Improvement, combination and commercialization of processing and inversion methods of magnetotelluric data

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SUMMARY

As well as the magnetotelluric exploration tends to 3D level and is effected by distortion field, the data processing and inversion methods need to be improved. We propose a new concept of generalized static shift resistivity and related new static shift correction method throughout model constraints, and improve the nonlinear conjugate gradient inversion method, increasing the efficiency more than 20 times and accuracy more than 2 times. Furthermore, we designed and developed a new software platform (EMinv), combining the new methods above and composing of new visualization module to display all the geoscience data/results. EMinv eliminated all the operations for data format conversion and software connection, using our new rule and integrated standard. The platform is applicable for both of production and scientific research.

Keywords: magnetotelluric exploration, static shift correction, 3D inversion, combined software platform

INTRODUCTION

Magnetotelluric (MT) sounding is one of the most important methods for deep crust exploration and prospecting. In most cases, MT data collected in 3D arrays are interpreted using two-dimensional inversion methods. While the 2D assumption is valid in some cases, the approximation does not hold in most cases, especially in areas with a complex geoelectrical structure. Hence, 3D methods for electromagnetic (EM) inversion have been the focus of recent research. In addition, the static shift effect is a very common phenomenon in MT field data that seriously affects data accuracy and interpretation. In this study, we propose and integrate our new static shift correction method into our new inversion algorithm, and develop a platform with new design to integrate the processing and inversion of EM data and to facilitate the complex explanation of all the geoscience data/result.

STATIC SHIFT CORRECTION

We establish the relationship between geological constrain factors and static shift effect using theoretical derivation, 3D numerical simulation and observation test. The apparent resistivity and impedance phase of all the impedance tensor will be affected by static shift, changing with the frequency. We propose the concept of generalized static shift resistivity to constrain the initial inversion model to correct static shift, and this resistivity value is established by the relationship of the data from different components of impedance (more details in Zhang et al., 2016).

Synthetic model forwarding and field experiments are carried out to verify the correction method. The field test is based on the real data collecting of a profile in the Westen China, which inversion results are shown in figure 1. There is only one station at 3100 m where we dig a big hole to set a conductor as the inhomogeneous body to produce the static shift data.

Figure 1a shows the normal inversion result using the normal data collected before the observation factors test. Figure 1b shows the inversion result without static shift correction using the data with the test, and there is a heterogeneous body with low resistivity at the surface of the test station (located at 3100 m). Figure 1c shows the inversion result with our static shift correction using the test data. At the 3100 m location, the inversion model with correction is very similar to the normal model, and the shallow low-resistivity layer, middle high-resistivity body and deep low-resistivity body are reflected accurately. Figure 1d shows the comparison of the data and inversion responses, where the correction response better fits the abnormal data, illustrating that our correction method is very effective.

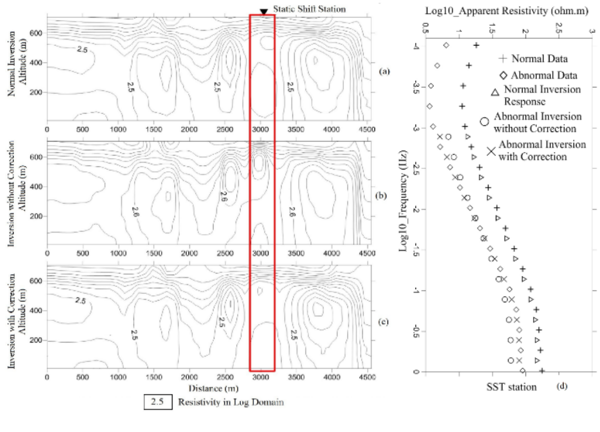

Figure 2. Static shift correction verification using real data. (Zhang et al., 2016)

THREE-DIMENSIONAL INVERSION

We change the previous nonlinear conjugate gradient inversion algorithm by refining the preconditioning factor, choosing frequency - based parallel structure, constructing the objective function, reducing the number of iterations in forward modeling and adding static shift correction, topographic and marine effects to inversion. These changes improve the computing efficiency and accuracy of the algorithm.

The audio-magnetotelluric (AMT) data of an iron ore in China (figure 2a) were used to verify the reliability and efficiency of the 3D inversion method. The major strata are sandstone, volcanic rock, and Cretaceous magmatic rocks. Moreover, shallow faults were developed. The sandstone and faults are resistivity lows in the model because of abundant water, but the volcanic and magmatic rocks are resistivity highs.

The model space was discretized using a mesh grid of 32×41×38 and ten frequencies from 1000 to 10 Hz were used for inversion. The initial model was a 100-Ω m half space with generalized static shift resistivity on the sruface. The computation time was approximately 20 min on a PC with 12 CPU threads. Four electrical layers (figure 2b) can be consistent to the four strata of geological profile (in figure 2c), and the faults are clearly reflected. All the structures are shown clearly in figure 2d.

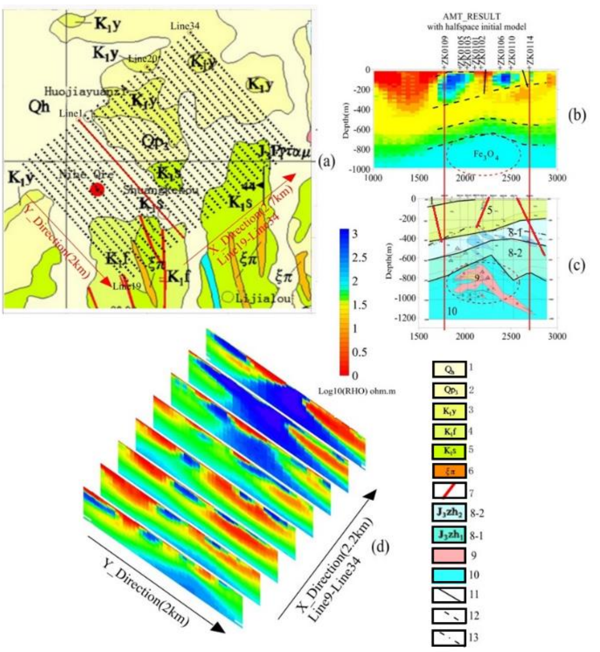

Figure 1. (a) Geological map with stations. (b) AMT 3D inversion profile. (c) Geological profile. (d) AMT 3D inversion model (Zhang et al., 2014)
1–3, sandstone; 4–5, 8, volcanic; 6, 10, subvolcanic; 7, fault; 9, magnetite; 11, stratigraphic boundaries and faults; 12, speculated stratigraphic boundaries; 13, alteration boundary.

EMINV SOFTWARE PLATFORM

We designed and developed a new software platform, composing of processing and inversion modulars for MT/EM data and comprehensive display for all the geoscience data/results. For MT data, pre-processing project includes fast fourier transform, remote reference processing and impedance estimation. Processing project of magnetotelluric data includes power spectrum editing, data selection, data rotation and data sorting. Impedance distortion phase tensor and tipper are used to analyse the strike direction and medium dimension of the data. Underground electrical structure can be obtained using 1D, 2D and 3D inversion. For the geoscientific results, visualization in different dimensions and a UI similar as GIS are used to facilitate the comprehensive interpretation. New self-improved processing, inversion and interpretation algorithms were applied in this platform. This comprehensive platform eliminated all the operations for data format conversion and software connection, using our new rule and integrated standard. The platform is applicable for both of production and scientific research.

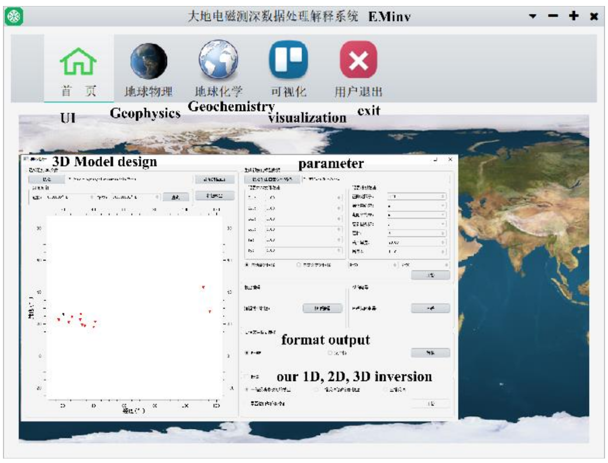

Figure 3. EMinv Platform (after Zhang, 2021).

CONCLUSIONS

We decrease the human factors and extra cost in our new method for the static shift correction and inversion. The combined method and production have been promoted to numerous scientific research and production institutes and universities, receiving unanimous praise and generating huge economic and social benefits.

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