Crust and Upper Mantle Electrical Resistivity Structure in the Panxi Region of the Eastern Tibetan Plateau and Its Significance

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Abstract: The Panxi region is located in the frontal zone of positive squeezing subduction and side squeezing shearing between the Indian plate and the Eurasian plate. The long-period magnetotelluric (LMT) and broadband magnetotelluric (MT) techniques are both used to study the deep electrical conductivity structure in this region; magnetic and gravity surveys are also performed along the profile. According to the 2-D resistivity model along the Yanyuan-Yongshan profile, a high-conductivity layer (HCL) exists widely in the crust, and a high-resistivity block (HRB) exists widely in the upper mantle in general, as seen by the fact that a large HCL exists from the western Jinpingshan tectonic zone to the eastern Mabian tectonic zone in the crust, while the HRB found in the Panxi tectonic zone is of abnormally high resistivity in that background compared to both sides of Panxi tectonic zone. In addition, the gravity and magnetic field anomalies are of high value. Combined with geological data, the results indicate that there probably exists basic or ultrabasic rock with a large thickness in the lithosphere in the Panxi axial region, which indicates that fracture activity once occurred in the lithosphere. As a result, we can infer that the high-resistivity zone in the Panxi lithosphere is the eruption channel for Permian Emeishan basalt and the accumulation channel for basic and ultrabasic rock. The seismic sources along the profile are counted according to seismic record data. The results indicate that the most violent earthquake sources are located at the binding site of the HRB and the HCL, where the tectonic activity zone is generally acknowledged to be; however, the earthquakes occurring in the HCL are not so violent, which reflects the fact that the HCL is a plastic layer, and the fracture threshold of a plastic layer is low generally, making high stress difficult to accumulate but easy to release in the layer. As a result, a higher number of smaller earthquakes occurred in the HCL at Daliangshan tectonic zone, and violent earthquakes occurred at the binding site of high- and low-resistivity blocks at the Panxi tectonic zone.

Key words: Earthquake, deep electrical resistivity structure, long-peroid magnetotelluric, Emeishan basalt, Panxi region

1 Introduction

The Panxi tectonic zone, located in the eastern margin of the Tibetan Plateau and the middle-eastern region of the Hengduan Mountains, is one of the boundary structures of the Sichan-Yunan block and the Yangtze block. The Panxi tectonic zone is situated in the frontal zone of the front compressional subduction and the side compressional shearing from the Indian Plate to the Eurasian Plate. The Anninghe, Zemuhe, and Xiaojiang fault zones are important active faults and strong earthquake zones of the Panxi and its adjacent areas. Since the 1970s, the artificial source, gravity and magnetic measurements, magnetotelluric

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studies, and other deep geophysical explorations have been performed in this district. Among these surveys, the magnetotelluric profile of Ninglang-Luzhou and Lijiang-Qiaojia indicates the one-dimensional electrical resistivity structure of the Panxi district (Kong et al., 1987). However, the detection results present insufficient resolution for the regional abnormal structure and deep exploration. In the 2000s, a MT method with a two-dimensional inversion study was conducted in the North and South areas of the Panxi region (Sun et al., 2003; Zhao et al., 2008; Wang et al., 2009, 2013a, 2013b, 2014), preliminarily obtaining the electrical resistivity structure model of this region.

With the continuous improvement of magnetotelluric instrumentation and data processing methods, a more in-depth study of the upper mantle electrical resistivity structures of the crust and lithosphere must be conducted, as well as a study of their relationships with the seismic activity in the Panxi and its adjacent areas. In addition, many scholars have proved the existence of the Emeishan mantle plume through geochemical data and extensively exposed the Emeishan large igneous provinces (Wang et al., 1993; Song et al., 2002; Wang et al., 2004; Xu et al., 2004; Xia et al., 2012); however, current studies lack evidence for deep geophysical data, especially the argument of the relationships between the deep electrical resistivity structure and the mantle plume. Therefore, it will be of great significance to study the deep electrical resistivity structure and the mantle plume as well as the relationship between the active blocks and to explore the deep driven mechanism of the active block movement and its controlling effects on strong earthquakes. Such studies would provide a relevant basis for the prediction of strong earthquakes and the activity rules of seismic zones.

2 Geological Background

The Panxi region is an important part of the terraced boundary belt in western and eastern China. The Panxi region is also a new area of intense tectonic movement. This region has great difference in altitude, from an average altitude of 4500–5000 m in the Western Tibet Plateau and 3000–3500 m in the Panxi Plateau down to 600 m in the Sichuan Basin (Zhang et al., 2004). The crustal thickness of the Panxi region is 20–30 km more than those of the Sichuan Basin and the South China block. The eastern boundary of the Sichuan-Yunan block is one of giant active fault zones, with most frequent strong earthquakes in the Chinese mainland (Chen et al., 2008) during the 150 years before 1973, including the 10 large earthquakes of over Ms 7.0 that occurred in the fault zone along the Xianshuihe to Anninghe and Zemuhe (Zhang et al., 2004).

Zhao et al. (2008) studied the electrical resistivity structure through the arrangement of the Shimian-Leshan magnetotelluric profile, they indicated that the low-resistivity layer in the approximately 10- to 15-km-thick crust in the eastern margin of Tibet Plateau is a “pipe-flowing” layer formed under the squeezing action of the eastern Tibet Plateau to the southeast edge. Bai et al. (2010) studied this pipe-flowing layer by arranging four magnetotelluric profiles; they found that there are two high-conductivity channel flows with a total length of over 800 km that extend horizontally from the Tibetan Plateau to southwest China.

Although several magnetotelluric profiles have been completed in studies of the Panxi tectonic zone and its adjacent areas, most of these studies are just on the crustal level due to the limitations of the instrument frequency response. Consequently, the long period magnetotelluric method can be used for the study of deep electrical resistivity structure of the Panxi region, so as to explore the relationship between the electrical resistivity structure and its geological significance.

3 Field Experiments

3.1 Measuring line

In 2010 and 2012, we laid a magnetotelluric profile with a total length of approximately 240 km along the Yanyuan-Yongshan. The profile begins with the Jinpingshan tectonic zone, extends across the Panxi and Daliang tectonic zone, and ends at the Mabian tectonic zone to explore the deep electrical resistivity structure in the Panxi region and to investigate the relationship between the electrical resistivity structure and the strong earthquakes in this region.

3.2 Data acquisition

Fifty-three broadband mangetotelluric sites were arranged along the profile, with an average site pitch of approximately 5 km, and 14 long-period magnetotelluric sites were arranged along the profile with a site pitch of 20 km (Fig. 1). The MT observation instrument used was the V8 multifunctional electrical instrument produced by Canadian Phoenix Company. The LMT instrument used to collect data at the low-frequency range was the LEMI-417/M produced by Ukrian. The observation was made at the same site by using two sets of instruments to collect two orthogonal horizontal electric-field components, namely, Ex and Ey, as well as three magnetic-field components, i.e., Hx, Hy and Hz. Next, the high- and low-frequency data from two sets of instruments are combined to obtain magnetotelluric data. These two sets of instruments have an effective frequency coverage over the range of 320 Hz-approximately 20000 seconds, and an

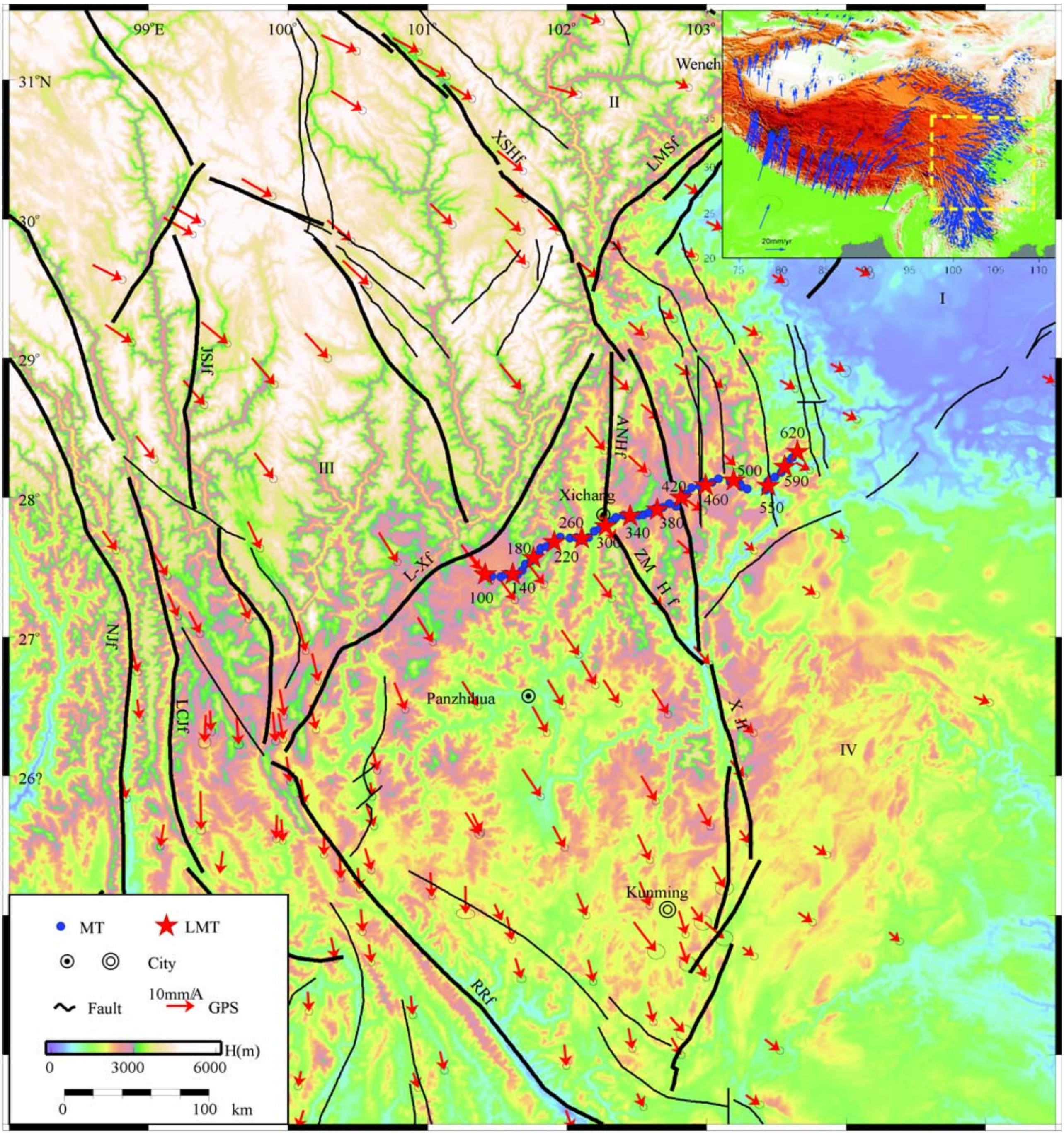

Fig. 1. Map of the eastern Tibetan Plateau and the locations of the LMT and MT sounding sites. a, Site 480ss; b, Site 480R470.
The faults taken from Deng et al. (2003), and reference 1:500,000 geological map database of the People's Republic of China, the GPS data from Zhang et al. (2004). NJf: Nujiang fault, LCJf: Lancangjiang fault,JSJf: Jinshajiang fault, RRf: Red River fault, XSHf: Xianshuihe fault, ANHf: Anninghe fault, ZMHf:Zemuhe fault, XJf: Xiaojiang fault, LMSf: Longmenshan fault, LQSf: Longquanshan fault; 140:LMT site; I: Sichuan Basian; II: Songpan-Ganze block; III: Sichuan-Yunnan block; IV: Yangtze block.

effective detection depth up to 150km or more.

3.3 Data processing

In the data processing, higher quality observation data of each site are obtained by using robust technology (Egbert et al., 1986). We used the SSMT2000 and MT-editor software to obtain the apparent resistivity and phase curves for the MT data, and PRC-MTMV software was used to obtain the curves in the LMT data processing (Varentsov et al., 2003). Furthermore, a remote reference processing was implemented at some sites (Gamble et al., 1979); the results indicate that data processing can eliminate the non-related noise at those sites, which can adequately recover some of the outliers (Fig. 2).After processing the MT and LMT data based on above methods, we combine the impedance tensor data of two different frequency bands with the Rhoplus algorithm (Parker and Booker, 1996) to obtain the impedance tensor of the whole frequency band. Next, we use the G-B decomposition method (Groom and Bailey, 1989) to obtain the electrical strike in the study region (Fig. 3), which is consistent with the regional geological structure trend. Subsequently, we rotated the impedance tensor of each site to the strike, thereby obtaining the apparent resistivity and impedance phase at each site. Fig.4 shows the result of combining the apparent resistivity and the impedance phase of the MT and the LMT. The overlap part of the two frequency bands is found to be joined well. It's find that some breakdown points appear on the apparent resistivity and impedance phase curves at the low-frequency portion of the MT data (greater than 512s), from a hardware perspective, the fluxgate magnetometer is able to compensate for the insufficient response to the magnetic field signal from induction coil, resulting in high-quality data curves at this frequency range (Ye et al., 2010); these high-quality data are the reason for the choice of LEMI-417/M (collect the lower frequency data) to study the electrical resistivity structure in this region.

The scatter diagram of apparent resistivity and impedance phase at each site can roughly reflect the electrical character underground. All the LMT site apparent resistivity and phase scatter diagrams along the profile are showed (Fig. 5), site 100 to 220 are located in Jinpingshan tectonic zone, the apparent resistivity is high value at high frequency and low value at low frequency, which imply there high resistivity at surface and low

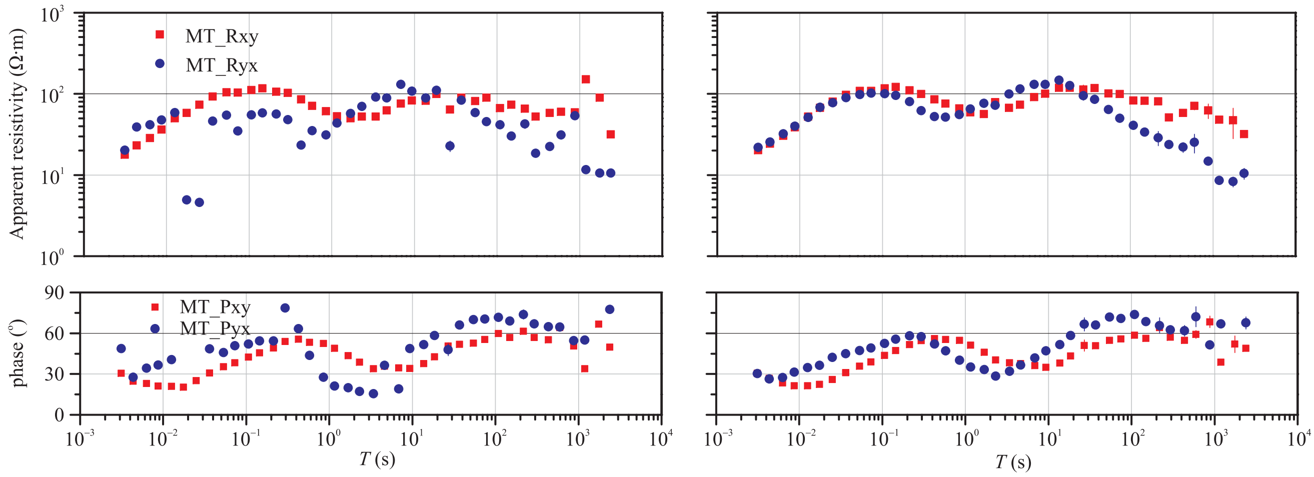

Fig. 2. Comparison of the results with and without remote reference technology.
The left column shows the single site process of site 480, the right column shows the site 480 referenced by site 470. Note that in the range of 0.9s to 0.5s, two outliers appear at the single site process; however, these outliers can be recovered by using remote reference technology, and the apparent resistivity/impedance phase lines are smoother in the overall view.

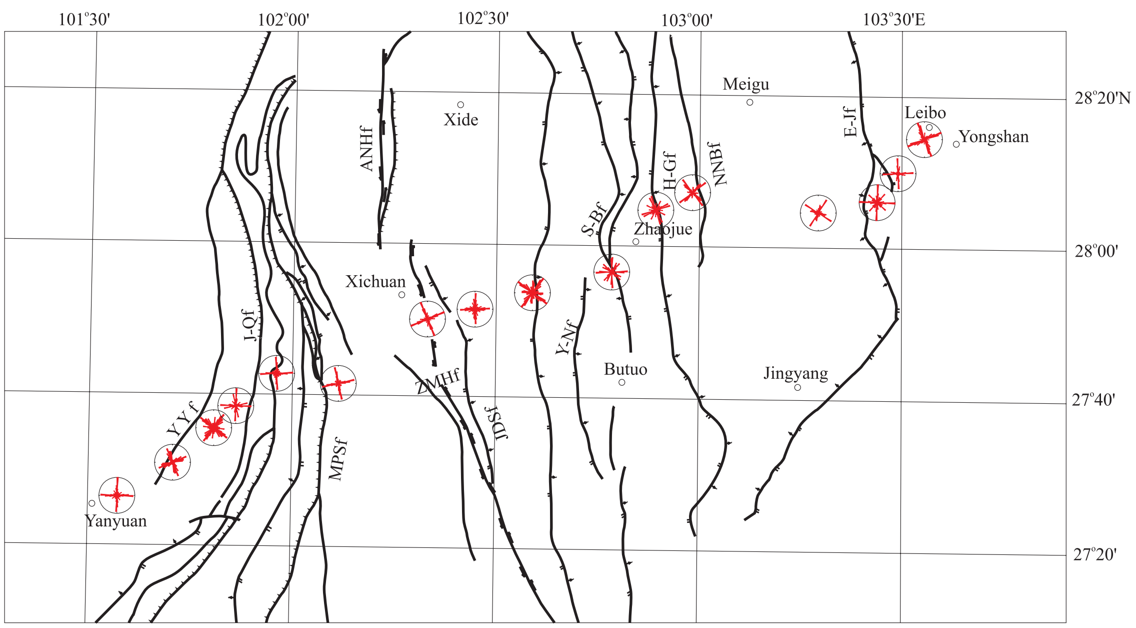

Fig. 3. The rose diagram showing the electrical strike by G-B decomposition.

resistivity at depth. The apparent resistivity value up to ten thousand is found at site 260 to 300, which located in Panxi tectonic zone, however, the site 340 to site 550 show high-low-high from high to low frequency on apparent resistivity, which located in Daliangshan tectonic zone, the Mabian tectonic zone including site 590 and 620 is low value at high frequency and changed high at low frequency. The value of two-dimensional skewness along the profile is less than 0.4 at most frequencies and sites (Fig. 6), which means 2D inversion is suited to get the electrical character along the profile.

We calculated the RMS and Roughness at different values of regularization factor (tau) with L-curve method (Hansen, 1992), it shows that a knee point was found when tau equal 30(Fig. 7), so we chose the final model in case tau equal 30. It's recognized that using TM mode to inversion is more reasonable than TE mode or TE+TM mode, and TM mode data should be prior used to inversion for field data (Cai and Chen, 2010), so 2D inversions were conducted with TM modes using the NLCG algorithm (Rodi and Mackie, 2001). The initial model is homogeneous half space, and the resistivity value is 100 ohm·meters.

In order to get the fine structure in crust, we used all 53 MT sites to inversion. Due to the insufficient response to the magnetic field signal on low frequency from induction coil, we study the upper mantle electrical resistivity structure by using only 14 LMT sites, and the winglink v2.20 software was used to inversion. Fig.8 shows the fitness of the calculated and the measured responses on all MT sites, overall, the 2D responses match the measured data well, except for the phase curve at some sites, with an average misfit error of approximately 2.43, and the RMS of LMT data is about 1.64, the final 2D crust resistivity model presented in Fig. 9b and upper mantle model presented in Fig. 9c respectively.

4 Electrical Resistivity Structure

From the 2-D resistivity model, we can see that, in general, the high-conductivity layer (HCL) exists over wide regions in the crust and the high-resistivity block (HRB) exists over wide regions in the upper mantle, based on the fact that a large HCL exists from the western Jinpingshan tectonic zone to the eastern Mabian tectonic zone in the crust, while the HRB observed in the Panxi tectonic zone is abnormally high in that background. The study profile crossed four tectonic zones, with each zone exhibiting a different electrical character; we will introduce the tectonic zones individually from west to east.

4.1Jinpingshan tectonic zone

The Jinpingshan tectonic zone is located to the west of the Jinhe-Qinghe fault. Overall, three resistivity layers are found in this region: a high-resistivity layer in the shallow crust, a low-resistivity layer in middle and lower crust, and a high-resistivity layer in the upper mantle. In addition, the Jinhe-Qinghe fault zone extends westward and disappears in this low-resistivity layer. Permian, Triassic and Quaternary, and Cenozoic magmatic rocks are observed at the surface in this region.

4.2 Panxi tectonic zone

The Panxi tectonic zone is sandwiched between the Jinpingshan tectonic zone and the Daliangshan tectonic zone, which is greatly impacted by the Anninghe-Zemuhe-Xiaojiang fault. There are several fault zones on the surface in this region, including the Mopanshan, Anninghe, and Zemuhe faults. The location of the epicentre of the Xichang Puge Ms 7.5 major earthquake in 1850 is between the Anninghe and Zemuhe strike-slip faults (Tang and Wei, 1993). The upper crust of the Panxi tectonic zone has a very thick high-resistivity block above

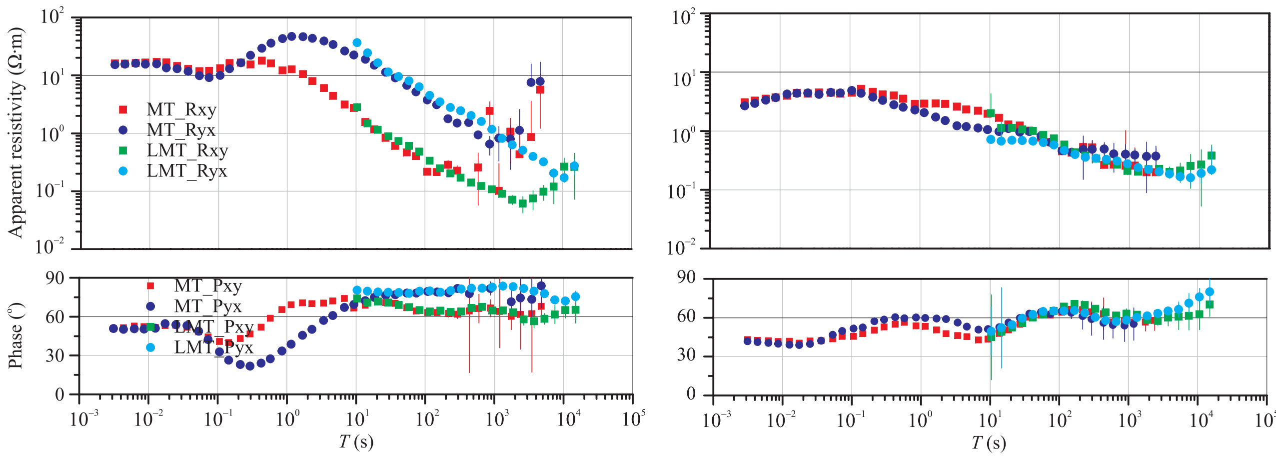

Fig. 4. Result of the combination of MT and LMT apparent resistivity and impedance phase.
The overlap sections of the MT and the LMT are found to fit well, and the lower frequency parts of the MT (>512s) have a greater breakdown point or error bars; however, the LMT can provide the exact value at the same frequency.

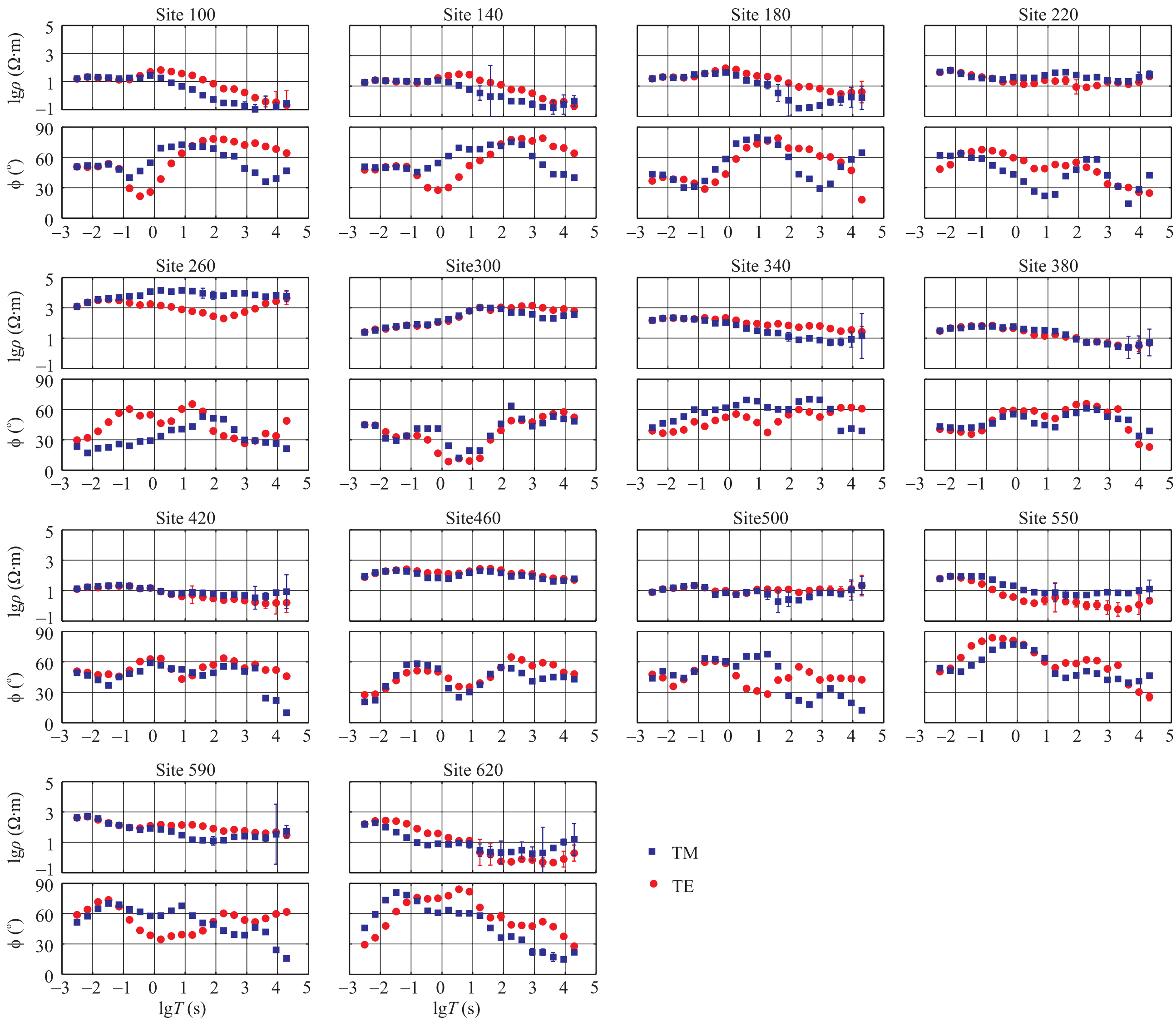

Fig. 5. Scatter diagrams of all LMT sites along the profile.
The top row shows the apparent resistivity and the bottom row shows the impedance phase at each site.

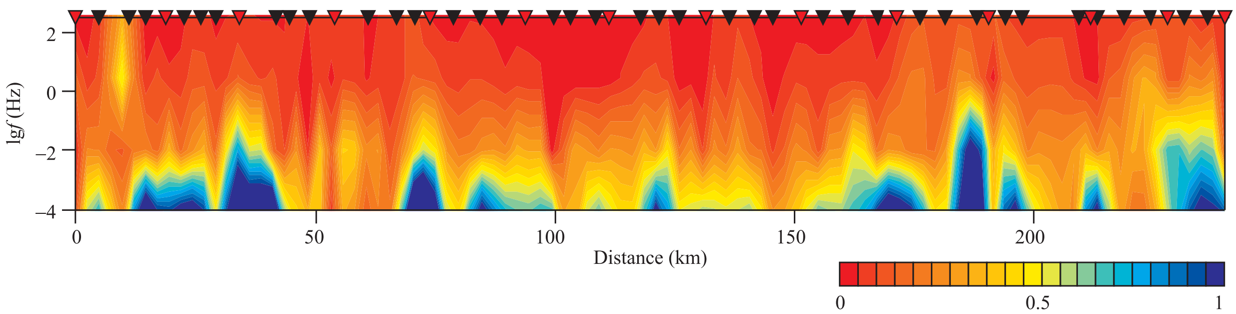

Fig. 6. Two-dimensional skewness of impedance tensor along the profile.

the altitude of approximately 30km, and the resistivity can be up to thousands of ohm·meters. This high-resistivity block extends from the surface to the upper crust in depth and laterally from the Jinhe-Qinghe fault eastward to Zemehe fault; we infer that a blind fault (LDSZ1and LDSZ2) exists on both sides of the block (Fig. 9c). Based on the surface geological research, this block may reflect the basic, ultra basic igneous complex and deep metamorphic granulite (Xu et al., 2007). Below the high-resistivity block, there is an HCL of subhorizontal crust-mantle transition zone at a depth of approximately 45 km to55 km, and under the HCL, a large HRB area is present.

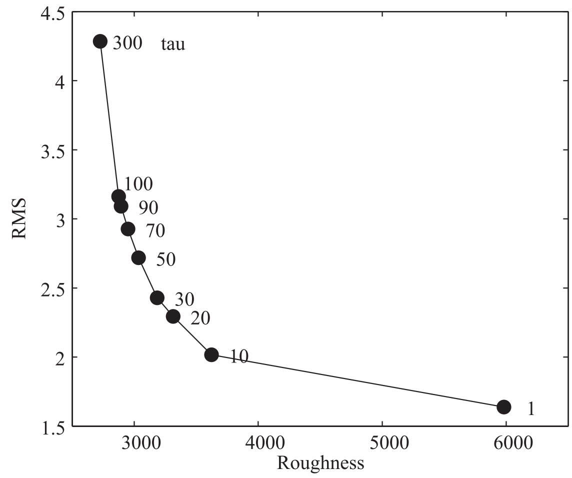

Fig. 7. L-curve chart of RMS and Roughness when tau is changed.

A P-wave of three-dimensional velocity structure indicates that there is a wide range of low-velocity zones at the top of the upper mantle of depth of approximately 50km, and a high-velocity body at the depths of above 30 km and under 60 km (Wang, 2003). The results of the adjacent magnetotelluric sounding profiles, including Ninglang-Luzhou (Li and Jin, 1987), Lijiang-Qiaojia (Kong et al., 1987), and Mianning-Yibin (Wan et al., 2010) are similar to our result. This region mainly consists of Precambrian metamorphic rocks and magmatic rocks.

4.3 Daliangshan tectonic zone

The surface faults, which are the Jiaodingshan, Yuexi-Ningnan, Shimian-Butuo, Hanyuan-Ganluo, Niuniuba faults, are indicative of the complex geological structure of the Daliangshan tectonic zone. With an obvious overall layering of the electrical resistivity structure of Daliangshan lithosphere high-conductivity zone, the middle and upper crust consists of high-resistivity blocks of different sizes and shapes. There is a large range of the low-resistivity body under the high-resistivity blocks, connecting the HCL from the lower crust of the western Panxi tectonic zone, and the low-resistivity body exhibits a subsidence trend in the upper mantle. Under the low-resistivity body, there appears a high-resistivity body in the upper mantle.

4.4 Mabian tectonic zone

The E'bian-jinyang fault is the boundary of the Daliangshan tectonic zone and the Mabian tectonic zone, which is a part of the Sichuan Basin; the Mabian tectonic zone is of high conductivity in the crust and high resistivity in the upper mantle, and the upper Permian and Permian Emeishan Basalt is found at the surface.

5 Discussion

5.1 Panxi lithosphere high resistivity column

The electrical resistivity structure of the Panxi tectonic zone presents significant inconsistencies with that of its adjacent zones. In the case that the HCLs of the Jipingshan and Daliangshan tectonic zone are generally found, however, the axial part of the Panxi region, the HCL almost completely disappeared and the abnormal HRB is approximately 50 km in width and approximately 40 km in depth, revealing the significant electrical conductivity inhomogeneity of the lithosphere in the Panxi region. In addition, a high-resistivity block is commonly found beneath the depth of 60 km of the axial portion, exhibiting

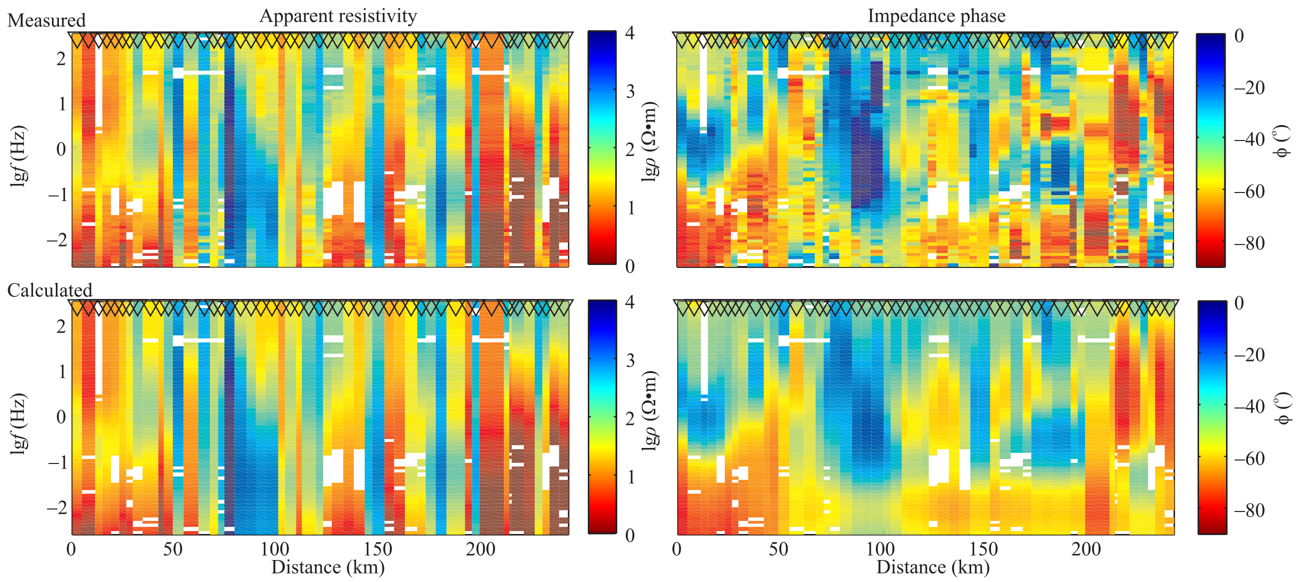

Fig. 8. Fitness of the 2D calculated and measured responses.
The top row shows the pseudo-sections for measured data, and the bottom row shows the response of the 2D inversion model, with tau=30, and RMS=2.43.

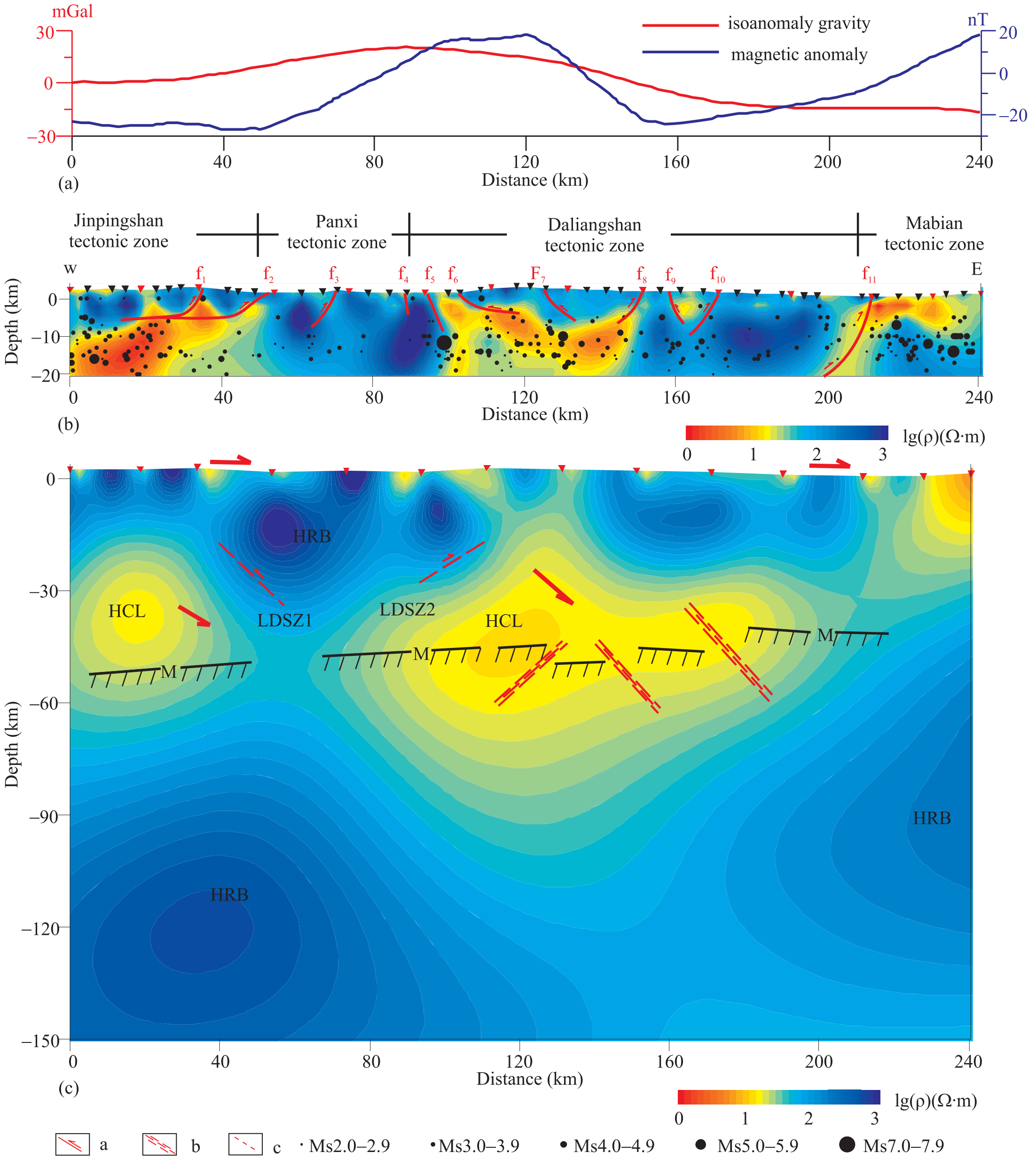

Fig. 9. Crust and upper mantle resistivity model derived from two-dimensional inversion.

(a) shows the isoanomaly gravity and magnetic anomaly along the profile, which reveal the high value of the gravity and magnetic fields in the Panxi tectonic zone, (b) shows the 2-D resistivity model using all MT site data, which mainly reflect the crust electrical resistivity structure, and (c) shows the 2-D resistivity model using only LMT data, which mainly reflect the upper mantle electrical resistivity structure. The black solid circles show the earthquake source locations (China Earthquake data centre) from Jan. 1, 1970, to Dec. 25, 2014; the Ms 7.5 Puge earthquake occurred under f4 and f5 at the year of 1850 along the profile from Tang and Han (1993). f1=Yanyuan fault, f2=Jinhe-Qinghe fault, f3=Mopanshan fault, f4=Anninghe fault, f5=Zemuhe fault, f6=Jiaodingshan fault, f7=Yuexi-Ningnan fault, f8=Shimian-Butuo fault, f9=Hanyuan-Gannao fault, f10=Niuniuba fault, f11=E'bian-Jinyang fault; a=reverse fault, b=LDSZ=Lithosphere Ductile Shear Zone(Cai et al., 2008),c= Blind fault, M=Moho(Cui, et al., 1987; Teng, et al., 1994); HCL=high-conductivity layer; HRB=high-resistivity body.

the "bread" shape, i.e., with a smaller upper part, its two sides tend to gently taper down to the bottom boundary of the lithosphere and connect with the Jinpingshan and Daliangshan tectonic zones. Furthermore, the high-resistivity block of the Panxi lithosphere is abnormally obvious between the Yanyuan and Dalianghan lithosphere high-conductivity zone. Here, the electrical column structure formed by the high-resistivity blocks in the crust of the axial Panxi region and the upper mantle high-resistivity blocks is called the Panxi lithosphere high resistivity column.

5.2 The geological significance

The block movement in the Sichuan-Yunnan region appears as the coexistence and mutual overlapping of the translation, rotation and uplift (Xu et al., 2003). The major question regarding the mantle plume is mainly the lack of deep geophysical exploration (Xu et al., 2007). A huge volcanic eruption occurred west of the Yangtze in the Middle and Late Permian, forming the famous Emishan large igneous province (LIP). A set of coarse clastic rocks is located under the Emishan basalt and is mainly distributed into two strip-shaped regions. One region is the Butuo, Puge, Huidong, and Xichang areas of the Sichuan region and the Qiaojia area of the Yunan region, exhibiting a set of limestone conglomerate and boulder conglomerate that are tens to hundreds of meters thick. The other region is the Yanyuan and Yanbian areas of the Sichuan region. These two strip-shaped coarse clastic rocks are mainly distributed at the edge of dome-shape uplift belts (He et al., 2006). After projecting these two strip-shaped areas into our MT profile, the Panxi lithosphere high-resistivity column is found to be between these two strip-shaped areas. Abnormal gravity and magnetic fields are found in the anomalies of the Panxi high-resistivity column. The Bouguer gravity anomaly indicates the high-gravity anomaly of the axial part of the Panxi tectonic zone, and a high-magnetic anomaly is also found (Fig. 9a), which indicates that there exist highly magnetic materials and the Precambrian basement. The laboratory simulations indicate that the rising mantle plume usually leads to large-scale crustal uplift and the formation of dome-like uplift (Campbell and Griffiths, 1990). The obvious and rapid dome uplift occurred in the Emeishan LIP; in addition, the uplift amplitude in the centre of the dome exceeds 1km (He et al., 2003). The three-dimensional velocity result indicates that the high-velocity body widely exists in the middle crust and the upper mantle (Wang et al., 2003). According to the resistivity model, combining the rock exposure, gravity and magnetic data to yield the three-dimensional velocity data, we can conclude that there may be basic and ultrabasic rocks with larger thicknesses in the lithosphere of the west axial part of the Panxi region, which reveals the fracture activities of lithosphere. A large number of molten pyrolite upwelled to the higher position along the fracture, thus forming a very thick accumulation of basic and ultrabasic rocks, which was the residue after the melting of the mantle plume (Xu, 2004). After 200 to 300 million years, the temperature here has become similar to the normal temperature of the lithosphere (lower than the melting temperature of pyrolite). The basic and ultrabasic rocks also became cool and solidified; subsequently, the rocks lost the electrical characteristics of low resistivity as the molten pyrolite due to long-term strong compression. Thus, the anomalies of high resistivity, high seismic wave velocity, high density and high magnetism are formed. Thereby, it can be concluded that the current Panxi lithosphere high-resistivity column may be the eruption channel for Emeishan basalt in the Permian as well as the accumulation channel for huge thick basic and ultrabasic rocks. Therefore, the mantle plume is the main dynamic mechanism for the formation of Emeishan basalt.

5.3 Earthquake

Strong earthquakes are the results of instability and stress fracture in continuous accumulations of the deformation of non-contiguous areas up to the limiting state under the effects of regional structure (Zhang et al., 2004). Strong shocks and violent earthquakes are controlled by major active faults and usually occur in the high-stress accumulation area or the blocked segment of active faults (Yi et al., 2008). The eastern boundary of the Sichuan-Yunan block is one of the huge active fault zones, with the most frequent earthquakes in the Chinese mainland (Chen et al., 2008). We counted the earthquakes that occurred along the study profile from Jan. 1, 1970, to Dec. 25, 2014(China Earthquake data centre), and the Ms7.5 Puge earthquake under the Zemuhe fault along the profile from Tang and Han (1993). We found that most source locations of earthquakes are in the binding site of high-and low-resistivity blocks. Note that HCL may be partly caused by partial melts in the crust (Unsworth et al., 2005), which means that the HCL may represent plastic material. The causative mechanism of the Ms7.5 Puge earthquake may be as follows: during the compression and shear of the Sichuan-Yuanan block and the Yangtze block, due to the strong differential movement, tectonic deformation and strong discontinuity occurred at the boundary zone of active blocks (Chen et al., 2008), the stress is transmitted and conversed between rigid blocks (HRB) and plastic blocks (HCL). The stress is highly centralized in the rigid blocks under the long-term regional compression dynamics. Thus, reaching the rock fracture limit in 1850 resulted in the occurrence of energy release and the rupture event, thus driving the fracture of the Anninghe fault and causing the Ms7.5 Puge earthquake to occur. Unlike the Panxi tectonic zone, there were fewer violent earthquakes in the Daliangshan tectonic zone in the past, but there were more small earthquakes. This result is probably because the HCL existed widely in the Daliangshan tectonic zone, where the stress is transmitted and conversed between plastic blocks, enabling the plastic blocks to be easily deformed and to inhibit the accumulation of high stress so that the energy can easily reach the released threshold. Accordingly, the stress can be released several times in a certain period, resulting in smaller but a higher number of earthquakes. Some scholars also discussed the relationship between the electrical resistivity structure and the environment before, such as the lateral variation area of low resistivity layer in the crust in the strong earthquake activity area (Wan, et al., 2010); each earthquake appears to have nucleated in a region of low resistivity within the HRB (Zhao, et al., 2012).

6 Conclusions

(1)We used the MT combined LMT to study the deep electrical resistivity structure in the Panxi region through implementation of some technologies, such as Robust and remote reference; high-quality data from 53 MT sites and 14 LMT sites were obtained.

(2)Compared with its two sides, the Panxi tectonic zone is abnormal, with high resistivity, high density, and high magnetic field. The results from the resistivity model combined with the other geophysical data imply that the Panxi lithosphere high-resistivity column is the main eruption channel for Emeishan basalt in the Permian and the accumulation channel for huge thick basic and ultrabasic rocks.

(3)According to the seismic record data, we found that there may some relationship between electrical resistivity structure and seismic source; most violent earthquakes occurred at the binding site of high- and low-resistivity blocks, while earthquakes that occurred in the HCL were not so violent. Note that the HCL is of plastic character and the HRB is of rigid character and that the fracture threshold of the plastic layer (HCL) is low and that of the rigid body (HRB) is high. Under the compression and shear of the Sichuan-Yuanan and Yangtze block, tectonic movement leads to the accumulation of stress due to the rigid character of HRB; as a result, the HRB can accumulate more stress for a longer period, so when the stress reached the threshold of the HRB, the high stress was released and a violent earthquake occurred at the Panxi tectonic zone. In contrast, a higher number of smaller earthquakes occurred in the HCL at the Daliangshan tectonic zone.

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