

Geophysical survey over molybdenum mines using the newly developed MTEM system

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Abstract—Funded by major national scientific research and equipment development project, the development of multi-channel transient electromagnetic system is led by the Institute of Geology and Geophysics, Chinese Academy of Sciences. It consists of pseudo random coded waveforms and high power transmitter with measurement function, multi-channel array receiver, high rate data transmission and master system, and electromagnetic imaging software with multiple signal stacks. It can be used to detect electrical structure at 4000 meters depth range. In this paper, we introduced the system's composition, methods and principles, integration scheme, and then the integrated test results for the multi-channel transient electromagnetic system conducted at Cao-si-yao molybdenum mines were given.

Keywords—multi-channel transient electromagnetic; pseudo random coded waveforms; high power transmitter

I. INTRODUCTION

In 2000, a new electromagnetic observation system for Multichannel transient electromagnetic (MTEM) method was researched by University of Edinburgh. Ziolkowski et al^[1-3] used the developed MTEM instrument for geophysical prospecting over gas reservoir and oil-gas field and obtained ideal exploration result. The system transmits m sequence waveform with wide spectrum, one in the family of pseudo random binary sequences (PRBS). It deploys several electric bipoles to measure more than one received voltages at the same time and was able to record 30 channels one time when the Cao-si-yao Survey was conducted. The number of channels will be increased furtherly in the future system. It also simultaneously records the transmitted waveform due that the transmitter cannot transmit currents as it is designed because of the complex and dynamically varied impedance condition of the earth. In some early literatures, the real-time recorded transmitted waveform is referred to as the system response. The earth impulse responses can be recovered by deconvolving the received voltage for the transmitted current

measured in real time, which allows similar seismic data processing method to process and interpret the data.

Funded by major national scientific research and equipment development project, multi-channel transient electromagnetic (M-TEM) system development has entered the stage of instrument integration. The transmitter system includes generator, uncontrolled rectifier bridges, pulse width modulated DC/DC full-bridge converter, H Inverter Bridge and pattern generator which can generate pseudo random coded waveform. The dynamic range of MTEM electromagnetic data acquisition station is 160dB, minimum detectable voltage is 50nV, synchronization precision is 5 μ s, and the sampling rate is 16Ksps. Its advantages include low power consumption, small size and light weight. The acquisition stations transfer data based on TCP/IP protocol.

Acquisition and processing of MTEM data of a single-line survey along a 4.8km profile over Cao-si-yao molybdenum ore deposit was conducted. Though 50Hz electric power noise was widespreadly observed over the study area, good earth impulse response curve was still obtained at long offset. After that, the peak time of the obtained earth impulse response were extracted and used to calculate the subsurface apparent resistivity value. The obtained 2D inversion result showed a resistivity structure that was consistent with known geological data.

II. THEORY AND SYSTEM COMPOSITION OF MTEM

MTEM system transmits pseudo random electric current signal into the earth via finite long grounded wire. The electromagnetic field response and the transmitted electric current on land are recorded at the same time. Then, the earth impulse response can be obtained by deconvolution. Furthermore, the subsurface apparent resistivity values are calculated in order to reconstruct the subsurface resistivity distribution and locate the desired geological targets via 2D or 3D survey. Fig. depicts the typical field survey configuration.

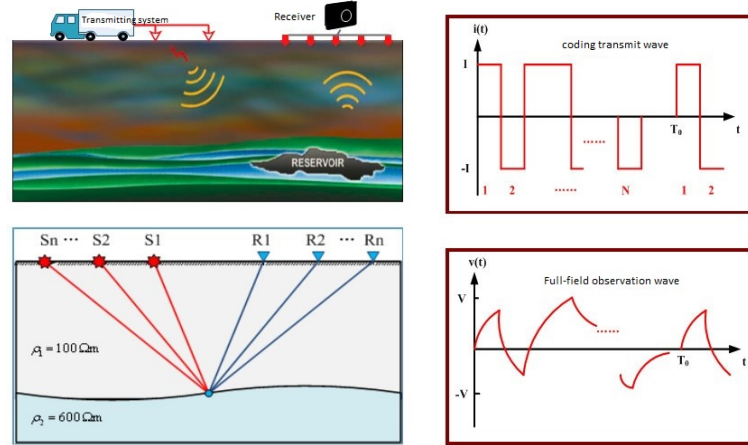


Fig. 1 Sketch map of MTEM working device

In MTEM method, the earth is considered as a linear time-invariant system. Thus, the received voltage response can be denoted as the convolution of transmitted electric current and the earth impulse response, plus additional noise.

$$v(t) = s(t) * g(t) + n(t) \quad (1)$$

where, $s(t)$ denotes the coded current and launching system response, which includes response of the transmission circuit, grounded electrode and the cable which connects the grounded electrode, $g(t)$ denotes the earth impulse response, and $n(t)$ denotes the noise. The apparent resistivity value for each receiver offset with respect to a given current dipole position can be obtained using the equation given below,

$$\rho_a = \mu r^2 / 10 t_{peak} \quad (2)$$

where μ is permeability, r is offset (m), ρ_a is resistivity ($\Omega \cdot m$), t_{peak} is the peak time of the earth impulse response. Then, we can obtain the apparent resistivity section along the whole

profile.

III. MTEM TEST SURVEY AT MOLYBDENUM MINES IN CAO-SI-YAO, XINGHE COUNTY, INNER MONGOLIA

A. Overview of Testing Site

Cao-si-yao molybdenum mine is located at the southwestern intersection between the Da Tong-Shang Yi northeastward structure-magmatic rock belt and Shang Du-Wei northwestward structure - magmatic rock belt at the middle segment of the Da Tong - Shang Yi northeastward structure - magmatic rock belt of the eastern part of Liang Chen Fault-uplift. The main rock type in this area is the Archean Eon granulite lithofacies crystalline basement with sedimentary cover. This area is characterized by complex structures from multi-period folds, ductile shear deformation and faults.

The known ore body of Cao-si-yao molybdenum mines is 1900m long in east-west direction, 1400m wide in north-south direction, while the single drill maximum ore body thickness is more than 900m. According to the current exploration



Fig. 2 Survey line of Cao-si-yao field test. Yellow line is the control range of molybdenum mines, while red line is the survey line for MTEM integrated test

control degree, the reserve estimate indicates that about 200

the profile length was 4800m, the length of transmit dipole

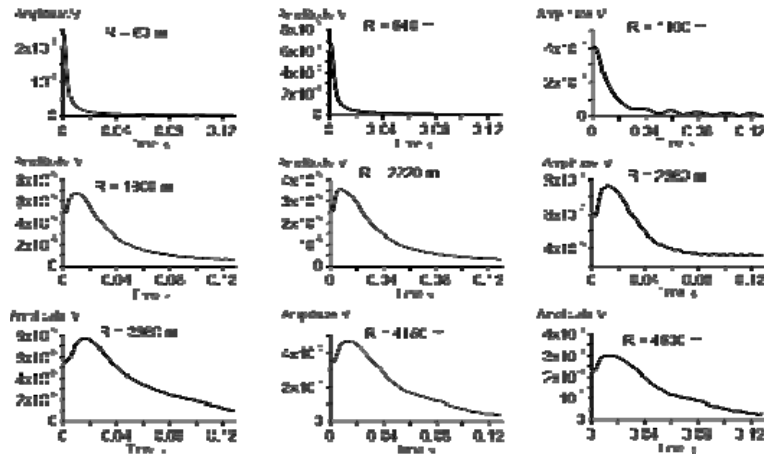


Fig. 3 The earth impulse response at different offsets

million of

molybdenum metal can be obtained from this ore area and that Cao-si-yao molybdenum mine will become the world's second largest molybdenum mine.

The IP anomaly over Cao-si-yao mining area is very obvious. The area where the mining site overlaps with the hydrothermal alteration zone is the best area for the development of molybdenum ore body. According to the IP result, this test area is a good site for geophysical survey and is suitable for MTEM tests.

B. Data Acquisition of MTEM Tests

In July 2015, MTEM survey was carried out along line L2 (red straight line in Fig.) within the test zone. The area outlined by yellow line is the control range of molybdenum mines. The azimuth of line L2 is nearly NW40°, while the profile is 4.8km long. Points 1600 and 3100 represents the north boundary and south boundary of molybdenum mines, respectively.

For this test, we used electric dipole to transmit 12 order PRBS electric current code type, whose element frequency is 512Hz, to the earth repeatedly in 30 cycles. Since there were only 10 receivers available for the study, the 10 receivers with three channels for each were used to collect data from 30

was 300m, and the maximum current was 15A. Similarly, like seismic survey, M-TEM data were recorded at different offsets by moving the transmitter dipole at an interval of 300m towards the receiver units while keeping the receivers stationary. Hence, we were able to obtain the earth impulse response at different offsets.

C. Data Processing and Interpretation

The earth impulse response was obtained by deconvolving the electric field signal measured at the center of the transmitting electric dipole with the corresponding electric field signal measured by the receivers. Fig. shows the obtained earth impulse response at offsets ranging from 60m to 4500m. The peak time of the response curves, which increases gradually with offset, was used to calculate the apparent resistivity value for each receiver offset with respect to a given current dipole position using (2).

The apparent resistivity section can be drawn using the obtained apparent resistivity values from each earth impulse response, as shown in Figure 4. The resistivity distribution indicates the presence of a two layer geological section, the shallower one is the weathered Huangtuyao Formation, Mesozoic Era with low resistivity, and the deeper one is granite with high resistivity. This coincides with local geological setup.

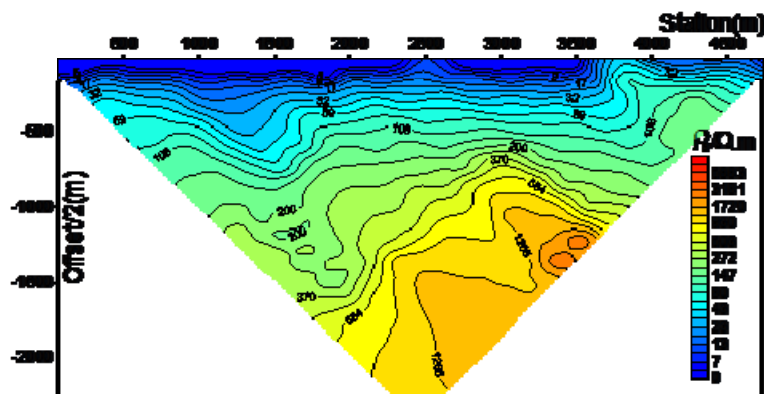


Fig. 4The apparent resistivity section map

stations simultaneously. The electrode spacing used was 40m,

IV. CONCLUSION

In this paper, we introduced the theory and method of M-TEM and presented the field test result of M-TEM system integration. The accuracy of the transmitted pseudo random code was preliminarily verified. Furthermore, the verification of the feasibility of M-TEM receiver implementation plan laid the foundation for the mass production of the receiver system. The whole process that defines a functional geophysical survey system which are; data collection, data processing, inversion and interpretation were actualized. Both the data collected and interpretation result obtained proved that the system is reliable. However, there is still room for improvement, especially on the current system and data processing software, which will lead to an upgrade of the whole system.

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