Crustal Electrical Conductivity Structure of Southern Tibet from Magnetotelluric Survey*

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ABSTRACT: Two superwide bands of frequency magnetotelluric (MT) profiles (Yadong-Xuegula, Jilong-Cuoqin) across the Yaluzangbu suture were deployed along the west-east direction, for the research into the electrical conductivity structure in the shallow and deep crust along the west-east and north-south directions in the southern part of Tibet plateau. The main characters of the electrical conductivity structure in this region are: (1) large-scale high resistive bodies exist near the Yaluzangbu suture surface, which extends to the maximum depth of more than 30 km. They are the reflection of the Gangdise granite; (2) small-scale conductive bodies exist in the southern part of the Yaluzangbu suture, and large-scale ones under the suture and in the northern part; (3) conductive bodies widely spread in the crust along the profiles. They are discontinuous, mainly decline to the north and become larger in scale, steeper near the suture, deeper gradually from south to north; (4) under the Yaluzangbu suture, the conductive bodies become larger in scale, more conductive gradually from west to east. These important electrical characters are caused possibly by the India plate subduction to the north. The variation in characters of the large-scale conductive bodies from west to east may be the proof that the plate collision might cause substantial movement along the west-east direction.

KEY WORDS: southern Tibetan plateau, Yaluzangbu suture, magnetotelluric sounding, electrical conductivity structure.

INTRODUCTION

As a typical intercontinent-collision area, Tibetan plateau is a presently popular region noticed by geoscientists all over the world, since it is an ideal and natural lab for the study of the geological evolution of the innerland mountain-creating zone and of the process of the crust-mantle deep dynamics as well as of the interaction between the surface and the crust movement. The study of the Tibetan plateau evolution is important not only in solving some theoretical problems about continental dynamics and global changes in geosciences; but also in exploring the formation conditions, distribution rules of mineral, oil and underground geothermal resources in plateau, as well as the evolutionary principles of climate and environment, to solve the problems that are continuously created in Tibet and other areas in its neighborhood.

The Yaluzangbu suture in the southern part of Tibetan plateau is a crucial section in the colliding

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process between the India plate and the Europe-Asia plate, and the deep structure becomes an emphasis in geological study, which is followed with interest by domestic and foreign researchers.

MT sounding is a method using natural source electromagnetic fields to obtain the information of underground electrical conductivity structure by observing the orthogonal electromagnetic components on the surface. As there are rich frequency portions from high to low in the natural fields, and the electromagnetic fields of different frequency portions have different penetrating depths, MT method could reach the sounding purpose. In the study of crust-mantle structure, MT and seismology are regarded as two mainstay methods, which are complemented and tested with each other, and there are many successful examples of using these two methods simultaneously to solve continental dynamic problems in the world.

Now there are many significant developments in MT data collection and processing. MT24 of EMI Company of America and V2000 of Canadian Phoenix Company are the very representative of modern MT systems. A three-dimensional data collecting network mode replaced the traditional single-station mode, which greatly improved the quality of data and efficiency of fieldwork. As to data processing, Robust reprocessing method replaced the traditional least square method to process time series data, which could suppress the effect of irrelevant noises, and obtain the tensor impedance elements in a high quality (Egbert and Booker, 1986). The technique for the decomposition of tensor impedance can efficiently be used to analyze the underground geoelectrical structure and to afford the rich information of relevant underground structure (Groom and Bailey, 1989; Wannamaker et al., 1984). Two-dimensional inversion method becomes mature and practical, and the features of modern MT sounding are representative of these progresses (Rodi and Mackie, 2001; Smith and Booker 1991).

On the basis of thorough analysis of the former work done in Tibet, the joint research group of China University of Geosciences (Beijing), University of Washington (Seattle) and Geological Survey of Canada have focused on the MT survey in Tibetan plateau in a large scale since 1995, funded largely by the Ministry of Land and Resources (the former of which is Ministry of Geology and Mineral Resources), National Natural Science Foundation of China and Natural Science Foundation of America (Wei et al., 2001; Chen et al., 1996).

One of the scientific goals is to explore the electrical conductivity structure of crust-mantle in the southern Tibetan plateau and the features of electrical conductivity structure in Yaluzangbu suture for the research into the subduction conditions of India plate and the distribution of underground geotherm in order to form the precise geophysical basis for the study of Tibetan plateau uplifting system. To achieve this goal, two MT profiles were laid out crossing Yaluzangbu suture respectively along Yadong-Xuegula in 1995 and Jilong-Cuoqin in 2001. Superwide band MT signals ($250-3 \times 10^{-5}$ Hz) were successfully acquired by using MT24 and LIMS in match. Modern techniques of MT data processing and inversion method were systemically adopted to process the data and the comparatively precise models of the crust-mantle electrical conductivity structure in southern Tibet were obtained.

DATA-COLLECTING IN FIELD

According to the goal, two MT profiles were laid out in Yaluzangbu suture from south to north, crossing Himalaya, Tethyan Himalaya and Gangdise belts. The location of the survey lines is shown in Fig. 1.

The fieldwork was carried out in the summer of 1995 and 2001 respectively. There were 49 MT stations together, 49 of which are broadband stations, 32 are LIMS stations, and the total length of the two profiles is about 490 km. From east to west, the first one is Yadong-Xuegula profile (100-line), which is about 250 km long with 29 stations (including 24 LIMS stations) starting from Yadong of Himalaya in the south, reaching Xuegula of the southern Gang-
dise belt, the second is Jilong-Cuoqin profile (800-line), which is about 240 km long with 20 stations (including 8 LIMS stations) starting from Jilong in the south, crossing Saga and reaching Cuoqin.

For the two profiles, most station spaces are about 10 km, few are 20 to 30 km, and more stations are located in the crucial structure and key areas.

MT24 and LIMS system were jointly used in data collection. Broadband MT systems are MT24 produced by American EMI Company, which has a remote reference function with the frequency from 250 to 0,000 5 Hz. In order to guarantee the quality of broadband data, the recording time in every station is no less than 20 h. LIMS system is the most advanced instrument at present used to record long-period MT signals from 20 to 30000 s, which is produced by Canadian Phoenix Company. In order to obtain the high-quality data, many LIMS systems are often used at the same time, offering reference to each other with the remote reference technique, and the recording time in every station usually lasts for more than three weeks.

DATA-PROCESSING AND INVERSION
Modern techniques are used in processing Tibetan MT data, which could guarantee the reliability of geoelectrical model.

Process of Time Series Data
In order to obtain high-quality tensor impedance element, the Robust evaluation is a common method to reprocess MT time series data at present. Firstly, the bad segments were removed from the time series data recorded by LIMS and MT24, and then the Robust evaluation with long-distance reference is used to process the remaining time series data.

Data Mergence of Two Kinds of Instruments and Correction of Some Distorted Data
Rhoplus theory supplies an important means to test the agreement of apparent resistivity and phase data in one site (Parker and Booker, 1996). Owing to the two different instruments adopted in Tibetan MT data acquisition, the data mergence of apparent resistivity and phase data is normal for most stations. But for some other stations there is a small vertical shift in apparent resistivity curve for the two systems, and the phase curves could be well merged. As to these vertical shifts, the apparent resistivity data recorded by MT24 is corrected according to the data of LIMS collected in line with the Rhoplus theory.

Owing to the noises and weak signals in certain frequency-band domain, the value at some frequency points or at several continuous points are still abnormal although the recording time of the raw time series data is long and the Robust evaluation method was used to reprocess the time series data. These abnormal values are also strictly corrected in line with Rhoplus theory. These corrected data can ensure the absence of false structure information in the inversion results.

Defining Strike of Underground Geological Body
It is also a mature technique to determine the strike of underground bodies by decomposing tensor impedance. Tensor impedance of the merged data of every station is decomposed frequency by frequency. The result shows that most stations, as to the two profiles, have a strike of near east-west direction in most frequency ranges, but some are heavily distorted by local three-dimensional bodies.

Two-Dimensional Inversion
There are many methods for two-dimensional inversion, but the rapid relaxation inversion and the conjugate gradient (CG) inversion are typical. The conjugate gradient inversion method, a very practical method with good effects up to now, is applied to the TM mode inversion of both the apparent resistivity and the phase data, so that the best fitting results of the whole profile can be obtained. Figures 2 and 3 show the resistivity models of the two profiles respectively obtained from the two-dimensional inversion.

ANALYSIS OF INVERSION RESULT
The basic electric structure of each profile shows the following features.

Yadong-Xuegula Profile (100-line)
From Fig. 2, the resistivity model of Yadong-Xuegula profile shows the following 4 main features: (1) There is a large-scale high resistive body in the upper crust on the southern end of the profile, which extends up to about 40 km in depth. This resistive body is representative of crystal body of Himalaya. (2) There is a very thick and highly resistive body (Fig. 2, IV) in the upper crust at the north of Yaluangzhu suture, which extends up to about 20 km underground. (3) There are discontinuous high con-
ductive bodies (Fig. 2, I, II) in the upper crust, which decline to the north. High conductive body II declines to the south on the northern end of the profile. The central depth of conductive body I is about 20 km from the surface and that of conductive body II is about 40 km. (4) The resistivity in depth of the profile becomes relatively high on the southern end.

Jilong-Cuoquin Profile (800-line)

From Fig. 3, the resistivity model of Jilong-Cuoquin profile shows the following main features.

(1) Highly resistive bodies on the surface (Fig. 3, IV) are discontinuous. In the middle part of profile, the resistive body extends very deep to about 30 km, but less than 20 km on both sides of the profile.

(2) The Yaluzangbu River crosses this profile on the surface between stations 25 and 26. The underground large-scale conductive body II is the reflection of the Yaluzangbu suture, with its central depth about 30 km below the surface. There is a small-scale conductive body (Fig. 3, I) in the south, which is about 20 km deep below the surface.

(3) There are commonly conductive bodies (Fig. 3, I, II, III) in the crust from south to north along the profile. These conductive bodies are discontinuous with their scale gradually larger and larger, often declining to the north, their attitude steeper near the suture and their depth deeper. After station 34, the central depth of conductive body III becomes gradually shallower with its attitude slowly inclining to the south.

(4) The resistivity in the low crust on the southern end of the profile is relatively high.

CONCLUSIONS

The combination of the main electrical conductivity features of the two MT profiles crossing southern Tibetan plateau and the regional geological analysis shows the following three conclusions on the crustal electrical conductivity features of Yaluzangbu suture.

(1) The similarities of the electrical conductivity feature along the two profiles widely exist. Very thick and highly resistive blocks representative of Gangdise granite occur in the upper crust near Yaluzangbu suture as well as in the northern part. There is a small-scale conductive body in the south of Yaluzangbu suture, but adjacent to this conductive body, there is a large-scale conductive body, declining to the north, with its attitude steeper near the suture. These important features arise probably from the subduction of India plate towards the north, which presents us with reliable evidence for the study of the collision between India plate and Europe-Asia plate, as well as of the subduction of India plate.

(2) There are still some differences between the two profiles, which mainly focus on neighborhood of Yaluzangbu suture. The scale of conductive bodies becomes larger from west to east, the conductivity becomes better, and the position of the profile moves towards the south compared with that of the Yaluzangbu River. These west-east changes serve as the potential evidence for the substantial west-east movement caused by the plate collision.

(3) The discontinuous and highly conductive bodies commonly in the crust of the southern Tibet, representative indirectly of the features of the underground heat structure, provide some important evidence for the research into the formation principles and distribution of the rich underground geotherm in Tibet.

From the electrical conductivity structure, this research presents new valuable data for some significant geological problems about the subduction of the
India plate, the structure features of the Yaluzangbu suture, as well as the deep crust-mantle structure in Tibetan plateau. All these data will positively influence our recognition of the Tibetan plateau uplifting system.

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