The application of ground high-precision magnetic survey to the geology and mineral investigation in Huanghe Town area

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Abstract. Three projects have been done to investigate the geology and mineral distribution in Huanghe town area A’nyemaqen-Bayanhar orogen, during the year 2013–2017. Ground high-precision magnetic method on a scale of 1:50000 has been used to study the magnetic character of the geological body and rocks. Correction has been taken in order to normalize magnetic anomaly calculated by different zero points. With the understanding of magnetic character, the distribution of stratum and geological structure can be known. After four years’ job, 16 faults have been recognized and an acid-intermediate intrusive lithosome has been found.

1. Introduction
Located in the south of East Kunlun Fault, the Indosinian folds inside the A’nyemaqen-Bayanhar orogen is one of important metallogenic area of Au and Sb. Several Au, Sb deposit have been found, such as Dachang deposit and Jiageilongawa deposit, and it has great potential to find more. Having a full understanding of geological structure and deposit in this area has great significance to natural resource survey in our country and to protect the Yellow River, as Huanghe town in Maduo country Qinghai province is the area where source region of Yellow River located. Wet land and grassland cover most of this area, and near surface engineering explorations are not allowed. Without any pollution, the ground high-precision magnetic method is one of the most environment-friendly and effective methods to study the distribution of stratum, geological structure and igneous rock in this area.

2. Geology summary
Many vertical fractures are developed in coal seam, and the fracture density is relatively high. The coal seam with vertical fractures is regarded as HTI coal seam. Hudson proposed that cracks be regarded as closed and parallel coins [4]. Assuming that there is no fluid flow between cracks and the density and aspect ratio of cracks are small, HTI equivalent medium model is established. Its elastic coefficient matrix C is expressed as:

\begin{equation}
\begin{bmatrix}
C_{11} & C_{12} & C_{13} \\
C_{12} & C_{22} & C_{23} \\
C_{13} & C_{23} & C_{33}
\end{bmatrix}
\end{equation}

According to the study before, the area we talk about in this paper is Bayanhar marginal foreland in Kunlun-Changmahe subduction accretionary prisms of Hol Xil-Songpan-Ganzi remnant oceanic basin in northwest Yangtze Block. It belongs to the north Bayanhar-Jiageilongwa-Changmahe Indosinian-Yanshanian metallogenic belt, north Tibet Tethys metallogenic province [1–3].

Sedimentary stratum is widely developed in this area. The oldest is Maqu group sedimentary of Middle Permian, then the Changmahe group and the Gande group of Middle Triassic, then the Quguo group of Neogene, and the youngest is the Quaternary stratum. Changmahe group and the stratum beneath built up Wuhema-Niele anticline and Galaci syncline in the middle of Xiajangjie-Cebudi area.
Gande group is in the middle and southwest part of this area and extending out from east, west and south direction. There is a fault between Changmahe group and Gande. Quguo group fragmentally developed in south Huanghe town. Quatemary stratum developed along rivers in this area.

Large scale overthrust brittle faults in NWW direction are typical geological structure in this area. Faults in NE-NEE and NW direction are younger, twisting and cutting off faults in NWW direction normally. Kunlun-Gande Fault went across this area from Youerqu to Daxixiuxia and it is 27km in length dividing Kunlun Kunlun-Changmahe subduction accretionary prisms and Bayanhar marginal foreland. Originating from Maqin country, Lamajiahuo Fault went across Hekesi then extending out of this area in SE direction. Qiamuqia Fault laid in the northeast of Qiamuqia extending out from NW direction, 41km in length. It is a reversed fault with a breaking section facing NE, dividing stratum Changmahe group and Gande group. Jiangrigama Fault is also dividing stratum Changmahe group and Gande group and 34km in length.

Igneous rock mostly developed in Xiacangjie area. Wuhema porphyaceous biotite granite located in the east of Changmahe town. It is equiaxed in shape and 65km² in size on the ground intruding Wuhema-Niele anticline and stratum Gande group. Nanmuta porphyry-like granite located in Nanmuta, 56km² in size on the ground, intruding stratum Changmahe group, but only 1.7km² of it extending in our area. Xiacangjie porphyritic monzonitic granite is oval stock intruding stratum Changmahe group, 4.65km² in size. Magmatic rock is rare in Youyun and Huanghexiang area, only one acid-intermediate intrusive stock was found in the south of Jiangrigama area, dominated by geological structure.

![Figure 1. Geological outline.](image)

3. Geophysics summary
According to Bouguer gravity map on a scale of 1:1000000, the regional gravity contour lines spread out in NW direction. The value falls down from NE direction to SW direction. The highest value located in Dongchenggongma area and the lowest value show in the northeast corner of Maqin country. The gravity value in our area is low and slow. The aeromagnetic map on a scale of 1:1000000 shows that Bayanhar basin mostly located between East Kunlun Fault and Hol Xil Fault, in mountain area the magnetic value is high, out of mountain area the value is low and slow. So, the magnetic value in our area is negative and slow. There are also zero-value lines of aeromagnetic ΔT map crossing Xiacangjie area in the NW direction.

4. Ground high-precision magnetic survey
According to the geological background and design files of regional geology and mineral investigation, prospecting lines were set in 45° direction, prospecting network is 500m×100m. Ground high-precision magnetic survey on a scale of 1:10000 has been done after magnetic survey on a scale of 1:50000 in order to carefully examine the magnetic anomaly found before. The direction and length of prospecting line on a scale of 10000 depends on the shape and the character of the magnetic anomaly, but the least distance between prospecting point is 20m. Magnetic susceptibility and remnant intensity
of magnetization of rocks have been measured by Gauss Second Position method. Following the criterion of ground high-precision magnetic survey (DZ/T0071—1993), GPS for navigation in these projects have been carefully adjusted. And the GSM-19T magnetometers have also been carefully tested in order to find out appropriate parameter to make it sure that magnetic survey is accurate. After four years job, ground high-precision magnetic survey on a scale of 1:50000 covered about 4736km\(^2\) area, 68.8km magnetic profile survey have been done and the magnetic susceptibility and the remnant intensity of magnetization of 1260 block of rocks have been measured.

5. Magnetic data correction

Three projects have been done in different year. Because the ground high-precision magnetic survey in these three projects is separated and independent, three zero point have been set. As the magnetic anomaly \(\Delta T\) in ground high-precision magnetic survey is relative value to zero point, different zero-point lead to different anomaly. In order to get a normalized magnetic anomaly map in our area, correction should be done.

The magnetic anomaly \(\Delta T\) is usually calculated by a formula listed as follows:

\[
\Delta T_i = T_{i}^{dc} - \Delta T_i^{nor} - \Delta T_i^{h} - T_0
\]  

(1)

Index ‘dc’ represents the diurnal correction, index ‘nor’ represents the normal gradient correction, index ‘h’ represents altitude correction, while index ‘0’ represents zero point.

Normally, the value of magnetic anomaly calculated by different zero points can be normalized by subtracting the deviations between different zero points. But the deviation between different zero point should be carried out by taking diurnal observation in the same time, rather than subtracting their magnetic field value directly. In our projects diurnal observation of different zero points had not been taken, so we should use another way to find out the deviation between them.

Now, transform formula (1) into another form. The index ‘1’ and ‘2’ represent that the value is calculated by two different zero points.

\[
\Delta T_1 = T_1^{dc} - \Delta T_1^{nor} - \Delta T_1^{h} - T_{01}
\]

(2)

\[
\Delta T_2 = T_2^{dc} - \Delta T_2^{nor} - \Delta T_2^{h} - T_{02}
\]

(3)

We can make a further expansion

\[
\Delta T_1 = T_1^{dc} - (T_1^{nor} - T_{01}^{nor}) - \Delta T_1^{h} - T_{01}
\]

(4)

\[
\Delta T_2 = T_2^{dc} - (T_2^{nor} - T_{02}^{nor}) - \Delta T_2^{h} - T_{02}
\]

(5)

Then formula (4) subtract formula (5)

\[
\Delta T' = (T_1^{dc} - T_2^{dc}) + (T_1^{nor} - T_2^{nor}) + (T_{02}^{nor} - T_{01}^{nor}) + (\Delta T_2^{h} - \Delta T_1^{h}) + (T_{02} - T_{01})
\]

(6)

Table 1. Parameters of zero points.

| Name                  | \(T_0\) (nT) | Normal Gradient (nT) | Altitude (m) |
|-----------------------|--------------|---------------------|--------------|
| Huanghe town (2016)   | 52815.7      | 53027.9             | 4253         |
| Youyun town (2015)    | 52605.7      | 52897.2             | 4182         |

If the observation point is the same one, then this deviation includes the deviation of two different zero point and the annual variation of geomagnetic field. Apparently, if the value of two different zero point is carried out in different year; their deviation should include annual variation. It is why that subtracting the deviation between two different zeros point directly is not available in order to have a
normalized magnetic anomaly map.
Furthermore, the deviation by two different zero point in a same observation point can be used as the corrected value. In our projects, there is no same observation point, so we pick out adjoining observation points (the distance between them is less than 100m) in gentle magnetic field then use their average deviation as correction to normalize magnetic data.

| No.  | Altitude (m) | $T_i$   | $T_{dc}$ | $T_{nor}$ | $\Delta T$ | Area              |
|------|--------------|---------|----------|-----------|-----------|-------------------|
| 218/214 | 4188      | 52756.5 | 52784.2  | 52988.9   | 7.0       | Xierirou (2015)   |
| 2/32   | 4125      | 52675.8 | 52557.2  | 52855.7   | -7.8      | Qupanglangxie(2016) |
| 192/216 | 4185      | 52749.7 | 52777.4  | 52984.4   | 4.8       | Xierirou (2015)   |
| 2/34   | 4216      | 52672.5 | 52553.4  | 52852.2   | 8.1       | Qupanglangxie(2016) |

**Figure 2. $\Delta T$ map without correction.**

**Figure 3. $\Delta T$ map after correction.**

### 6. Magnetic character and interpretation

According to the data of testing, the magnetic susceptibility and the remnant intensity of magnetization of rocks in our area is poor. The magnetic susceptibility of sedimentary rocks is relatively high and varies in large scale, the magnetic susceptibility of vein rocks is low and varies in small scale while magnetic susceptibility of acid-intermediate is low compared to some sedimentary rocks. It is possible that negative anomaly occurs when acid-intermediate rock intrudes into sedimentary rock.

The magnetic map after correction shows that the amplitude of magnetic anomaly is between -50 to 50 nT. Positive value is located in riverside and wetland, negative value is located in grassland and bedrock area. The gradient map shows that there are series of bands in NW direction. Combined with geological information, we believe that these anomaly bands are the reflection of NW direction
geological structure in magnetic field. Based on this information, 16 geological structures and 4 lithosomes have been recognized. There are two examples listed as follows.

6.1. Monzonitic granite lithosome
Located in southwest of Jiangrigama area, a 0.2km² outcrop is exposed on the ground. According to the ΔT map, the anomaly in this area is a narrow negative contour. It is about 1.5km in length and the lowest value of it in profile is about -40nT. Gradient map show that the narrow negative contour is separated by two bands which in NW direction. Analyze the relationship between stratum and magnetic anomaly, we found that the south of the anomaly is Quaternary stratum. The magnetic value in this area is low and gentle. The lowest magnetic value is showed just behind the outcrop of monzonitic granite lithosome. The magnetic value rises when moving away from the stock. So, the narrow negative anomaly is caused by monzonitic granite lithosome underground.

6.2. Gamma fault
There is a ΔT anomaly band in the middle of Xiacangjie area. It is about 27km in length and extends in NW direction. The magnetic anomaly is made up of series of positive value contour in bead shape or oval shape. The NW side of this band is just located on the outcrop of Gamma fault. So, the run of Gamma fault underground in Xiacangjie area can be recognized by ΔT anomaly band.

| Name                     | blocks | susceptibility \((10^6\times4\pi\cdot\text{SI})\) | remnant intensity \((\times10^3\text{A/m})\) |
|--------------------------|--------|-----------------------------------------------|---------------------------------------------|
|                          | range  | average                                      | range                                      |
| monzonitic granite       | 10     | 46.06—279.41                                 | 84.363                                     |
| granite                  | 12     | 4.76—18.11                                   | 8.985                                      |
| porphyry-like granite    | 9      | 6.71—20.38                                   | 8.637                                      |
| quartz vein              | 16     | 30.58—375.48                                 | 103.30                                     |
| feldspathic quartz sandstone | 56   | 5.79—619.72                                 | 85.65                                      |
| siltstone                | 18     | 1.13—526.96                                  | 57.73                                      |
| coarse sandstone         | 36     | 3.67—708.84                                  | 51.21                                      |
| gray sandstone           | 9      | 268.51—996.57                                | 450.56                                     |
| feldspathic sandstone    | 259    | 1.007—548.46                                 | 26.895                                     |

7. Conclusion
In this paper, the normalized magnetic map has been made by using correction. The correction value includes not only the deviation between different zero points but also the annual variation of geomagnetic field.

The magnetic character in Huanghe town and surrounding area have been showed, and the relationship between magnetic anomaly and geological structure have been analyzed. The narrow negative contour of magnetic anomaly is believed to be caused by acid-intermediate lithosome underground and a series of positive values contour in bead shape or oval shape is the reflection of
faults.

We also suggest that a unified profile which combined with geology and geophysics survey should be made. So, the magnetic difference among stratum, geological structure and lithosome can be identified by applying ground high-precision magnetic survey on the profile. Then, geology plotting in the shallow cover area can be done conveniently.

![ΔT contour in Jiangrigama.](image1)

![Gradient contour of ΔT in Jiangrigama.](image2)

![ΔT contour in Xiacangjie.](image3)

![Gradient contour of ΔT in Xiacangjie.](image4)

References

[1] Ai X 2002 Gold mineralization in crypto explosion breccia pipes: Their ore forming geological conditions, tectonic settings and prospecting criteria Mineral Deposits 21(Sup0) 569—572.

[2] Cui Z, Meng Q and Liao G 2012 The application of the new-round high-precision aeromagnetic prospecting in the middle part of the Da Hinggan Mountains Geophysical and Geochemical Exploration 2 192—197.

[3] Guan Z N 2005 Geomagnetic field and magnetic exploration Geological Publishing House