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Research study on the short offset time-domain electromagnetic method for deep exploration

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ABSTRACT

As a kind of geophysical method, the principle of transient electromagnetic method (TEM) observes the secondary vortex field in the gap of the primary field, which is applied to the investigation of resources and environmental engineering survey. In order to realize the rapid and precise detection of the deep targets (due to its relative great detection depth and high accuracy), the short offset time-domain electromagnetic method (SOTEM) is proposed in this paper. In addition, its feasibility, observation and interpretation techniques are researched. The results show that SOTEM has the same near source detection capability as the central loop configuration when choosing the step waveform, and as a result, the primary and secondary fields can be separated theoretically. The application has shown the effectiveness and superiority of SOTEM in the deep target exploration.

1. Introduction

With the rapid development of China's economy, the reserves of shallow resources are rapidly disappearing. For this reason, China has proposed the strategies of exploration in the 'second deep space' and exploration of 'deep-blind' resources (Teng, 2006). In order to realize the effective detection of mineral resources at 500–2000 m in the subsurface, it is very important to develop electromagnetic techniques with higher resolution and deeper detection depth.

The transient electromagnetic method (TEM) is a time domain electromagnetic method. The most common configuration is called loop source TEM, which is used for shallow target exploration. This device realizes zero-offset observation which is impossible for the frequency domain EM methods (Nabighian, 1979; Kaufman and Keller, 1983). The loop source TEM technique has been widely applied for a variety of exploration purposes including metal, coal, groundwater, permafrost, marine geology, engineering geology within 0–0.5 km (Edwards and Chave, 1986; Goldman et al., 1991; Vrbancich, 2012; Xue et al., 2012). This device has small volume effect and high detection precision, but its detection depth is relatively small.

Another common mode of TEM is the long-offset electric source TEM (LOTEM) (Strack, 1992) which has been widely used in oil and gas exploration due to its great detection depth. However, LOTEM also has some obvious drawbacks, including weak signal and great volume effect, which limits its application in deep mineral exploration. In recent years, scholars have shown great interest in near source detection techniques of electric source TEM, and have made abundant research and application achievements (Ziolkowski, 2010; Nestor and Alumbaugh, 2011; Um et al., 2012). It is generally believed that when we detect targets in short offset, a strong primary field is able to submerge the second field so that the observed signals mainly originate from the surface, and the detection depth decreases with the decrease of the transmitter-receiver distance.

On the basis of previous studies (Xue et al., 2013; Chen et al., 2015, 2016; Zhou et al., 2015a,b), this paper proposes a new method, referred to as the short-offset transient electromagnetic method (SOTEM). The deep detectabilities of SOTEM are analyzed by studying the distribution of EM fields, as well as the interaction characteristics with the earth. The bisection method is used to calculate the all-time apparent resistivity, and the 1D image inversion method is adopted to realize the fast one-dimensional inversion of the SOTEM data. A practical measurement in

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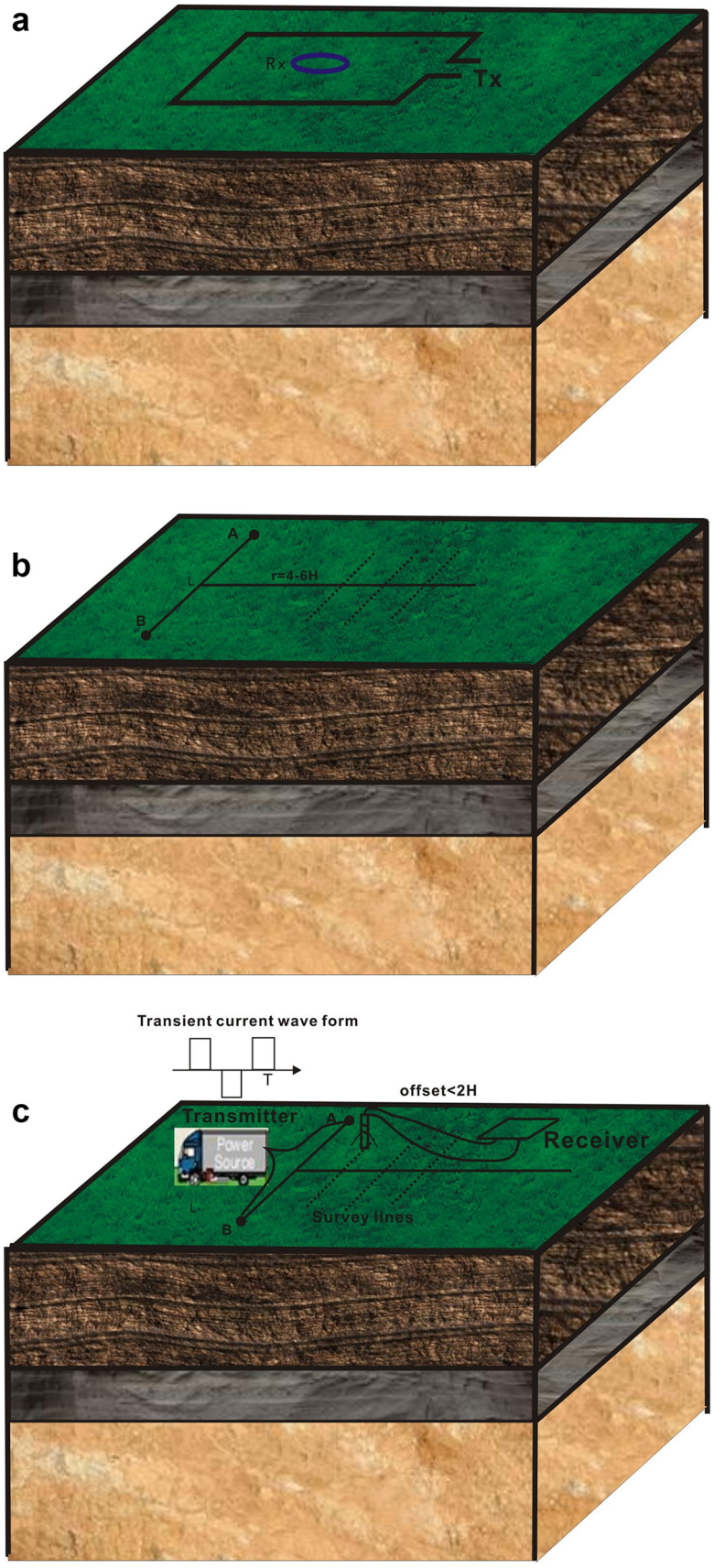

Fig. 1. Schematic diagram of magnetic and electric source TEM. (a) central loop device, (b) long-offset transient electromagnetic method (LOTEM), (c) short-offset transient electromagnetic method (SOTEM).