Bulgarian Chemical Communications, Special Edition H, (pp. 14 – 18) 2017

Distribution and magnetic features of igneous rocks in the Gaize-Nima area of Tibet plateau based on magnetic data

C.G. Zhang[1]*, G.L. Zhang[2], M.H. Zhang[3], J.G. Chen[4]

[1]*School of Earth Sciences and Engineering, Xi'an Shiyou University, No. 18 Dianzi 2 Road, Xi'an, Shaanxi, China*
[2]*Tianjin Geological Survey Center, China Geological Survey, No. 4 Dazhigu 8 Road, Tianjin, China*
[3]*Development and Research Center, China Geological Survey, No. 45 Fuwai Street, Beijing, China*
[4]*Huabei Department, BGP Inc. of CNPC, Middle Section, North Station East Road, Renqiu, Hebei, China*

Received September 20, 2016; Revised January14, 2017

Gaize-Nima, a part of the Qinghai-Tibet Plateau, has magnetic characteristics and a distribution of temporal and spatial development of igneous rock which are closely associated with Qinghai-Tibet plateau tectonic movement. This research aims to lay a foundation for ore-prospecting prognosis and regional tectonic zonation by investigating the magnetic characteristics and distribution of temporal and spatial development for igneous rock in the Gaize-Nima area of the Qinghai-Tibet Plateau, China. In this research, the aeromagnetic anomaly by reduction to the pole was calculated based on the aeromagnetic total intensity anomaly data at a scale of 1:200,000. Besides, the aeromagnetic anomaly data was subjected to anomaly decomposition using the regularization filtering method to obtain data about the local magnetic anomaly (LMA) and regional magnetic anomaly (RMA) in the Gaize-Nima area. Besides, based on existing research in geology and geophysics, the characteristics of the aeromagnetic anomaly, LMA and RMA were analysed. Moreover, the corresponding relationship between the igneous rock exposed on the surface, and the magnetic anomaly, was studied. In addition, the magnetic characteristics of the igneous rock exposed on the surface in Gaize-Nima were demonstrated. Moreover, this research explored the temporal and spatial distributions of igneous rock and inferred the distribution characteristics of concealed igneous rocks therein. Results show that the ophiolite and ultrabasic rock in the area were characterised by strong magnetism; while, basic, and intermediate rocks generally exhibited weak magnetic characteristics; acidic rock was characterised by medium-strong magnetism. In this area, the acidic rocks (Neogene and Jurassic), the intermediate rocks (Cretaceous and Jurassic), as well as the basic rocks (Cretaceous and Permian), showed weak magnetism. The acidic rocks (Palaeogene and Cretaceous), and the dolerite (Neogene and Jurassic) both presented stronger magnetism. The magnetism of the ultrabasic rocks and ophiolite (Jurassic) was strongest. The distribution characteristics of magnetic anomaly and igneous rock exposed revealed that there were two concealed ophiolite belts (Jurassic) in Gaize-Laiduoqangma and Songqin, respectively. Moreover, there were three groups of concealed ultrabasic rocks belts (Jurassic) in South Baiqing, Gaize, and Emule, and there were large areas of concealed acidic rocks in Duoba, Bangduo, North Cuoqin, Chachangle, west Nale, and west Kangqiongle.

Keywords: Igneous rock, magnetic features, magnetic anomaly, Gaize-Nima, Tibet plateau

INTRODUCTION

The Qinghai-Tibet Plateau is bordered to the North by the Altun Mountains and Qilian Mountain, to the south by the Himalayan range, to the west by the Karakorum Mountains, and to the east by the Hengduan Mountains. It covers an area of 2.6×10^6 km^2 with an average elevation of 4000 m above sea level. It is located in the Tarim basin, Gansu corridor, Sichuan basin, and the low plain of Indus river (the Ganges), and is known as "The roof of the world". As a part of the Qinghai-Tibet plateau, the magnetic characteristics, and the temporal and spatial development of igneous rock in the Gaize-Nima area are shown to be closely related to the tectonic movement of the Qinghai-Tibet Plateau. Existing studies have achieved many favourable results by investigating this area using geological information [1, 2, 3, 4], and performing inversion and explanation of the physical properties of crustal structures in this area, based on geophysical materials [5, 6, 7]. Furthermore, previous research has conducted analysis of the geochemical characteristics of ophiolite, the temporal and spatial distribution of granite [8, 9, 10], and also explored the relationship between tectonics and igneous rock in this area [11, 12]. It is known that aeromagnetic data play an essential role in research into the temporal and spatial distribution behaviour of igneous rock. Existing studies mainly adopted data from the aeromagnetic survey of the midwest Qinghai-Tibet plateau at a scale of 1:1,000,000 collected by China's Aero Geophysical Survey and Remote Sensing Centre for Land and Resources, Beijing, China from September, 1998 to April, 1999. The complex magnetic anomaly characteristics of the midwest Qinghai-Tibet plateau are attributed to

* To whom all correspondence should be sent:
E-mail: chunguan-zhang@163.com

the complex fault tectonics in this area [13, 14, 15, 16, 17]. Based on the aforementioned aeromagnetic data, Yao et al. [18] analysed the relationship between aeromagnetic anomalies and the presence of ophiolite. Xiong et al. [19] also explored the distribution of igneous rock in the Midwest Qinghai-Tibet plateau.

To discuss the magnetic characteristics of igneous rock in Gaize-Nima, this research collected the ΔT anomaly data based on the aeromagnetic survey at a scale of 1:200,000 undertaken by the Airborne Survey and Remote Sensing Centre for the Nuclear Industry in response to the consignation of China's National Petroleum Committee from 1994 to 1995. This research analysed the characteristics of the aeromagnetic anomalies, LMA and RMA, by separation of the magnetic anomaly data. Besides, it researched the relationship between the igneous rock exposed on the surface, and magnetic anomaly, so as to reveal the magnetic characteristics and the temporal and spatial development of igneous rock.

Geological setting

The Gaize-Nima area is located between 82º to 90º E and 31º to 33º N and covers an area of 175,000 km^2. The research areas included: the Gangdise block, the Bangongcuo-Nujiang suture zone, and the Qiangtang block [20, 21].

Based on the geological map of the Qinghai-Tibet plateau, and adjacent areas, published by Chengdu Institute of Geology and Mineral Resources, China in July, 2004, the authors drew a geological map of the Gaize-Nima area (see Fig. 1). The igneous rock exposed on the surface in this area revealed that acidic rock is widely distributed in the Gangdise block, and sparsely distributed across the Qiangtang block and Bangongcuo-Nujiang suture zone. Intermediate rock is primarily distributed in the Gangdise block, and sparsely distributed in the Qiangtang block around Baiqing, there is no intermediate rock found in the Bangongcuo-Nujiang suture zone; basic rocks are dispersed across Nale-Chalicuo and Yanhu in the Gangdise block, Gaize in the Bangongcuo-Nujiang suture zone, and the surrounding areas of Yagencuo, Baiqing in the Qiangtang block, and in areas near Changshanliang; while ultrabasic rocks are mainly distributed in South Gaize in the Gangdise block and Emule belt; it shows small areas of distribution in south Baiqing in Qiangtang block and no distribution in the Bangongcuo-Nujiang suture zone; ophiolite was found to be mainly distributed in Gaize-Laiduoqiangma and Songqin of the Bangongcuo-Nujiang suture zone, and present but not distributed in the Gangdise block and Qiangtang block. Acidic rocks consisted of: Neogene granite, Paleogene adamellite, Cretaceous adamellite, Cretaceous granodiorite, Cretaceous granite, Cretaceous granite-porphyry, Cretaceous granodiorite porphyry, Jurassic granite; while intermediate rocks included: Cretaceous diorite-porphyrite, Cretaceous quartz diorite, Cretaceous monzodiorite, Jurassic quartz diorite, and Jurassic diorite; basic rocks consisted of: Neogene dolerite, Cretaceous gabbro, Jurassic dolerite, and Permian gabbro. Ultrabasic rocks and ophiolite were Jurassic.

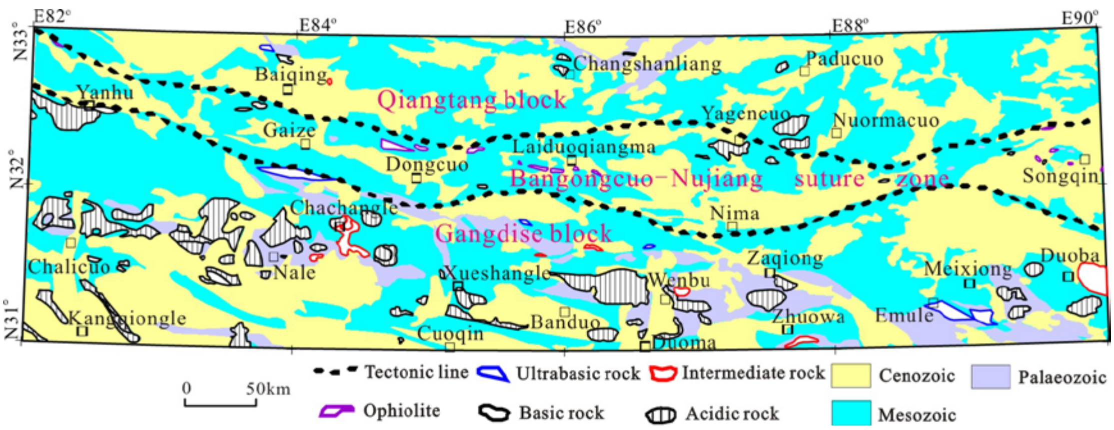

Fig. 1. Geologic sketch map of Gaize-Nima Area in Qinghai-Tibet plateau (modified after Geng et al., 2011 [21]).

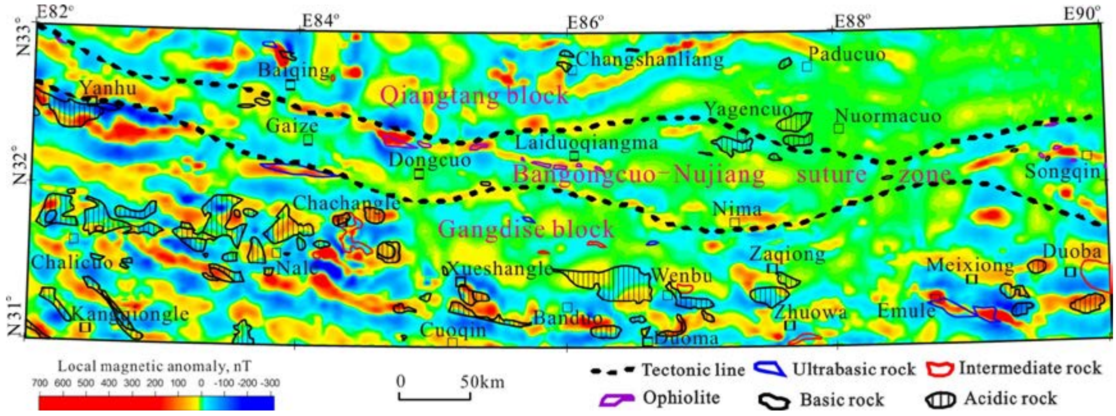

Fig. 2. Local magnetic anomaly map of Gaize-Nima Area in Qinghai-Tibet plateau.

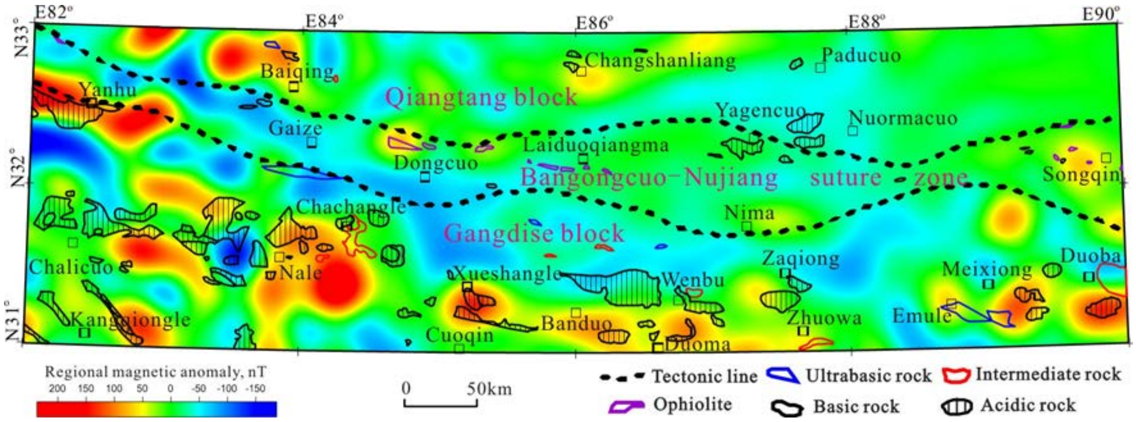

Fig. 3. Regional magnetic anomaly map of Gaize-Nima Area in Qinghai-Tibet plateau.

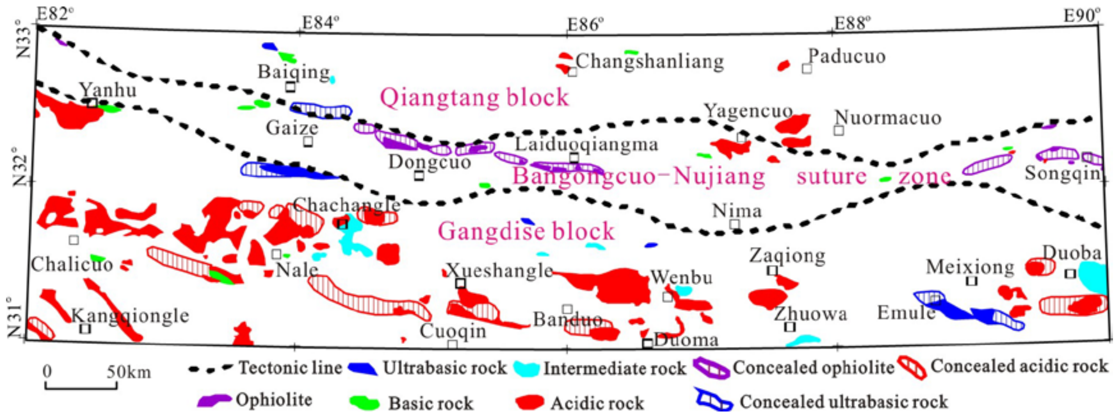

Fig. 4. The distribution map of igneous rocks of Gaize-Nima Area in Qinghai-Tibet plateau.

CHARACTERISTICS OF THE MAGNETIC FIELD

The magnetic inclination technique for the reduction to the Pole of magnetic anomalies was used to conduct the reduction to the pole of ΔT data and obtain aeromagnetic anomaly values. The time for calculating geomagnetic inclination and geomagnetism declination is 1995.00a. The mean height (4900 m) of this area was taken as the topographic height. The longitude to be calculated used the latitude of 86° for the central meridian of this area; the latitude interval for the reduction to the pole was 0.5°. LMA is able to reflect, primarily, the effects of magnetic field induced by the local geological body; while RMA can present the effects of magnetic force and magnetic field resulting from large scale geological bodies. In this study, the mature filter regularization technique [22] was used to separate the aeromagnetic anomaly to obtain LMA and RMA. By processing the results obtained by repeated analysis and comparison through varying filter windows, the filter window for 40 km, which was in agreement with that of the ophiolite and ultrabasic rocks in this area, was chosen as the basic reference Figures for LMA and RMA.

As shown in the LMA (Fig. 2), LMA presented apparent zonation characteristics. Similar to the aeromagnetic anomaly, the LMA in the Qiangtang block was distributed into east and west blocks: the LMA in the former was moderate; while the that in the latter was well-developed. The high LMA in the Bangongcuo-Nujiang suture zone showed a zonal distribution, in particular it indicated a tenuous distribution in the Songqin and Laiduoqiangma; the LMA in the Gangdise block was high and developed in large areas in the Chalicuo-Cuoqin-Zhuowa-Duoba area. The LMA in the Qiangtang block did not agree well with the distribution trend of the aeromagnetic anomaly: the high LMA in the zone adjacent to the north boundary of the Bangongcuo-Nujiang suture zone was generally distributed in agreement with the fault, and this showed that it was influenced by the fault. The high LMA in the Qiangtang block in East Baiqing was shown to be distributed in a South-North trend. The LMA in the Changshanliang-Paducuo zone presented a strip distribution owing to the effect of the magnetic materials in the formation. In addition, much the same as the characteristics of the aeromagnetic anomaly, the high LMA distribution in the Bangongcuo-Nujiang suture zone was subject to the faulting on its south and north boundaries. The LMA in the Gangdise block is shown in the east, middle, and west zones respectively. Its distribution in the west zone, involving Chalicuo-Nale-Duoma, generally showed a NWW tendency; while the Zaqiong-Emule area exhibited a North-West trend. This phenomenon differed from that of the LMA in the east and west sides. Besides, East Duoba showed an East-West tendency.

As shown in the RMA (Fig. 3), the zonal distribution in a North-South trend was obvious. The areas in the Qiangtang block (Baiqing and Changshanliang) showed a high RMA; while that in the Baiqing-Changshanliang, and Nuormacuo, zones was low; the RMA in the Bangongcuo-Nujiang suture zone was low from a macro-perspective; however Dongcuo, Nima, and Songqin showed a high RMA; in the Gangdise block, the RMA was shown in northern and southern areas: the high RMA in the former zones were shown in Chalicuo-Nale-Duoma-Duoba; while the low RMA in the northern zone was distributed in Chachangle-Dangqiong-Nouth Xiongmei.

Distribution and magnetic features of igneous rocks

In this research area, the relationship between the igneous rock exposed on the surface and the magnetic anomaly is shown in Fig. 2 and Fig. 3. As shown in Fig. 2, regardless of the influence of RMA, the Jurassic ophiolite in the Bangongcuo-Nujiang suture zone, and the Jurassic ultrabasic rocks in the Gangdise block showed better correlation with the aeromagnetic anomaly compared with LMA. The igneous rocks exposed on the surface in many other zones agreed well with LMA, such as; the Cretaceous adamellite and Paleogene adamellite in the Duoba, the Cretaceous adamellite in Xueshangle, the Paleogene adamellite in Duoma, the Cretaceous granodiorite in Chachangle, the Cretaceous granodiorite and Neogene granite and Neogene dolerite in Nale, and the Jurassic quartz diorite in Wenbu. The igneous rocks exposed on the surface in some areas were uncorrelated with the trend in LMA, these included: the Cretaceous adamellite, Cretaceous granodiorite, and Cretaceous granite porphyry in the Kangqiongle, and the Jurassic granite in Changshanliang. As seen in Fig. 3, the igneous rocks exposed on the surface were usually found in the belt zones with high RMA, and were even exposed in large areas such as: the Yanhu, Chalicuo-Duoma, Emule-Duoba, Baiqing, Changshanliang, Songqin, and Dongcuo. Only in south Xiongmei, were the igneous rocks with high RMA not exposed on the surface, which suggested that the RMA in the area was influenced by magmatic activity.

There were 102 zones with exposed igneous rocks in the research area, among which, acidic rock occurred in 62 zones, intermediate rock in nine zones, basic rock in 12 zones, ultrabasic rocks in six zones, and ophiolite in 13 zones. The corresponding relationship between the igneous rock and magnetic anomaly suggested that: the Jurassic ophiolite and Jurassic ultrabasic rocks were both distributed in zones with high LMA, and coincided well therewith. This indicated that the ophiolite and ultrabasic rocks in the area showed stronger magnetism. Among the 12 zones with basic rock, five zones were found to be in locations with a high LMA; while there were only two zones showing good coincidence with high LMA, which revealed that the overall magnetism of the basic rock was relatively weak; for the nine zones with intermediate rock, there were two zones found in locations with high LMA, and only one zone indicating good correlation therewith. This phenomenon showed that the intermediate rock exhibited weak magnetism; in the 62 zones with acidic rock, there were 23 zones in places with a high LMA, and 18 zones coinciding well with a high LMA. These results indicated that the acidic rock had, in general, strong magnetism. In temporal sequence, the magnetism in the acidic rocks of the

Neogene and Jurassic was weak, while the acidic rocks of the Paleogene and Cretaceous were slightly stronger; the intermediate rocks of the Cretaceous and Jurassic both showed weak magnetism; the dolerite of the Neogene and Jurassic had strong magnetism; the magnetism of the gabbro from the Cretaceous and Permian was weak. The ultrabasic rocks, and ophiolite showed strong magnetic characteristics.

On the basis of the corresponding relationship of the igneous rock exposed on the surface in this area and the magnetic anomaly, this research speculated that the concealed igneous rocks and results were as shown in Fig. 4: the concealed Jurassic ophiolite belt (7 km wide and 177 km long) was discovered in the Gaize-Laiduoqiangma zone; while the concealed Jurassic ophiolite belt (8 km wide and 100 km long) was found in Songqin; in south Baiqing, the concealed Jurassic ultrabasic rocks (8 km wide and 42 km long) were discovered; moreover, the concealed Jurassic ultrabasic rocks (8 km wide and 66 km long), and the Jurassic ultrabasic rock belt (10 km wide and 82 km longt) were found in south Gaize and Emule respectively. In addition, the concealed acidic rocks which were developed in different areas were discovered in areas such as: Duoba, Bangduo, North Cuoqin, Chachangle, West Nale, and West Kangqiongle.

CONCLUSIONS

(1) In the research area, ophiolite and ultrabasic rocks were characterised by strong magnetism; while basic, and intermediate, rocks were generally shown to have weak magnetism. Acidic rock primarily showed medium-strong magnetism.

(2) The rocks developed in this area involved acidic rocks from the Neogene and Jurassic, the intermediate rock was Cretaceous and Jurassic, the basic rock of the Cretaceous and Permian presented weak magnetism; while the acidic rocks of the Paleogene and Cretaceous, and the dolerite of the Neogene and Jurassic, both showed stronger magnetism. Among them, the ultrabasic rocks and ophiolite of the Jurassic indicated the highest magnetism.

(3) In this area, there were two concealed Jurassic ophiolite belt zones: Gaize-Laiduoqiangma and Songqin; meanwhile, there were three groups of concealed belt zones of Jurassic ultrabasic rocks in South Baiqing, South Gaize, and Emule. Moreover, large areas of acidic rocks were found in other areas including: Duoba, Bangduo, North Cuoqin, Chachangle, West Nale, and West Kangqiongle.

Acknowledgements: *This work is supported by Natural Science Basic Research Plan in Shaanxi Province of China (Program No. 2017JM4007). We are also grateful for the valuable comments of referees for improving the original manuscript.*

REFERENCES

1. J. Yu, H. Lei, Q.Wang, C. Liu, *Xinjiang Petroleum Geology*, **24**, 509 (2003).
2. G.Pan, X.Mo, Z. Hou, D. Zhu, L. Wang, G. Li, Z. Zhao, Q. Geng, Z. Liao, *Acta Petrologica Sinica*, **22**, 521 (2006).
3. S. Cao, X. Luo, F. Tang, L. Chen, *Geology in China*, **31**, 51 (2004).
4. Z. Wu, P. Ye, C. Yin, *Geoscientica Sinica*, **34**, 31 (2013).
5. Z. Zhang, D. Liu, Q. Fan, Y. Duan, *Plateau Earthquake Research*, 20, 54 (2008).
6. S. Jin, W. Wei, G. Ye, M. Deng, H. Tang, U. Martyn, *Chinese Journal of Geophysics*, **52**, 2666 (2009).
7. Q. Zhong, H. Fang, C. Liu, X. Li, J. Lu, B. Gao, *Geological Bulletin of China*, 29, 870 (2010).
8. X. Mo, G. Dong, Z. Zhao, S. Zhou, L. Wang, R. Qiu, F. Zhang, *Geological Journal of China Universities*, **11**, 281 (2005).
9. B. Wang, J. Xu, Q. Zeng, Z. Kang, J. Chen, Y. Dong, *Acta Petrologica Sinica*, 23, 1521 (2007).
10. S. Fan, R. Shi, L. Ding, D. Liu, Q. Huang, H. Wang, *Acta Petrologica et Mineralogica*, **29**, 467 (2010).
11. Y. Jiang, T. Xu, Y. Zhao, *Journal of Geomechanics*, **15**, 336 (2009).
12. S. Cao, Z. Wang, F. Luo, J. Huang, W. Xiong, *Acta Geologica Sinica*, 88, 2018 (2014).
13. M. Jiang, H. Wang, *Geological Science and Technology Information*, **20**, 95 (2001).
14. F. Zhou, Z. Yao, Z. Liu, Y. Zhang, *Geophysical & Geochemical Exploration*, **26**, 12 (2002).
15. D. Xue, M. Jiang, L. Wu, Q. Li, X. Wang, *Geology in China*, **33**, 912 (2006).
16. R. He, R. Gao, H. Zheng, J. Zhang, *Chinese Journal of Geophysics*, **50**, 1131 (2007).
17. S. Xiong, Y. Ding, Z. Li, *Geological Review*, **58**, 201 (2012).
18. Z. Yao, F. Zhou, D. Xue, Z. Liu, Y. Zhang, *Geophysical & Geochemical Exploration*, **26**, 165 (2002).
19. S. Xiong, F. Zhou, Z. Yao, D. Xue, *Geophysical & Geochemical Exploration*, 31, 404 (2007).
20. J. Lu, M. He, H. Fang, Y. Ye, Q. Zhong, B. Gao, *Geophysical & Geochemical Exploration*, **34**, 787 (2010).
21. Q. Geng, G. Fan, L. Wang, Z. Peng, Z. Zhang, *Geological Bulletin of China*, **30**, 1261 (2011).
22. Y. An, Z. Guan, Computing Techniques for *Geophysical and Geochemical Exploration*, 7, 13 (1985).