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Geochemistry of Late Carboniferous Liushugou Formation Volcanic Rocks in the Bogda, Xinjiang

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Abstract

The Bogda tectonic belt is one of the most important tectonic belts in the interior of the continent, and it is also one of the key areas for intraplate tectonic research. Late Paleozoic magmatic events in the Bogda structural belt are of great significance for understanding the subduction and closure of oceanic basins This paper selects the volcanic rocks of Liushugou Formation in the basalt sections of Maquanwan areas in the North section of Bogda as the research object. Based on the field geological survey, combined with chronology and geochemical research, the petrogenesis and tectonic background are revealed. As well as the late Carboniferous tectonic evolution of the Bogda tectonic belt, it provides a new basis for discussing the late Paleozoic tectonic movement in Bogda.The Maquanwan basalt has high Al, Na, Sr, low K, Yb, Y, Ti, and δEu are positive anomalous geochemical characteristics, indicating that its magma originates from the partial melting of the subducting oceanic crust, and has typical subduction zone island arc basalt Earth chemical characteristics.

Keywords

Bogda; Volcanic Rocks; Geochemistry; Island Arc Setting.

1. Introduction

The Bogda tectonic belt is one of the most important tectonic belts in the interior of the Chinese mainland, and it is also one of the hot research areas of intraplate continental tectonics[1]. The Bogda tectonic belt is located in the southern flank of the North Asian tectonic domain, connected to the Junggar Basin and the Siberian Plate in the north, adjacent to the Carboniferous volcanic rocks of the Turpan-Hami Basin and the Jueluotage Basin in the south, and the Hongliuxia-Suji Fault and the Karaoke Basin in the east[2]. The Maili-Moqinura ophiolite is connected[18 it is the intersection of three major tectonic units, and it is also a key area for understanding the tectonic evolution of the Paleo-Asian Ocean. During the Paleozoic period, the Paleo-Asian Ocean had relatively complete characteristics of the Paleozoic arc-ditch-basin system, and in it, magmatic rocks of different periods, types and properties and related volcanic-sedimentary rock series were developed; The entire tectonic evolution process of oceanic expansion, subduction reduction, collisional orogeny, and post-orogenic extension, as well as the control process related to basin formation[3]. In the Late Paleozoic, the evolution process of the closure of the Paleo-Asian Ocean was mainly characterized by continental-continental collision orogeny Scholars hold different views on its formation and evolution: (1) On the basis of rifts, closure-compression through rifts Pressure orogeny[4], (2) Lagging back-arc basin[5]; (3) Continental-continental collision orogeny[6], The tectonic evolution of the Bogda tectonic belt is strictly controlled by the regional paleo-ocean evolution and orogenic processes.

2. Majuanwan Volcanic Rock

The Maquan Bay basalt is mainly composed of basalt, basaltic andesite, and andesite; the lower section is composed of tuff intercalated with argillaceous siltstone and carbonate rock, containing

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brachiopod fossils. The basic light gray-green volcanic rock has an outcropping width of 200 m, and develops quartzite dikes and basic dikes (Figure. 1)

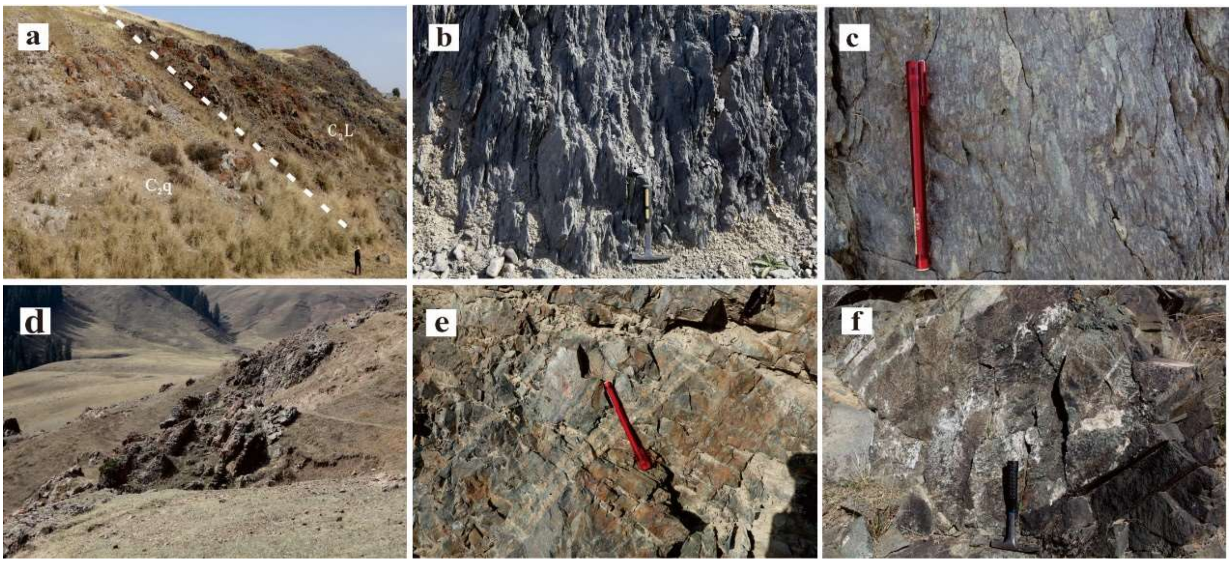

Figure 1. Field characteristics of volcanic rocks of Liushugou Formation in Majuanwan

Maquanwan basalt is mainly composed of basic plagioclase (15%-20%) and pyroxene (5%-10%). Among them, the basic plagioclase is mainly labradorite, which is in the shape of euhedral-semihedral long plate and lath, and the ratio of length to width is 6:1 to 10:1. It is developed, with a ring-shaped structure and slight sericitization; the feldspar is in the shape of thin strips, the particle size is more than 0.1 mm × 0.2 mm, and the triangular lattice is formed in an irregular arrangement. Magnetite composition. Granular ordinary pyroxene, magnetite and volcanic glass are filled in the elongated plagioclase lattice. Ordinary pyroxene crystals are small, showing the structure of dissolution spots. Ordinary pyroxene is euhedral short columnar, with a particle size of about 0.2 mm to 0.3 mm, showing a typical mesograin structure (Figure 2).

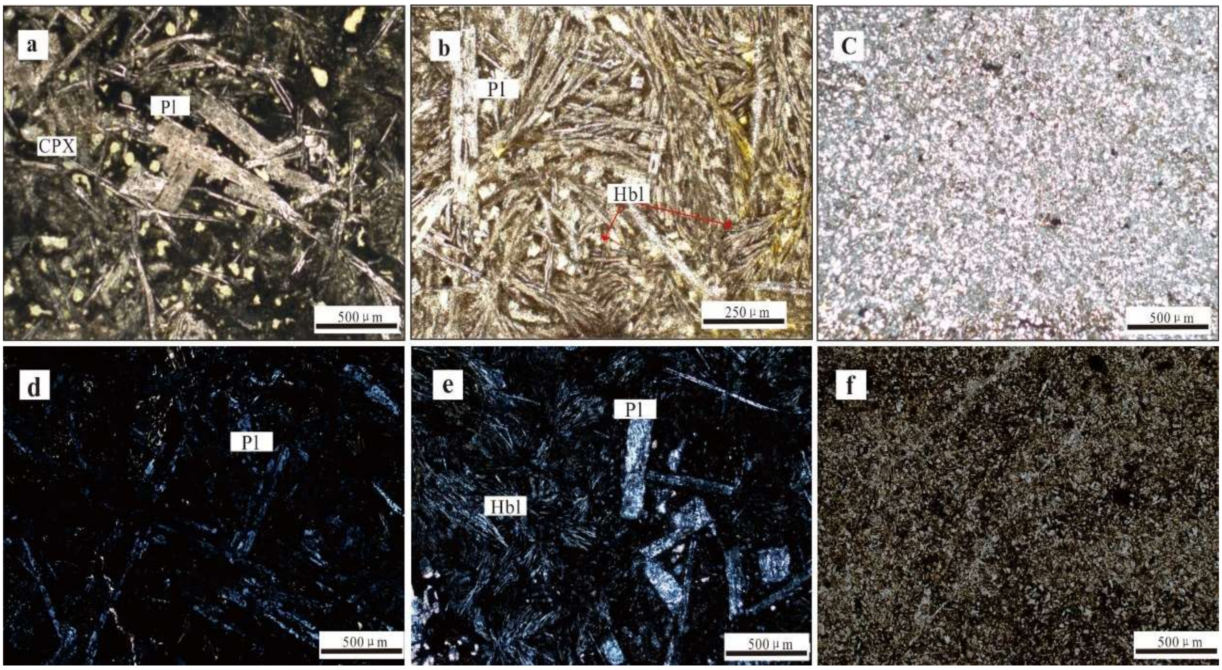

Figure 2. Microstructure photograph of Basalt in Majuanwan Section

3. Geochemical Analysis of Basalt in Maquan BayMajuanwan

3.1 Major Element

The content of the major element SiO2 in the seven Maquanwan basalt samples varies from 49.60% to 50.65%, with an average value of 49.87%, belonging to basic magmatic rocks. low; the content of K2O is less, the variation range is 0.37%-1.76%, the average is 1.01%; the content of Na2O is 4.29%-5.63%, the average is 4.85%; the overall content of total alkali (Na2O+K2O) is relatively small, It is 5.35%-6.32%, the average is 5.86%, but it is especially poor in K2O, the K2O/Na2O ratio is low, the average is 0.22; the Al2O3 content is high, 18.69%-20.23%, the average is 19.52%; Mgo The content is 4.01%-4.51%, the average is 4.26%, and the content is not high; the CaO content varies from 6.39% to 8.02%, and the average is 6.96%; the P2O5 content is relatively small, 0.13%-0.16%, and the average is 0.15 %; The basalt samples in this group are rich in Al, Ca and poor in K and Ti. The Rittman index σ varies from 4.58% to 5.27%, with an average value of 5%, which belongs to alkaline rocks (σ>4). The MF varies from 50.02 to 59.57 with an average value of 54.44. The magnesium index Mg# varies from 46.88 to 50.85 with an average value of 48.80. The Mg# value of the basalt samples in the study area is significantly lower than that of the primary magma (Mg#=68-75)[7], and the Mg-Fe index is small, indicating that differential crystallization occurred during the magma ascent, indicating that the magma may originate from the partial melting of the depleted asthenospheric mantle (Table 1).

In the major element classification diagram (Figure. 3a.), it can be clearly seen that the volcanic rocks in Maquan Bay are obviously concentrated in the trachybasalt area, and one sample entered the basalt area. The AFM map shows that all samples belong to the calc-alkaline series of rocks (Figure 3b.)

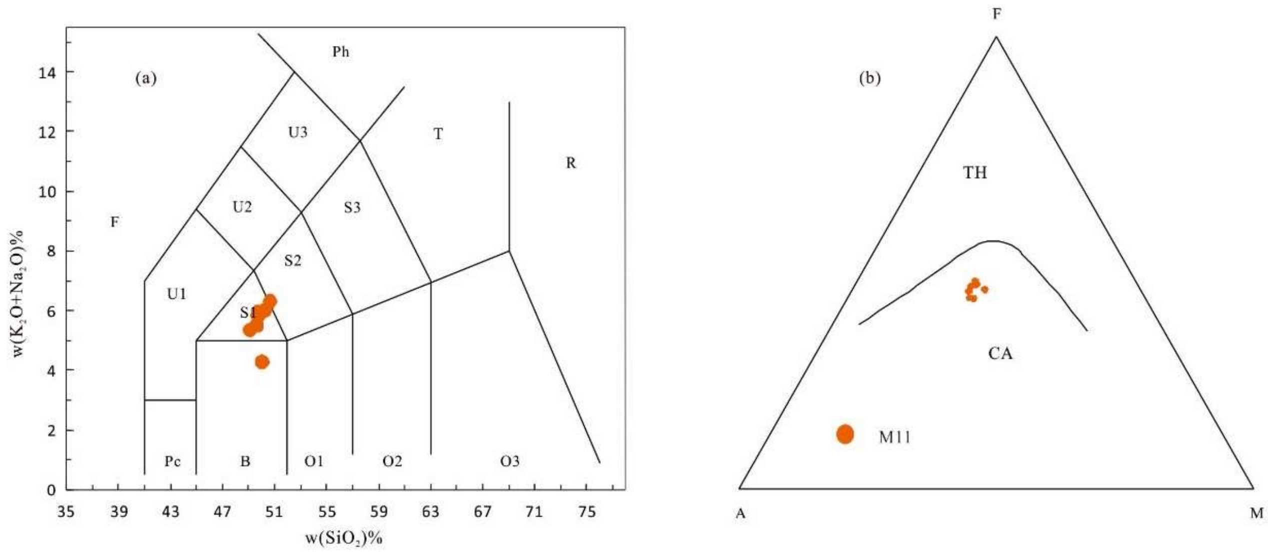

Figure 3. The diagrams of TAS and AFM of Majuanwan basalt

References are cited in the text just by square brackets. (If square brackets are not available, slashes may be used instead,.) Two or more references at a time may be put in one set of brackets The references are to be numbered in the order in which they are cited in the text and are to be listed at the end of the contribution under a heading References, see Table 1.

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Table 1. Whole-rock major elements data (%) of Majuanwan basalt

lithology	Majuanwan						
Sample serial number	M11-1	M11-2	M11-3	M11-4	M11-5	M11-6	M11-7
ω(SiO2)	50.03	50.65	49.77	50.24	49.71	49.60	49.10
ω(Al2O3)	18.69	19.34	20.23	19.71	19.85	19.42	19.43
ω(TiO2)	1.13	1.11	0.95	1.04	1.02	1.02	1.11
ω(Fe2O3)	2.56	2.26	2.82	2.97	3.34	3.18	2.85
ω(FeO)	6.40	5.78	4.97	5.13	5.02	5.24	5.24
ω(TFe2O3)	9.67	8.68	8.35	8.67	8.91	9.00	8.67
ω(CaO)	6.39	6.26	6.79	6.59	6.82	7.88	8.02
ω(MgO)	4.51	4.33	4.35	4.05	4.03	4.01	4.53
ω(K2O)	1.76	1.70	1.17	0.37	0.52	0.88	0.68
ω(Na2O)	4.29	4.62	4.80	5.63	5.32	4.62	4.67
ω(MnO)	0.096	0.122	0.116	0.135	0.137	0.124	0.125
ω(P2O5)	0.163	0.163	0.141	0.164	0.163	0.161	0.137
ω(H2O+)	3.35	3.11	3.36	3.60	3.72	3.35	3.82
ω(H2O-)	0.43	0.35	0.41	0.35	0.39	0.37	0.35
ω(K2O+Na2O)	6.05	6.32	5.97	6.00	5.84	5.50	5.35
Littman Index σ	5.20	5.22	5.27	4.96	5.08	4.58	4.70
MF	59.57	52.24	50.03	54.02	56.34	57.03	51.86
TFeO	8.70	7.81	7.51	7.80	8.02	8.10	7.80
Mg#	48.04	49.71	50.79	48.06	47.26	46.88	50.85
loss on ignition	3.07	2.82	3.13	3.26	3.37	3.06	3.35
sum	99.80	99.81	99.78	99.86	99.84	99.78	99.84

3.2 Rare Earth Elements and Trace Elements

The ΣREE of the basalt in the study area is 439.12 ppm to 49.34 ppm, with an average value of 45.38 ppm, which is close to the content of ΣREE of E-MORB (49.09 ppm); LREE/HREE is 2.85 to 3.05, with an average value of 2.98; There is a slightly weak positive δEu anomaly, indicating that the basaltic magma in this area is the product of a certain degree of differentiation. The original magma mainly experienced the separation and crystallization of olivine and pyroxene, while the plagioclase is mainly a melt phase; (La/Yb)N ranged from 1.97 to 2.33, with an average of 2.14, indicating that light rare earth elements were slightly enriched, and the fractionation of light and heavy rare earth elements was obvious. From the standardized distribution map of chondrites (Table 2), it can be seen that the basalt curve in the study area is slightly enriched right-dipping curve of light rare earth (LREE), which is basically consistent with the E-MORB curve, while the E-MORB curve is The product of mixing N-MORB and OIB to different degrees. The magma originates from the mixed region of depleted mantle and enriched mantle. The trachybasalt has strong compatibility elements Ni (14.0 μg/g~62.1 μg/g), Cr (52.6 μg/g~70.4 μg/g) are lower than the reference values of 250 μg/g and 300 μg/g of the original magma respectively, suggesting that it is the product of the original magma evolution, and the numerical conclusion is drawn with Mg# It is basically the same, indicating that this kind of basalt primitive magma mainly comes from the depleted mantle that replaces a small amount of enriched mantle magma, and obvious differential crystallization occurred during the magma ascent; Ba is slightly enriched, Sr is strongly enriched, and Rb and Cs are slightly depleted. The high-field-strength element Nb is strongly depleted, and Hf is slightly enriched; the rest elements are consistent with the distribution of incompatible elements in most rock samples[7].

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Table 2. Trace elements and REE (ppm) date of Majuanwan basalt

Sample	M11-1	M11-2	M11-3	M11-4	M11-5	M11-6	M11-7
Y	18.59	19.56	16.05	18.62	18.33	19.95	15.63
La	5.64	6.06	5.26	5.73	5.47	5.58	4.61
Ce	13.76	13.89	11.37	13.79	12.33	12.96	10.83
Pr	2.18	2.14	1.77	2.00	1.91	2.02	1.67
Nd	11.10	10.89	8.99	10.30	9.79	10.40	8.75
Sm	2.96	2.90	2.43	2.80	2.75	2.81	2.42
Eu	1.07	1.13	1.06	1.09	1.05	1.09	0.97
Gd	2.72	2.74	2.30	2.65	2.54	2.64	2.21
Tb	0.54	0.55	0.45	0.52	0.50	0.54	0.44
Dy	3.57	3.62	3.04	3.54	3.38	3.58	2.96
Ho	0.71	0.71	0.59	0.68	0.66	0.72	0.59
Er	1.96	2.05	1.67	1.93	1.87	2.05	1.63
Tm	0.31	0.32	0.27	0.31	0.30	0.33	0.26
Yb	1.93	2.00	1.62	1.92	1.83	2.03	1.54
Lu	0.31	0.33	0.27	0.30	0.30	0.33	0.26
Li	21.38	18.64	20.65	13.01	14.38	12.65	17.42
Be	0.57	0.59	0.45	0.58	0.56	0.62	0.51
Sc	34.52	27.98	25.95	29.39	29.80	30.53	27.14
V	306.88	289.83	247.40	267.92	247.25	278.98	319.14
Cr	66.78	52.61	58.40	64.30	58.44	70.41	65.04
Co	27.63	23.04	21.62	25.08	23.54	24.60	22.18
Ni	16.64	13.63	14.74	62.09	14.03	14.92	15.02
Cu	27.88	57.19	26.37	29.90	29.82	88.47	22.16
Ga	17.36	18.62	18.98	18.03	17.57	20.35	18.91
Rb	31.67	32.89	24.30	7.43	9.31	15.55	10.46
Sr	663.11	632.19	1005.08	470.81	529.56	890.24	476.76
Zr	67.02	76.63	64.55	74.72	66.37	80.92	59.50
Nb	1.52	1.61	1.25	1.65	1.46	1.62	1.23
Mo	0.45	0.43	0.23	0.16	0.14	0.45	0.19
Cd	0.03	0.02	0.03	0.03	0.03	0.04	0.02
In	0.04	0.04	0.04	0.05	0.04	0.04	0.03
Cs	0.97	0.96	0.94	0.40	0.46	1.05	0.84
Ba	427.95	377.76	378.26	123.32	168.77	371.70	238.47
Hf	2.12	2.33	1.93	2.23	2.02	2.37	1.86
Ta	0.14	0.14	0.17	0.14	0.13	0.15	0.13
W	0.18	0.15	0.12	0.29	0.14	0.12	0.12
Tl	0.14	0.14	0.11	0.03	0.04	0.07	0.05
Pb	0.77	0.55	1.16	1.18	0.71	1.49	0.59
Bi	0.02	0.01	0.00	0.02	0.01	0.01	0.00
Th	1.00	1.15	0.83	0.95	0.92	1.10	0.77
U	0.37	0.36	0.28	0.37	0.35	0.39	0.25
ΣREE	48.76	49.34	41.10	47.57	44.67	47.07	39.12
HREE	12.05	12.33	10.21	11.86	11.39	12.21	9.88
LREE/HREE	3.05	3.00	3.03	3.01	2.92	2.85	2.96
La_N/Yb_N	2.09	2.18	2.33	2.14	2.14	1.97	2.15
δEu	1.15	1.22	1.38	1.22	1.21	1.23	1.29
Nb/Zr	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Th/Ta	7.39	8.35	4.81	6.74	7.19	7.41	5.96
Th/Yb	0.52	0.58	0.51	0.50	0.50	0.54	0.50
Nb/U	4.15	4.45	4.47	4.46	4.18	4.17	4.88
La/Ta	41.63	43.96	30.55	40.53	42.79	37.62	35.84
Ta/U	0.37	0.38	0.62	0.38	0.37	0.38	0.51

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4. Discussion

4.1 Maquanwan Volcanic Rock Tectonic Setting

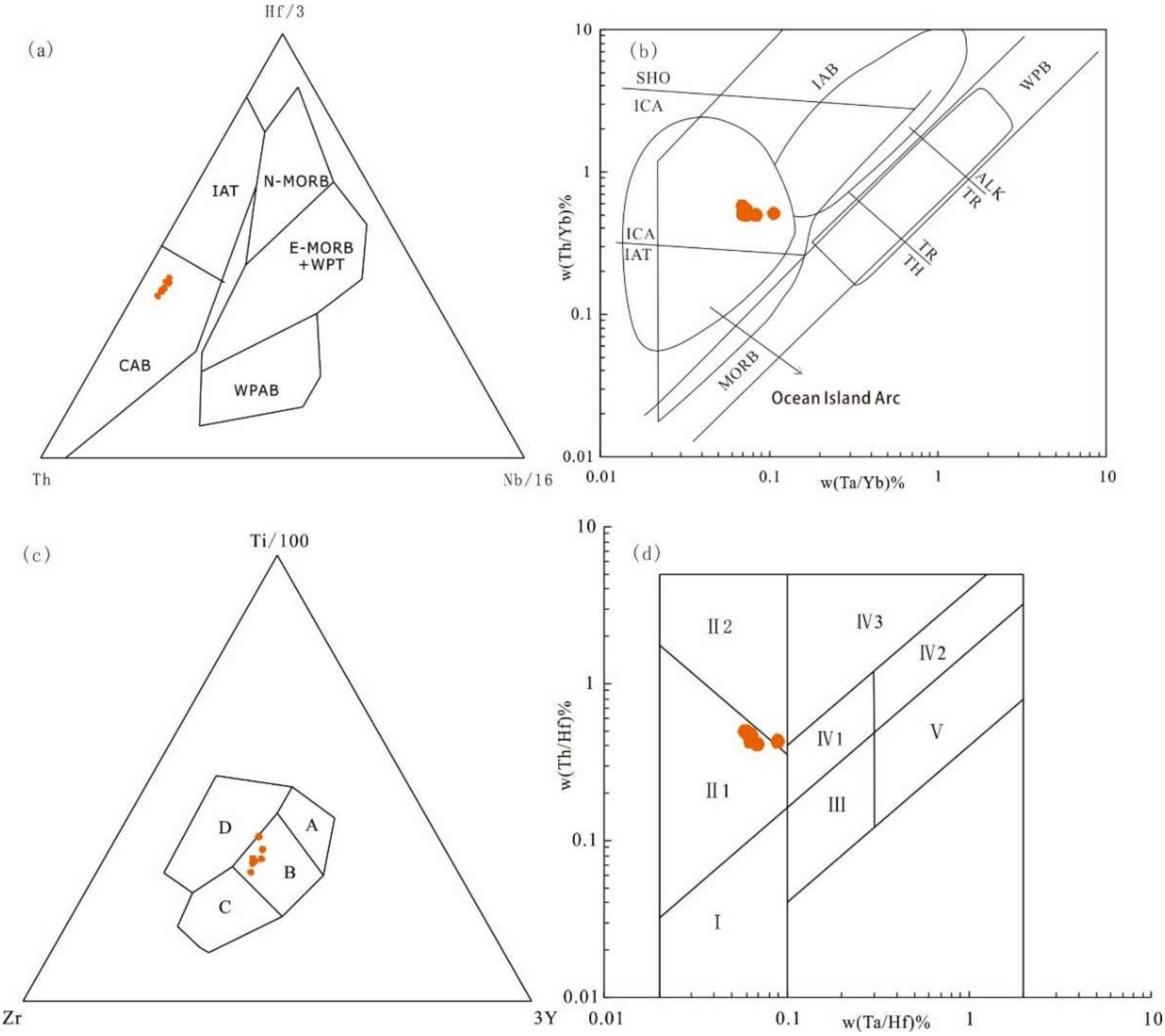

Figure 4. The diagrams of environment discrimination of Majuanwan basalt

Maquanwan basalt has high Al, poor Ti, especially low K, rich Na, low Yb, low Y, Eu positive anomalies, high Sr geochemical characteristics, showing that its magma originated from partial melting of subducting oceanic crust, formed in the Subduction-related tectonic environment. Among them, the large ion lithophile Sr is strongly enriched, while the high field strength elements Nb and Hf are relatively depleted, which indicates that it may be affected by the source fluid of the subduction zone. It is a right-dipping curve of the set, which shows the characteristics of a subduction zone island arc as a whole. Hf, Th, and Ta are inactive elements, and because they are less affected by metamorphism, alteration, partial melting and segregation crystallization, they can well reflect the nature of the basalt magma source. In the Hf/3-Th-Ta (Figure.4a) tectonic environment discrimination diagram, the Maquanwan basalt (La/Yb) N<1) falls in the CAB calc-alkaline basalt area; The basalt environment discrimination diagram composed of field strength elements, in the Th/Yb-Ta/Yb diagram (Figure.4b), the main body of the basalt sample in the study area falls into the ICA island arc calc-alkaline basalt area; from Ti/100- Zr-3Y diagram (Figure.4c) The main body of Maquan Bay basalt is invested in the island arc puller-calc-alkaline basalt area in the B area; the ratios of Th/Hf and Ta/Hf change little during the partial melting process, and hardly change Affected by the effects of separation crystallization, assimilation and contamination, its values can still remain stable, so the values of Th/Hf and Ta/Hf can better reflect the characteristics of trace elements in the source area,

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and can be used to discriminate the tectonic environment, from the Ta/Hf-Th/Hf diagram (Figure. 4d), the main body of Maquanwan basalt is put into the boundary part of the oceanic island arc basalt area and the continental margin island arc and continental margin volcanic arc basalt area; Maquanwan basalt is enriched Large ion lithophile element, accompanied by negative anomalies of Ta and Nb. Combined with the results of geochemical projection, it shows that the Carboniferous volcanic rocks in the study area have obvious island arc calc-alkaline basalt characteristics.

The ratios of some high-field-strength elements can also be used to determine the tectonic environment of basalt formation. The ratio of Th and Ta changes little in the process of deep magma, and can be used to restore the composition of the magma source area and identify the tectonic environment; La is a strong incompatible element, and the La/Ta ratio is relatively stable, so La/Ta is relatively stable. The ratios of Ta and Th/Ta can be used as indicators for judging the tectonic environment. The Th/Ta and La/Ta values of basalts formed in the mid-ocean ridge environment are relatively small, ranging from 0.75 to 2 and 10 to 20, respectively; Th element is an element with a large ionic radius. It is easy to escape from its overlying sedimentary strata into the underlying mantle wedge, so the Th/Ta ratio in the mantle wedge magma under the subduction background is high, and the Th/Ta and La/Ta ratios are between 3-5 and 30- 40. The average Th/Ta (4.81-8.35) of Maquanwan basalt is 6.83, and the average La/Ta (30.55-43.96) is 38.99 (Table 2). Combined with the results of geochemical mapping, it shows that the Maquanwan basalt has the characteristics of typical subduction zone island arc basalt.

4.2 Mahuanwan Volcanic Rock Source

The basalt in the study area has low SiO_2 content (49.60%-50.65%) and total alkali (K_2O+Na_2O) content (0.37%-1.76%). The total amount of ∑REE is low, the overall LREE is more enriched than HREE, the fractionation of light and heavy rare earths is obvious, the partition curve is slightly rightward, and there is a slight positive anomaly in Eu; the trace elements Ta, Th, Nb elements are obviously depleted, and Ti elements are not depleted. As well as a slight enrichment of U elements, very similar to the partially molten basalts in the early magmatic evolution stage of the volcanic rocks in the Bogda orogenic belt. If the continental crustal material participates in the evolution of mantle-derived basalt magma, the incompatible element Nb in the magma will decrease significantly; at the same time, according to the process of the gradual decrease of the emplacement temperature of oxides MnO and TiO_2 as the magma decompresses upward, The ratio of Sr and Ba shows an increasing trend, which indicates that the plagioclase differentiation stacking occurred during the magmatic emplacement process, showing that Eu is anomalous, and the content of Sr and Ba elements gradually increases. While in partial melting, the melting of plagioclase results in a positive anomaly of Eu in the melt. The Maquanwan basalt has a low Nb/Zr ratio of 0.02 (close to the value of the depleted mantle), and according to the Zr-Nb diagram (Figure.5a), it indicates that the basalt magma in the study area mainly originated from the depleted lithospheric mantle. In addition, the enrichment of Ba, U and other elements and the low Na/La value are also reliable indicators for judging whether magma is contaminated by the crust. It can be seen from the original mantle spider web map of trace elements that Ba, U and other elements are relatively enriched in basalt, and the Maquanwan basalt has a low Nb/La (0.24-0.29), with an average value of 0.27, less than 1; Nb/Ta (7.27-11.71), the average value is 10.54, the ratio is less than 17.50; La/Ta (30.55-43.96), the average value is 38.99, and the ratio is greater than 25; Th/Ta (4.81-8.35), the average value is 6.83, and the ratios are all greater than 2, indicating that the crustal material was added in the process of magmatism and was contaminated by a certain degree of crustal material.

The variation trend of Mg# can be used as a basis for identifying the formation mechanism of magmatic rocks. The Mg# of basalt in this area (46.88-50.85) is lower than that of basalt original magma (68-75), indicating that the degree of differentiation and evolution of the magma forming the basic magma is weak. In the La/Yb-La/Sm diagram (Figure. 5b), it is shown that partial melting dominates during magmatic evolution and is hardly affected by crystallization differentiation. According to the cobweb diagram of normalized trace elements in the original mantle , Nb and Th

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showed negative anomalies, which seemed to indicate that crustal contamination occurred during the upward migration of magma. The incompatible elements Ta and Th among the trace elements are very sensitive to the contamination of the crust. If the Th/Ta value is higher, it means that the contamination of the crust exists. The Th/Ta value of the original mantle is roughly 2.3, and the average Th/Ta value of the upper crust is greater than 10. Maquanwan basalt Th/Ta (4.81-8.35), with an average value of 6.83, indicates that there is a certain degree of crustal contamination; similarly, Nb/U and Ta/U values are also "indicators" for judging crustal contamination , the average Nb/U value of the continental crust is 8.93, the average Nb/U value of the original mantle is 33.59, the Nb/U value of ocean island basalt and mid-ocean ridge basalt is 47 ± 10, and the Ta/U value is 2.7. Maquanwan basalt Nb/U (4.15-4.88), with an average of 4.40; Ta/U of 0.35-0.59, with an average of 0.49 (Table 2). It can be seen that the Nb/U value is much smaller than that of the original mantle, oceanic island basalt, mid-ocean ridge basalt and continental crust, indicating that the degree of assimilation and contamination is very weak; the Ta/U value is lower than that of the global mid-ocean ridge basalt and intraplate oceanic island. Relative homogeneity of basalt. The basalt magma in this area originates from the depleted lithospheric mantle. During the upwelling process of the magma, it was contaminated by a certain degree of crustal contamination, and showed a high degree of partial melting, but was less affected by crystallization differentiation.

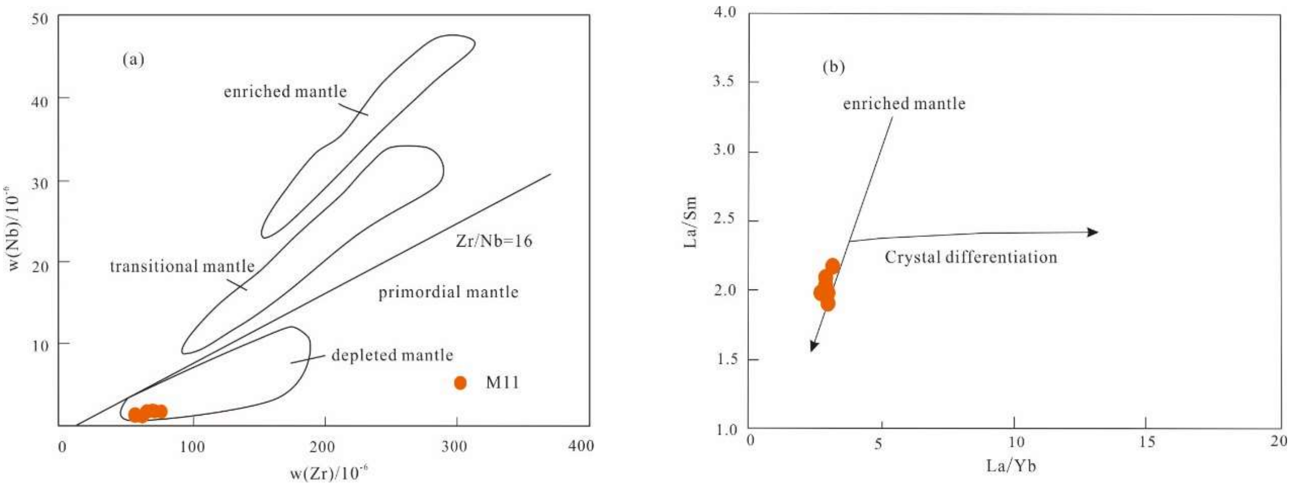

Figure 5. The diagrams of magma source of Majuanwan basalt

5. Conclusion

1) The Maquanwan basalt has high Al, Na, Sr, low K, Yb, Y, Ti, and δEu is a positive anomalous geochemical feature.

2) The Maquanwan basalt magma originates from the partial melting of the subducting oceanic crust and has the characteristics of subduction zone island arc basalt.

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