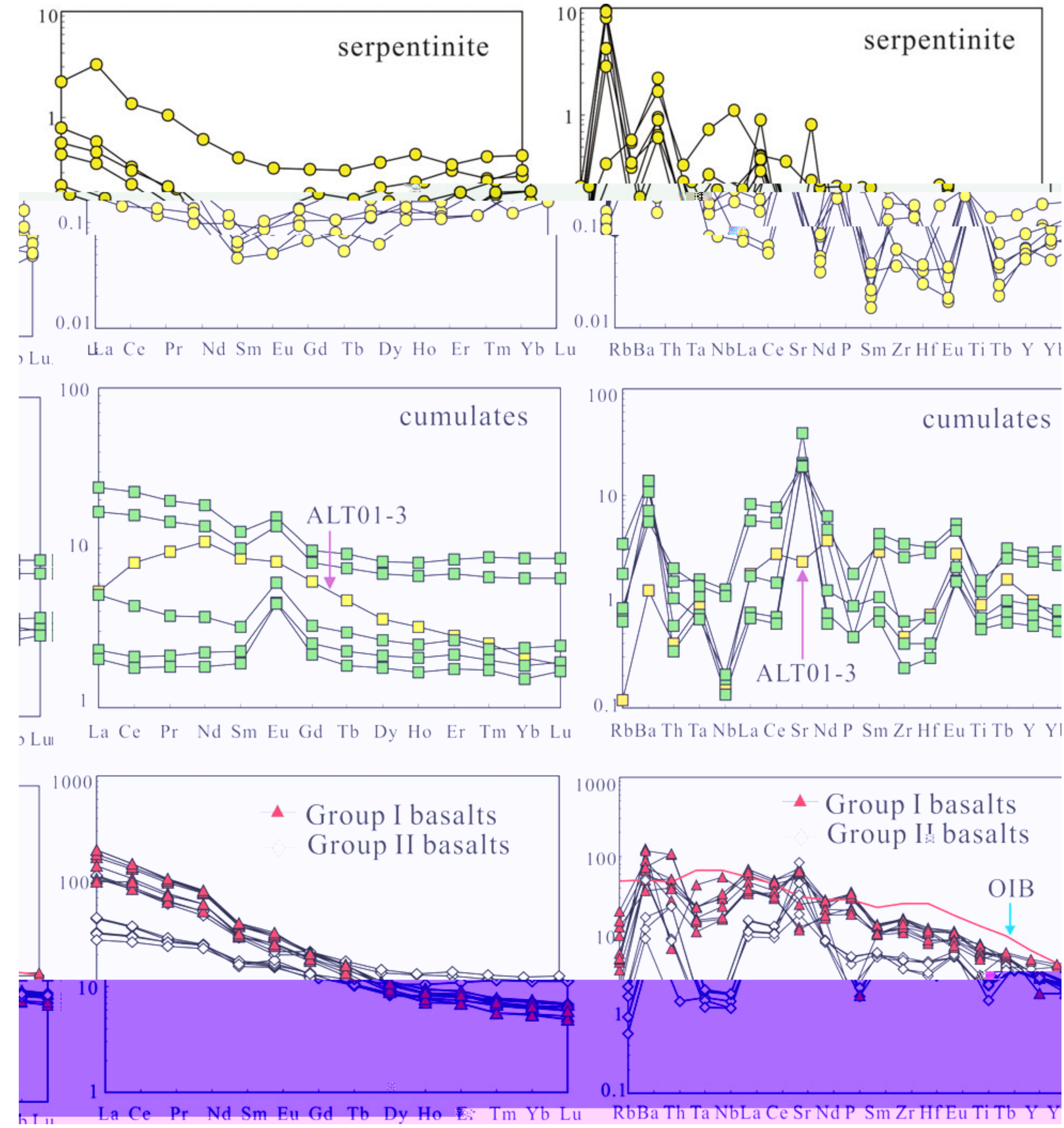
4.b.2. Pyroxene compositions

4.c. Whole-rock elemental geochemistry

4.c.1. Serpentinites and cumulates



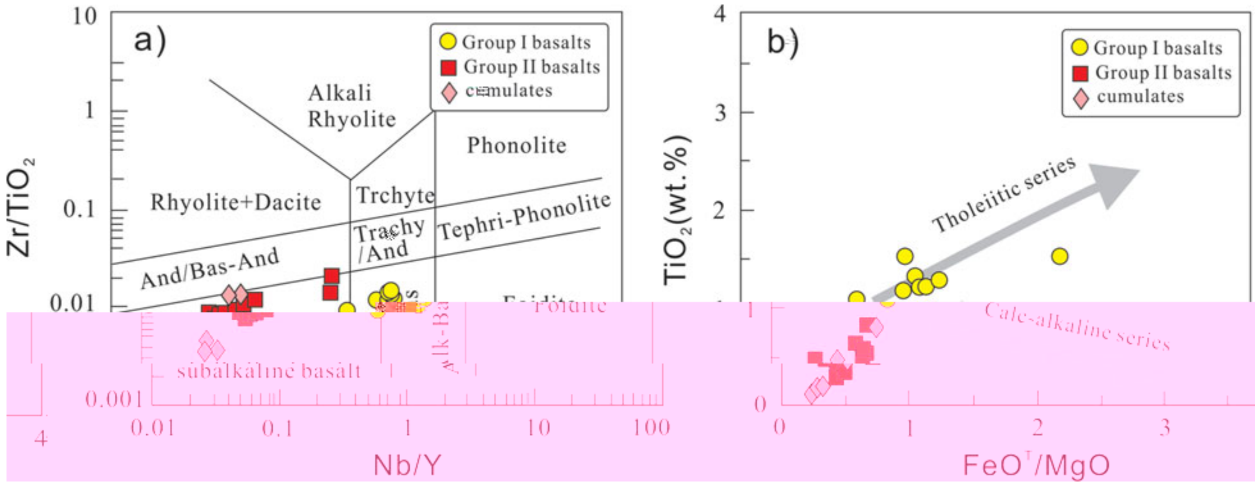
4.c.2. Basalts



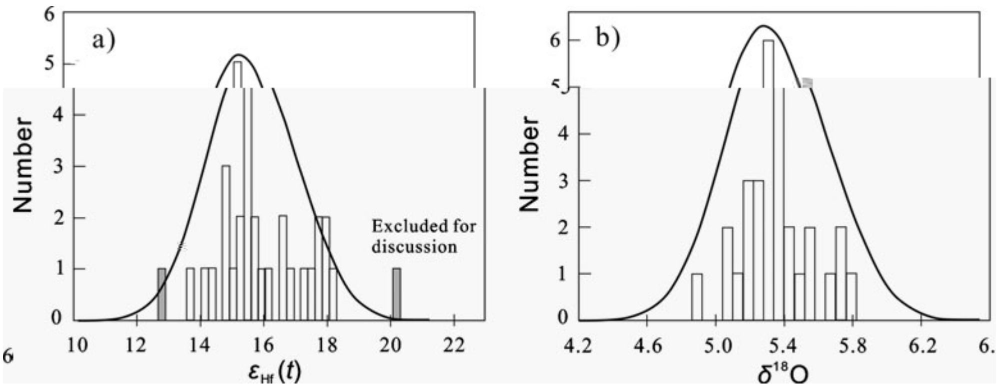
... = 0. 0 1.14) ... 1.02 1.21) ... 0.44 ... 0. ... (~0.11) ...

4.d. Whole-rock Sr–Nd and zircon Hf–O isotopes

... (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.).



[illegible]



[illegible]

[illegible] (2013 [illegible] 01) [illegible] (n = 4 5) [illegible] 13 [illegible] 20. [illegible] ε(t) (> 16) [illegible] 15. [illegible] 4. 1‰ [illegible] 5. 3‰ [illegible] 5.3 ± 0.23‰ [illegible]

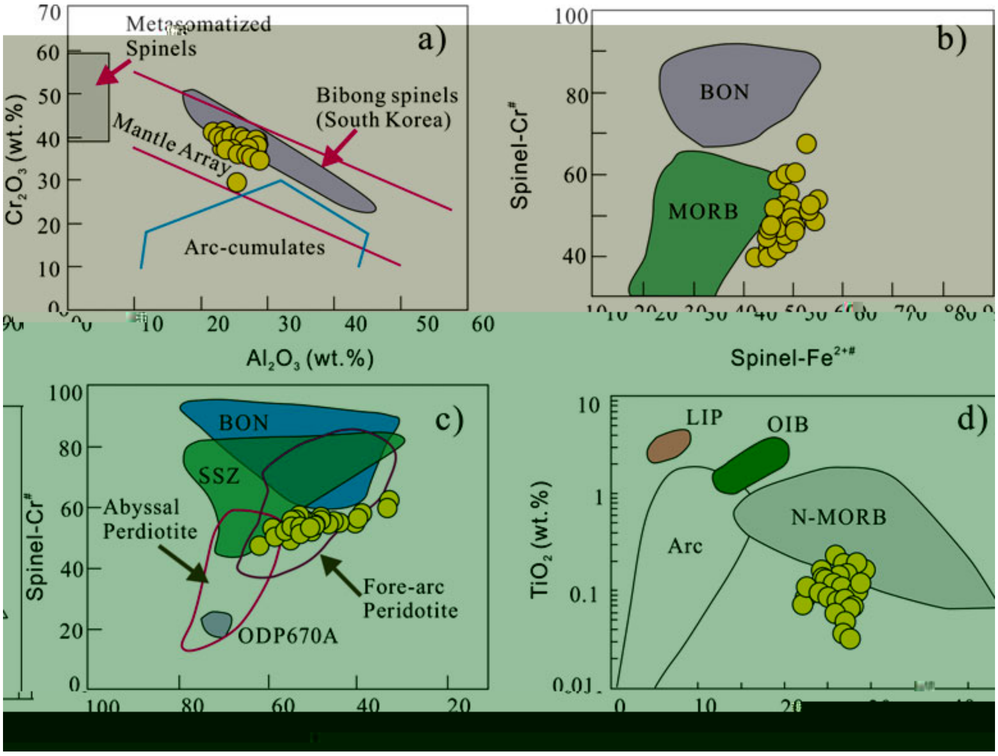
[illegible] ~400 [illegible] ε(t) [illegible] 20 [illegible] (*et al.* 200).

5. Discussion

5.a. The individual members of the Zhaheba ophiolite

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

[illegible] 1), [illegible]

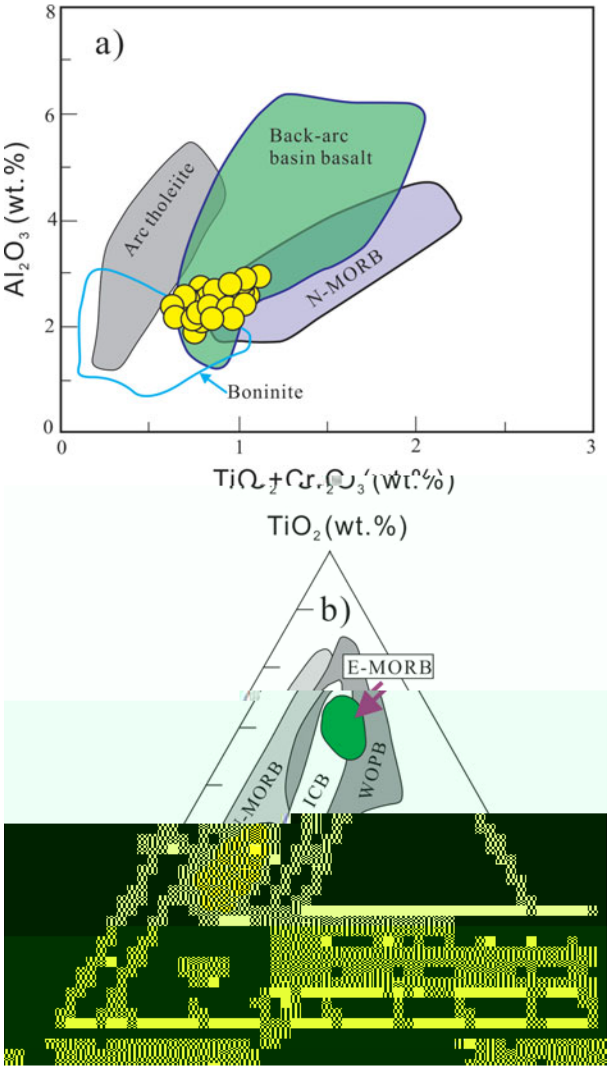


10. ( ) ( ) 3 (%) & , 2000). ( ) . (100 /( )) 2+ . (100 2+/(2+ +)) 1 4 & , 2001). ( ) . (100 /(+)) . (100 /(+)) et al. 1 5). ( ) 2 3 & , 2001).

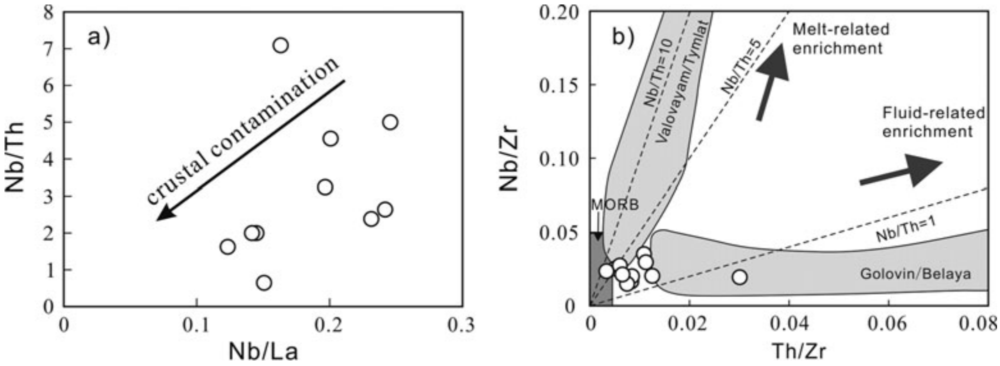
(500 4 0) (et al. 2003 et al. 2015), (430 400) (et al. 200 b, 2014) (3 0 350) (et al. 2003 / et al. 2006).

5.b. Origin of the serpentinite and cumulates

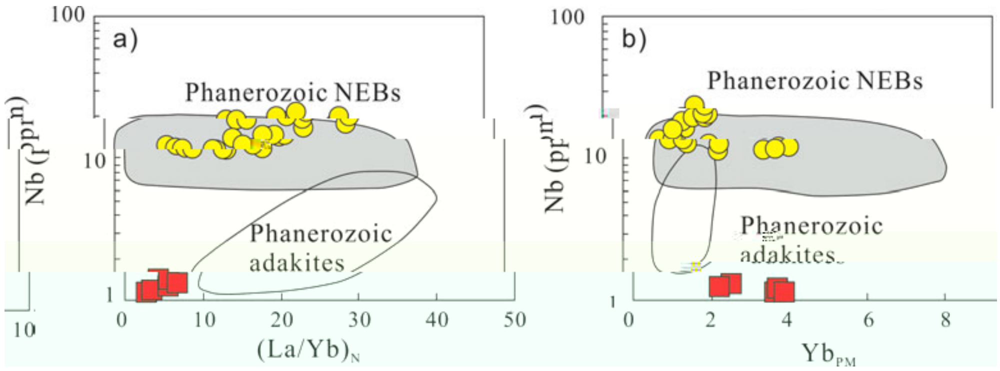
& , 2002 et al. 2010



5.c. Petrogenesis of the Devonian basalts

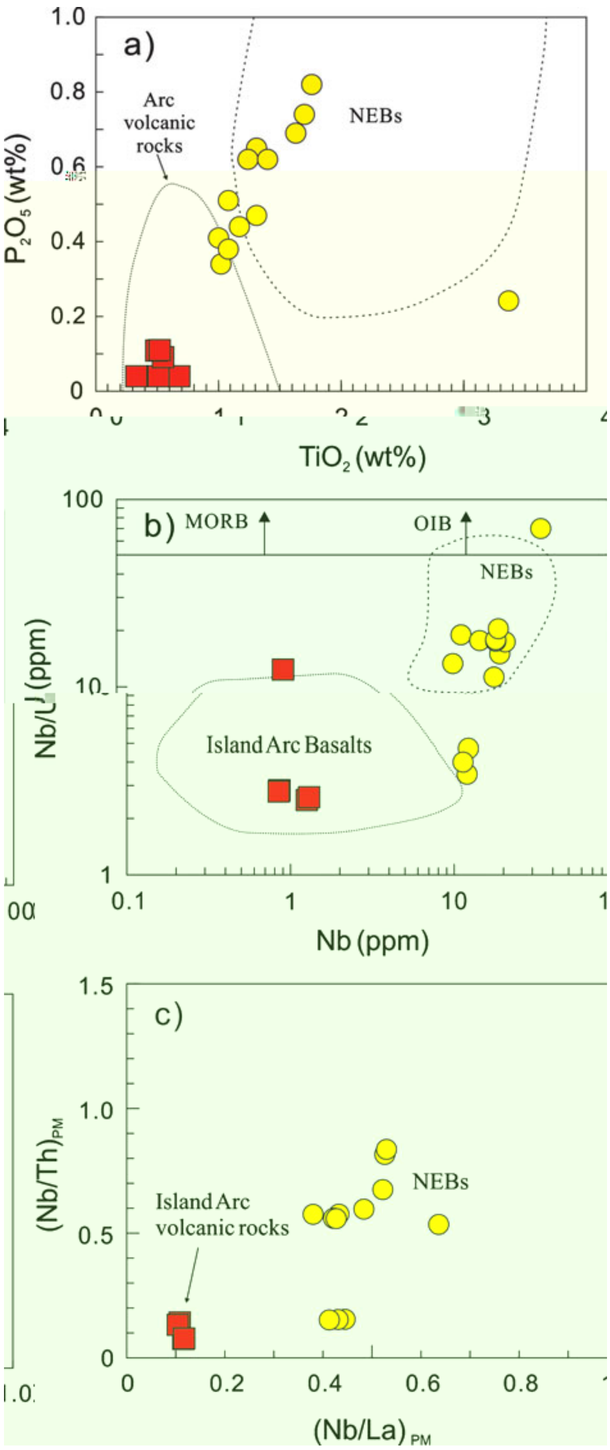


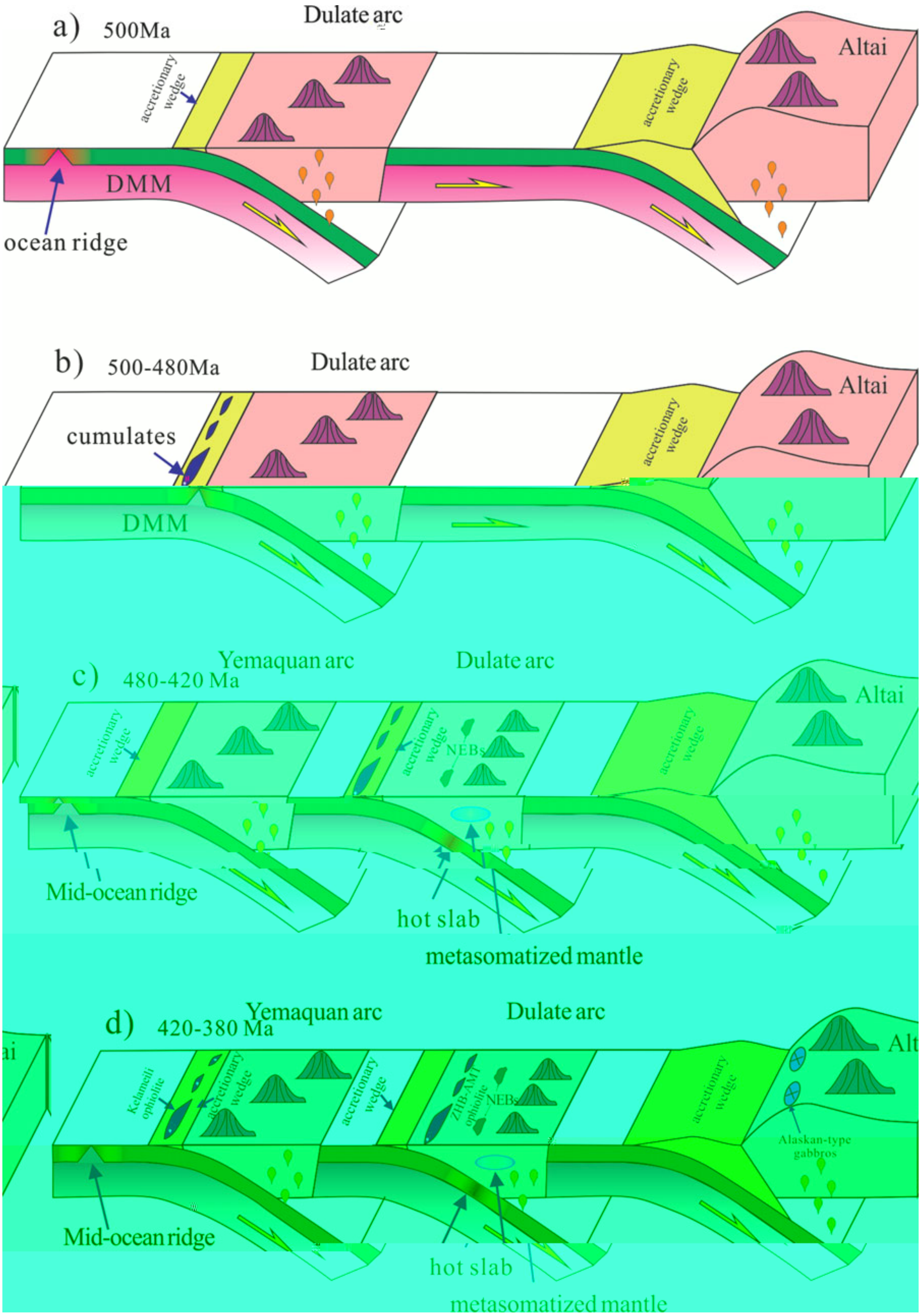
12.



13.

5.d. Implications for the Palaeozoic accretion process in eastern Junggar


a)
Arc volcanic rocks
NEBs
P_2O_5 (wt%)
TiO_2 (wt%)
b) MORB
OIB
NEBs
Island Arc Basalts
Nb/U (ppm)
Nb (ppm)
c)
NEBs
Island Arc volcanic rocks
$(Nb/Th)_{PM}$
$(Nb/La)_{PM}$


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

6. Conclusions

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

(2) [illegible]

(3) [illegible]

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

Supplementary material

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

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