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RESEARCH ARTICLE

Features of faults in the central and northern Tibetan plateau based on results of INDEPTH (III)-MT

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Abstract The features of the faults in the central and northern Tibetan plateau are discussed, based on two super-wide band magnetotelluric (MT) sounding profiles belonging to the INDEPTH (III)-MT project, which were finished between 1998 and 1999: one is from Deqing to Longweicuo (named line 500), the other is from Naqu to Golmud (line 600). This work assists research on the collision and subduction mode between the India and Asia plates. The MT results show that there is a series of deep faults, F1 to F10, in the central and northern Tibetan plateau. Of these faults, F2 is an earlier main fault which leans to the north, and F1 is a later main overriding fault. The Jiali deep fault zone, which has a very complex space structure, is composed of these two faults. F3, F4 and F5 are super-deep faults. They are high-angle faults and lean a little to the south. The main fault zone of the Bangong–Nujiang suture is composed of these three faults. Because of later activity in the structure, several shallow faults formed in the upper crust within the Bangong–Nujiang suture. The Tanggula fault zone is composed of two main faults, F6 and F7, and a series of sub-faults. The shallow segments of the main faults are in high angles and the deep segments of main faults are in low angles. These two faults generally lean to the south and extend into the lower crust. The Jinshajiang suture is composed of the Jinshajiang fault (F8) and the Kekexili fault (F9), and there is a series of sub-faults in the upper crust between these two faults. The Jinshajiang suture is a very wide suture caused by continent-continent collision. The Middle Kunlun fault (F10), which is the main structure of the Kunlun fault zone, is a high angle, super-deep fault. It is the north boundary of the Songpan–Ganzi–Kekexili block. Based on the conductive structure of the profile, the southern part of the Middle Kunlun fault belongs to the Tibetan plateau, but it is not certain whether the northern part of the Middle Kunlun fault belongs to the Tibetan plateau. There are conductive bodies stretching from the crust into the upper mantle below the Bangong–Nujiang suture and Jinshajiang suture. This may suggest heat exchange between the crust and mantle.

Keywords INDEPTH-MT, magnetotelluric sounding, fault features, heat exchange between crust and mantle

1 Introduction

In 1992, the Chinese Academy of Geological Sciences of the Ministry of Geology and Mineral Resources of China (MGMR) started the Project INDEPTH (International Deep Profiling of Tibet and the Himalaya) in cooperation with earth scientists from several universities in the United States. This project aims at imaging the structure of the crust beneath the Tibetan plateau accurately by using deep seismic reflection profiling technology (Zhao and Nelson, 1993).

In order to study the texture, structure, the thermal structure and the state of the deep material of the Tibetan crust from conductivity further, the participants decided to apply magnetotelluric sounding research to INDEPTH (INDEPTH-MT) in 1995. This cooperative research, which has lasted for ten years now, has been obtaining a series of important scientific achievements in the geological field up to the present (Leshou et al., 1996; Wei et al., 1997, 2001). Conductivity research in the central and northern Tibetan plateau crust and upper mantle, which began in 1998, is part of Project INDEPTH-MT. It not only proves that there is a quite special electrical property structure in the Tibetan plateau crust and mantle but also provides new basis for the research of the features of the faults in the central and northern Tibetan plateau.

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2 Field experiment

INDEPTH (III)-MT is part of the third stage of Project INDEPTH. The magnetotelluric component of this project has been a successful joint effort by the China University of Geosciences, the Geological Survey of Canada and the University of Washington (Seattle). The field experiment will be finished in two years.

2.1 The location of survey lines

The sites of the survey lines are shown in Fig. 1. The two lines were finished between 1998 and 1999: one is from Deqing (the western bank of Namucuo) extending NNW to Longweicuo (named line 500), and the other is from Naqu along the Qingzang highway to Golmud (named line 600). It is impossible to site the MT measuring point equidistantly due to severe topography and bad traffic, but it is certain that the point distance is less than 15 km.

The length of the Deqing–Luoweicuo profile (line 500) is about 380 km. There are 58 points along the profile, which contains 26 long-period stations (LIMS station), and the distance between points is about 6–7 km. The Naqu–Golmud profile is about 600 km long. There are 43 points along this profile, approximately 13–14 km apart. In order to site accurately, GPS is applied to locate the geographic coordinates for all points and the error is less than 100 m.

2.2 Instrument

In China, the lowest frequency of the observation signal for MT is merely 0.000 5 Hz. Obviously, the investigation depth is not far enough for research into the very deep crust of the Tibetan plateau. Therefore, we must collect magnetotulleric signals, whose period is up to ten thousand seconds. To study the near surface structure adequately, we also need to collect the frequency that reaches hundreds of Hz. But currently, there is no MT acquisition system with such a wide band. Therefore, the local area network MT system-MT-24NS (EMI Corporation of USA) and the long period intellectualized MT system (LIMS) were applied in the magnetotelluric sounding in Tibet. The collective frequency range for MT-24NS is $3.2 \times 10^2 - 4.6 \times 10^{-4}$ Hz and that for the LIMS is $0.1–3 \times 10^{-5}$ Hz. Using the two instruments and relevant data, we obtained super-wide ($3.2 \times 10^2 - 3 \times 10^{-5}$ Hz) MT data. When collecting field evidence between 1998 and 1999, the authors used two sets of MT-24NS local area network MT system. The collection of super-long period signal was carried out by using the LIMS system, which was provided by America and Canada. 15 LIMSs were used in 1998 and 14 in 1999.

2.3 Observation method and technique

The combination of wide band MT-24NS and long period LIMS was used to collect the super-wide band signal. Although the data of the two sets of system were spliced at the same point, to obtain the super-wide MT data, the observation results of the same frequency must be comparable. Thus, a strict technique is necessary to assure high-quality data. Since the structure direction of Tibet is approximately EW, the *x*-axis point was aligned to the magnetic north and the *y*-axis point to the east when the stations were arranged. In general, the combination of MT-24NS and LIMS at the same point

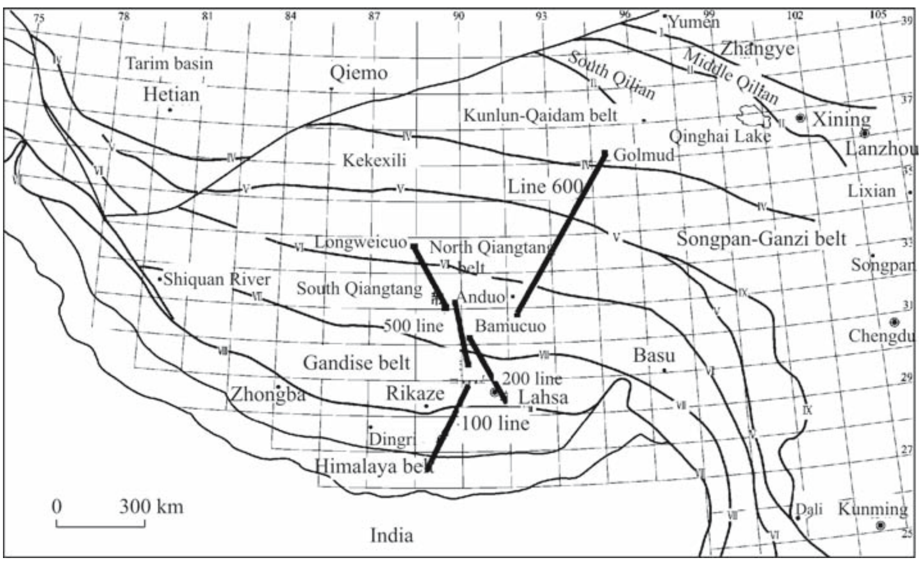

Fig. 1 INDEPTH-II profile position (provided by Zhao Zhidan)

I. North Qilian suture belt; II. Muli–Lajishan suture belt; III. Northern Qaidam suture belt; IV. Maqin suture belt; V. Jinshajiang–Ailaoshan suture belt; VI. Longmucuo–Shuanghu–Lancangjiang suture belt; VII. Bangongcuo–Nujiang suture belt; VIII. the Indus–Brahmaputra suture belt; IX. Ganzi–Litang suture belt used the same electrode system. Thus, the electrode and the polar distance are invariable, as well as the buried location.

When locating the LIMS station, the host must be placed in the center of the survey station. At 3–5 km beside the host there were three magnetic field sensors in the soil buried at a depth of 0.5 m. The x-axis pointed to the magnetic north and y-axis pointed to the east.

The authors used MT-24NS to collect the wide band data at each point, and placed one LIMS survey station at every wide-band MT survey station to collect the super-long period MT data. By applying the Rhoplus analytic method, the wide-band data and the super-long period data were spliced to the super-wide band data (Fig. 2), at a frequency of 320–1/20 000 Hz. In order to assure the quality of data observation, the observational technique of remote reference channel was used in all survey stations.

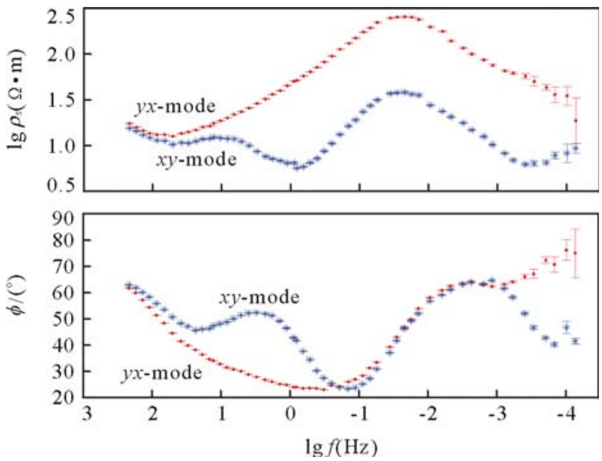

Fig. 2 Super-wide band MT sounding curve of site Tbt-628

3 Data processing and inversion

In order to acquire exact MT sounding and a reliable inversion model, the MT data processing (such as Robust Process, Rhoplus Analysis and Complex Impedance Tensor Decomposition) and many 2-D inversion methods (such as 2-D Rapid Relaxation Inversion-RRI, 2-D Occam Inversion and 2-D Conjugate Gradient Inversion) were applied to deal with magnetotelluric data collected from the central and northern Tibetan plateau. Figure 3 shows the resistivity models for lines 500 and 600 which derived from the 2-D inversion of MT data by the application of the conjugate gradient (Martyn, 2002). In this figure, the x-coordinate represents the profile line and y-coordinate represents inversion depth. The contour is a resistivity contour, the value of resistivity is in Ω·m unit. The red color in the figure indicates high conductivity and the blue indicates high resistivity.

From Fig. 4, we can see that the calculated MT pseudo-section of lines 500 and 600 is compatible with the observed ones, which indicates that the electrical conductivity models

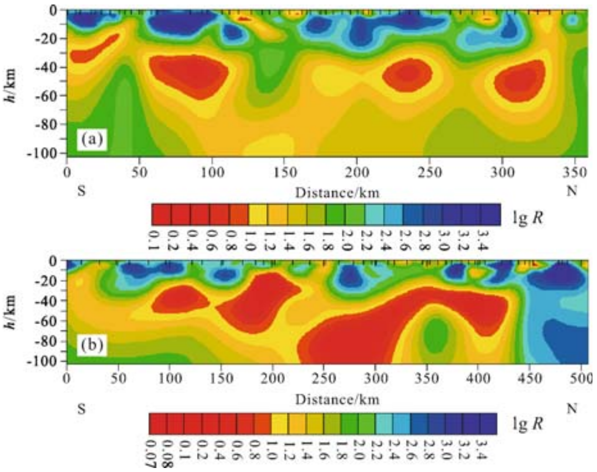

Fig. 3 Line 500 (a) and line 600 (b) resistivity models from 2D MT inversion

can reflect the electrical distribution of the crust. Based on this research, we can conclude that: (1) there are two electrical interfaces that lean to the north underneath 10–40 km and 50–70 km; (2) in the crust and mantle, a high-resistivity feature appear in the north to the Middle Kunlun fault; in the south, the electrical structure is complex, mainly in high resistivity with a large fluctuation and great thickness, accompanied by local low-resistivity anomalous bodies; (3) along the NS, the crust electricity is characterized by hierarchy on the longitude, split on the transverse; (4) the mid-lower crust is made up mainly of a discrete high-conductivity body which shows local good conductivity; (5) a low-resistivity channel that extends into the upper mantle was found in the position of suture; (6) several shallow gradient zones that lean to the south are found in the upper part of the crust and 5–6 of them extend into the middle–lower crust and merge with the transverse electrical gradient zones. Based on these characteristic features, the analysis of the regional tectonic setting and other geophysical data can provide a series of new basis for the research on the features of the faults in the central and northern Tibetan plateau.

4 Features of the faults in the central and northern Tibetan plateau

4.1 Regional tectonic setting

The main tectonic units of the central and northern Tibetan plateau include the Gangdisi–Lhasa block, Qiangtang block, Songpan–Ganzi–Kekexili block and Kunlun–Qaidam block (Research Institute of Geology and Mineral Resources of Chengdu, 1986; Yin, 2001). The Gangdisi–Lhasa block is bounded by the Indus–Brahmaputra on the south and Bangong–Nujiang on the north, adjacent to the Himalaya and Qiangtang blocks. The tectonic line of this block trends east-west and within it block faults are growth. Yanshanian–Himalaya acidic intrusive rocks occur in the southern part.

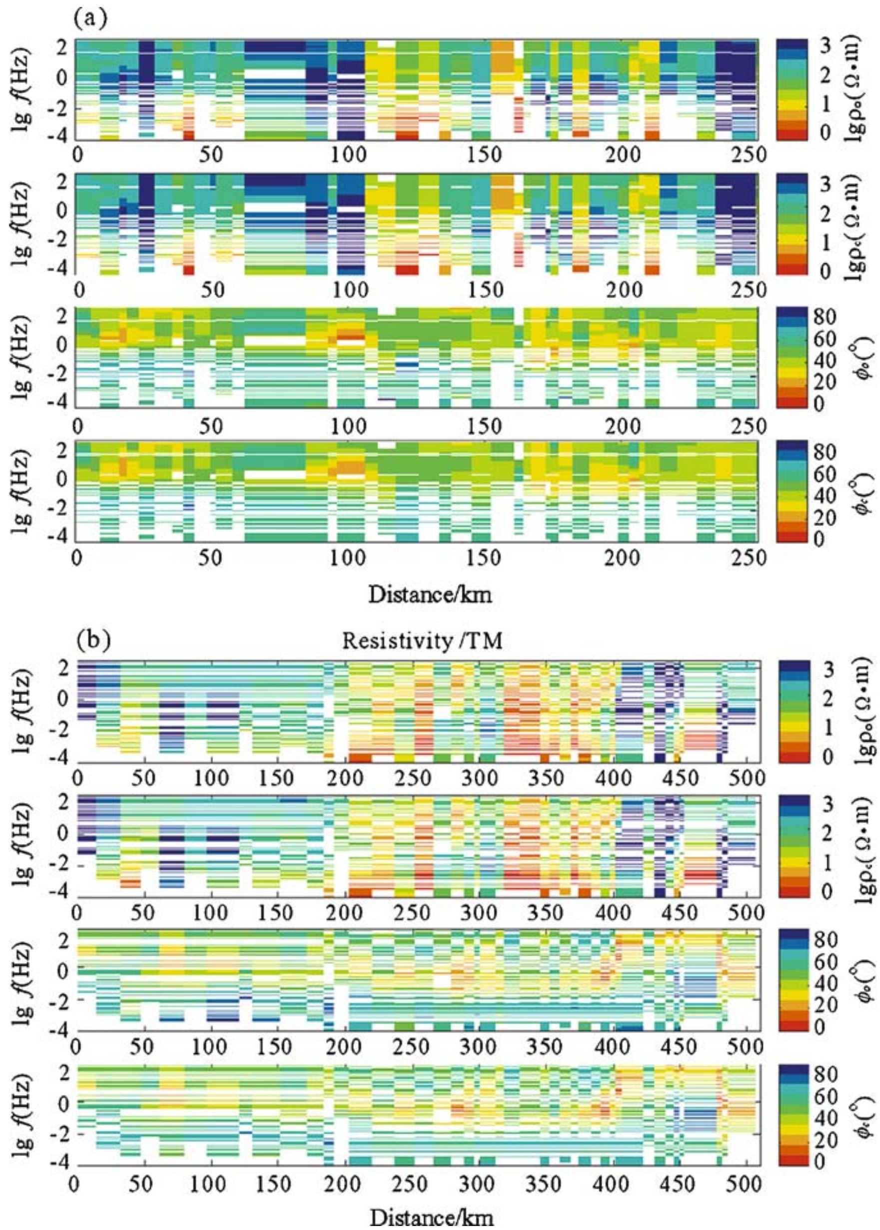

Fig. 4 Observed and calculated MT pseudo-sections of line 500 (a) and line 600 (b)
ρ_o. observed apparent resistivity; ρ_c. calculated apparent resistivity; φ_o. observed impendance phase; φ_c. calculated impendance phase

The Qiangtang terrane is distinguished from the southern Gangdisi–Lhasa block and the northern Songpan–Ganzi–Kekexili block by the Bangong–Nujiang suture and Jinshajiang suture (Fig. 1). The terrane is bounded by the Karakoram–Qiangtang belt of folded strata in the west and Tanggula–Sanjiang belt of folded strata in the southeast. The trend of the tectonic line is east-west, the trending fault is developed and the folding transected by the NE and NW faults is smooth. The Songpan–Ganzi–Kekexili block lies between the East Kunlun–Qaidam block and Qiangtang block. Its western part is a narrow geological tectonic belt, and its western end is truncated by the sinsitral Aerjin fault. At the east of the Aerjin fault, the block is bounded by the Jinshajiang suture in the south, and the Animaqing–Kunlun–Muzitage suture in the north (Fig. 1). The tectonic line of this block trends east-west, to the southeast the direction turns to NNW. The East Kunlun–Qaidam block is bounded by the Animaqing–Kunlun–Muzitage suture in the south, and South Qilian suture in the north.

Line 500 is from Deqing (the middle part of Gangdisi–Lhasa block) in the south. Along the north-west trend, the line crosses the Bange lithobody and the Bangong–Nujiang suture, then goes into the Qiangtang block. The survey is made in the Qiangtang block; astride the southern Qiangtang basin; across Qiangtang anticlinal axis and arriving in Longweicuo, which is in the northern Qiangtang basin. Line

600, which is to the east of line 500, starts from Naqu (the northern Gangdisi–Lhasa block) in the south; crosses the Bangong–Nujiang suture, north-west trending into Anduo (the southern Qiangtang block); over Tanggulashan, through Jinshajiang suture and Kunlun fault; across the Qiangtang block and Songpan–Ganzi–Kekexili block; into the Kunlun–Qaidam block and arriving in Golmud.

Obviously, the two lines control the tectonic area of Deqing–Golmud. This area is important for research into the tectonic pattern in the central and northern Tibetan plateau and discussions on tectonic evolution. Knowledge of the features of the faults can help us understand the collision, the underthrust deep processes and the subsurface coupling effects between India and Asia.

4.2 The main faults in Deqing–Golmud

The distribution of the contour reflects the sectional structure of the crust and upper-mantle in the profiles (Fig. 5). In fact, any substratum has conductivity. Although subsurface conductivity is affected by many factors and shows complex features, the borders of different conductivity bodies are consistent with the lateral zone of the resistivity contour. Thus, the sectional structure of the different conductivity mediums along the profile by the resistivity contour can be inferred. Furthermore, the tectonic pattern can be inferred.

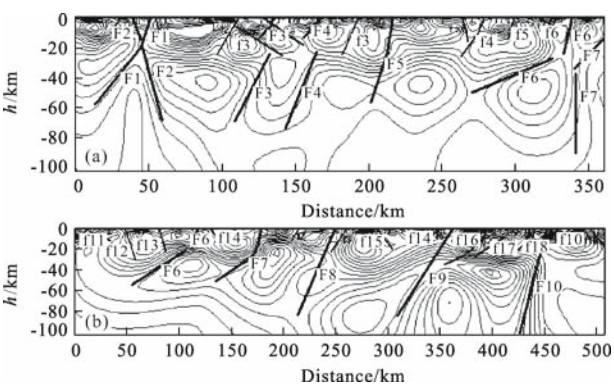

Fig. 5 Resistivity contour of line 500 (a) and line 600 (b)

Based on the material analysis, when the subsurface faults developed and their structure was incompact and crushed, the faults were filled with a large amount of fluids and other low-resistivity media and formed a low-resistivity anomaly zone that has obvious electrical differences from the surrounding strata. On the other hand, the developed faults would destroy the normal stratigraphic order and make abnormal stratigraphic structure change. Because of the respective conductivity characteristics of different strata, the change of the stratigraphic structure would cause a relevant distortion in the geoelectric structure. So there are obvious electrical lateral zones in the place where the faults developed. In general, the extended direction of the resistivity section denotes the inclination of the faults, and the downward depth is transected by the faults. Based on the geophysical interpretation, the faults of the upper crust in Deqing–Golmud lean to the south and the transected depth does not exceed 20 km (Fig. 5). The conductivity of the crust indicates that there are a series of deep faults, F1 to F10, in locations 512, 514, 540, 550, 565, 595 and 599 on line 500, as well as locations 435, 605, 619, 643 and 668 on line 600. These faults are compatible with a series of important deep faults in the central and northern Tibetan plateau. Of these faults, the Jiali deep fault zone is composed of F1 and F2. The main fault zone of Bangong–Nujiang suture is composed of F3, F4 and F5. The Tanggula fault zone is composed of two main faults, F6 and F7. The Jinshajiang suture is composed of Jinshajiang fault (F8) and Kekexili fault (F9). The Middle Kunlun fault (F10) is the main structure of the Kunlun fault zone.

4.2.1 Jiali fault (F1, F2)

The Bengcuo and Gelincuo *en echelon* faults were found in the Karakoram–Jiali fault by the Sino-French research team between 1980 and 1982. They had an obvious mark of dextral movement in the Quaternary and later formed the historical earthquake and paleo-earthquake deformation zone. From these we can deduce that the maximum displacement of hydrographic net is about 5–7.5 km. The right-lateral movement of these *en echelon* faults apparently supports the viewpoint proposed by Tapponnier that the Karakoram–Jiali fault is the southern edge where the Tibetan plateau is extruded eastward (Tapponnier et al., 1981a, b). However, there are only a few research reports published on the spatial distribution of the Karakoram–Jiali fault and the moving characteristics of the Quaternary (Shen et al., 2001).

The crust and mantle electricity model of line 500 indicates that the characteristics of the sectional electricity structure at the place where the Jiali fault passes through are complicated. Viewing from the resistivity contour, there are two suits crossing the gradient zone (F1, F2), which extends into the lower crust between site 510 and site 516. The two large high-conductivity bodies exist at their sides. The high-conductivity body which slopes off toward the south thrusts to the north (Figs. 3a, 5a). It apparently shows that F2 is an earlier main fault that leans to the north, and F1 is a later main overriding fault, which is the result of the subduction of the Indian continent. The Jiali deep fault zone, which has a very complex space structure, is composed of these two faults.

4.2.2 Bangong–Nujiang suture (F3-F5)

The Bangong–Nujiang suture lies in the middle of Tibet, and is the boundary of the Qiangtang and Gangdisi–Lhasa blocks. This suture is one of the three main sutures of the Tibetan plateau, and has become the most important region for research on the evolution of the plateau.

The research of Chen (1983) shows that the sediment and paleontology of the Upper Devonian, Carboniferous, Permian and Triassic have different characteristics in the southern part of the suture. However, the features of the Upper Jurassic and Tertiary are the same (Research Institute of Geology and Mineral Resources of Chengdu, 1986). This indicates that the Bangong–Nujiang suture formed in the Upper Jurassic, so there are extensive layers from the upper Jurassic to the Tertiary in the suture. Therefore, the position of the Bangong–Nujiang suture belt is difficult to locate. As such, it is more difficult to discuss the deep structure of the suture.

Few geophysical methods have been applied in research on the spatial structure of the Bangong–Nujiang suture belt in the Tibetan plateau. In 1988, it was found that the Yadong–Golmud rift along the Qingzang Road transects the Bangong–Nujiang suture (Wu et al., 1989). But because of the limitation of the conditions, little information was available on the spatial structure of the suture. Another important area of research is the synthetic geophysical detection, which was conducted in Kuala–Sangehu of Ali in 1994 by the Institute of Geology and Geophysics of Chinese Academy of Sciences (Pan and Kong, 1998). The research indicates that the position of the Bangong–Nujiang suture in the detection profile is around Gaize. The velocity structure data of the shallow layer reflect that the suture is a wide thrust that leans a little to the south, the basal slip is about 6–8 km. A Cenozoic sedimentary basin, 80 km wide and 11 km deep formed in the southern suture. The basin is bounded by the Bangong–Nujiang suture in the north, a buried-overriding fault which deepens to basement (40 km north of Dawacuo) in the south.

Based on the P_m reflection impedence of the Bangong–Nujiang suture, the Moho around the suture appears to have suddenly slipped and uplifted 10 km in the north. Some staircases were found in the process of uplift. The Moho in the north leaned to the north, through the Bangong–Nujiang suture and inserted into the Qiangtang block. The latest seismic detection is the refraction/wide-angle reflection processed by Project INDEPTH-III along the Deqing–Longweicuo Section (Zhao et al., 2001). This profile is 450 km east of Cuole–Sangehu and is approximately the same as MT line 500.

Actually, whatever the detection results of Cuole–Sangehu or Deqing–Longweicuo seismic data are, all prove that the Bangong–Nujiang suture is made of super-deep faults. The Moho of both sides slipped, the crust thickness became thinner and thinner from south to north. But we have to realize that the existing refraction/wide-angle reflection results cannot make the knowledge of spatial structure of Bangong–Nujiang consistent. Thus, the electricity model of line 500 has obvious scientific meanings. It can provide a new foundation for further research into the Bangong–Nujiang spatial suture.

There are 7 suits of transverse electricity lateral zones in the crust between 530–565 (Figs. 3a, 5a). Their spatial positions are compatible with the location of the Bangong–Nujiang suture confirmed by geological data. These zones should be the sectional trace of suture faults. Based on the extended depth, these zones can be divided into deep faults which transected the upper crust, and super-deep faults which transected the whole crust (F3, F4, F5). The main fault zone of the Bangong–Nujiang suture is composed of these three faults, which lean a little to south. Of these faults, F3 and F4 have obvious southward slip traces in the upper crust (Fig. 5a), which indicates that the effect on Bangong–Nujiang by the upper structural movement is strong and the faults (F3, F4, F9, F10) that developed in the upper crust may have formed later.

In the middle-lower crust, the medium between F3 and F4 shows secondary conductivity and stylolite. It leans a little to south and the bodies of its two sides are smooth, large and highly conductive. The differences between their tops are relatively small compared with the differences between their bottoms. The maximum bottom depth is about 74 km for a high-conductivity body in the southern suture as well as 65 km for a high-conductivity body in the north.

Through the stylolitic conductive body in the upper mantle along the main faults of the suture, we can know that the electric resistivity decreases and there is a low-resistivity channel extending into the upper mantle. It may prove that the Bangong–Nujiang suture is a place where the heat was transmitted between the crust and mantle.

4.2.3 Tanggula fault (F6, F7)

The Tanggula fault lies in the middle-south of the Qiangtang block. It is composed of the southern (F6) and northern (F7) Tanggula faults. Few researches have been done on this fault except the Yadong–Golmud geotraverse finished in 1988 that runs through it. In the Tanggula region, the electricity interface is vertical with low, symmetrical gravity. So it can be inferred that there exists a developed deep fault, i.e., the Tanggula fault (Guo et al., 1990; Meng et al., 1990). Although the research of the Yadong–Golmud geotraverse proved the existence of the Tanggula fault, the fault structure is not yet well understood.

Both line 500 and line 600 run through Tanggula fault, so the 2D conductivity models from the two profiles reflect the conductivity structure of deep faults in Tanggula. Between points 580–599 of line 500 (the inferred position of Tanggula fault), the middle-upper crust has a conductivity of less than $10\ \Omega\cdot m$, the top depth of the high-conductive body which extends into the shallow crust is about 35 km and the bottom is 66 km deep and leans to south. There are low-resistivity channels and many electricity lateral zones between 588–599. The top of the lateral zone around 588 leans a little to the north and the bottom leans to south; while the lateral zone near 595 grows sharply steep (Figs. 3a, 5a). This may infer that the Tanggula fault of line 500 may lean to south, and the transected depth extends into the lower crust. Between points 425–455 of line 600 (Figs. 3b, 5b), the middle-upper crust also has a conductivity of less than $10\ \Omega\cdot m$, but the high-conductive body is smaller than that of line 500, with the top depth being about 25 km and the bottom depth 55 km; it is horizontal and leans a little to the south. Similarly, between 435–440, there also exists a suit of middle-lower crust high conductivity bodies and low-resistivity channels where resistivity is higher than that of line 500. The locations of the conductivity lateral zone of 425, 435 and 450 are consistent with the position of the Tanggula fault. They lean to the north, with a steep top and smooth bottom, bearing the similar characteristics to Tanggula shown by line 500.

The Tanggula fault zone is composed of two main faults, F6 and F7, and a series of sub-faults. The shallow segments of the main faults lean at a high angle while the deep segments lean at a low angle. These two faults lean to the south generally and extend into the lower crust. There are big high-conductivity bodies in the middle-lower crust between F6 and F7; the bodies are like elliptic columns, extending north-west, plunging and growing larger from east to west.

4.2.4 Jinshajiang suture (F8, F9)

The Jinshajiang suture is the boundary of the Qiangtang block and Kekexili block. The suture is also one of the most important faults in the Tibetan plateau. This fault had been active since the Caledonian cycle. The magma activity of the eastern fault mostly occurred in the Indo-Chinese epoch. For the western fault, the magma activity mainly took place in the Indo-Chinese and Variscan epochs. Ophiolites were found in Derong, Deqin and Xiewu, forming tectonic contact with the surrounding rock. The surrounding rocks are clastic rocks and pelite of the Paleozoic and Triassic (Research Institute of Geology and Mineral Resources of Chengdu, 1986). These data reflect that the Jinshajiang fault is a super-deep fault to a certain extent. From 1996, the seismic detection results of Tanggula Gap–Golmud and Yushu–Gonghe were collected by the cooperative program between the Chinese Academy of Geological Sciences and French Academy of Universe Science carried out in North Tibet. They showed that the Jinshajiang suture is a deep fault that extends into the upper mantle and leans to south (Xu et al., 2001).

In the summer of 1999, 2D electricity models (Fig. 3b, 5b) for the crust and mantle of Naqu–Golmud (line 600) were obtained. From the position of the profile, line 600 is consistent with the Yadong–Golmud geotranverse and the seismic detection profile of Tanggula Gap–Golmud. There are seven transverse electricity lateral zones in the upper crust between Wenquan and Wudaoliang (the middle of line 600) (Fig. 5b). They were found in the position of the faults. The majority of them are shallow faults (<10 km) leaning to the south formed in the upper crust (F2–F5). The location of F8 between 619–622 (near Tuotuohe) is compatible with the Jinshajiang fault. Its electricity structure shows a narrow top and wide bottom, it leans to the south and extends into the lower crust, which is similar to the result of seismic tomography. The electricity lateral zone of 643 (F9) is compatible with the Kekexili fault. The upper crust of this fault manifests a wide and loose textured low resistivity zone. The zone leans to the south, extends into the middle-upper crust and transects the high-conductivity layer, showing the sharp change on the transverse in the lower crust.

Based on the deep characteristics of line 600 electricity model, the Jinshajiang suture is composed of the Jinshajiang fault (F8) and Kekexili fault (F9), and there is a series of sub-faults in the upper crust between these two faults. The Jinshajiang suture is a very wide suture formed by continent-continent collision.

Judging from the general characteristics of the conductivity structure, the upper crust between F8 and F9 is thick where there exist large high-conductivity bodies extending into the upper mantle in the middle-lower crust. The sectional shape is mushroom-like and is similar to the crust and mantle high-conductivity bodies along the Bangong–Nujiang suture. However, their electrical conductivity is different. Comparing the electricity models of line 500 and line 600 (Fig. 3), we can see that the conductivity of the Jinshajiang suture is higher than that of Bangong–Nujiang suture. But we have to pay attention to the similarity of their sectional structure. The temperature is the main factor affecting the research into the crust and mantle electricity structure. Thus, the conductivity of the underground medium can reflect changes in geothermal structure. The spatial structure of high conductivity bodies in the crust and mantle may be the trace of heat transmission between crust and mantle. The comparison and analysis of the typical electrical features of the Bangong–Nujiang and Jinshajiang sutures can help us further understand the evolution of the Tibetan plateau.

4.2.5 Kunlunshan fault (F10)

The Kunlunshan fault is the boundary of the Songpan–Ganzi–Kekexili block and Kunlun–Qaidam block. It is composed of the South Kunlun fault, Middle Kunlun fault and North Kunlun fault (Research Institute of Geology and Mineral Resources of Chengdu, 1986). Its conductivity structure has obvious abnormal characteristics.

In the north of line 600 (Fig. 5b), there are 6 suits of conductive lateral zones (f6–f10, F10) that lean steeply southward in the upper crust among 653–674 (Kunlunshan). Of all these zones, the depth extent of f6–f10 is less than 15 km. There are low resistivity pathways between f6 and f7, f8 and F10. The positions of f6 and f7 on the profile are compatible with the South Kunlun fault and the positions of f8–f10 are consistent with a series of sub-faults. The fault located in 668 (F10), which crosses the upper crust and extends into the upper mantle, is a super-deep fault. The conductivity of the northern side is different from that of the southern side of the fault in that the southern side is highly conductive and the northern side has low conductivity. This is the characteristic of the continental border. It apparently indicates that the south of the Middle Kunlun fault belongs to the Tibetan plateau, but it is not certain whether the north of the Middle Kunlun fault belongs to the Tibetan plateau.

The Middle Kunlun fault (F10), as the main structure of the Kunlun fault zone, is a high-angle, super-deep fault. It is the north boundary of the Songpan–Ganzi–Kekexili block.

5 Conclusions

Tibet has been studied by many geoscientists for several decades and many evolution models have been proposed for the collision and subduction between India and Asia. The lack of exact and reliable evidence led to the differences of opinion about the structure of the crust and upper mantle of the Tibetan plateau. The research of Project INDEPTH (III)-MT provides new evidence for the evolution of collision and subduction activity between India and Asia from the perspective of conductivity.

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