Geol. Mag. **154** (3), 2017, pp. 419–440. © Cambridge University Press 2016
10.1017/S0016756816000042

( )

- ‡, - ‡†, - , - ‡
& - ‡

, , 100037, ,
‡ , 210016,
, , , 36 4 -5305,

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

Ab ac ,

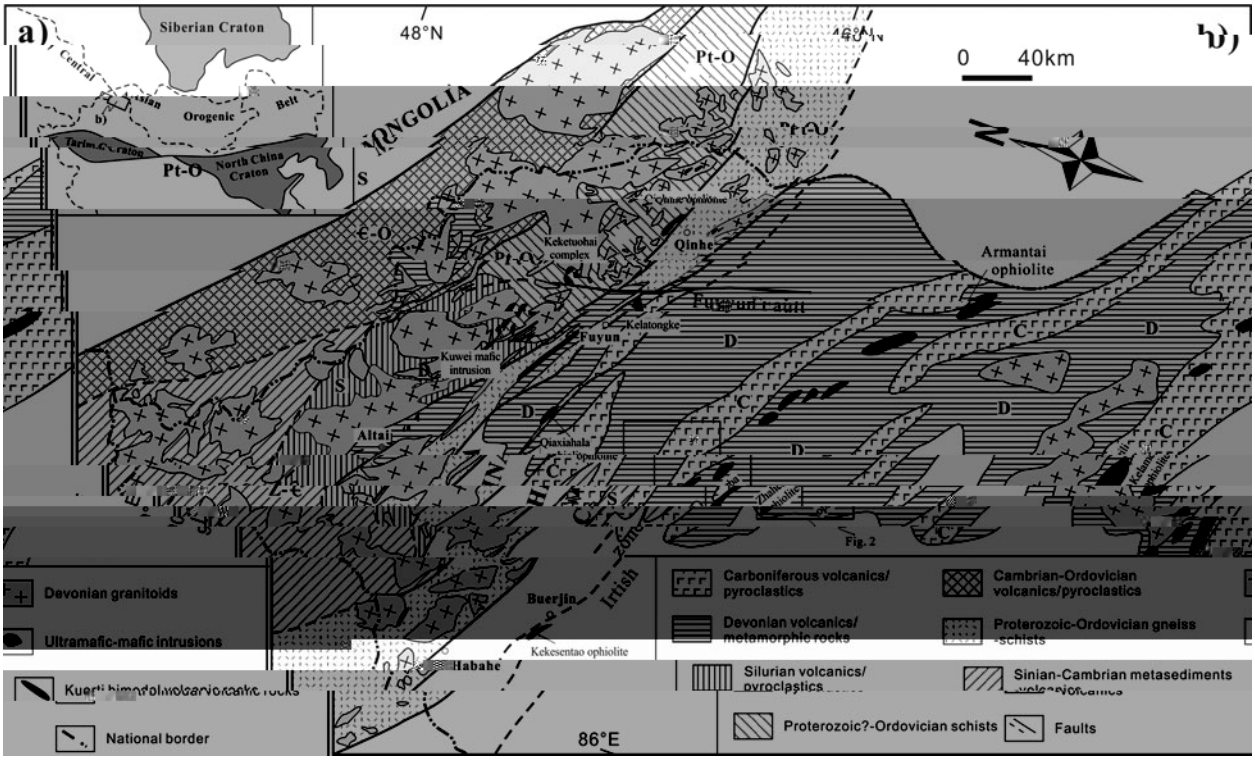
( )
. ~4 5
~400 . ,
. - . ,
ε (*t*) (13 20) δ[1] (+5.3 ‰)
.
/ - .
, ,
- , -
. , -
- ,
- . ,
-
.
, - , , ( ),
.

1. I c

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

† 1 6 .

, . . - -
- . -
- , - - -
, -
- , -
- .
-
( ),
(ö , & , 1 3 , & , 2000 *et al.* 2002 *et al.* 2004, 200 *a*) (. 1).
, -
(*et al.* 200 *a*,*b* , & , 2012). ,
, -
, , , ,
,
(, 1 3 *et al.* 2003 *et al.* 2003 *et al.* 200 *a*) (. 1). -
, -
, ,

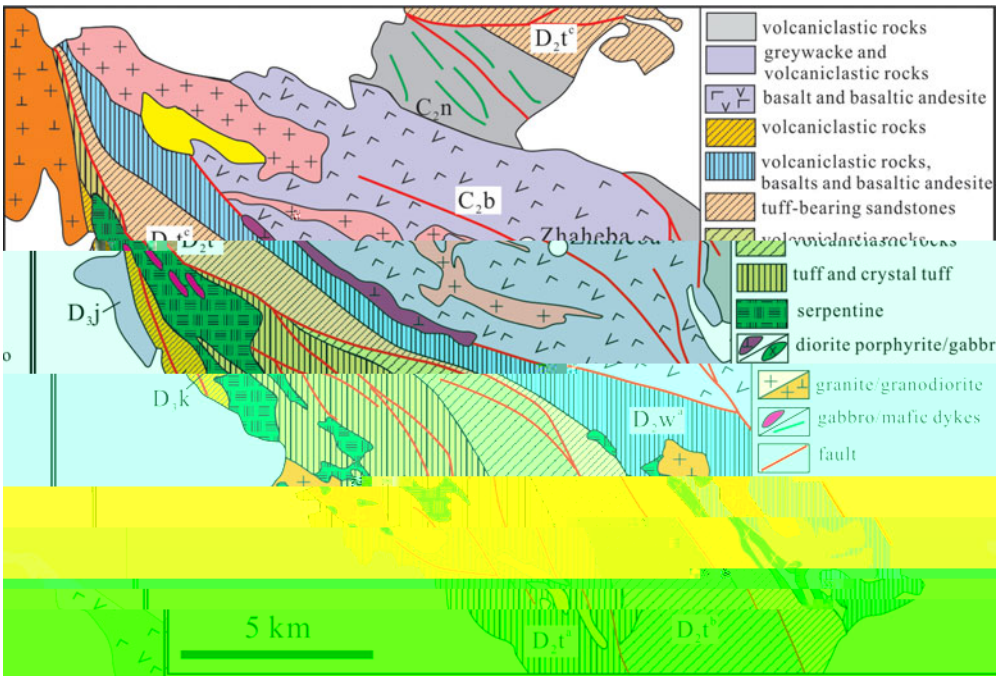


1. ( ) ( ) ( )
(*et al.* 200).

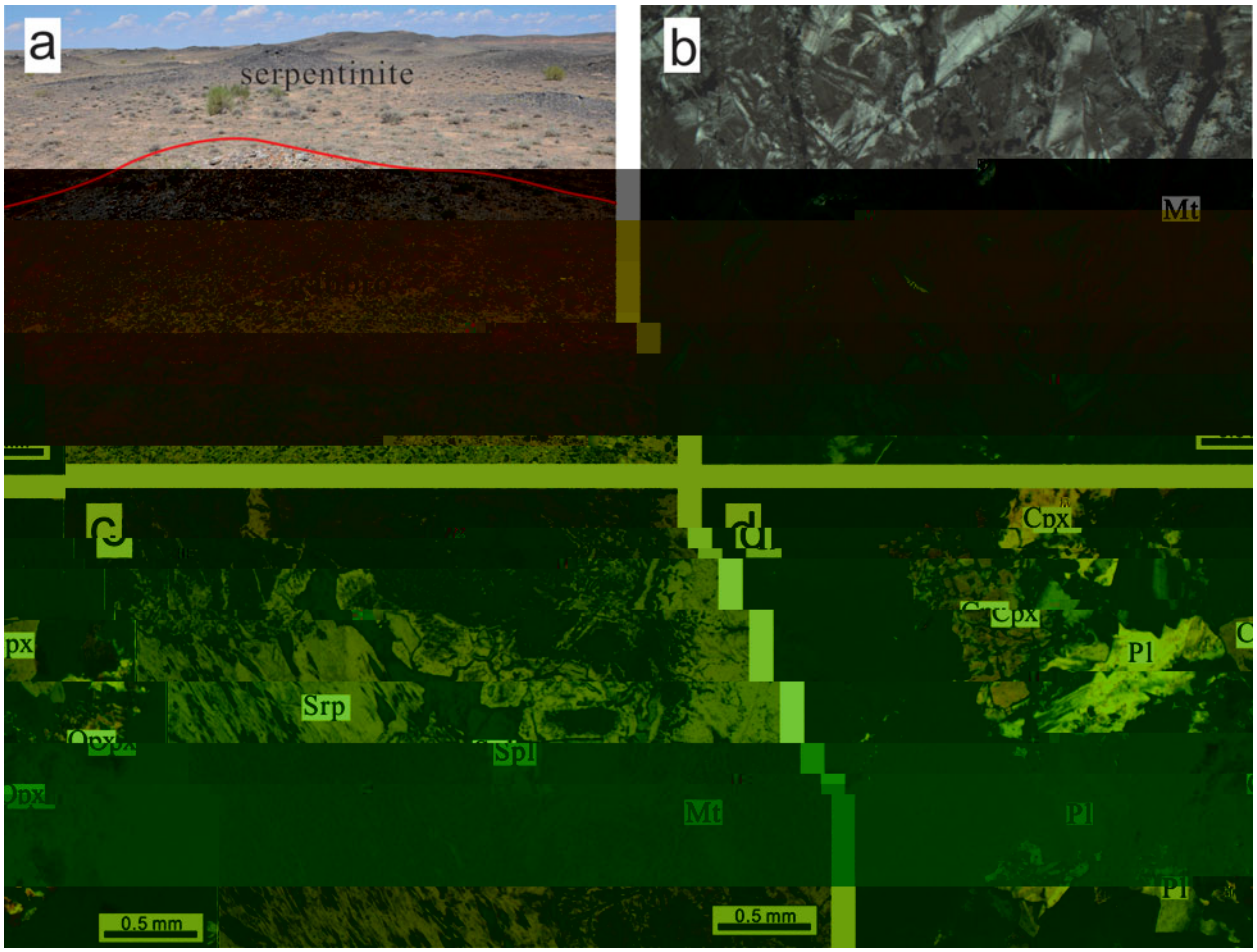
> 0% ,
. , - (. 3 ,).
, , -
(. .
(1) *et al.* 2013). -
- .
(2) (40 70%) (30 50%)
- . (5 10%)
(. 3).

2. R a , b va a
a

-
- ,
-
, - . -
(1 ,
2). , , ( )
. ( )
( ) (*et al.* 2006).
,
.
.
(. 3). - ,
15 . - ,
- - (. 2). ,
(. 2, , -
). 1 .
5 1
. -
. - (, 1 3).



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



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

-

.

3. A a ca , c

3.a. Z c U Pb a a H

(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*). 1 /16

(, 1 /16 = 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. 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). ′ / 6
143 /144 6 / =
0.11 4 146 /144 = 0.′21 , .
′ / 6
0.′102
′ 0.′0506 -1,
143 /144 0.512104 -
1 0.5126′1 -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

1. ,

	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 (%)					
2	3 .▾0	4 .20	3 .41	3 .62	3 .22	3 . 2	3 .05	4▾.22	46.4	51.2▾
2	0.05	0.20	0.05	0.05	0.04	0.05	0.04	0.14	0.12	0.2▾
2 3	0.61	1. 6	1.04	0.6▾	0. 0	0.▾4	0. 0	1 .2	1 .64	1 .33
2 3	.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.
	0.12	15.42	0.15	0.14	0.2	0.10	0.145▾24.1(10. 0)21			

1.

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
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 (%)					
4 .1▼	45. ▼	4 .▼	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 .5	16.5	16.1	15. 3	15. ▼	16.▼6	15.55	15.4	1 .61
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▼
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
52. 4	55.5	-616 .1(52. 4)-56 4. (55.▼3.5▼.3)-630 .▼(4. (0.▼ . (16.▼6)-56).1 (0.066)-56▼(5-1.05 6					113..22)-6240. .42(15.55)-56		4(3. 4)-56 4. ▼5)361 2 .5643(10
4 1240.1(44) 5241 1 .(1▼ 5)-11 5(.(1▼ 5)3▼(2▼4▼).(1▼ 5)-3.61(0.02).2(.▼ 5. 5▼).(1▼ 5) 5. 1(0.0)-6-56 4. 3( )-5 2.6 55.5)-5▼4.. (0.050) 0 -20.03▼ 0.06 4▼.05. 5 ( )-6.0									
3 ( )-5 2.6 0.0 2									

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

1.

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 .	/	/	/	/
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 .3	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	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	256.3	205.4	20 .	114.20	/	/	/	/
4 .0	44.1	4 .0	4.	103	44.1	/	/	/	/
12.0	11.1	11.2	14.3	13.6	12.0	/	/	/	/
0.5	1.420	1.030	3.130	3.230	0.5 3	4.	1 .1	22.0	1 .2
1	1 50	5	20	24	6 6	1	31	111	6
13.0	13.0	13.2	21.1	22.	12.5	13.2	13.2	14.3	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	12.3	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	1.220	1.030	0.365	0.406	0.336	/	/	/	/
11	32	346	25	50	4.3	/	/	/	/
10.30	. 40	.610	26.40	26. 0	10.50	30.6	32.2	40.1	26.4
23.00	1 . 0	1 .40	51.50	54.30	22.30	5 .	62.	2.3	52.5
2.30	2.520	2.510	5.350	6.1 0	2.630	6.	. 4	10.5	6.4
11. 0	11.30	11.60	22.30	24.30	11.60	2 .5	31.2	43.1	24.4
2.540	2.300	2.6 0	4.4 0	4.300	2.330	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	2.354	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	3.24	3.35
0.46	0.446	0.444	0.32	0.35	0.46	0.4	0.52	0.5	0.3
1.350	1.230	1.240	2.120	2.2 0	1.310	1.32	1.33	1.45	2.25
0.1 0	0.16	0.105	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
0.134	0.164	0.165	0.2 1	0.323	0.133	0.20	0.13	0.13	0.34
1.3 0	0. 41	1.040	3.2 0	3.510	1.460	5.33	3.23	4.16	3.32
0.0 4	0.062	0.051	0.5 3	0.644	0.03	1.35	0.6	1.16	0.6
0.151	2.0	1.50	2.35	1.	0.33	/	/	/	/
0.3 4	0.206	0.200	45.20	35.10	0.413	.13	.03	4.1	21.06
1. 0	0.361	0.313	. 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	1.3	0.63	1.46	2.5

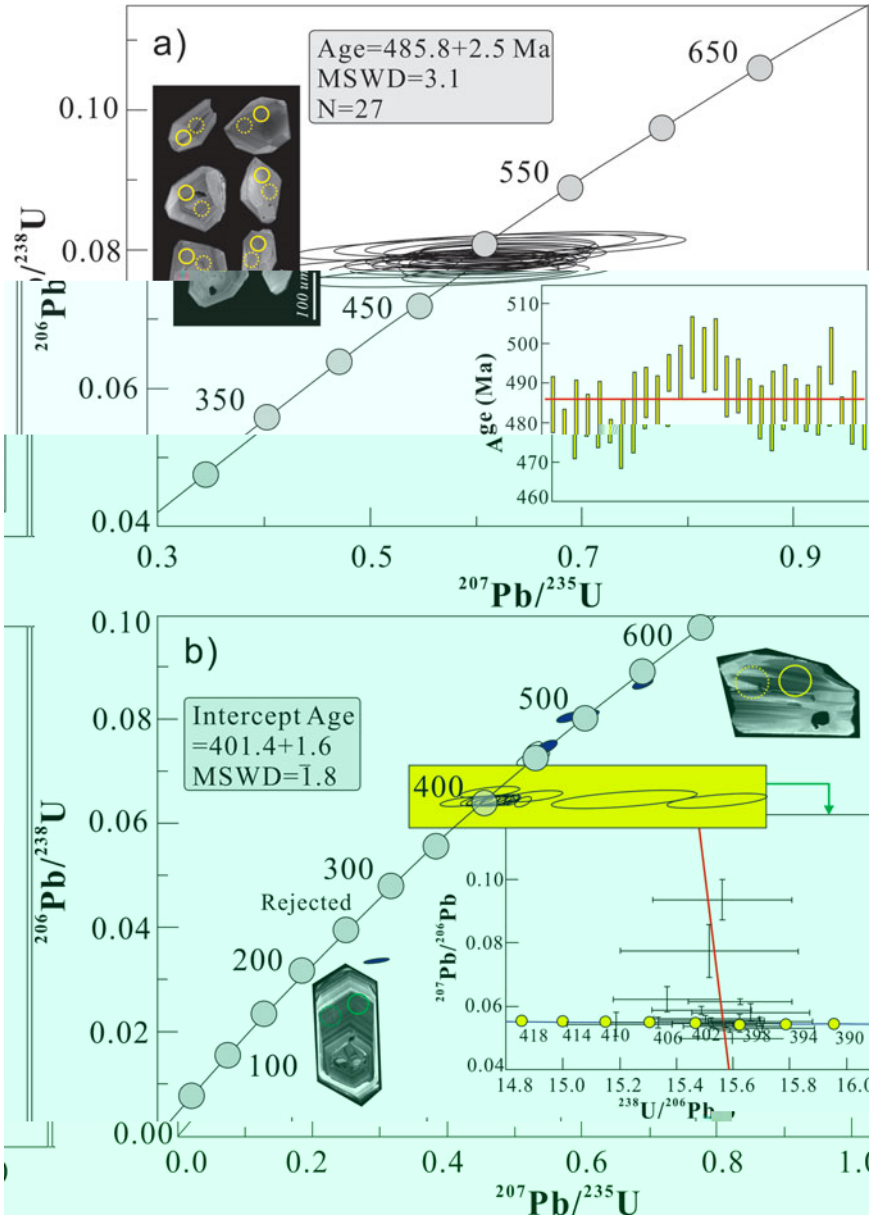
, , , , / .

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

2.

			( )	( )	$^{▼}$ / ^{6}	$^{▼}$ / ^{6} (1σ)	($^{▼}$ / ^{6})	( )	( )	$^{14▼}$ / ^{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) 401 .



4. ( ) . 1σ 2σ ( ) .

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

, -
(2, . 4).
-
. , 2
450
500 .
21 1 -
206 23
401 ± 2 (= 3.3).
206 23 207 235 , -
401.4 ± 1.6 (= 1.) (
206
. 4),
23
.
(, 1 3).

4.b. M a c

4.b.1. Spinel composition

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

4.b.2. Pyroxene compositions

(= 4 6).
2 -
(0.5 %) -
(-
5 // .
. /). -

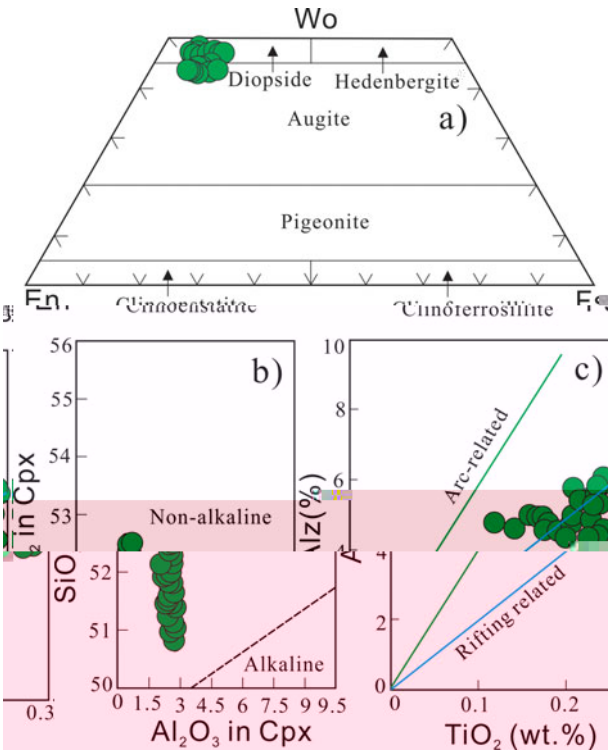
41 4 . , 46 55 . 1 .
(. 5). - -
2 3, 2 2
(. 5 ,).

4.c. W - c a c

4.c.1. Serpentinites and cumulates

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

.- .

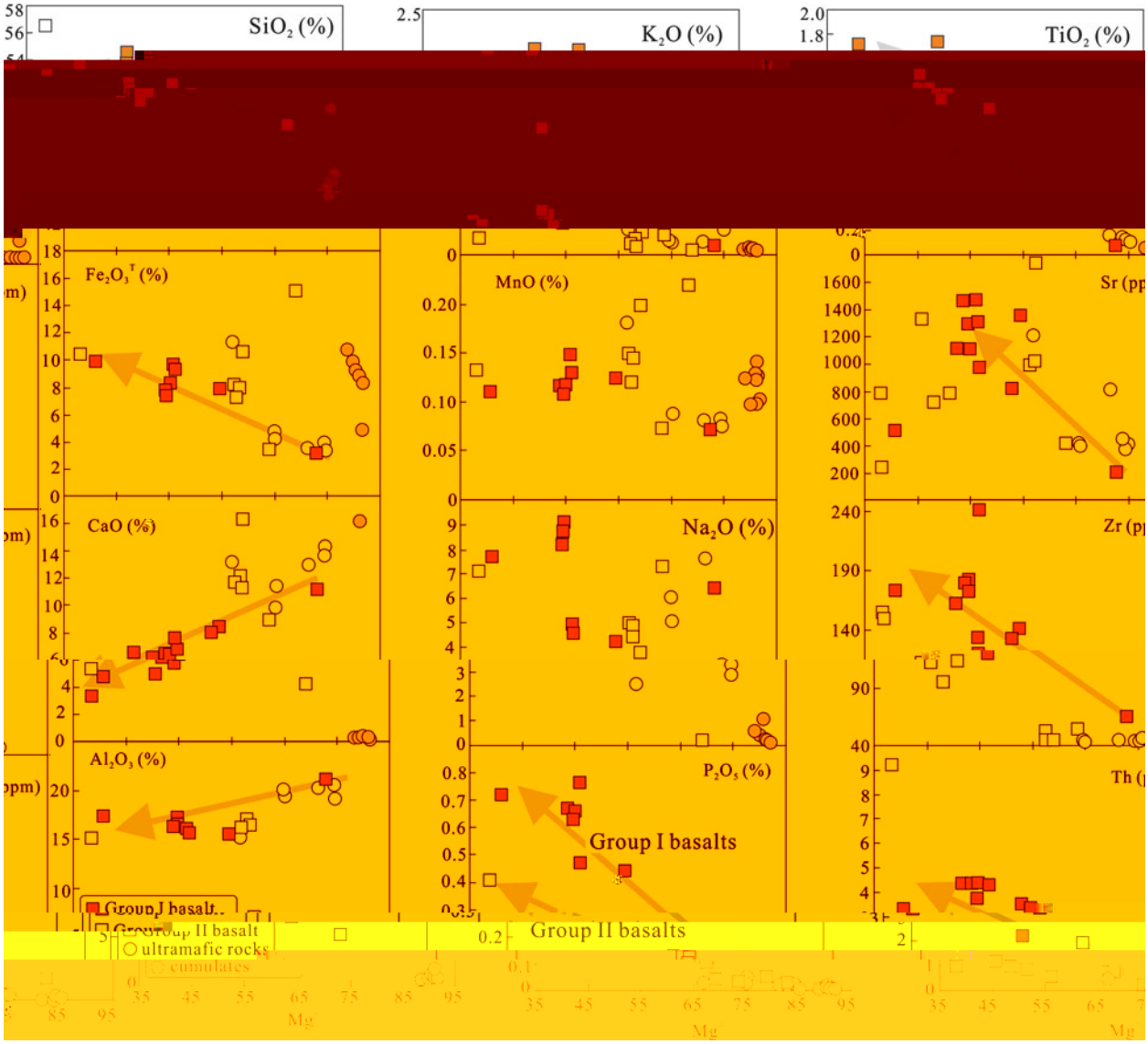


5. ( ) ( )

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

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

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



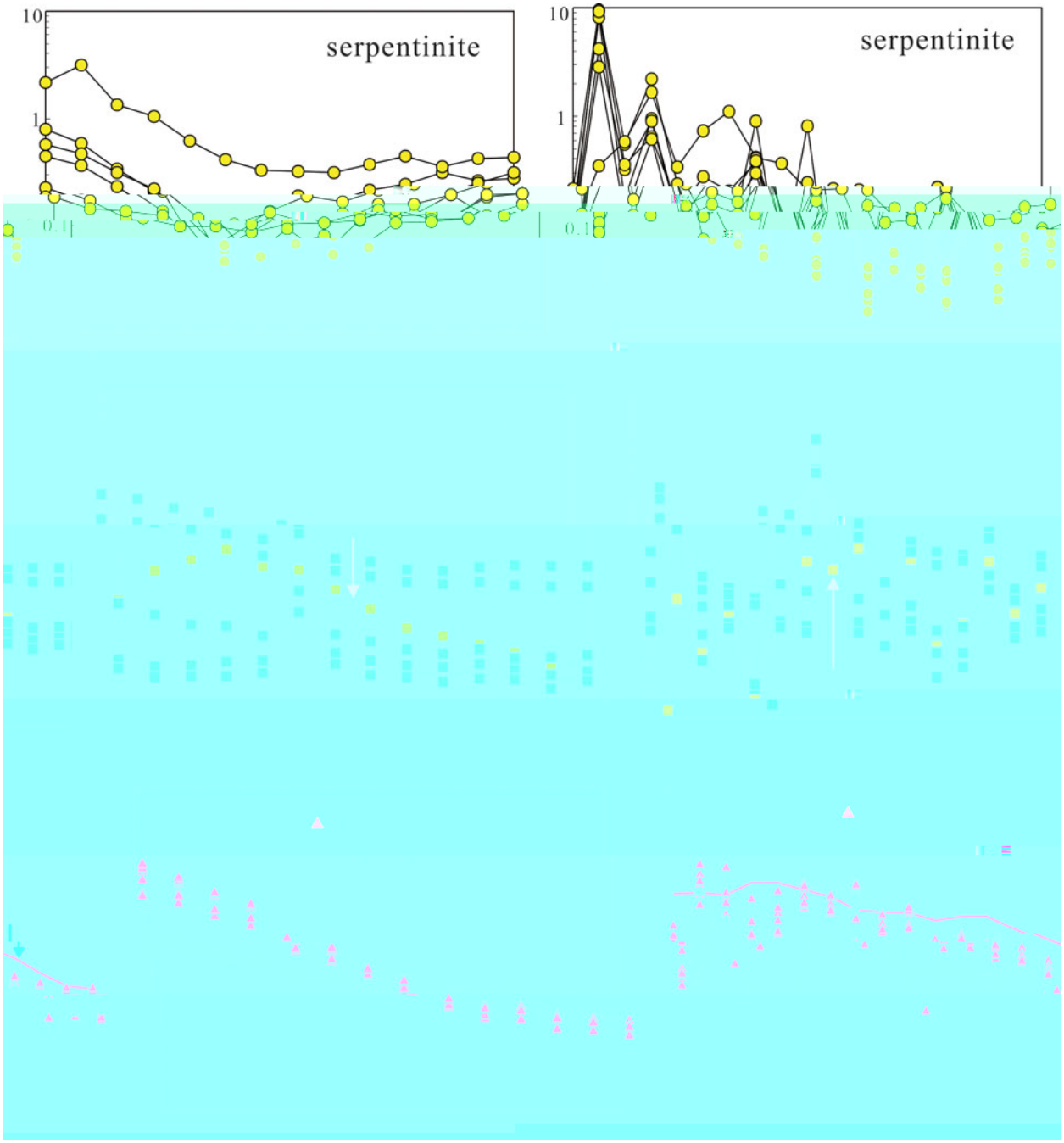
6. ( ) (. . 2, 2, 2, 2, 2 3, 2 3, , ,) (*et al.* 200 *a*).

. - 1). ,

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

4.c.2. Basalts

124 205 2 50 60 . 1 2 (/) 10 43.15 % 5.65 % (52 %, 30 (20)

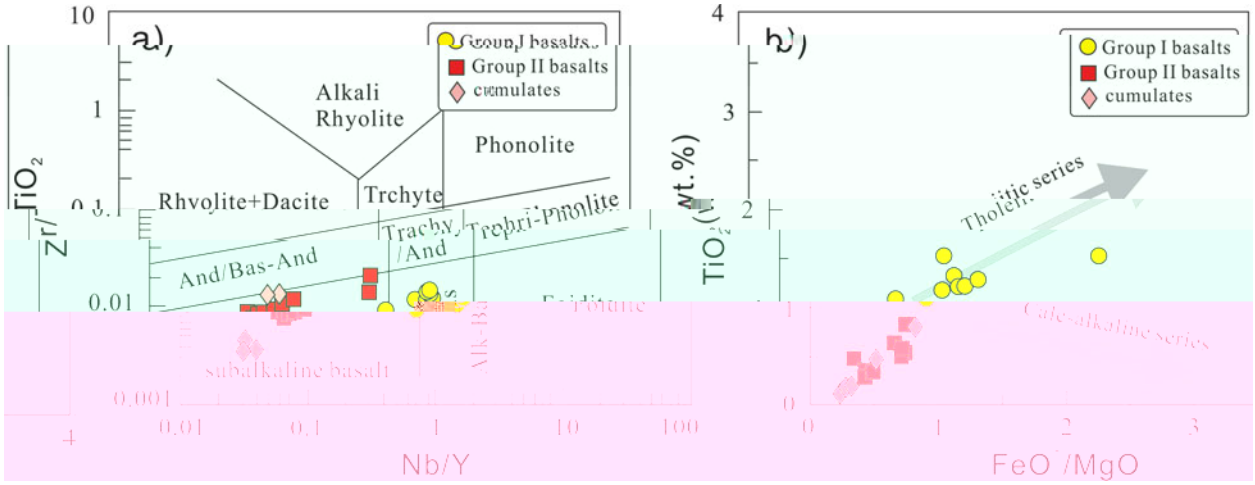


. ( ) - - - -
& (1).

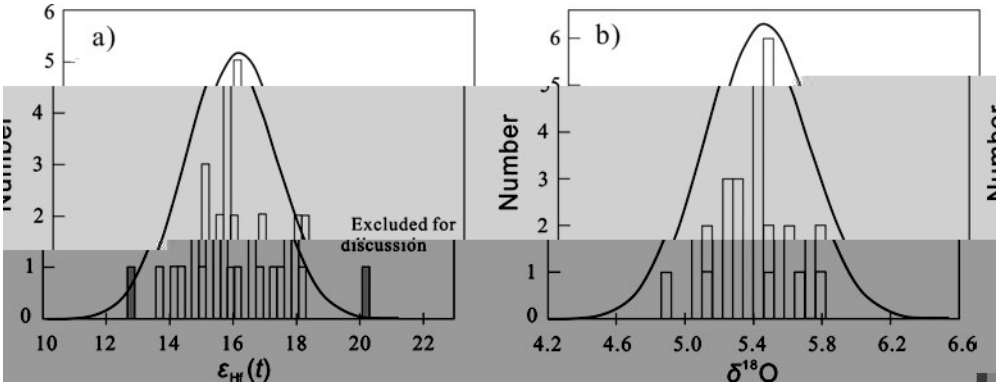
(/ = 0.0 1.14)
(.). 2 -
(/) 4 6
(/ = 1.02 1.21) (.).
- - ,
1 -
/ 0.44
0. , -
. 2
1 -
/ (~0.11).
(.).

4. . W - c S N a c H

2. 1
2 -
. / 6 -
(0.0024 0.0452) / 6 (0.04030
0.0536),
/ 6 (0.04015 0.05111,
2013 03 1). 147 /144
0.0 0.13 4 143 /144
0.51200 0.512 3 ε (*t*) -
+6.3 +7.5 (2013 03 1
+1.).



. ( ) ( ) (/ 2 . /)
(& , 1). ( ) - 2 . / - .
- (1 4).



. ( ) ε (*t*) ( ) .

(2013 01) (-
2
// . . / , .),
(= 4 5) 13 20.
2 5 5 .
ε (*t*) (> 16)
,
.
ε (*t*),
15. .
δ1 4. 1‰ 5. 3‰,
(.).
,
-
δ1 5.3 ± 0.23‰
(.).
~400
ε (*t*) 1.4 .2
- 6 0
20 .
-

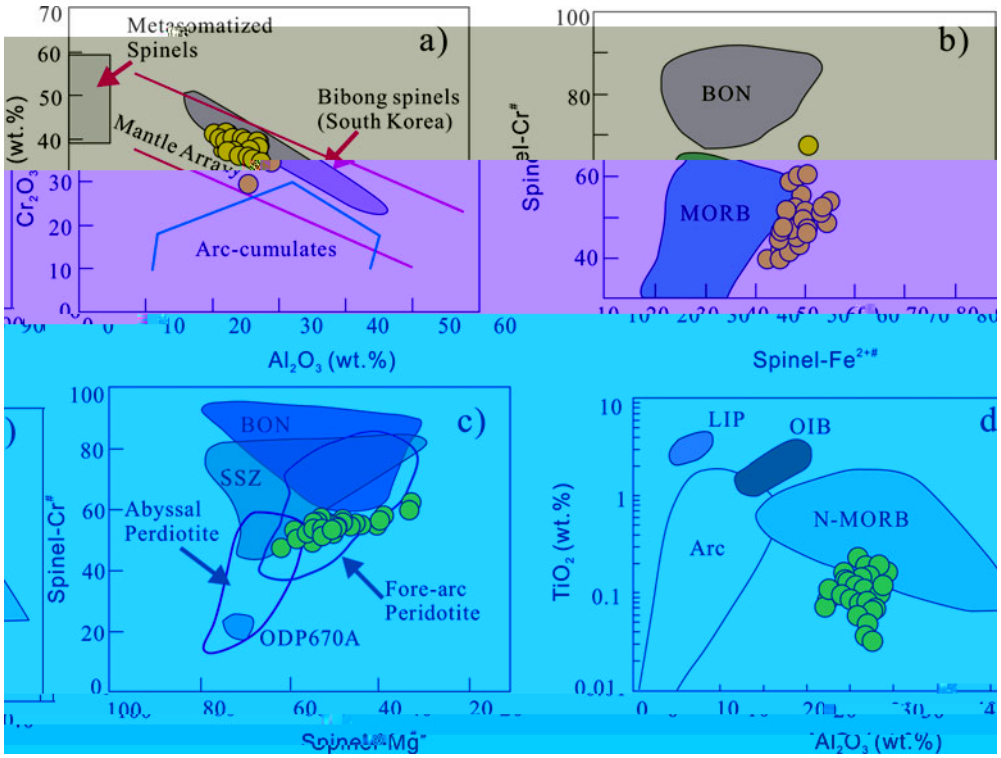
(*et al.*
200).

5. D c

5.a. T y 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),
, . .



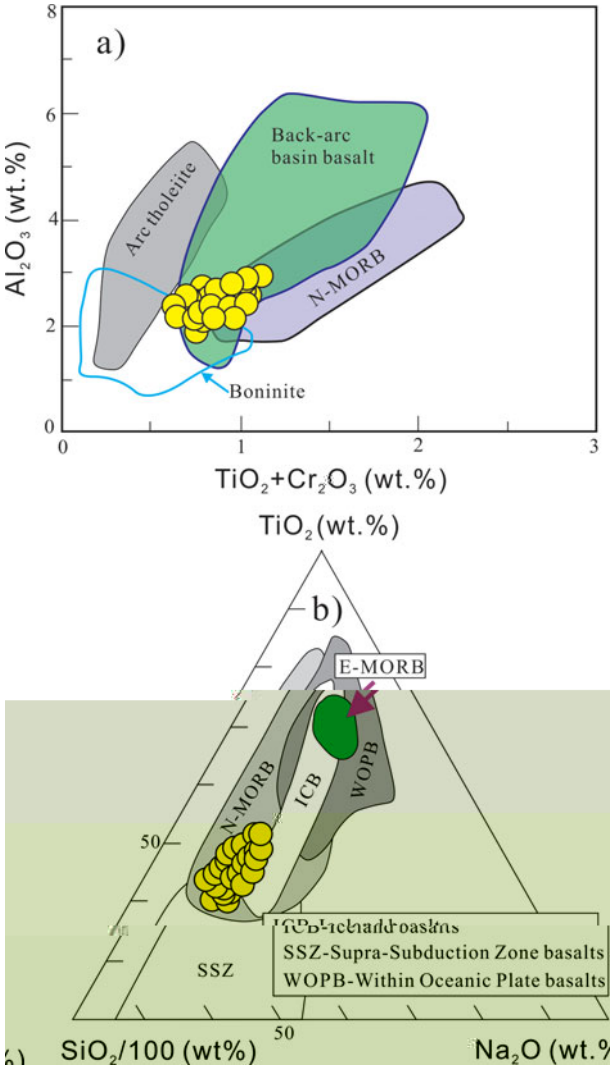
10. ( ) . ( ) 2 3 2 3 (%) (& , 2000). ( ) . (100 /(+)) 2+ . (100 2+/(2+ +)) (, 1 4 & , 2001). ( ) . (100 /(+)) . (100 /(+)) (et al. 1 5). ( ) 2 2 3 (, & , 2001). , - , - .

(500 4 0) (et al. 2003 et al. 2015), (430 400) (et al. 200 b, 2014) - (370 350) (et al. 2003 et al. 2006).

5.b. O a c a

-

(, & , 2002 et al. 2010



11. ( ) ( ) $_2{}_3$. $_2$+ $_2{}_3$ ( ) $_2$ $_2$/100 $_2$

, - - - - .

(-).

- , - - . , 5 , - - . $_2{}_3$. $_2$+ $_2{}_3$, - - (. 11). $_2$/100 $_2$ $_2$ - , - - (. 11). - - (.). . ,

. ,

/ / (. 12), . , - . , / / - - (. 12). , - - . *et al.* (2002) - ( ). , - - .

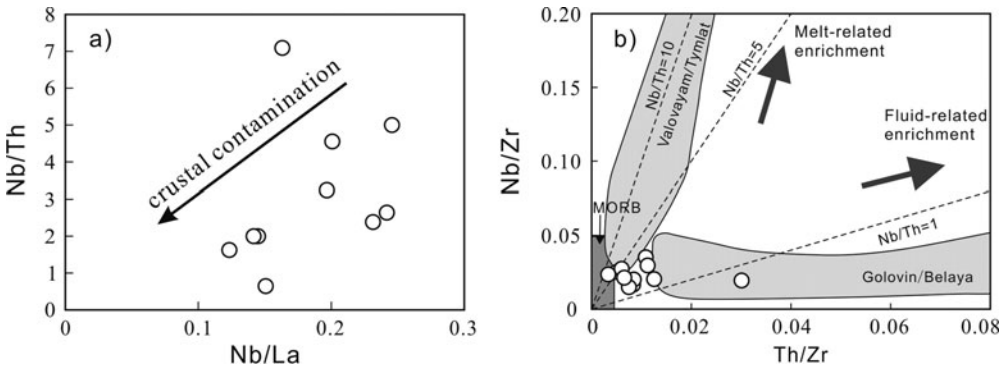
5.c. P D a ba a

, , . . 1 - 2. 1 (11 24 , 15), $_2{}_5$ (0.4 0.6 %) / - (11 15, 60) (/) , - ( ) (, & , 1 2 - & , 2001) (. 13).

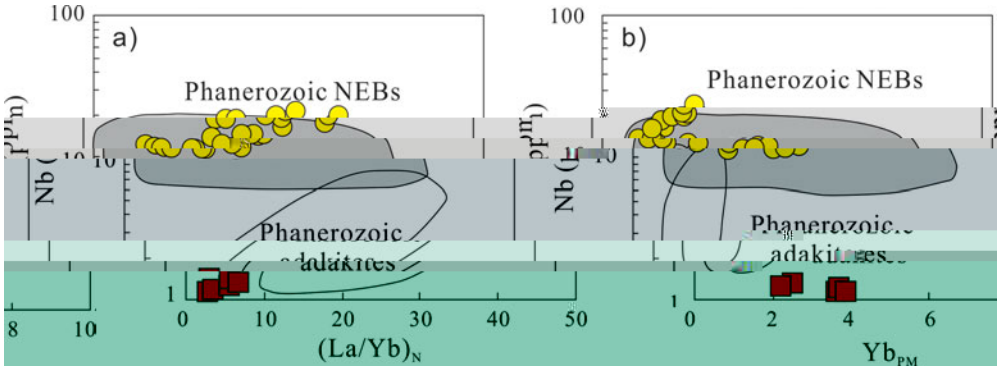
-(1) (. . , & - , 2002); (2) - (, & , 1 2 & , 1 3 *et al.* 1 6).

1 .

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



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



13. ( ) ( ) (/) ( ) . , 1
- ( ).

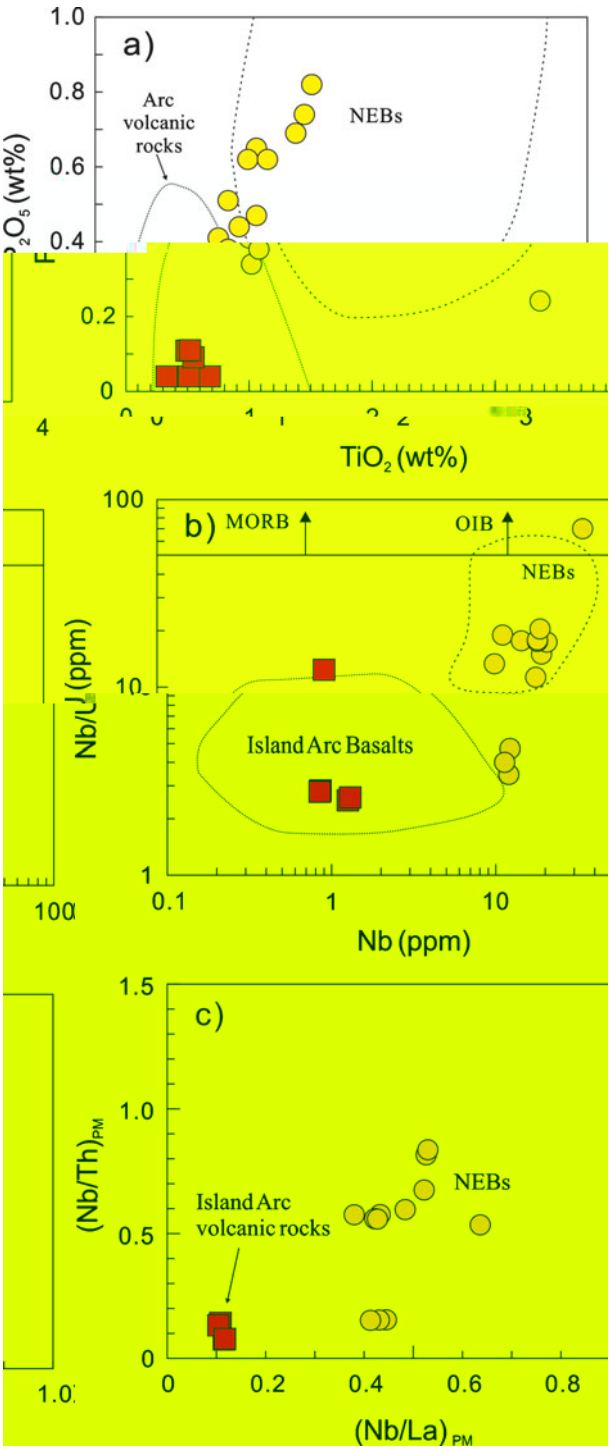
. 1
ε (*t*) (1. ‧.5) (‧ / 6) (0.‧04120 0.‧06133)
, -
(2).
ε (*t*) (‧ / 6)
.
- . , 1
.
.
2 -
2, ,
/ (< 0.3), / / (.),
- /
(,
& , 1 1. , 2002).
. ,
2 (/) (0.‧ 1.0), (/)
(0.1 0.2) / (0.6 1.0) ,
2 -
-
(& , 1 6).
1 , 2
/ (/) (1. . 14).

(. 14). , 2
. ,
1 2 .
-
,
.

5. . I ca Pa a c acc c a J a

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

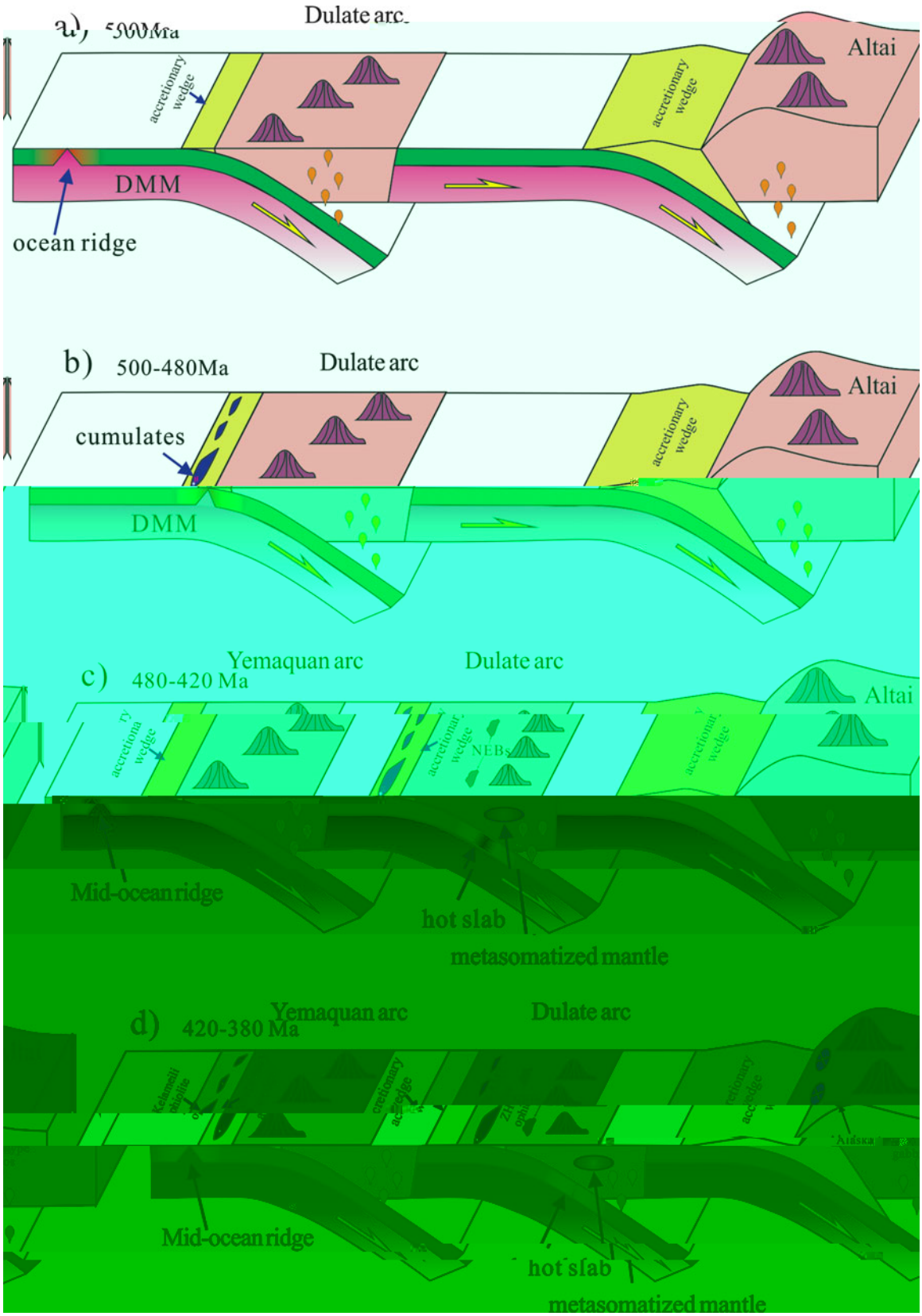
-
, -
, ,
- (*et al.* 200‧, 200 *a*,*b* *et al.*
200 *a*).
-
(*et al.* 200 *b*).



14. ( ) ( ) 2 5 2 . ( ) / . ( ) (/) (/) - . - ( ) , & (1 2) *et al.* (1 5), .

, - . , - - . , *et al.* (2015) - 400 3 0 . ,

460 3 5 *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). (5.), - 1 - 2 . - , - (1 , 15). *et al.* (200 , 200 *b*) - - , . , - - - (*et al.* 200). (, & , 1 1, , - & , 200 , *et al.* 2013). (. 15). (1) (*c.* 500), - . , - - (. 15). , , - . (2) (500 4 0), - - (. 15). , - - . (3) (4 0 420), - (45 , *et al.* 2015) - . - - (440 , *et al.* 2014) . - (. 15). , - - , - .


a) 500Ma
Dulate arc
accretionary wedge
Altai
DMM
ocean ridge
b) 500-480Ma
Dulate arc
cumulates
Altai
DMM
c) 480-420 Ma
Yemaquan arc
Dulate arc
Altai
NEB
Mid-ocean ridge
hot slab
metasomatized mantle
d) 420-380 Ma
Yemaquan arc
Dulate arc
Mid-ocean ridge
hot slab
metasomatized mantle

15. ( )

.

(4) (420 3 0) (*et al.* 2014 *et al.* 2015).

1 ( ) 2

(. 15).

(400 3 0).

6. C c

(1) ~4 5 , *c.* 400 .

(2)

(3)

Ac ▼ . 305 (2011 06 03-01).

S a a a

// . . /10.101▼/ 0016▼56 16000042.

R ◄ c

, . 1 4.

. *Chemical Geology* **113**, 1 1 204.

, . . & , . . 2001.

. *Journal of Petrology* **42**, 22▼ 302.

, . ., , . . & , . . 200▼.

. *Lithos* **97**, 2▼1 .

, . ., , . . & , . . 2002.

, , . *Geology* **30**, ▼0▼ 10.

, . ., , ., , . ., , . ., , . . & , . . 200 .

. *Earth Accretionary Systems in Space and Time* (. . & .), . 1 36.

. 31 .

, . & , . . 2002.

. *Geological Magazine* **139**, 1 13.

, . 1 3.

, , , . *Geological Society of America Bulletin* **105**, ▼15 3▼.

, . . 1 ▼▼. *Ophiolites.* , 220 .

, . . & , . . 1 3.

. *Geology* **21**, 54▼ 50.

, . ., , . . & , . . 1 2.

. *Journal of Geological Society, London* **149**, 56 ▼ .

, . . . & , . 1 4.

. *Contributions to Mineralogy and Petrology* **86**, 54 ▼6.

, . & , . . . 2003.

(2) , , . *Ophiolites in Earth History* (. & . .), . 43 6 . 21 .

, . & , . 2011.

. *Geological Society of America Bulletin* **123**, 3 ▼ 411.

, . ., , . ., , . ., , ., , . . & , . . 2015.

. *Chinese Journal of Geology* **50**, 140 54 ( ).

, . & , . 2000.

(/)

. *Contributions to Mineralogy and Petrology* **140**, 2 3 5.

, ., , . . & , . 1 1.

. *Lithos* **27**, 25 ▼▼.

, . ., , . ., , . & , . 2011. -
- - - .
Geological Bulletin of China **30**, 150 13 (
).
, . ., , . ., , . ., , . .
& , . 2011. -
-
? *Geochimica et Cosmochimica Acta* **75**, 504 ▼2.
, ., , . ., , . . & ,
. 2001. -
- -
. *Nature* **410**, 6▼▼ 1.
, ., , . & , . 2002.
( ) .
. *Chemical Geology* **182**, 22▼ 35.
, . & , . 1 6. -
,
. *Journal of Geophysical Research: Solid Earth (1978–2012)* **101**, 11 31 .
, . & , . 2000. -
- - 2.▼ -
-
, . *Contributions to Mineralogy and Petrology* **139**, 20 26.
, . , . ., , . ., , . & , . 2012.
- -
, . *Geological Bulletin of China* **31**, 126▼ ▼ (
).
, . ., , . ., , . ., , ., , . .,
, . & , . 2014. -
,
( ). *Chinese Science Bulletin (Chinese Version)* **59**, 2213 22.
, . ., , . . & , . 2000.
. *Transactions of the Royal Society of Edinburgh: Earth Sciences* **91**, 1 1 3.
, . & , . 1 0.
,
. *Journal of Petrology* **31**, 6▼ ▼1.
, ., , . ., , ., , . ., , . .,
, . ., , . & , . 2003.
. *Earth Science Frontier* **10**, 43 56 (
).
, . ., , . . & , . 2001.
, -
. *Journal of Petrology* **42**, 655 ▼1.
, . 1 6. -
- .
Nature **380**, 23▼ 40.
, ., , ., , ., , .,
, . & , . 2000. -
. *Tectonophysics* **326**, 255 6 .
, . ., , . ., , . ., , . ., , . & ,
. . 2010*a*.
50
-
- . *Lithos* **114**, 1 15.
, . ., , . ., , ., , . ., , . . &
, . 2004.
-
, . *Geological Magazine* **141**, 225 31.
, . ., , . ., , . ., , ., , . ., ,
. ., , . ., , . ., , . ., ,
, . . & , . 2010*b*. -
. *Geostandards and Geoanalytical Research* **34**, 11▼ 34.
, . ., , . ., , ., , . ., , . ., ,
. ., , . ., , . & , . . 2013.
. *Chinese Science Bulletin* **58**, 464▼ 54.
, . & , . 200 .
. *Lithos* **113**, 2▼4 1.
, . ., , . ., , . ., , . ., , ., ,
. & , . . 2010.
- - . *Chinese Science Bulletin* **55**, 1535 46.
, . . 2003. *User's Manual for Isoplot 3.00: A Geochronological Toolkit for Microsoft Excel*. -
4,
▼3 .
, ., , . ., , ., , . ., ,
. ., , ., , . ., , . ., , . .,
, . . & , . . 2015.
( ) .
- -
.
Gondwana Research, 6 2015.
10.1016/ . .2015.04.004.
, . 1 ▼4.
. *American Journal of Science* **274**, 32 355.
, ., , ., , . & , . 1 5.
-
( ). *Geology* **23**, 51 4.
, . 1 . *Structure of Ophiolites and Dynamics of Oceanic Lithosphere*. ,
, 36▼ .
, . . 1 ▼.
.
Journal of Petrology **38**, 104▼ ▼4.
, . ., , ., , . ., , ., , . & ,
. . 200 *a*. -
. *Acta Petrologica Sinica* **25**, 16 24 (
).
, . ., , ., , ., , ., , . .
& , . . 200 *b*.
, , .
Acta Petrologica Sinica **25**, 14 4 1 (
).
, . ., , ., , . . & , . . 200▼.
^{40} /^{3} -
,
, . *Acta Petrologica Sinica* **23**, 162▼ 34 ( ).
, . ., , ., , ., , . & ,
. 2002. , - ,
1▼6 -
. *Proceedings of the Ocean Drilling Program, Scientific Results, vol. 176* (. . , . . . ,
. . & . .), . 1 60. -
, .

, . ., , . ., , . & , . . 200 .
- , -
-
. *Chinese Science Bulletin* **14**, 21 6 1.
, . ., , . ., , ., , . . & , . .
2010.

, . *Lithos* **117**, 1 20 .
, ., , . & , . 200▼.
- ,
-
- - . *Journal of Asian Earth Sciences* **30**, 666 5.
, . . 200 .

. *Lithos* **100**, 14 4 .
, . . 2014. -
. *Elements* **10**, 101 .
, . & , . 2001. ,
- - , -
2.▼ ,
, -
. *Contribution to Mineralogy and Petrology* **141**, 36 52.
, ., , ., , . & ,
. 2013. -
( )
, , -
- .
Gondwana Research **24**, 3 2 411.
, . ., , . ., , ., , . &
, . 1 6. -
, -
, ( ).
Journal of Petrology **37**, 6 3 ▼26.
, ., , ., , ., , .,
, . & , . . 2013. -
,
, -

. *Precambrian Research* **231**, 301 24.
, ., , . ., , ., , . .
. & , . 2012. -

. *Precambrian Research* **192 195**, 1 0 20 .
, . ., , . . & , . 1 1. -

. *Philosophical Transactions of the Royal Society of London* **335**, 3▼▼ 2.
, ., , ., , ., , . .,
, . . & , . . 1 5. -
-
. *Nature* **377**, 5 5 600.
, . . ., , . . & , . . 1 3.

. *Nature* **364**, 2 30▼.
, . ., , . ., , ., , . & ,
. . 2014. (~440) ,
-
, ( ).

. *Lithos* **206 207**, 234 51.
, . . 2002. . *Reviews of Geophysics* **40**, 3-1 3-3 .
, ., , . ., , . ., , . ., ,
. ., , ., , . ., , . . & , . .
200 .

-
. *Science in China Series D – Earth Sciences* **52**, 1345 5 .
, . . & , . . 1 .

. *Magmatism in the Ocean Basin* (. . & . .),
. 52 4 . , -
. 42.
, ., , ., , ., , ., , ., , .,
, ., , . & , . 200 .

. *Chemical Geology* **247**, 352 3.
, ., , ., , . ., , . ., , . . &
, . . 200▼.

. *Acta Petrologica Sinica* **23**,
1 33 44 ( ).
, . ., , . ., , . . & ,
. . 1 .
. *Contributions to Mineralogy and Petrology* **133**, 1 11.
, ., , . ., , . ., , ., , . .,
, . . & , . . 2006. ,
,
, -
. *Journal of Geology* **114**, ▼35 51.
, ., , . ., , . ., , ., , .
. & , . . 200 .

. *Lithos* **110**, 35 ▼2.
, ., , . . & , . . 2012.
-
. *Earth-Science Reviews* **113**, 303 41.
, . . & , . . 1 ▼▼. -
-
. *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.
, . ., , . ., , ., , . ., , . .,
, . ., , . . & , . 200 .
-
, -
. *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*. -

-

,

, .

International Journal of Earth Sciences **98**, 11 21▼.

, . ., , . ., , ., , ., , . ., , . ., , . ., , . ., , . ., , . . & , . 200 *b*. -

. *American Journal of Sciences* **309**, 221 ▼0.

, . 1 3. *Regional Geology of the Xinjiang Uygur Autonomous Region*. -

, . 2 145 ( ).

, . ., , . ., , . ., , ., , . . & , . . 2015. - -

. *Journal of Asian Earth Sciences* **113**, ▼5 .

, ., , ., , . . ., , ., , ., , ., , . . & , . 2012.

. *Gondwana Research* **21**, 246 65.

, ., , ., , ., , ., , ., , ., , . & , . 200▼.

.

Chemical Geology **242**, 22 3 .

, ., , . ., , . ., , . . & , . 2006.

, ( )

.

Acta Geologica Sinica **80**, 254 63 (-).

, . ., , . ., , ., , . ., , . & , . 2003. -

, .

Chinese Science Bulletin **48**, 2231 5.

, . ., , ., , . ., , . . & , . . 2013.

, ,

. *Lithos* **179**, 263 ▼4.

, . ., , ., , . ., , . ., , ., , . ., , . . & , . . 2012.

. *Journal of Asian Earth Sciences* **52**, 11▼ 33.

, . ., , . ., , ., , . . & , . . 200 . ,

- . *Acta Petrologica Sinica* **24**, 1054 5 ( ).

, . & , . . 1 6. .

Annual Review of Earth and Planetary Sciences **14**, 4 3 5▼1.