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### Abstract

The study area is located in the central part of the Iberian Peninsula, within the Iberian Massif. The study area is characterized by a complex tectonic history, with several phases of deformation and metamorphism. The main objective of this study is to constrain the timing and kinematics of the Late Cretaceous–Early Tertiary extensional tectonics in the Iberian Massif. For this purpose, we have carried out a detailed structural and kinematic analysis of the extensional tectonics in the study area. The results show that the extensional tectonics in the study area is characterized by a series of normal faults that developed during the Late Cretaceous–Early Tertiary. The extensional tectonics in the study area is related to the Iberian Massif extensional tectonics, which is a result of the collision of the Iberian Massif with the African continent. The extensional tectonics in the study area is characterized by a series of normal faults that developed during the Late Cretaceous–Early Tertiary. The extensional tectonics in the study area is related to the Iberian Massif extensional tectonics, which is a result of the collision of the Iberian Massif with the African continent.

### 1. Introduction

The Iberian Massif is a large tectonic block that occupies the central part of the Iberian Peninsula. It is characterized by a complex tectonic history, with several phases of deformation and metamorphism. The main objective of this study is to constrain the timing and kinematics of the Late Cretaceous–Early Tertiary extensional tectonics in the Iberian Massif. For this purpose, we have carried out a detailed structural and kinematic analysis of the extensional tectonics in the study area. The results show that the extensional tectonics in the study area is characterized by a series of normal faults that developed during the Late Cretaceous–Early Tertiary. The extensional tectonics in the study area is related to the Iberian Massif extensional tectonics, which is a result of the collision of the Iberian Massif with the African continent.

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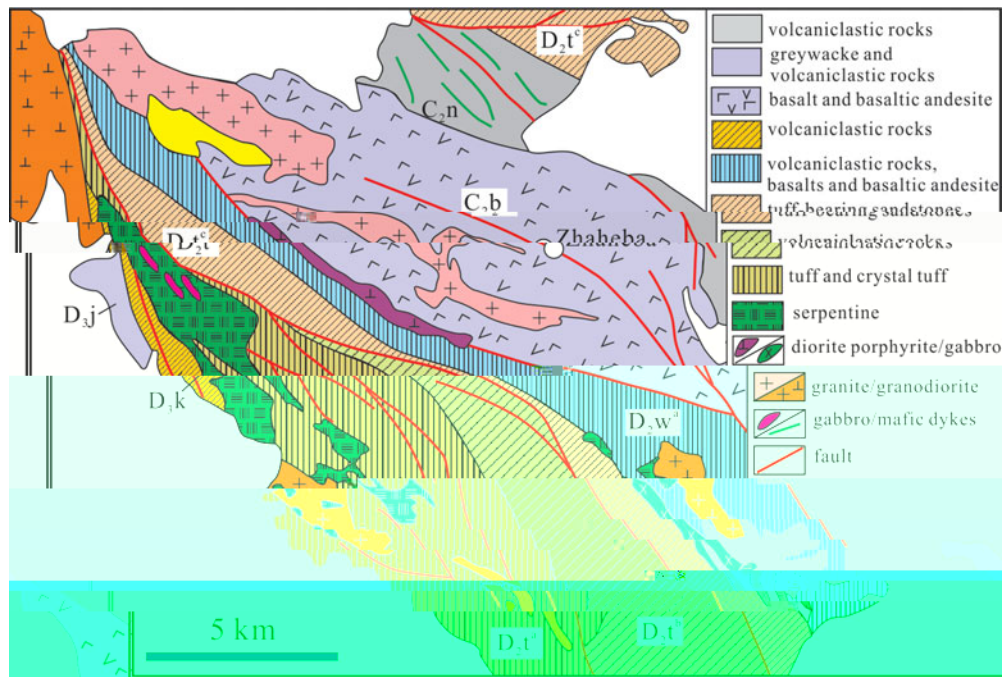


Figure 2. Geological map of the Zhaheba ophiolite complex (after *et al. 2000, 2001* and *et al. 2000, 2001*).

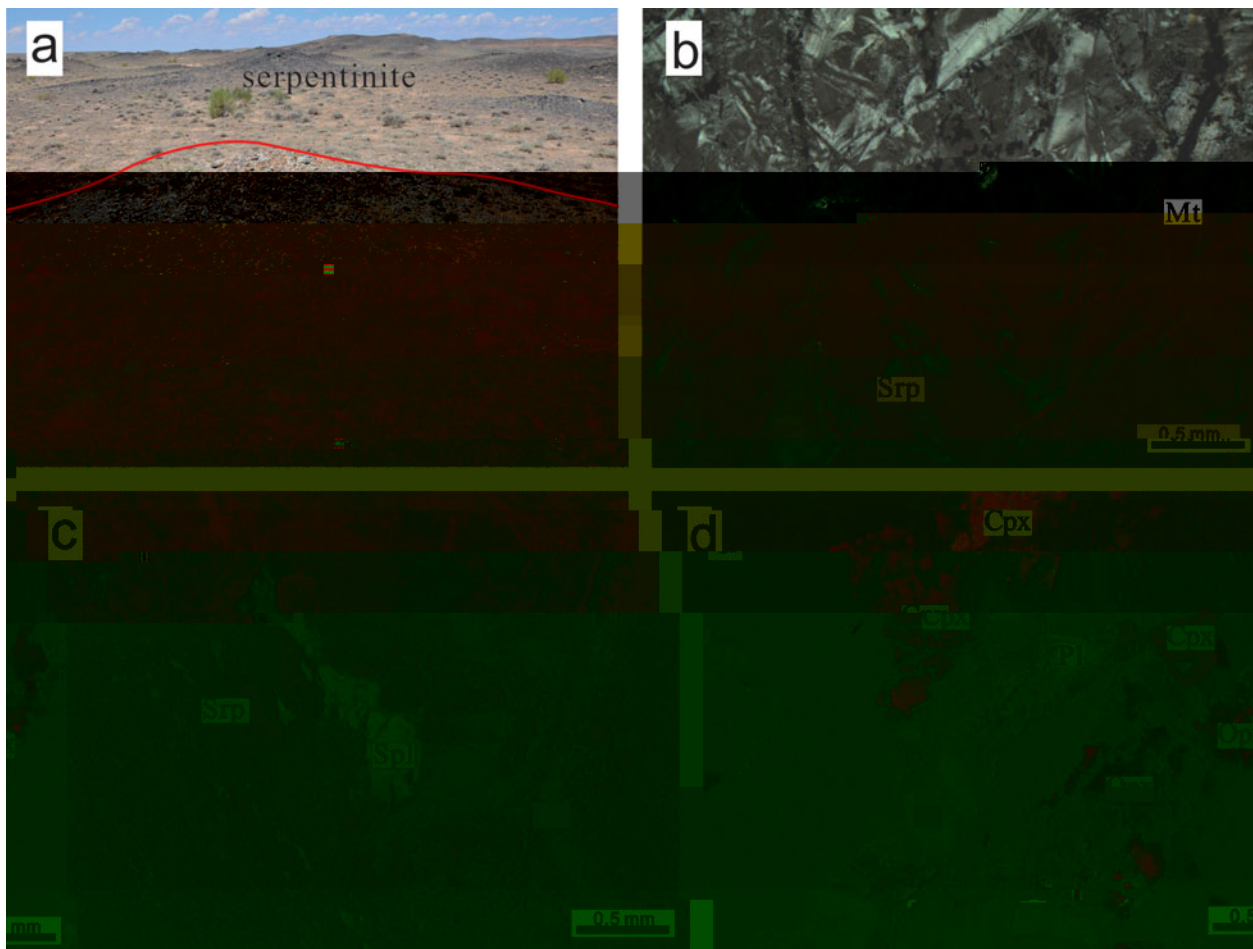


Figure 3. (a) Field photograph of a serpentinite outcrop. (b) Photomicrograph showing mineral grains (Mt, Stp) in serpentinite. (c) Photomicrograph showing mineral grains (Stp, Cpx) in serpentinite. (d) Photomicrograph showing mineral grains (Stp, Cpx) in serpentinite.







1.  $^{40}\text{Ar}/^{39}\text{Ar}$  100%

Sample	Age (Ma)	Sample	Age (Ma)	Sample	Age (Ma)	Sample	Age (Ma)	Sample	Age (Ma)	Sample	Age (Ma)
2013 01 5	3.0	2013 01 6	1.20	2013 01 (1)	3.60	2013 01 (1)	46.0	2013 01 (1)	4.30	2013 03 2	23.40
										2013 03 3	43.00
										2013 03 4	25.20
										2013 03 5	32.0
										2013 01 3	6.56





Table 2. U-Pb zircon ages and  $\epsilon_{\text{Pb}}(t)$  values for the Zhaheba ophiolite. The number of grains analyzed is given in parentheses.

Sample	Grain #	Age (Ma)	$\epsilon_{\text{Pb}}(t)$	$^{206}\text{Pb}/^{238}\text{U}$	$^{207}\text{Pb}/^{235}\text{U}$	$^{206}\text{Pb}/^{238}\text{U}$ (1 $\sigma$ )	$^{207}\text{Pb}/^{235}\text{U}$ (1 $\sigma$ )	$^{206}\text{Pb}/^{238}\text{U}$ (2 $\sigma$ )	$^{207}\text{Pb}/^{235}\text{U}$ (2 $\sigma$ )	$^{143}\text{Sm}/^{147}\text{Sm}$	$^{143}\text{Sm}/^{147}\text{Sm}$ (1 $\sigma$ )	$^{143}\text{Sm}/^{147}\text{Sm}$ (2 $\sigma$ )	$\epsilon_{\text{Sm}}(t)$
2013-01	3	485.8	3.2	0.065	0.45	0.002	0.040	0.030	0.040	2.4	10.0	0.13	6.1
2013-01	10	485.8	6.6	0.065	0.45	0.0024	0.045	0.035	0.045	2.3	11.6	0.1235	6.1
2013-03	1	485.8	2.0	0.065	0.45	0.0335	0.063	0.050	0.063	4.4	22.3	0.121	1.0
2013-03	2	485.8	1320	0.065	0.45	0.0063	0.042	0.035	0.042	4.5	2.6	0.1046	6.3
2013-03	3	485.8	516	0.065	0.45	0.0452	0.053	0.045	0.053	5.2	36.0	0.512	6.4
2013-03	4	485.8	140	0.065	0.45	0.01	0.042	0.035	0.042	4.55	24.5	0.1123	5.5

$$\epsilon_{\text{Pb}}(t) = 10000 \left( \frac{^{143}\text{Sm}/^{144}\text{Sm}}{(^{143}\text{Sm}/^{144}\text{Sm})_0} - 1 \right) \epsilon_{\text{Sm}}(t)$$

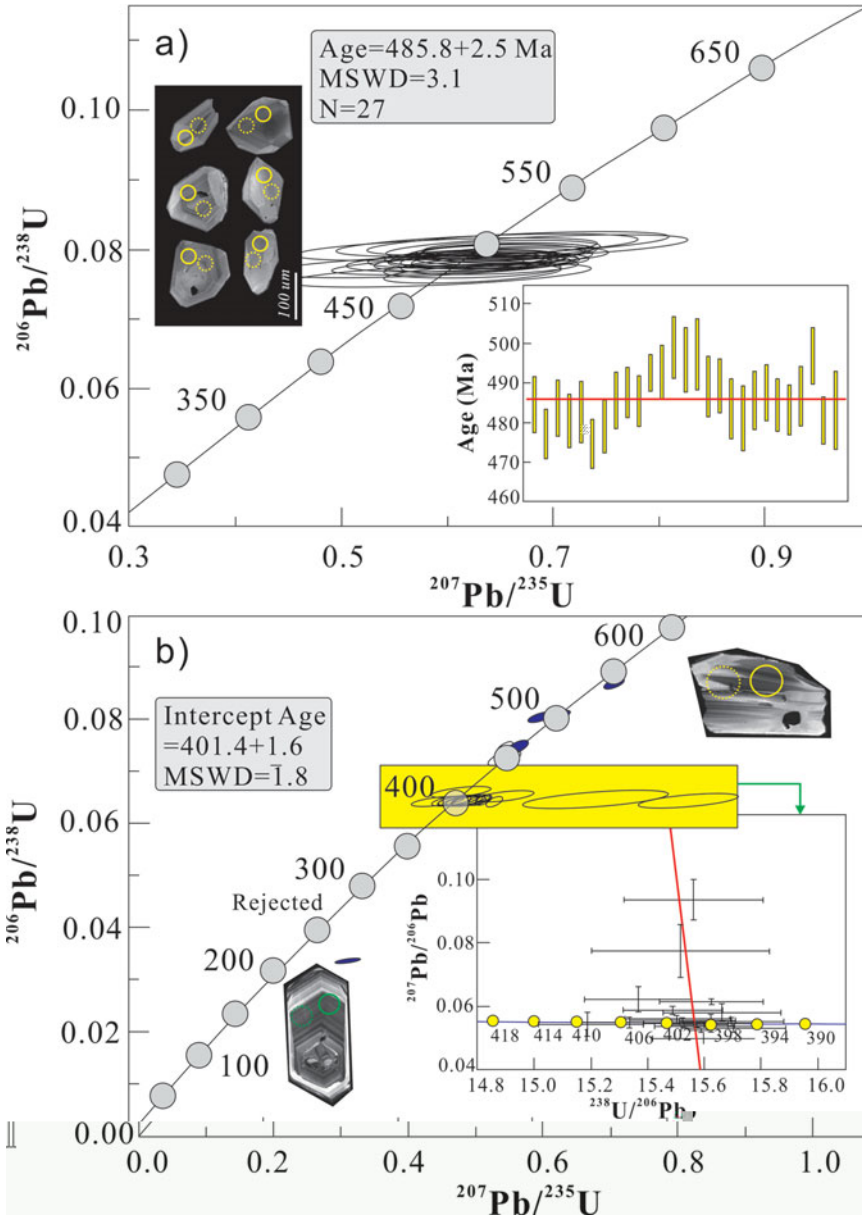


Figure 4. U-Pb zircon age spectra for the Zhaheba ophiolite. (a) Concordia diagram showing a linear fit to 27 grains, yielding an age of 485.8 ± 2.5 Ma (MSWD=3.1). (b) Concordia diagram showing an intercept age of 401.4 ± 1.6 Ma (MSWD=1.8). The yellow shaded region in (b) indicates the intercept age. The red line in (b) indicates the age of a specific grain. Inset (a) shows zircon grains with a 100 μm scale bar. Inset (b) shows a zircon grain with a 100 μm scale bar.

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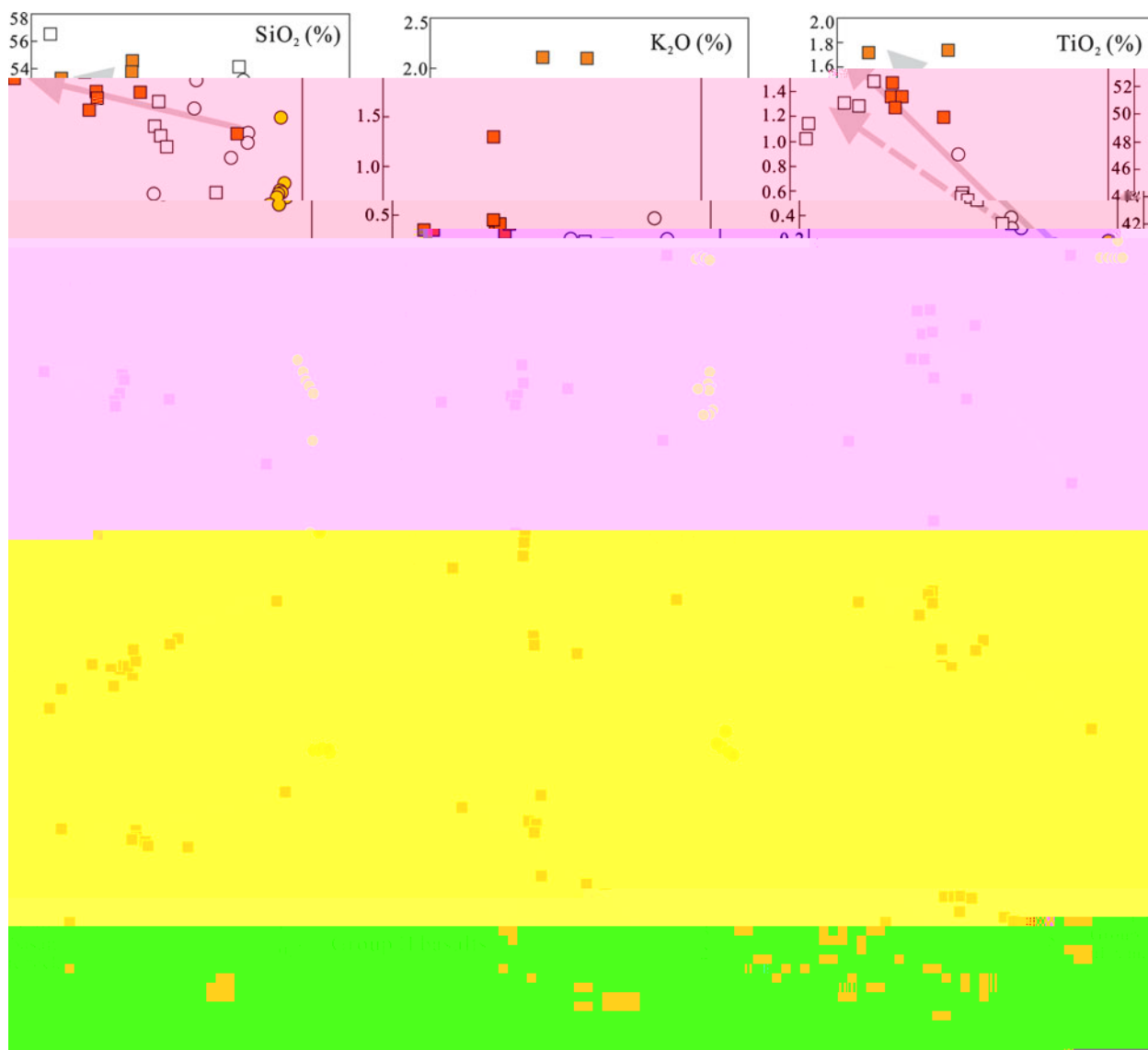


Figure 6. (a) SiO<sub>2</sub> vs. K<sub>2</sub>O, (b) SiO<sub>2</sub> vs. TiO<sub>2</sub>, and (c) K<sub>2</sub>O vs. TiO<sub>2</sub> diagrams for the Zhaheba ophiolite. The shaded regions represent different rock types: light pink for basalt, light purple for andesite, yellow for diorite, and green for gabbro. Data points are from this study (filled symbols) and from literature (open symbols). The dashed red arrow indicates the trend of increasing silica content and decreasing potassium and titanium content.

1. 2013年01月31日  
 2. 43.15%  
 3. 5.65%  
 4. 52%  
 5. 1.3  
 6. 1.1  
 7. 2.2  
 8. 0.2  
 9. 0.4

4.c.2. Basalts

1. 43.15%  
 2. 5.65%  
 3. 52%

1) 124  
 2) 205  
 3) 50  
 4) 60  
 5) 30  
 6) 20  
 7) 10  
 8) 20  
 9) 10









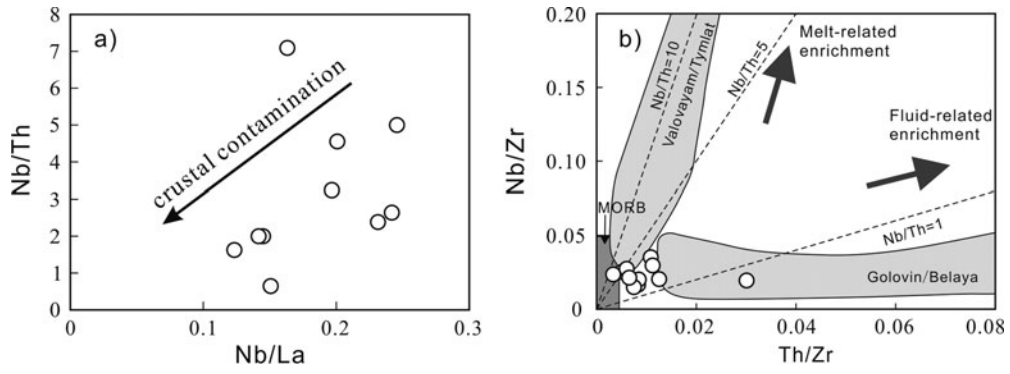


Fig. 12. (a) Nb/Th vs Nb/La diagram showing the effect of crustal contamination. (b) Nb/Zr vs Th/Zr diagram showing the effect of melt- and fluid-related enrichment.

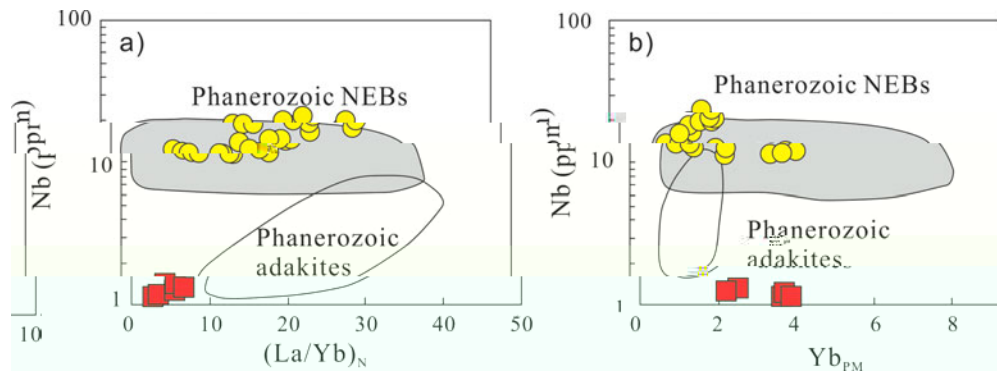


Fig. 13. (a) Nb vs (La/Yb)<sub>N</sub> diagram. (b) Nb vs Yb<sub>PM</sub> diagram. Both diagrams show the distribution of Phanerozoic NEBs and adakites.

1.  $(\text{La}/\text{Yb})_N = 0.04126$ ,  $(\text{Nb}/\text{Th}) = 0.06133$

2.  $(\text{La}/\text{Yb})_N = 0.1$ ,  $(\text{Nb}/\text{Th}) = 0.1$

3.  $(\text{La}/\text{Yb})_N = 0.2$ ,  $(\text{Nb}/\text{Th}) = 0.2$

4.  $(\text{La}/\text{Yb})_N = 0.3$ ,  $(\text{Nb}/\text{Th}) = 0.3$

5.  $(\text{La}/\text{Yb})_N = 0.4$ ,  $(\text{Nb}/\text{Th}) = 0.4$

6.  $(\text{La}/\text{Yb})_N = 0.5$ ,  $(\text{Nb}/\text{Th}) = 0.5$

7.  $(\text{La}/\text{Yb})_N = 0.6$ ,  $(\text{Nb}/\text{Th}) = 0.6$

8.  $(\text{La}/\text{Yb})_N = 0.7$ ,  $(\text{Nb}/\text{Th}) = 0.7$

9.  $(\text{La}/\text{Yb})_N = 0.8$ ,  $(\text{Nb}/\text{Th}) = 0.8$

10.  $(\text{La}/\text{Yb})_N = 0.9$ ,  $(\text{Nb}/\text{Th}) = 0.9$

11.  $(\text{La}/\text{Yb})_N = 1.0$ ,  $(\text{Nb}/\text{Th}) = 1.0$

12.  $(\text{La}/\text{Yb})_N = 1.1$ ,  $(\text{Nb}/\text{Th}) = 1.1$

13.  $(\text{La}/\text{Yb})_N = 1.2$ ,  $(\text{Nb}/\text{Th}) = 1.2$

14.  $(\text{La}/\text{Yb})_N = 1.3$ ,  $(\text{Nb}/\text{Th}) = 1.3$

15.  $(\text{La}/\text{Yb})_N = 1.4$ ,  $(\text{Nb}/\text{Th}) = 1.4$

16.  $(\text{La}/\text{Yb})_N = 1.5$ ,  $(\text{Nb}/\text{Th}) = 1.5$

17.  $(\text{La}/\text{Yb})_N = 1.6$ ,  $(\text{Nb}/\text{Th}) = 1.6$

18.  $(\text{La}/\text{Yb})_N = 1.7$ ,  $(\text{Nb}/\text{Th}) = 1.7$

19.  $(\text{La}/\text{Yb})_N = 1.8$ ,  $(\text{Nb}/\text{Th}) = 1.8$

20.  $(\text{La}/\text{Yb})_N = 1.9$ ,  $(\text{Nb}/\text{Th}) = 1.9$

21.  $(\text{La}/\text{Yb})_N = 2.0$ ,  $(\text{Nb}/\text{Th}) = 2.0$

22.  $(\text{La}/\text{Yb})_N = 2.1$ ,  $(\text{Nb}/\text{Th}) = 2.1$

23.  $(\text{La}/\text{Yb})_N = 2.2$ ,  $(\text{Nb}/\text{Th}) = 2.2$

24.  $(\text{La}/\text{Yb})_N = 2.3$ ,  $(\text{Nb}/\text{Th}) = 2.3$

25.  $(\text{La}/\text{Yb})_N = 2.4$ ,  $(\text{Nb}/\text{Th}) = 2.4$

26.  $(\text{La}/\text{Yb})_N = 2.5$ ,  $(\text{Nb}/\text{Th}) = 2.5$

27.  $(\text{La}/\text{Yb})_N = 2.6$ ,  $(\text{Nb}/\text{Th}) = 2.6$

28.  $(\text{La}/\text{Yb})_N = 2.7$ ,  $(\text{Nb}/\text{Th}) = 2.7$

29.  $(\text{La}/\text{Yb})_N = 2.8$ ,  $(\text{Nb}/\text{Th}) = 2.8$

30.  $(\text{La}/\text{Yb})_N = 2.9$ ,  $(\text{Nb}/\text{Th}) = 2.9$

31.  $(\text{La}/\text{Yb})_N = 3.0$ ,  $(\text{Nb}/\text{Th}) = 3.0$

32.  $(\text{La}/\text{Yb})_N = 3.1$ ,  $(\text{Nb}/\text{Th}) = 3.1$

33.  $(\text{La}/\text{Yb})_N = 3.2$ ,  $(\text{Nb}/\text{Th}) = 3.2$

34.  $(\text{La}/\text{Yb})_N = 3.3$ ,  $(\text{Nb}/\text{Th}) = 3.3$

35.  $(\text{La}/\text{Yb})_N = 3.4$ ,  $(\text{Nb}/\text{Th}) = 3.4$

36.  $(\text{La}/\text{Yb})_N = 3.5$ ,  $(\text{Nb}/\text{Th}) = 3.5$

37.  $(\text{La}/\text{Yb})_N = 3.6$ ,  $(\text{Nb}/\text{Th}) = 3.6$

38.  $(\text{La}/\text{Yb})_N = 3.7$ ,  $(\text{Nb}/\text{Th}) = 3.7$

39.  $(\text{La}/\text{Yb})_N = 3.8$ ,  $(\text{Nb}/\text{Th}) = 3.8$

40.  $(\text{La}/\text{Yb})_N = 3.9$ ,  $(\text{Nb}/\text{Th}) = 3.9$

41.  $(\text{La}/\text{Yb})_N = 4.0$ ,  $(\text{Nb}/\text{Th}) = 4.0$

42.  $(\text{La}/\text{Yb})_N = 4.1$ ,  $(\text{Nb}/\text{Th}) = 4.1$

43.  $(\text{La}/\text{Yb})_N = 4.2$ ,  $(\text{Nb}/\text{Th}) = 4.2$

44.  $(\text{La}/\text{Yb})_N = 4.3$ ,  $(\text{Nb}/\text{Th}) = 4.3$

45.  $(\text{La}/\text{Yb})_N = 4.4$ ,  $(\text{Nb}/\text{Th}) = 4.4$

46.  $(\text{La}/\text{Yb})_N = 4.5$ ,  $(\text{Nb}/\text{Th}) = 4.5$

47.  $(\text{La}/\text{Yb})_N = 4.6$ ,  $(\text{Nb}/\text{Th}) = 4.6$

48.  $(\text{La}/\text{Yb})_N = 4.7$ ,  $(\text{Nb}/\text{Th}) = 4.7$

49.  $(\text{La}/\text{Yb})_N = 4.8$ ,  $(\text{Nb}/\text{Th}) = 4.8$

50.  $(\text{La}/\text{Yb})_N = 4.9$ ,  $(\text{Nb}/\text{Th}) = 4.9$

51.  $(\text{La}/\text{Yb})_N = 5.0$ ,  $(\text{Nb}/\text{Th}) = 5.0$

52.  $(\text{La}/\text{Yb})_N = 5.1$ ,  $(\text{Nb}/\text{Th}) = 5.1$

53.  $(\text{La}/\text{Yb})_N = 5.2$ ,  $(\text{Nb}/\text{Th}) = 5.2$

54.  $(\text{La}/\text{Yb})_N = 5.3$ ,  $(\text{Nb}/\text{Th}) = 5.3$

55.  $(\text{La}/\text{Yb})_N = 5.4$ ,  $(\text{Nb}/\text{Th}) = 5.4$

56.  $(\text{La}/\text{Yb})_N = 5.5$ ,  $(\text{Nb}/\text{Th}) = 5.5$

57.  $(\text{La}/\text{Yb})_N = 5.6$ ,  $(\text{Nb}/\text{Th}) = 5.6$

58.  $(\text{La}/\text{Yb})_N = 5.7$ ,  $(\text{Nb}/\text{Th}) = 5.7$

59.  $(\text{La}/\text{Yb})_N = 5.8$ ,  $(\text{Nb}/\text{Th}) = 5.8$

60.  $(\text{La}/\text{Yb})_N = 5.9$ ,  $(\text{Nb}/\text{Th}) = 5.9$

61.  $(\text{La}/\text{Yb})_N = 6.0$ ,  $(\text{Nb}/\text{Th}) = 6.0$

62.  $(\text{La}/\text{Yb})_N = 6.1$ ,  $(\text{Nb}/\text{Th}) = 6.1$

63.  $(\text{La}/\text{Yb})_N = 6.2$ ,  $(\text{Nb}/\text{Th}) = 6.2$

64.  $(\text{La}/\text{Yb})_N = 6.3$ ,  $(\text{Nb}/\text{Th}) = 6.3$

65.  $(\text{La}/\text{Yb})_N = 6.4$ ,  $(\text{Nb}/\text{Th}) = 6.4$

66.  $(\text{La}/\text{Yb})_N = 6.5$ ,  $(\text{Nb}/\text{Th}) = 6.5$

67.  $(\text{La}/\text{Yb})_N = 6.6$ ,  $(\text{Nb}/\text{Th}) = 6.6$

68.  $(\text{La}/\text{Yb})_N = 6.7$ ,  $(\text{Nb}/\text{Th}) = 6.7$

69.  $(\text{La}/\text{Yb})_N = 6.8$ ,  $(\text{Nb}/\text{Th}) = 6.8$

70.  $(\text{La}/\text{Yb})_N = 6.9$ ,  $(\text{Nb}/\text{Th}) = 6.9$

71.  $(\text{La}/\text{Yb})_N = 7.0$ ,  $(\text{Nb}/\text{Th}) = 7.0$

72.  $(\text{La}/\text{Yb})_N = 7.1$ ,  $(\text{Nb}/\text{Th}) = 7.1$

73.  $(\text{La}/\text{Yb})_N = 7.2$ ,  $(\text{Nb}/\text{Th}) = 7.2$

74.  $(\text{La}/\text{Yb})_N = 7.3$ ,  $(\text{Nb}/\text{Th}) = 7.3$

75.  $(\text{La}/\text{Yb})_N = 7.4$ ,  $(\text{Nb}/\text{Th}) = 7.4$

76.  $(\text{La}/\text{Yb})_N = 7.5$ ,  $(\text{Nb}/\text{Th}) = 7.5$

77.  $(\text{La}/\text{Yb})_N = 7.6$ ,  $(\text{Nb}/\text{Th}) = 7.6$

78.  $(\text{La}/\text{Yb})_N = 7.7$ ,  $(\text{Nb}/\text{Th}) = 7.7$

79.  $(\text{La}/\text{Yb})_N = 7.8$ ,  $(\text{Nb}/\text{Th}) = 7.8$

80.  $(\text{La}/\text{Yb})_N = 7.9$ ,  $(\text{Nb}/\text{Th}) = 7.9$

81.  $(\text{La}/\text{Yb})_N = 8.0$ ,  $(\text{Nb}/\text{Th}) = 8.0$

82.  $(\text{La}/\text{Yb})_N = 8.1$ ,  $(\text{Nb}/\text{Th}) = 8.1$

83.  $(\text{La}/\text{Yb})_N = 8.2$ ,  $(\text{Nb}/\text{Th}) = 8.2$

84.  $(\text{La}/\text{Yb})_N = 8.3$ ,  $(\text{Nb}/\text{Th}) = 8.3$

85.  $(\text{La}/\text{Yb})_N = 8.4$ ,  $(\text{Nb}/\text{Th}) = 8.4$

86.  $(\text{La}/\text{Yb})_N = 8.5$ ,  $(\text{Nb}/\text{Th}) = 8.5$

87.  $(\text{La}/\text{Yb})_N = 8.6$ ,  $(\text{Nb}/\text{Th}) = 8.6$

88.  $(\text{La}/\text{Yb})_N = 8.7$ ,  $(\text{Nb}/\text{Th}) = 8.7$

89.  $(\text{La}/\text{Yb})_N = 8.8$ ,  $(\text{Nb}/\text{Th}) = 8.8$

90.  $(\text{La}/\text{Yb})_N = 8.9$ ,  $(\text{Nb}/\text{Th}) = 8.9$

91.  $(\text{La}/\text{Yb})_N = 9.0$ ,  $(\text{Nb}/\text{Th}) = 9.0$

92.  $(\text{La}/\text{Yb})_N = 9.1$ ,  $(\text{Nb}/\text{Th}) = 9.1$

93.  $(\text{La}/\text{Yb})_N = 9.2$ ,  $(\text{Nb}/\text{Th}) = 9.2$

94.  $(\text{La}/\text{Yb})_N = 9.3$ ,  $(\text{Nb}/\text{Th}) = 9.3$

95.  $(\text{La}/\text{Yb})_N = 9.4$ ,  $(\text{Nb}/\text{Th}) = 9.4$

96.  $(\text{La}/\text{Yb})_N = 9.5$ ,  $(\text{Nb}/\text{Th}) = 9.5$

97.  $(\text{La}/\text{Yb})_N = 9.6$ ,  $(\text{Nb}/\text{Th}) = 9.6$

98.  $(\text{La}/\text{Yb})_N = 9.7$ ,  $(\text{Nb}/\text{Th}) = 9.7$

99.  $(\text{La}/\text{Yb})_N = 9.8$ ,  $(\text{Nb}/\text{Th}) = 9.8$

100.  $(\text{La}/\text{Yb})_N = 9.9$ ,  $(\text{Nb}/\text{Th}) = 9.9$

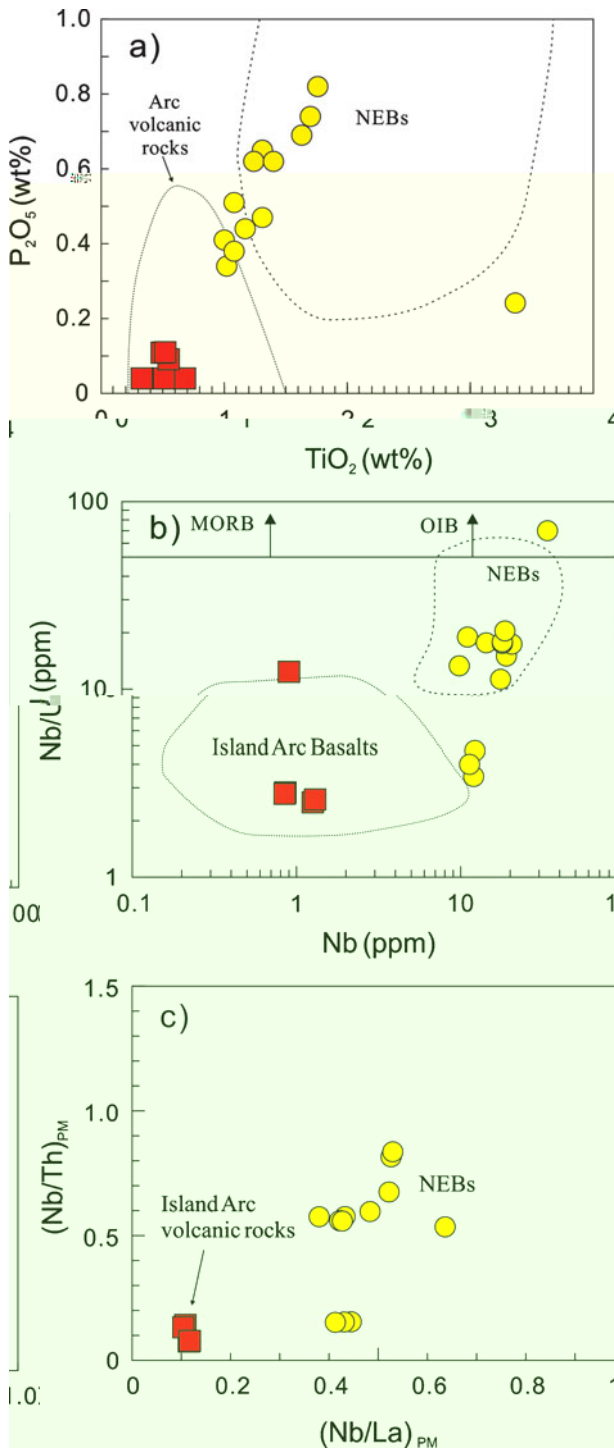
101.  $(\text{La}/\text{Yb})_N = 10.0$ ,  $(\text{Nb}/\text{Th}) = 10.0$

Fig. 14. (a) Nb vs (La/Yb)<sub>N</sub> diagram. (b) Nb vs Yb<sub>PM</sub> diagram. Both diagrams show the distribution of Phanerozoic NEBs and adakites.

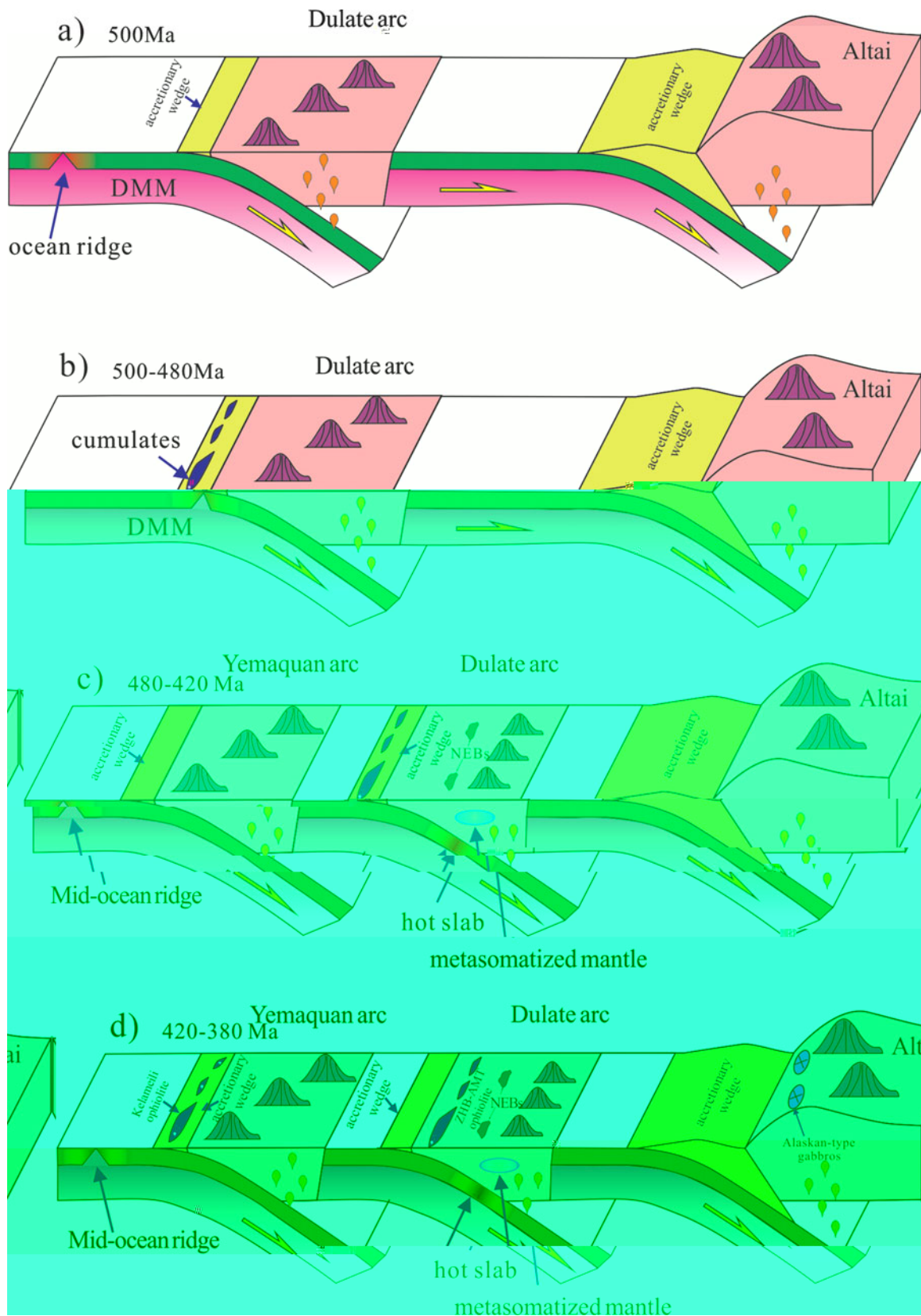
5.d. Implications for the Palaeozoic accretion process in eastern Junggar

(416) *et al.* 2014  
*et al.* 2015), (503)  
 45 *et al.* 2003 *et al.* 2015  
 (400) (1.1)  
*et al.* 2014),  
 2002).  
 (0.1-0.2), (0.6-1.0)  
 2000), 2000 a,b *et al.*  
 2000 a),  
*et al.* 2000 b).





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