Acta Geologica Sinica (English Edition), 2021, 95(supp.1): 94–98

Full-area Exploration Test of Deep Concealed Ore Bodies based on Tunnel Gravity

ZENG Youqiang[1,*], ZENG Gaofu[1], HUANG Lishan[1], GUO Jianlei[2] and WANG Jianchao[1]

[1] *China Nonferrous Metal (Guilin) Geology and Mining Company Limited, Guilin, Guangxi 541004, China*
[2] *Xi'an Research Institute of China Coal Technology & Engineering Group, Xi'an 710077, China*

Citation: Zeng et al., 2021. Full-area Exploration Test of Deep Concealed Ore Bodies based on Tunnel Gravity. Acta Geologica Sinica (English Edition), 95(supp. 1): 94–98.

Metal mineral resources are the product of the deep material and energy exchange with its deep power process (Wan, 2017). It is the foundation of contemporary national economic development, a priority area for the country's implementation of strategic development, and an important measure of overall national strength (Dong and Zhu, 2019). In order to reduce the degree of dependence on foreign countries, it is necessary to increase the exploration and development of metal mineral resources. Whether in theory or in practice, prospecting and discovering large, super-large ore deposits and polymetallic deposits in the second depth space inside the crust is the only way for prospecting and exploration in the 21st century. In the next ten years, one-third of our country's metal mines are prospected at depths of more than 1000 m, and some of them can reach 2000–3000 m underground (Cai et al., 2019). The difficulty of exploration has increased sharply, and traditional geological prospecting technologies can no longer meet the requirements, and it is necessary to vigorously develop geophysical prospecting methods (Lv et al., 2019). The location and detection of deep concealed ore bodies is the scientific frontier of prospecting prediction and one of the main problems and research hotspots in the field of mineral exploration. Geophysical exploration methods (such as direct current method, magnetic method, electromagnetic method, etc.) are usually used in half space. Detecting deep concealed ore bodies in the domain (surface), these methods have strong abnormal solvability and large electromagnetic interference, and the accurate spatial positioning of deep concealed ore bodies in the full area has become a major problem.

Gravity exploration is a method of geophysical exploration to ascertain the distribution of geological structures and minerals based on changes in the earth's gravity field. Gravity exploration can be divided into ground gravity, ocean gravity, aerial gravity, underground gravity and satellite gravity measurement. (Zeng, 2008) Among them, underground gravity measurement refers to the gravity measurement in drilling and vertical, horizontal and inclined roadways (Xu and Zhou, 1989). There is few study on the tunnel gravity method of deep concealed ore bodies (Han et al., 2020). Therefore, for the mine in crisis in Daye, Hubei, in order to avoid the interference of electromagnetic signals in the mining area, based on the tunnel gravity method, a full-area location detection experiment of deep concealed ore bodies is carried out, which provides reference for the gravity detection of deep underground ore bodies at home and abroad.

For ground geophysical prospecting, after obtaining the geophysical anomaly, it can be determined that the field source is in the lower half of the space. However, for geophysical prospecting of tunnels, it is necessary to solve the problem of the whole space domain, because the field source body may be in any position within the 360° range of the abnormal part of the tunnel, so the specific position of the ore body around the tunnel must be determined (that is, the front, back, left, right, up and down) is very difficult, or to determine the location of the ore body has multiple solutions. Moreover, it is also very difficult for the simple gravity measurement of the tunnel. Based on the gravity of the tunnel, this study carried out a full-area survey of deep concealed ore bodies, and used gravity anomalies and gravity gradient anomalies (X, Y, Z three directions) to solve the location of deep concealed ore bodies.

The formula for the abnormal gravity of the concealed orebody can be obtained by transforming the inclined rectangular parallelepiped into an upright rectangular parallelepiped by translation and rotation. Any inclined rectangular parallelepiped can be transformed into a measuring grid coordinate system through one coordinate translation and three coordinate axis rotations (Fig. 1a). This conversion relationship is in formula [2]: first, the coordinate origin is translated from point O to the center point of the cuboid (ε_c, η_c, ζ_c), and the coordinate system after translation is x'y'z'. Then rotate around the axis z' by angle is α, and the new coordinate system is called x"y"z" (Fig. 1b). Then rotate the angle β around x", and the new coordinate system is called x'''y'''z''' (Fig. 1c). Finally, rotate around y''' the γ angle, and the new coordinate system is called $x^{1v}y^{1v}z^{1v}$ (Fig. 1d).

The transformation relationship between coordinate system and coordinate system is (Gravity Exploration Data Interpretation Manual Compilation Group, 1983):

$$\begin{pmatrix} \mathrm{x}^{1v} \\ \mathrm{y}^{1v} \\ \mathrm{z}^{1v} \end{pmatrix} = \begin{pmatrix} d_{11} & d_{21} & d_{31} \\ d_{12} & d_{22} & d_{32} \\ d_{13} & d_{23} & d_{33} \end{pmatrix} \begin{pmatrix} x-\varepsilon_c \\ y-\eta \\ z-\zeta_c \end{pmatrix} \tag{1}$$

* Corresponding author. E-mail: qingqingqianer@126.com

http://www.geojournals.cn/dzxbcn/ch/index.aspx
https://onlinelibrary.wiley.com/journal/17556724

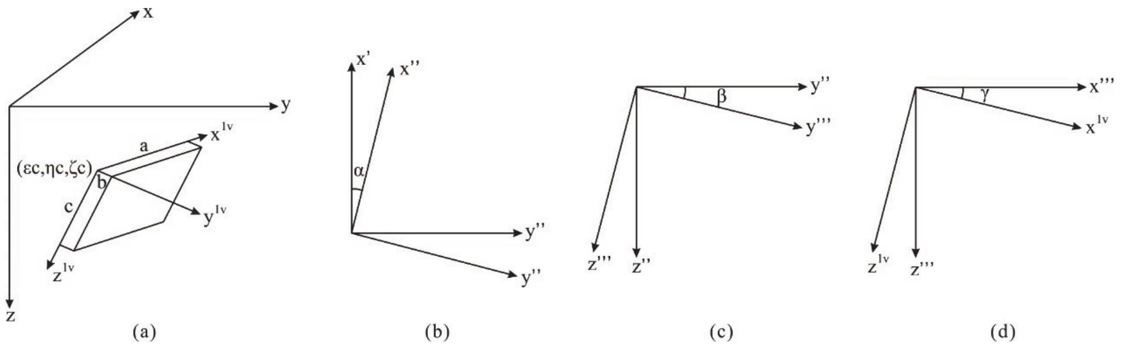

Fig. 1. Schematic diagram of transformation with coordinate system.

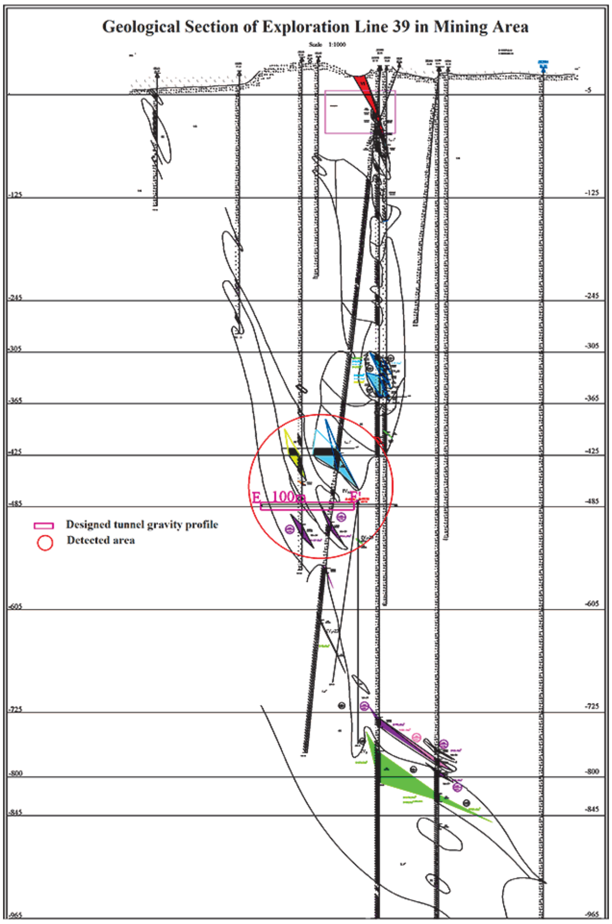

Fig. 2. Geological Section of Exploration Line 39.

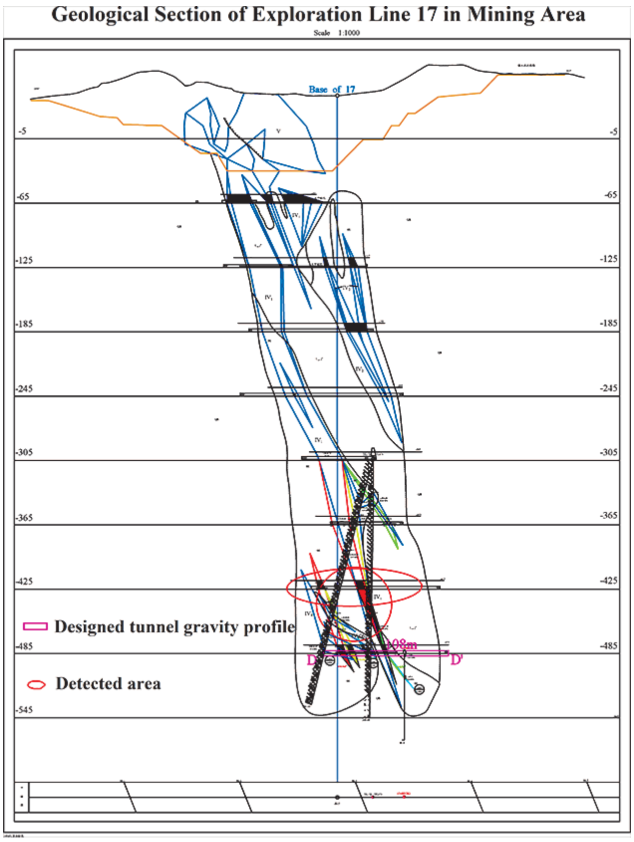

Fig. 3. Geological Section of Exploration Line 17.

In the observation network coordinate system, the partial derivatives V_x, V_y, V_z of the gravitational potential caused by the remaining mass of the cuboid along the coordinate axis are respectively; in the cuboid coordinate system, the partial derivatives of the gravitational potential caused by the remaining mass of the cuboid along the coordinate axis are $V_x^{1v}V_y^{1v}V_z^{1v}$, respectively, and the following are the following transformation relationship:

$$\begin{pmatrix} V_x \\ V_y \\ V_z \end{pmatrix} = \begin{pmatrix} d_{11} & d_{21} & d_{31} \\ d_{12} & d_{22} & d_{32} \\ d_{13} & d_{23} & d_{33} \end{pmatrix} \begin{pmatrix} V_x^{1v} \\ V_y^{1v} \\ V_z^{1v} \end{pmatrix} \tag{2}$$

$d_{12} = \sin\alpha\cos\gamma - \cos\alpha\sin\beta\sin\gamma$, $d_{13} = \cos\beta\sin\gamma$, $d_{21} = -\sin\alpha\cos\beta$, $d_{22} = \cos\alpha\cos\beta$, $d_{23} = \sin\beta$, $d_{31} = -\cos\alpha\sin\gamma + \sin\alpha\sin\beta\cos\gamma$, $d_{32} = -\sin\alpha\sin\gamma - \cos\alpha\sin\beta\cos\gamma$, $d_{33} = \cos\beta\cos\gamma$.

x, y, z, observation coordinates in the survey network coordinate system;

x^{1v}, y^{1v}, z^{1v}, observation point coordinates in the rectangular parallelepiped coordinate system;

V_x, V_y, V_z, gravitational potential caused by the remaining mass of the cube, partial derivatives along the x, y, and z axes.

The gravitational potential caused by the remaining mass of the cuboid V_x^{1v}, V_y^{1v}, V_z^{1v}; The partial derivative of the gravitational position along the x^{1v}, y^{1v}, and z^{1v} axes caused by the remaining mass of the cuboid; α, β, γ are the angle that the coordinate axis rotates around z', x'', y'''.

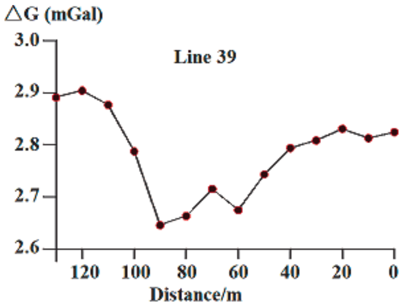

Fig. 4. Gravity anomaly curve of Exploration Line 39.

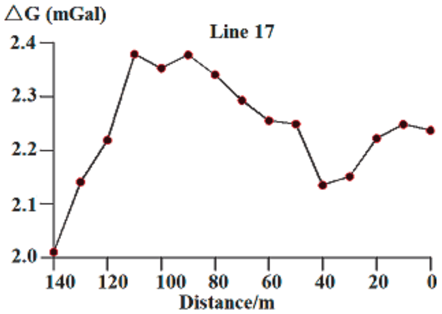

Fig. 5. Gravity anomaly curve of Exploration Line 17.

V_x^{1v}, V_y^{1v}, V_z^{1v} can be expressed as in the cuboid coordinate system (Gravity Exploration Data Interpretation Manual Compilation Group, 1983).

$$V_x^1 v = -G\sigma \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} (-1)^{(i+j+k)} \left[\eta_j ln(\zeta_k+\rho_{i,j,k}) + \zeta_k \ln(\eta_j+\rho_{i,j,k}) + \varepsilon_i \tan^{-1}\frac{\varepsilon_i\rho_{i,j,k}}{\eta_j\zeta_k}\right] \quad (3)$$

$$V_y^{1v} = -G\sigma \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} (-1)^{(i+j+k)} \left[\zeta_k ln(\varepsilon_i+\rho_{i,j,k}) + \varepsilon_i l\,n(\zeta_k+\rho_{i,j,k}) + \eta_j \tan^{-1}\frac{\eta_j\rho_{i,j,k}}{\zeta_k\varepsilon_i}\right] \quad (4)$$

$$V_z^{1v} = -G\sigma \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} (-1)^{(i+j+k)} \left[\varepsilon_i ln(\eta_j+\rho_{i,j,k}) + \eta_i l\,n(\varepsilon_i+\rho_{i,j,k}) + \zeta_k \tan^{-1}\frac{\zeta_k\rho_{i,j,k}}{\varepsilon_i\eta_j}\right] \quad (5)$$

where (3~5) are the gravity anomaly in the three-direction (X, Y, Z).

The mentioned copper deposit is a large skarn-type copper-iron deposit. The deposit is located at the northwest end of the Yangxin complex rock mass. The stratum of the mining area is relatively simple, mainly carbonate rocks of the Lower Triassic Jialingjiang Formation and Daye Formation, and the magmatic rocks are mainly quartz monzonodiorite porphyrite. The structure of the mining area is very complex, with developed folds and fault structures. The ore body is mainly produced in the contact part of the Tonglushan rock body and the lower Triassic Jialingjiang Formation and Daye Formation remnants, and is jointly controlled by faults and contact zone structures. Accompanying the widespread occurrence of contact metamorphism and thermal metamorphism of rocks in the mineralization zone, Cu, Fe, Au, and Ag polymetallic deposits were formed. After sampling and measurement, the average density (165 pieces) of skarn in the deposit is 2.68 g/cm^3, and the average density of copper-iron ore (90 pieces) is 4.3 g/cm^3. The density of copper and iron ore is 1.62 g/cm^3 higher than the density of the host rock, which is significantly different from the surrounding rock, creating favorable conditions for gravity exploration in the tunnel.

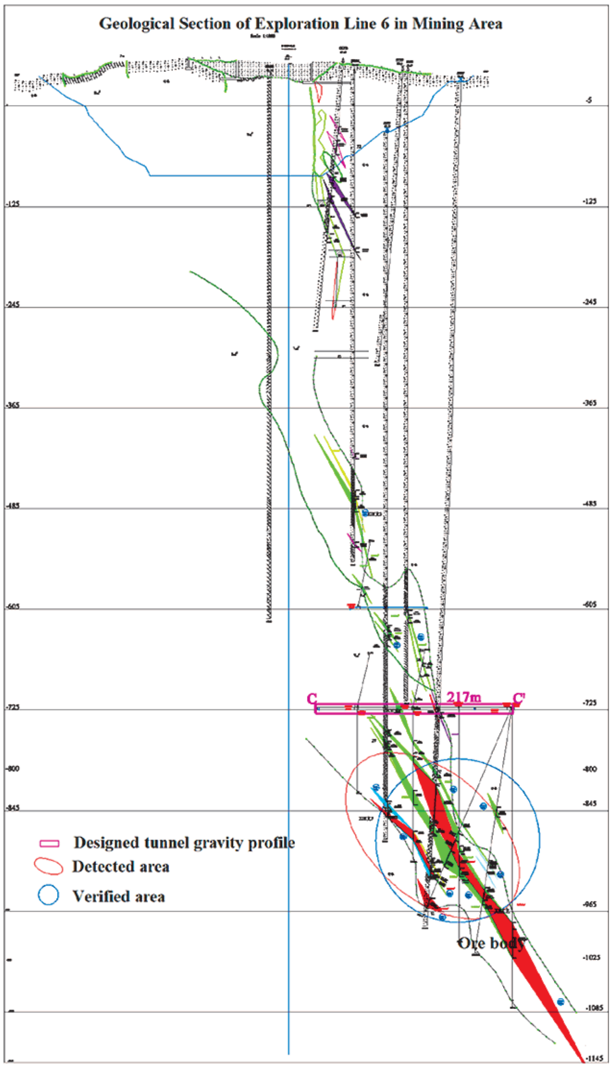

Fig. 6. Geological Section of Exploration Line 6.

The main steps are as follows:

(1) Data collection;

Data collection and identification of various rocks and ores in the survey area, and determine the types of rocks and ores. Basic geological data collection, sorting and measurement. By collecting and sorting out geological data, geophysical exploration data and drilling data in the work area, summarize the structural background, fault distribution and groundwater distribution in the work area. Complete the collection and measurement of density samples of coal seams and surrounding rocks

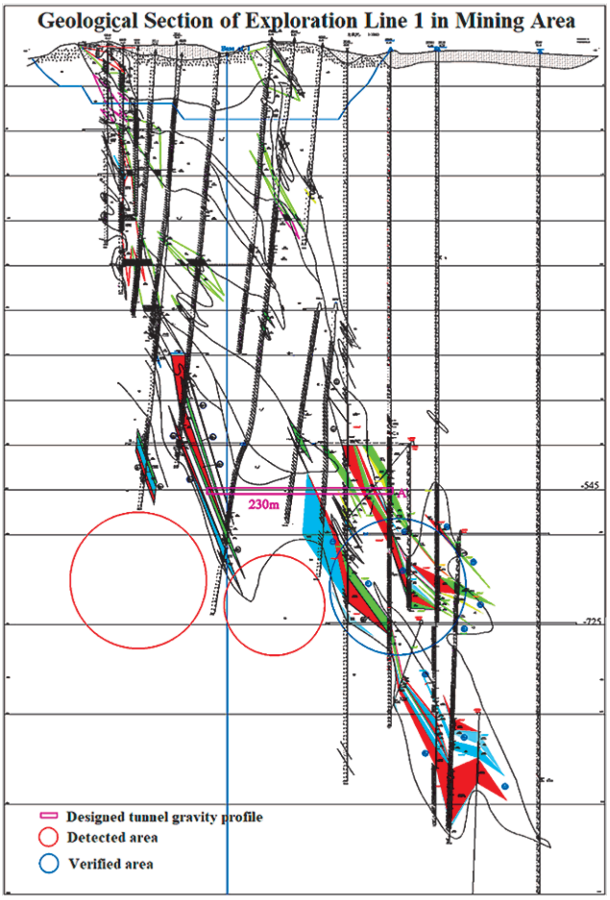

Fig. 7. Geological Section of Exploration Line 1.

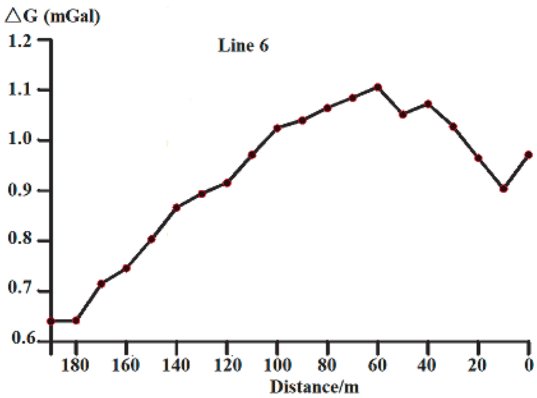

Fig. 8. Gravity anomaly curve of Exploration Line 6.

(2) Gravity observation in the tunnel;

Point coordinate measurement→Gravity base point selection→Measurement point gravity anomaly observation (including gravity anomaly and X, Y, Z gradient observation).

(3) Processing of tunnel gravity observation data;

Including solid tide correction, zero drift correction, terrain correction, Bouguer correction, latitude correction, tunnel correction, goaf correction, backfill correction, etc. Gravity acquisition and correction in underground tunnels. First, it is necessary to arrange the survey work in the underground tunnel. The gravity base point is arranged downhole to facilitate correction. The measurement error of the measuring point and the base point must meet the accuracy requirements. When collecting gravity data, try to avoid the vibration interference of surrounding mechanical equipment.

(4) Comprehensive geological interpretation.

Comprehensive geological interpretation. Combined with the existing geological, geophysical and drilling data, a comprehensive geological interpretation of the processed gravity anomaly is performed.

Through the above data processing flow. The data processing results are as follows:

In this paper, based on the tunnel gravity detection principle, this method has the following characteristics: (1) High detection accuracy, deep detection and accurate positioning of hidden ore bodies in the whole area; (2) It is suitable for the obvious difference in density between ore and ore-bearing rock and its anomaly is obviously larger than Positioning detection of deep inclined ore bodies with gravimeter detection accuracy. Good detection effect, such as rich lead-zinc ore, rich iron ore, copper-rich ore, uranium-rich ore, etc.; also suitable for positioning detection of low-density geological bodies (underground caves, low-density ore bodies, etc.); (3) Overcome deep the multi-solution problem of the spatial positioning of inclined ore bodies; (4) It is not affected by electromagnetic interference and is less affected by the terrain; (5) The observation surface does not need to be curved and flattened, which is extremely simple. (6) In this study of deep concealed ore body exploration experiments based on tunnel gravity, data interpretation still remains at qualitative interpretation, lacking quantitative interpretation. For quantitative interpretation and inversion, more research is needed.

Key words: tunnel gravity exploration, localization

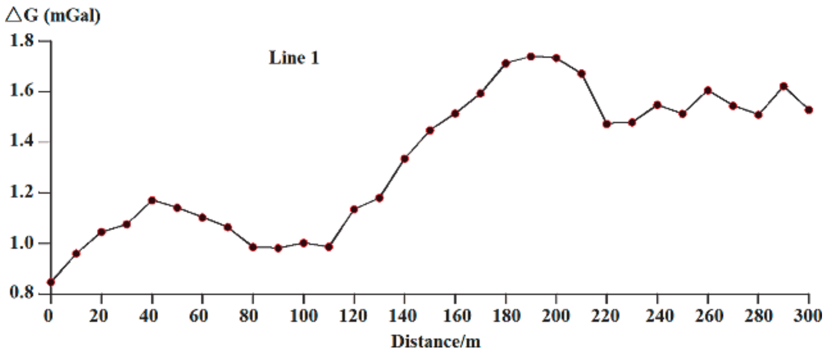

Fig. 9. Gravity anomaly curve of Exploration Line 1.

exploration in full-area, concealed orebodies; deep detection

Acknowledgments: This paper is the achievement of the project supported by Science and Technology Innovation Fund (Grant No. KDY2019001) and Integrated Geophysical Simulation Lab of Chang'an University (Key Laboratory of Chinese Geophysical Society).

References

Cai, M.F., Xue, D.L., and Ren, F.H., 2019. Current status and development strategy of metal mines. Chinese Journal of Engineering, 41(04): 417–426 (in Chinese with English abstract).

Dong, B.P., and Zhu, Z., 2019. Geological prospecting technology and its innovation in metal exploration. World Nonferrous Metals, 11: 78–79 (in Chinese with English abstract).

Gravity Exploration Data Interpretation Manual Compilation Group, 1983. Gravity Exploration Data Interpretation Manual. Beijing: Geological Publishing House.

Han, M.R., Wan, L., and Zhdanov, M., 2020. Join iterative migration of surface and borehole gravity gradiometry data. Active Geophysical Monitoring (Second Edition), 97–121.

Lv, Q.T., Zhang, X.P., Tang, J.T., Jin, S., Liang, L.Z., Niu, J.J., Wang, X.B., Lin, P.R., Yao, C.L., Gao, W.L., Gu, J.S., Han, L.G., Cai, Y.Z., Zhang, J.C., Liu, B.L., and Zhao, J.H., 2019. Review on advancement in technology and equipment of geophysical exploration for metallic deposits in China. Chinese Journal of Geophysics, 62(10): 3629–3664 (in Chinese with English abstract).

Zeng, H.L., 2008. Gravity Field and Gravity Exploration. Beijing: Geological Publishing House (in Chinese).

Wan, J.M., 2017. Development status and practical application of geophysical exploration technology. World Nonferrous Metals, 18: 175–176 (in Chinese with English abstract).

Xu, G.D., and Zhou, G.F., 1989. Gravity measurement in wells and tunnels. Beijing: Beijing Geological Publishing House (in Chinese).

About the first and corresponding author

ZENG Youqiang, male, born in 1987 in Loudi City, Hunan Province; master's degree; geophysical engineer, China Nonferrous Metal (GuiLin) Geology And Mining Company Limited. He is now interested in transient electromagnetic method with multi-radiation field source, E -mail: qingqingqianer@126.com; phone: 18392064719.