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Detection of an Emergent Fresh Groundwater Resources Using CSAMT for Beijing 2008 Olympic Games

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Abstract

This paper discusses the use of Controlled Source Audio- Frequency Magnetotelurics Method (CSAMT) in groundwater exploration and its ability to locate bedrock depth and position with especial emphases on the distribution of limestone formation and hence the water reserves in this formation. The method was applied in 2008 as a major exploration technique in Chao-bai River and Hui River area in Beijing, China. The study was conducted to find emergency water resources sites during Olympic Games which was held in Beijing, China in 2008. The comparison between the interpreted CSAMT data, the geologic and borehole information of the area are consistent. The study proved that the method has a peculiar advantage in identifying water bearing horizons and can provide a reliable evidence for an emergent water resource reserve.

Keywords: CSAMT, Groundwater exploration and bedrock.

Introduction

Many electrical geophysical methods are usually applied for groundwater exploration. The Electrical Resistivity Method is the most commonly applied geophysical tool for groundwater exploration, as it can determine aquifer thickness and depth to bedrock. It is also capable of determining the quality of groundwater i.e., wheather the water is saline, brackish, fresh or contaminated (Zohdy, 1974; Sotllar and Roux, 1975; Roger and Kean, 1980; Urish, 1983).

In 2008 Beijing Olympic Games which were held in Beijing, China, emergency water sources were planned to overcome any water shortages during the Games. The Authorities proposed the groundwater in the valleys of Beijing Chao-bai River and Haui River for this purpose. Accordingly this study was carried out to evaluate these groundwater sources. As well the study was planed to detect the bedrock position, to map the limestone distribution as well as to investigate the presence of water in the limestone. The method applied for this study was the Controlled Source Audio-frequency Magnetotellurics Method (CSAMT) (He, 1990; Shi, 1999; Piao, 1990 and Tang and He, 2005).

CSAMT is a frequency-domain electromagnetic method which uses a grounded dipole or horizontal loop as an artificial source. Over these years, CSAMT has emerged as a powerful exploration tool and has been found in mineral exploration, geothermal investigation, hydrocarbon exploration, long deep shield tunnel detection and groundwater contamination problems (Cagniard, 1953; Xu, and Liu, 1995, Wu and Shi, 1996; Yu, 1998; Di, 2002, 2004; Gong and Di, 2004).

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CSAMT uses an artificial signal source. The data can be collected on the ground surface or in a well. Usually the frequency ranges between several ten thousand Hertz and several Hertz. The low frequency gets the greater depth, therefore the exploration depth measured can be up to 1500 m under ground. Due to artificial signal source and more stable signal-noise ratio, dependable data can be achieved. Hence, the main advantages are the greater depth of detection, excellent lateral resolution, flexible survey design, and little topographic effect.
This study introduces geological, hydrological, lithological and geophysical characteristics in the area surveyed. Moreover the inversion results can be compared with known geological information in the area surveyed, and then the final interpretation was made.

Materials and Methods

Geological Setting

The survey area is located in the north of Beijing, near to the Eighth Water Factory of Beijing. The region is surrounded by mountains in northeast, northwest and north, while the south is plain. The main cover on the surface is sand and gravel, which belong to the Quaternary loose alluvial and diluvium layer. The bedrock is Limestone and Dolomite of Cambrian and Ordovician. In Fig.1, the bedrock geology in Mi- Huai-Shun area.

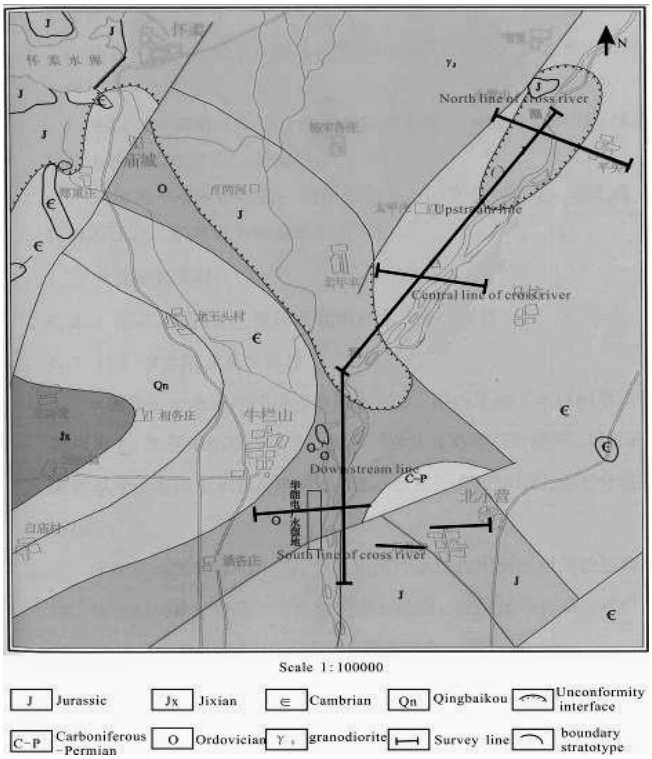

Fig. 1. Bedrock geology map in Mi-Huai-Shun area.

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Chao-bai River is the largest river in the region. There was perennial current before 1981, while after 1982 the reservoirs drew off and there is a seasonal current only, hence the groundwater of the region can be a source of supply.

The thickness of the Quaternary loose alluvial and diluvium layer in the study area is greater than 300 m. The characteristics of aquifer structure are particles from coarse sand to fine sand, from single layer to multilayer, and water mainly stores in multilayer structure of sand gravel stratum from depth of 3 to hundreds meter. Moreover, the deep deep karast aquifers may also exist in the area.

Csamt Method

CSAMT method was applied in order to detect the depth of the bedrock, and limestone distribution in the subsurface.

The CSAMT method, introduced by Goldstein (1971) and Goldstein and Strangway (1975) is an electromagnetic sounding technique which measures resistivity variations in the ground. CSAMT measures the electrical (E) and magnetic (H) components of the electromagnetic field. The E-field is sensed as a voltage across a grounded wire, while the H-field is sensed as a voltage in a high-gain magnetic antenna.

Based on electromagnetic theory and Maxwell Equation, three components of E and H could be calculated. And then the ratio of horizontal perpendicular components, E_x and H_y, gives the Cagniard resistivity of the ground (Cagniard, 1953).

Fig. 2 shows a sketch of CSAMT observation system. The transmitting system consists of one 30 kW generator and transmitter. The receiver system includes intellectualized digital receiver controlled by computer, magnetic coil and non-polarizing electrode. The transmitting dipole is parallel to the receiver dipoles.

The receiver instrument can simultaneously acquire different frequency series data of nine electrical components E_x and one magnetic component H_y at one time, that is to say, transmitting once, the nine sounding data can be completed. *X* is the direction of survey line; *y* is the direction which is vertical to survey line.

In this study, the working frequency varies from 9600 to 1 Hz. The distance between transmitter and receiver is 8000 m, and the length of transmitting dipole is 1600 m. The transmitting current is 15 A. The receiving dipoles are separated by 40m along the survey line. Here the upstream line was taken as an example. In Fig. 1, the survey lines were marked as block curves, including two north-south lines (one is upstream line, another is downstream line), three cross river lines (north, center and south).

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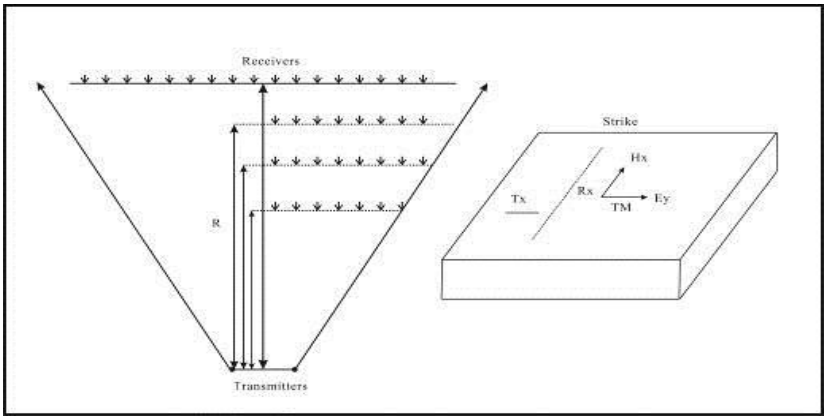

Fig. 2. Sketch of CSAMT observation system

Results and Discussion

In Fig. 3, there is integrated interpretation map of the north upstream profile. Horizontal axis: position of measure points, and vertical axis: sea level.

Comprising the inversion result of CSAMT data and known geologic information revealed by drilling, it is found that the CSAMT results agree well with the geologic facts.

Obviously, there is sharp definition in the resistivity contour map of Fig. 3, and this area can be divided into three layers. The shallowest represents as medium of low resistivity, because of the uneven ground connection, the lateral variation of resistivity is large, there are several irregular high resistivity mixed in the meantime. The depth of its lower interface is from 20 m to 80 m. Therefore it is deduced that the layer corresponds to the sand, gravel and local distribution of soil layer.

The second is medium of lower resistivity layer. The lowest resistivity is up to 40 ohm.m. The layer has a series of beaded, closed low resistivity anomaly. Experimentally, this layer should be continuous. It is inferred this layer may be the region of Quaternary aquifer which consists of sand, gravel and clay. Its upper interface shows the changes of water table, and the lower interface should be interpreted as the depth change of bedrock. The biggest depth is about 240 m, and the resistivity in this region is very low, so this area was considered as a favorable productive aquifer.

The last zone is the water insulation layer which is mainly limestone of Cambrian age. But it discontinues between station 5400 and station 6200. This zone has a relatively low resistivity, therefore the low resistivity values maybe due to the presence of the deep karst aquifer. This aquifer should be verified by drilling in the future.

Drilling Test for CSAMT Results

The locations of boreholes are presented in Figure 3: J1 locates at 4200 m, the interpreted bedrock depth is about 270 m, at present the drilling reaches to 150

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m, which does not meet the bedrock yet. J2 locates at 4500 m, and the interpreted bedrock depth is about 230 m, at present the drilling reaches only 140 m. J3 is at 4800m, the interpreted bedrock depth is about 165 m, at present the drilling reaches up to 170 m, meets bedrock at depth 165 m. J4 is at 5100 m, the interpreted bedrock depth is about 150 m, meets bedrock at depth 148 m. J5 locates at 5400 m, the interpreted bedrock depth is about 190 m, at present the drilling reaches to 70 m, not meets bedrock. J7 locates at 6000 m, the interpreted bedrock depth is about 300 m, at present the drilling reaches up to 140 m and does not meets bedrock.

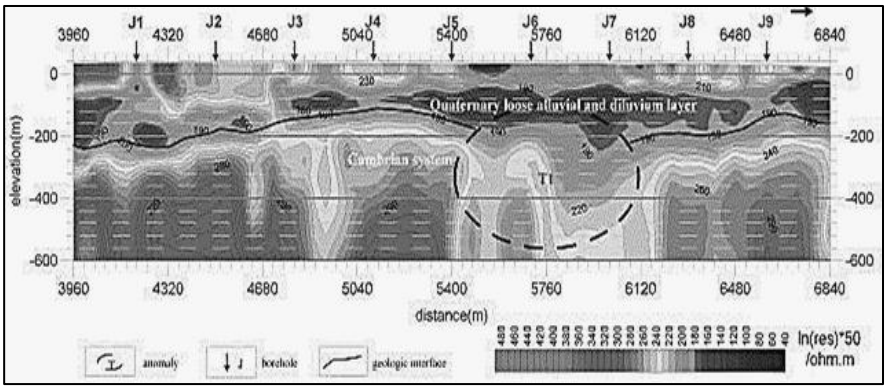

Fig.3. CSAMT inversion section and geologic interpretation map

Conclusions

According to electrical properties and geologic information, the upper stream profile was divided into three layers, and the results depicted the rolling shape of Quaternary loose alluvial and diluvium layer in the upper bedrock. It can supply the evidence for exploiting Quaternary water in future. Based on CSAMT result, one abnormal zone was deduced in the upstream profile. There may exist deep water in limestone.

The CSAMT result are well corresponding to geological data, which are controlled by boreholes. The results presented in this paper show that, the CSAMT method is a helpful exploration method for studying geologic structure of the water-bearing zone. Additional surface geophysical methods, such as seismic refraction and high density VLF surveys, have been recommended to locate water-bearing horizon.

Acknowlgement

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تحديد مصادر مياه جوفية عذبة بإستخدام الطريقة الماغنيتوتلورية المتحكمة فى مصدر الذبذبة للحاجة الطارئة في ألعاب أولمبياد بكين 2008م

آن ذى قوا[1] ، دى قنغ[1] – ين، وانغ قوانق جي[1]، والزين أحمد الزين[2]

مستخلص البحث

ناقش البحث إستخدام الطريقة الماغنيتوتلورية ذات المصدر المتحكم في الذبذبة في مجال إستكشافات المياه الجوفية ومقدرتها على تحديد عمق وموقع الصخر الأم وعلى وجه الخصوص توزيع تكوين الحجر الجيري وبالتالي تحديد المخزون المائي في هذا التكوين الصخري.

تم تطبيق هذه الطريقة كتقنية إستكشاف أساسية في العام 2008م بمنطقة نهر جاو باي ونهر هوي ببكين – الصين. أُجريت هذه الدراسة لتحديد مواقع لمصادر مياه للحاجة الطارئة أثناء الألعاب الاولمبية والتي جرت في مدينة بكين – الصين في 2008م.

أوضحت المقارنة أن هنالك توافقاً تاماً في نتائج تفسير معلومات (CSAMT) والمعلومات الجيولوجية ومعلومات الآبار بالمنطقة. كما أثبتت الدراسة أن هذه الطريقة لها محاسن متعددة في دراسة نطاقات المياه الجوفية وكذلك يمكن أن تعطي نتائج ودلائل واقعية لمصادر المخزون المائي في الحالات الطارئة.

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