Retraction Notice

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Characteristics and Geological Significance of Aeromagnetic Data in the South of Shanxi

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Abstract

The study area is located in the south margin of the North China Block, the south end of the juncture between the Ordos Block and the Hehuai Block, which is part of Fen-Wei Graben System and located in the south of Shanxi Cenozoic fault basin in the central part of the North China Craton. The study area has complex regional geological structure, intense tectonic movement and frequent magmatic activities. Based on the latest high-precision aeromagnetic data, integrated interpretation was completed, combining with the existing geological and geophysical research results. According to the block features in different zones of the RTP aeromagnetic data, this article thoroughly studied the characteristics of aeromagnetic anomalies and found the relationship between aeromagnetic anomalies and surface geological information, and the fault distribution, magmatic rock distribution and magnetic characteristics in this area are discussed.

Keywords

High-Precision Aeromagnetic Data, Magnetic Field Characteristics, Fault Structure Features, the South of Shanxi, Lithologic Characteristics

1. Introduction

The aeromagnetic survey in the study area started in 1960s, and has successively carried out 1:25,000 - 1:200,000 aeromagnetic survey in 15 blocks from 2000, most of which are metal aeromagnetic, and the whole area has carried out 1:1,000,000 structural aeromagnetic survey. In the 1980s, 1:25,000 - 1:200,000 aeromagnetic survey data were used for verification, mapping and card building of 1:500,000 aeromagnetic survey system. More than 100 aeromagnetic anomalies were delineated near Zhongtiao Mountain, and most of them were verified

in varying degrees. Over the years, many scholars have done a lot of scientific research in this area, and have made great achievements in the aspects of deposit geology, genesis, metallogenic background and exploration (Hu & Sun, 1987; Wu, 1992; Zhen, Du, Liu, & Wang, 1993; Sun, Ji, & Zhen, 1995; Wei & Wang, 1996; Jiang, Wang, & Zhang, 1997; Shen, Hu, Yang, & Cao, 2004; Xing, Zhao, Tu, & Xing, 2005; Shen, Zhai, Miao, Sima, & Li, 2006; Xue, Deng, Shang, & Cao, 2006; Chen, 2006; Xia, 2008; Liu, 2008; Zhao, Wang, Chen, & Chen, 2009; Zhen, 2012; Feng, Wang, Li, Zhao, & Zhao, 2015).

Compared with other geophysical measure, Aeromagnetic survey, as one of the important geophysical measures to perspective the geological deep structure information, not only covers well-distributed, but also is subjected to the minimum interference from the surface topography and has a strong penetration ability (Okuma, Stotter, Supper, Nakatsuka, Furukawa, & Motschka, 2009; Crawford, Betts, & Laurent, 2010; Tzanis, Kranis, & Chailas, 2010; Xiong, Yang, Ding, & Li, 2018). These characteristics make it possible to study the geological structure by using the regional aeromagnetic data. Although aeromagnetic survey provides an important reference for geotectonic division, basic geological research and Mineral Investigation in the study area, due to the limitations of technical conditions at that time, the sensitivity of aeromagnetic instruments is low, the accuracy of navigation and positioning (aerial photos, topographic maps visual navigation) is low, and the total accuracy of magnetic survey is low, which makes the local abnormal displacement of aeromagnetic larger and the distance between survey lines inaccurate, Partial aeromagnetic local abnormal response is not obvious.

In this paper, the latest 1:50,000 high-precision aeromagnetic survey data are used to find out the distribution characteristics of aeromagnetic anomalies in the study area and geological background of mineralization, so as to provide high-quality aero geophysical data and interpretation results for the investigation and evaluation of mineral resources.

2. Regional Geological Outline

The study area is located in the south margin of the North China Block, the south end of the juncture between the Ordos Block and the Hehuai Block, which is part of Fen-Wei Graben System (Ma & Su, 1985; Xing, Ye, Sun, Wu, Cheng, Li, & Song, 1991; Bai & Dai, 1994; Deng, Wu, Zhao, Zhao, & Mo, 1999; Zhao, 2009). From the perspective of structural trace, stratigraphic distribution and current topography, it is a half graben-like fault basin opening to the southwest. It is adjacent to Weihe basin across the Yellow River. It has experienced multiple geological tectonic activities and has complex regional geological structure, intense tectonic movement and frequent magmatic activities.

The strata are characterized by deep metamorphic rock series (migmatization) in the middle Archean and shallow metamorphic rock series in the Wutai system of Neoproterozoic-Ancient Proterozoic Hutuo system in the new Archean, which together form a crystalline basement. The Paleoproterozoic and Mesoproterozoic

Changcheng series are slightly metamorphic rocks. In the sedimentary caprock, Cambrian-Ordovician system is carbonate formation, the upper Carboniferous-lower Permian is coal measures, the upper Permian-Triassic-Jurassic-Cretaceous is continental sandstone and mudstone deposits, Cenozoic strata constitute rift basin (Feng et al., 2015).

From the view of fault distribution, the study area is a Cenozoic fault basin obviously controlled by marginal shovel fault, such as Zhongtiao Mountain fault in the southeast and Luliang Mountain fault in the Northwest. Therefore, the descending plates of these marginal fault zones often form graben-like depressions with different shapes. And there are fault systems with NEE, NE and NNE directions as the main direction and NW, EW directions as the auxiliary direction, which fault the graben basin into several substructural units with different shapes. Lishi fault and Zhongtiao Mountain fault jointly control the whole structural framework.

The magmatic activities in the study area are relatively frequent, especially in Zhongtiao Mountain area. The rocks are relatively complex. There are different types of magmatic rocks from middle late Archean, Proterozoic, Late Paleozoic, Mesozoic to Cenozoic, among which the magmatic activities in late Archean (Wutai Period), early Proterozoic (Luliang Period) and Mesozoic (Yanshan Period) are the most intense. The genesis of magmatic rocks can be divided into three types: crust derived remelting type, transitional crust syntectonic type and mantle derived type.

3. Regional Aeromagnetic Characteristics

Throughout the 1:50,000 aeromagnetic anomaly map of the study area, the magnetic field is characterized by rich information, clear appearance, obvious characteristics and strong regularity, showing a number of different magnetic field background and the division of the magnetic anomaly. Aeromagnetic anomaly has the characteristics of block, variable shape and great difference in intensity, which is obviously superior to the previous aeromagnetic exploration effect. It provides rich information for the basic geological research such as regional lithologic structural geological mapping and the exploration of polymetallic minerals Compared with the characteristics of the adjacent magnetic field, the overall magnetic field in the studying area is strong and peculiar.

Because the study area is located in the middle latitude, the high value of magnetic anomaly after the RTP moves northward. It is generally low in the southeast and high in the northwest, and the direction of abnormal extension is NEE-NNE. Taking Yongji-Yuncheng-Jiangxian-Yicheng-Fushan as the boundary, the magnetic anomalies on both sides are obviously different. In addition, the magnetic anomalies on both sides are obviously different from the north of Jishan to the west of Xiangfen. The change of magnetic field in the east of the study area is more complex. The characteristics of magnetic high anomaly belt in the background of low magnetic anomaly are mainly reflected by the Proterozoic

middle ancient rift (Ma et al., 1985). Yongji-Yuncheng-Xiaxian-Jiangxian is a narrow positive anomaly belt, which is consistent with Zhongtiao Mountain fault. The gentle negative magnetic anomaly from Ruicheng to Pinglu is the reflection of Cenozoic sedimentary strata. From the east of Pinglu to the east of Jiangxian, the negative magnetic anomaly is the main feature. There is a NE direction low gentle positive magnetic anomaly belt on the background of negative magnetic anomaly. The background field is divided into positive and negative inter phase and parallel arrangement of anomaly bands. The area from Qinshui to Yangcheng is a quiet negative magnetic anomaly with the lowest anomaly intensity in the study area. It is speculated that the area is a very thick sedimentary cover, which has not been greatly reformed in the long-term structural evolution process. The central part of the study area shows a large range of high magnetic anomalies, which roughly reflects the distribution range of Precambrian crystalline basement. The exposure of Archean biotite plagioclase gneiss in some areas from Linyi to Wenxi provides a strong evidence point. The area Yuncheng-Xiaxian-Jishan-Houma is gentle negative magnetic anomalies, which reflect the thick Cenozoic sediments in this area. The characteristics of magnetic anomaly in the west of the study area are gentle and moderate, low in the northwest and high in the southeast, reflecting the characteristics of structural basin margin. Therefore, based on the analysis of the magnetic characteristics of the strata, Zhongtiao Mountain is not a magnetic basement. The local positive magnetic anomaly belt is mainly the reflection of (super basic) complex or other magnetic intrusive rocks. The high magnetic anomaly in the middle of the study area is caused by the Archean crystalline basement.

Compared with the regional gravity anomaly, the magnetic anomaly in Hejin-Jishan-Wanrong-Linyi area is of high value, while the gravity anomaly in this area is of low value, which indicates that the basement in this area is subsidence and the magnetic body is invading at the same time. The regional magnetic anomaly is low from Pinglu to Yuanqu, and the regional gravity anomaly is high in a large range, which indicates that the basement is nonmagnetic. The regional magnetic anomaly and regional gravity anomaly are low in Yongji-Yuncheng-Wenxi-Xinjiang, which indicates that the basement is deep and the nonmagnetic body intrudes.

According to the block characteristics, gradient change and the shape, trend, anomaly combination and distribution of magnetic anomalies in different zones of the RTP aeromagnetic data, combined with the gravity and geological background, taking the deep faults confirmed by geology or the gradient zones, variation zones and linear anomaly zones reflected by gravity and magnetism as the boundary, three magnetic fields are divided successively from the northwest to the southeast (**Figure 1**), namely Gentle reduction of magnetic field of Yonghe-Xiangning (I), Wide and slow fluctuation increases magnetic field of Linyi-Xiangfen (II) and Fluctuating magnetic field of Ruicheng-Yuanqu-Qinshui (III), which correspond to different geotectonic units. According to the micro changes of aeromagnetic anomalies and regional geological data, each magnetic

Figure 1. Magnetic field of the study area based on aeromagnetic data (RTP).

field area is further divided into several sub areas with different magnetic characteristics.

4. Fault Structures Reflected by Aeromagnetic

The fault structures in the studying area are well developed, and the characteristics of the faults reflected by aeromagnetic are quite different, with various forms. On the basis of aeromagnetic data, this paper makes inferential interpretation of faults in the studying area by means of RTP, first order vertical derivative, upward continuation and other potential field conversion and processing, combined with gravity, geology and other data, through comprehensive analysis and research, 37 large-scale faults are inferred, including 5 regional large-deep faults (**Figure 2**).

In this paper, the overall fault structure is mainly distributed in NE and NW directions, forming an “X” type fault structural system. Among them, the NE fault has large scale and long extension, which is basically consistent with the regional stratigraphic trend, while the NW fault has small scale and limited extension. The NE faults have obvious control over magnetic field division, sedimentary formation, magmatism, metamorphism and mineral distribution; the NW faults have certain control over magmatism, mainly distributed in Zhongtiao Mountain uplift and the Cenozoic coverage area of Linfen-Yuncheng Basin; the rest faults have small scale and limited extension, and the spatial distribution is controlled by the former two.

height is 0.5 km, the aeromagnetic anomalies of Zhongtiao Mountain decrease rapidly (except for Yongji), negative magnetic anomalies appear in a large area, and the high magnetic anomalies in the northwest have no change. With the upward continuation height increasing to 5 km, most of the positive magnetic anomalies of Zhongtiao Mountain disappeared; after the upward continuation height reaching 10 km, only Xiangfen-Jishan-Hejin-Linyi area positive magnetic anomaly remained.

The Bouguer gravity anomaly shows that the Zhongtiao Mountain fault shows an obvious gravity gradient belt with an arc of NE-NNE direction as a whole, reflecting the characteristics of the East-West cracking of the Cenozoic Shanxi rift system. Along Yongji-Yuncheng-Jiangxian Yicheng-Fushan, there is an obvious large-scale gravity anomaly gradient belt, which is the reflection of Zhongtiao Mountain fault belt and plays an important role in controlling the change of the gravity field in the study area. Combined with the analysis of the magnetic characteristics of the strata, Zhongtiao Mountain is not a magnetic basement, and the local positive magnetic anomaly belt in this area is mainly the reflection of basic (super basic) complex or other magnetic intrusive rocks, and the regional high magnetic anomaly is caused by the Archean crystalline basement.

The gravity anomaly characteristics on both sides are obviously different. Combined with the analysis of regional density characteristics, the gravity low anomaly is mainly caused by the Cenozoic, the gravity high anomaly is mainly the reflection of Precambrian metamorphic strata, and the local anomaly may be the performance of magmatic rocks. The first vertical derivative (FVD) of gravity anomaly shows that the gravity value is higher in the East and lower in the west, and the gravity value decreases from -50 mgal to -140 mgal from the east to the West. The trace of the fault is very clear, which shows the characteristics of the NE-NNE gravity gradient belt. The isoline of the gravity gradient belt with larger gradient in the west of the fault is relatively close, while the isoline of the gradient belt with smaller gradient in the East is relatively loose, which accurately reflects the distribution of the main structure of Zhongtiao Mountain.

The fault we inferred is quite consistent with the Zhongtiao Mountain fault confirmed by the geology. The difference is that the Zhongtiao Mountain fault inferred based on the latest gravity and magnetic field characteristics extends northward to the vicinity of Mengshan Township, Pingyao, with a total length of about 360 km, passing through the south central area of Shanxi Province. In the study area, it extends to the east of Fushan, with a length of about 230 km. In the early study, it was believed that there was a Fushan fault between Jiangxian and Fushan County, which was formed in Mesozoic (Shanxi Bureau of Geology and Mineral Resources, 1989). According to the characteristics of gravity and magnetic anomalies, it is considered to be a part of Zhongtiao Mountain fault.

5. Lithologic Characteristics Reflected by Aeromagnetic

The study area is located in the south of Shanxi Province, at the intersection of different tectonic units. The metamorphic rocks are widely distributed, the li-

thology is complex, and the magnetic changes are large. According to the physical properties of rocks and ores, rocks of different types may have similar magnetic properties, while rocks of the same type may have large magnetic differences, reflecting complex and diverse magnetic anomaly characteristics in the magnetic field. The detailed and reliable delineation of metamorphic rocks and magmatic rocks is of great significance to the study of the tectonic magmatic activity and metallogenic geological conditions in this area, the summary of metallogenic laws and the prediction of minerals related to metamorphic rocks and magmatic activities.

Through comprehensive comparative analysis, the positive and negative magnetic fields and various magnetic anomalies in the area have certain corresponding relations with known geological bodies.

In the study area, the tectonic magmatic activities are frequent and intense, and the intrusive rock stages are complex; especially in the Zhongtiao Mountain area, the magmatic activities are many, the types of magmatic rocks are complex, and the lithology is variable, and they are distributed from acid neutral basic ultrabasic, most of them are in the form of batholith, dikes, stocks or dikes, and the large-scale bimodal intrusive magmatic activities and the geothermal column activities are strong Period related. The magnetic anomalies of intrusive rocks are generally positive anomalies of rising height. Due to different types of rocks, the amplitude can be from tens of nates to hundreds of nates. On the magnetic field map, most of the anomalies are circular and elliptical, and a few of them are banded, banded or even irregular (**Figure 3**). Except for a few ultrabasic intrusive rocks, on the aeromagnetic profile, the anomaly generally presents a relatively gentle peak shape, and the curve is generally relatively smooth, wide and slow.

The volcanic rocks in the area are andesite of Xiyanghe group in Zhongtiao Mountain, which are composed of andesite lava, andesite agglomerate, andesite agglomerate, andesite breccia and andesite tuff. Volcanic rock anomalies generally have very obvious characteristics on aeromagnetic profile, which are often manifested as multi peak jumping disorderly change anomalies with different strength or amplitude, mostly distributed in pieces, or in narrow strip distribution: due to the generally low magnetic properties of intermediate acid volcanic rocks, the local aeromagnetic anomalies caused by them are mostly jumping weak peak like anomalies, distributed in pieces, and single anomaly The intensity is low, the curve is generally low and gentle, with a certain degree of symmetry, and the north side is often not accompanied by a negative value. Basic volcanic rocks, especially basalts, are characterized by strong magnetic field, which is generally reflected as a series of peak shaped strong magnetic anomalies, sharp and steep curves, often accompanied by negative values on the north side, sometimes with typical serrated, and the two wings of a single anomaly are mostly symmetrical, mostly in strips along the fault structure, with obvious trend on the whole (**Figure 4**).

Figure 3. Characteristics of intermediate acid intrusive rocks reflected by aeromagnetic and geology. (a) aeromagnetic profile; (b) aeromagnetic anomaly; (c) geological map.

Figure 4. Characteristics of intermediate basic volcanic rocks reflected by aeromagnetic, geology and geochemistry. (a) aeromagnetic profile; (b) aeromagnetic anomaly; (c) the RTP aeromagnetic anomaly; (d) the first vertical derivative of aeromagnetic anomaly, e-geological map, f-geochemical anomaly.

The metamorphic rocks are divided into Wushui group, Jiangxian group, Lvliang Mountain Group and Zanhuan group. The distribution of all kinds of metamorphic rocks is controlled by faults. Metamorphic rocks are reflected in varying degrees in the magnetic field, showing large areas of low and gentle anomalies; according to the results of aeromagnetic inference, the iron ore bodies developed in the area are generally banded, elliptical or even circular, with obvious characteristics in the magnetic field, generally showing strong peak like anomalies.

6. Conclusion

Through the acquisition and interpretation of large-scale and high-precision aeromagnetic data, this paper systematically summarizes and reflects the progress, knowledge and achievements of 1:50,000 aeromagnetic survey in magmatic rock delineation, fault structure division and aeromagnetic prospecting in the south of Shanxi Province. It provides a clue for aeromagnetic prospecting, a scientific basis for the study of tectonic movement and magmatic rock activity, and further improves the level of geological and geophysical research in this area.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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