2D crust-upper mantle velocity structure along a seismic section in Nanling, South China

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Introduction

The cathaysia plate is at the forefront of the interactions between the Eurasian plate, the Pacific plate and the Philippine plate. China's famous nanling orogenic belt is located in the cathaysia plate. The composite action of multiple tectonic events such as pre-mesozoic tectonics, indo-chinese, yanshanian and Himalayan continental tectonics, subduction of the Pacific and Philippine plates and extensive and intense magmatic subduction formed the present cathaysia plate. Nanling area is rich in mineral resources and granite is widely distributed. Therefore, the study of the dynamics of nanling tectonic belt and cathaysia plate is helpful for us to understand the tectonic background and metallogenic law of this area.

Seismic tomography has a great advantage in studying the deep structure of the earth and understanding the velocity distribution in deep underground. In previous work, large scale body wave tomography (WCT) shows that there are widespread low-velocity anomalies in the mantle of the plate. Small-scale tomography (huang et al.,2010; Jiang et al., 2015) showed that the wave velocity anomaly in the upper mantle of south China has a large heterogeneity. However, these small-scale tomographic imaging work often did not cover the entire southeastern south China plate. There is still a lack of small-scale tomography in some places. Therefore, we set up a survey line of the portable station across the nanling area and studied the velocity anomaly distribution of the upper mantle in this area by using the method of teleseismic p-wave tomography.

Data and Method

We have arranged a survey line of high-density portable seismic station in nanling area (figure 1). The survey line starts from the xingguo-dayu fault zone in the east, reaches the changles-nanao fault zone in the west, and crosses the shaowu-heyuan fault zone and the zhenghe - taiPo fault zone in the middle. The interval between each station of the measuring line is 5km. The data used in this paper are from station nl15-nl87. 302 teleseismic events span from July 2017 to August 2019, with a total of 5,124 relative residual data. These events are all distant events with epicenters of 30 degrees to 90 degrees and magnitudes greater than 5.5 (figure 2). In addition, we also need to pay attention to two additions :(1) when selecting seismic events, we should also pay attention to eliminate seismic data with poor signal-to-noise ratio; (2) ensure that at least 8 stations receive data for each event. Seismic events that do not meet these two conditions should be eliminated.

figure 1

The method of TOMOG3D proposed by Zhao et al. (1992,1994), which USES snell's theorem and pseudo-bending method to determine the ray path (figure 3). The method is theoretically mature and has been widely used in south China (Xu et al., 2019; Jiang et al., 2015; Zhang., 2018; Huang and Zhao.,2006), it is easy for us to compare the results of tomographic imaging. The principle is as follows:

$$T_{ij}^{obs} = T_{ij}^{cal} + \left(\frac{\partial T}{\partial \varphi}\right)_{ij} \Delta\varphi_j + \left(\frac{\partial T}{\partial \lambda}\right)_{ij} \Delta\lambda_j + \left(\frac{\partial T}{\partial h}\right)_{ij} \Delta h_j + \Delta T_{0j} + \sum_k \frac{\partial T}{\partial V_k} \Delta V_k + E_{ij}$$

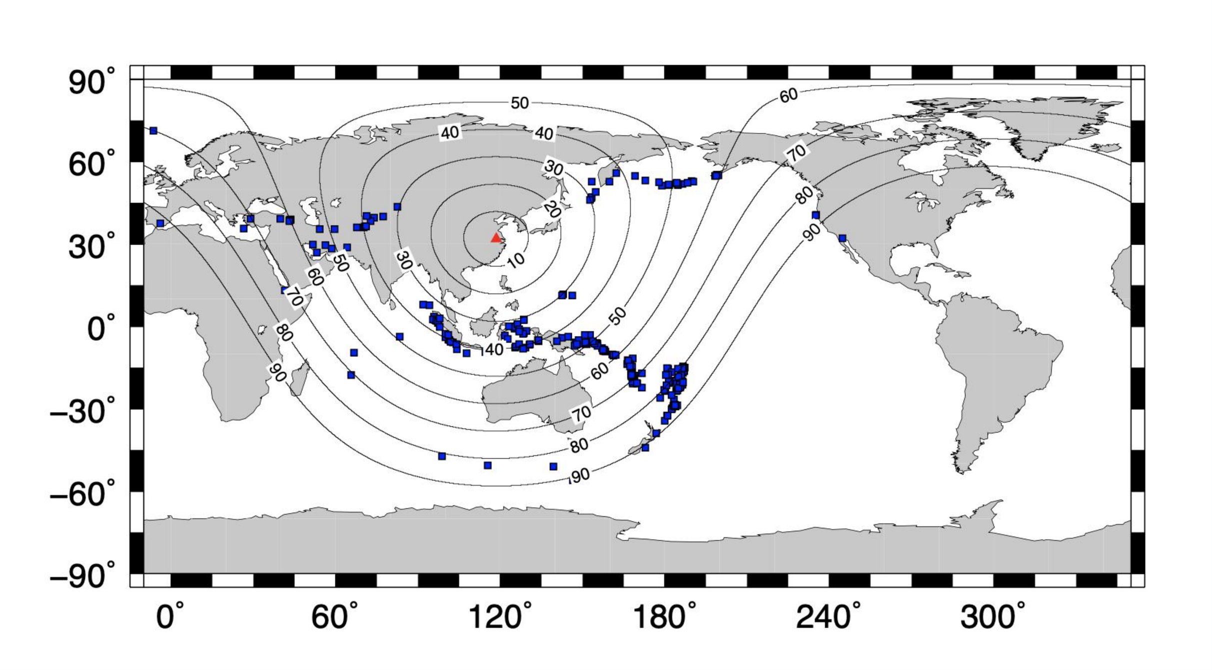

figure 2

The term on the left of the formula and the first term on the right of the formula respectively represent the observed and theoretical travel time of the JTH seismic event received by the ith station.

Absolute residual time:

$$t_{ij} = T_{ij}^{obs} - T_{ij}^{cal}$$

Relative residual time:

$$r_{ij} = t_{ij} - \bar{t}_j, \qquad \bar{t}_j = \frac{1}{m_j}\sum_{i=1}^{m_j} t_{ij}$$

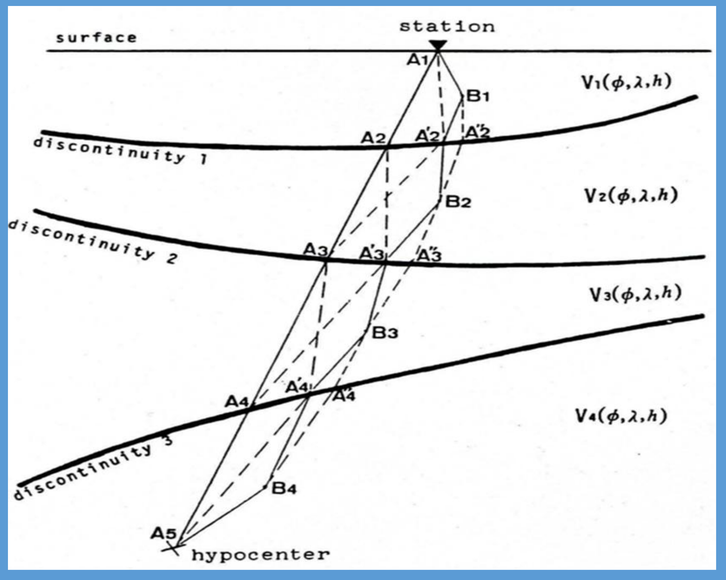

figure 3(D.P.ZHAO,1993)

We use the fast calculation method of relative travel time of teleseismic proposed by Jiang Guoming in 2012 to select the relative residual time(Jiang et al.,2012). The first arrival phase is almost perfectly aligned after the seismic wave is offset(fig.4and figure 5). The method can also discard the station data whose relative residual time is greater than 2.Then,the hypocenter parameters and velocity parameters are inversed based on relative residual time.

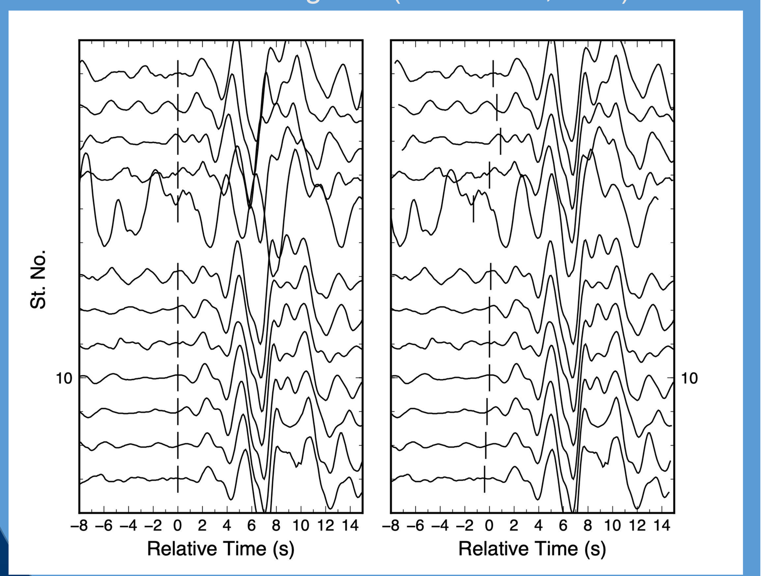

figure 4

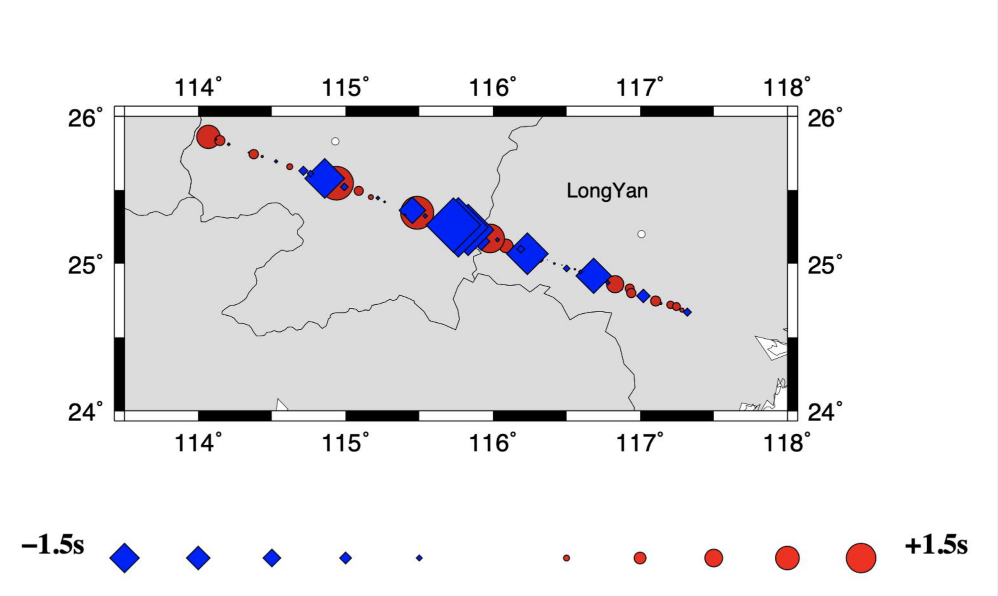

figure 5 relative residual time

Checkboard Test

In the TOMO3D method, the mesh subdivision of the model is different from other tomographic methods. TOMO3D assigns the initial velocity value to 8 points of the grid, and then calculates the velocity value of each grid by linear interpolation method. If the ray forms a good coverage under the research area and the model is divided reasonably. Then the velocity disturbance model of positive and negative phases can be recovered well. Due to the small research area and small amount of data, after repeated debugging, it was found that the detection version had the best test effect when the longitude and latitude interval was 0.5 degrees and the velocity disturbance was 3% (fig.6).

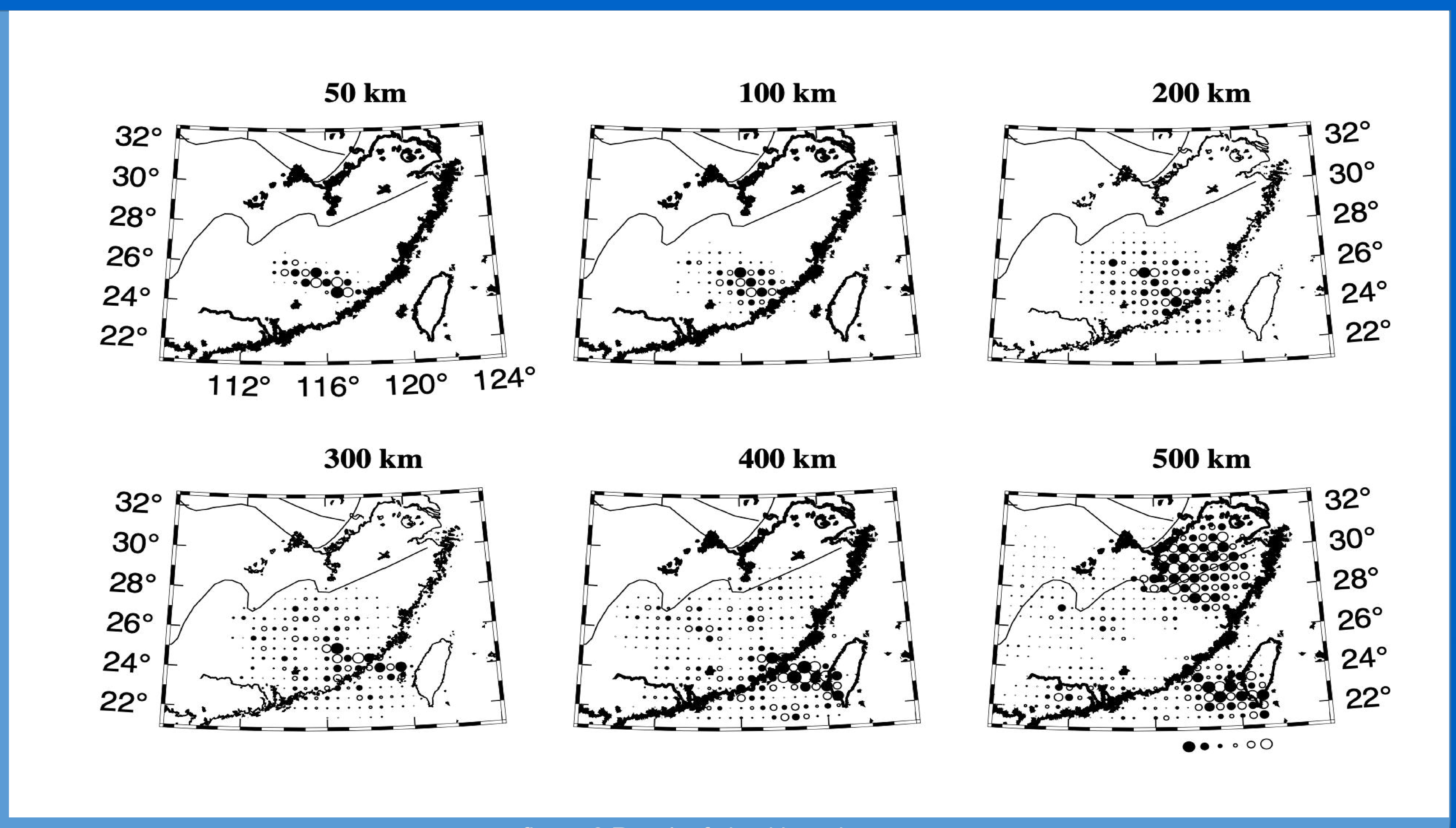

figure 6 Result of checkboard test

As we can see,For our study area, the initial velocity disturbance we set had a good recovery effect at 50-200 km underground and a poor recovery at 500km, because the distant seismic rays did not reach the surface vertically.

Result and discussion

In the inversion operation, 15.0 was selected as the damping factor to obtain 6 horizontal tomographic slices(fig.7) and a Longitudinal profile(fig 8) which is beneath our survey line.

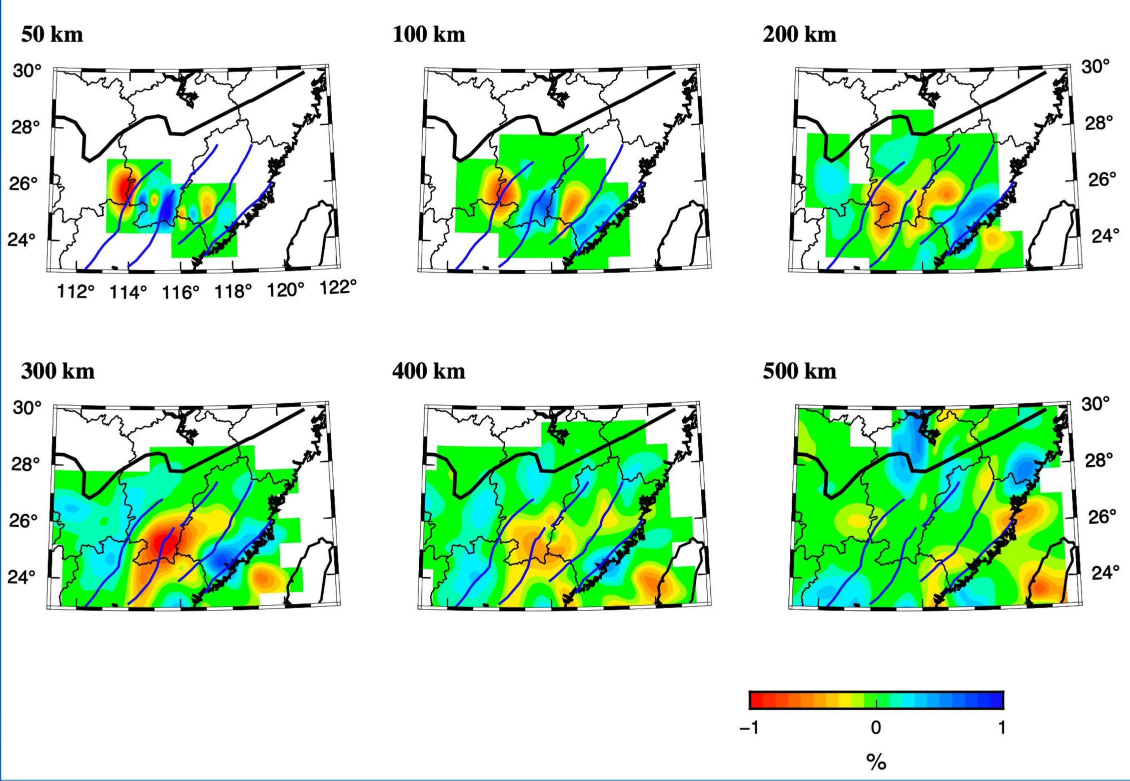

figure 7

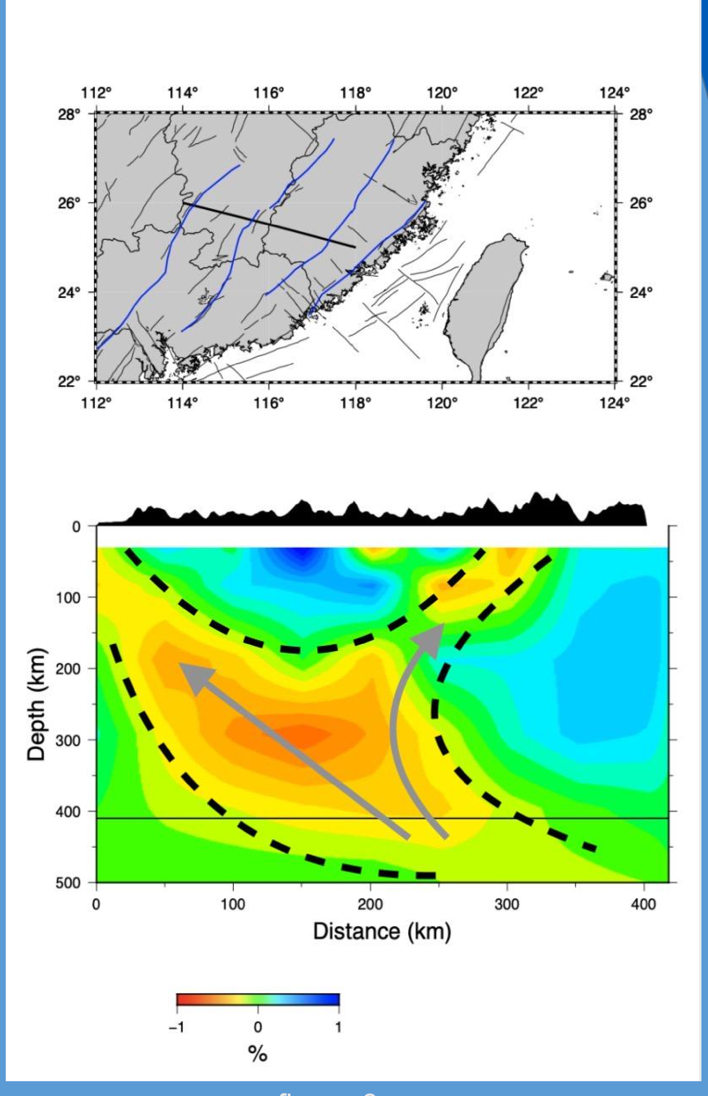

figure 8

According to result of tomography,we can see the most prominent feature is the extensive low-Vp anomalies(fig.7).In current consensus,Scholars attribute this feature to the existence of underground high heat flow and lithospheric thinning effect.two larger low-Vp anomalies are imaged in the uppermost mentle,one is located under the xingguo-dayu fault and another is located under the west side of zhenghe-taiPo fault.And the these low-Vp anomalies are connected with the deeper low-Vp anomalies,which is visible in figure 8.

A clear high-Vp anomaly in the upper mentle along the Fujian coastal area.This high-Vp anomaly was also observed in the previous work (Huang et al.,2010;Xu et al.,2019.,Pei et al.,2017).Huang interprets it as a cooled Mesozoic igneous rock. It is believed that the upper mantle and crust of SE China are not only significantly affected by the rising mantle material in Mesozoic, as the traditional view suggests(Huang et al.,2010). Petrology and isotopic dating also indicate that a large number of Mesozoic granites are exposed on the surface of this area(fig.9), and mantle source materials and energy participate in the formation of these granites in different ways (Yang et al.,2017).

However, the high-speed anomaly under shaowu - heyuan(fig.7,8) may have different causes. Most geochemists believe that the granite formation in south China is directly related to mantle source materials. Distribution of Mesozoic granite and metal deposits in south China (fig.9) (Yang et al., 2017). It can be seen that near the boundary of fujian and jiangxi, the distribution density of granite and ore deposits is far less than that of the surrounding area, and even some places form granite void zone. This indicates that the bottom penetration of mantle source material in this area is low. Therefore, I prefer to interpret the high-Vp anomaly under shaowu-heyuan as an existing lithosphere. In addition, in the three-dimensional electric structure of the south China lithosphere (Han 2017) made by the previous researchers, a high resistance anomaly was found at the same position of the high-speed anomaly. Han interpreted it as a weak and thin fragile-shaped lithosphere in 2017, and believed that the thickness was between 130 and 150km, which is also consistent with our results to some extent. If the inference is correct, if a survey line parallel to the nw direction of the existing survey line is set up in the following work, the high-speed anomaly connected with it should be found on the north side of the border of fujian and jiangxi.

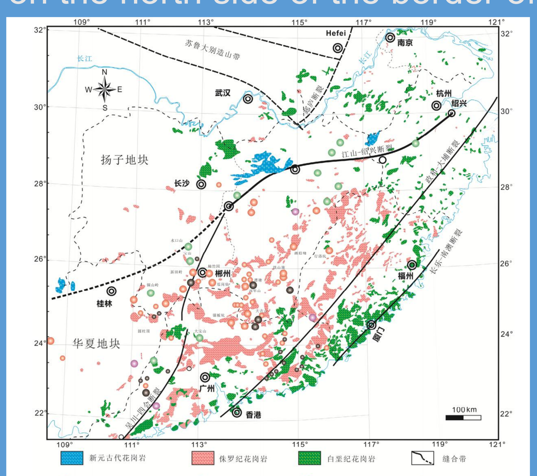

figure 9 (Yang et al.,2017)

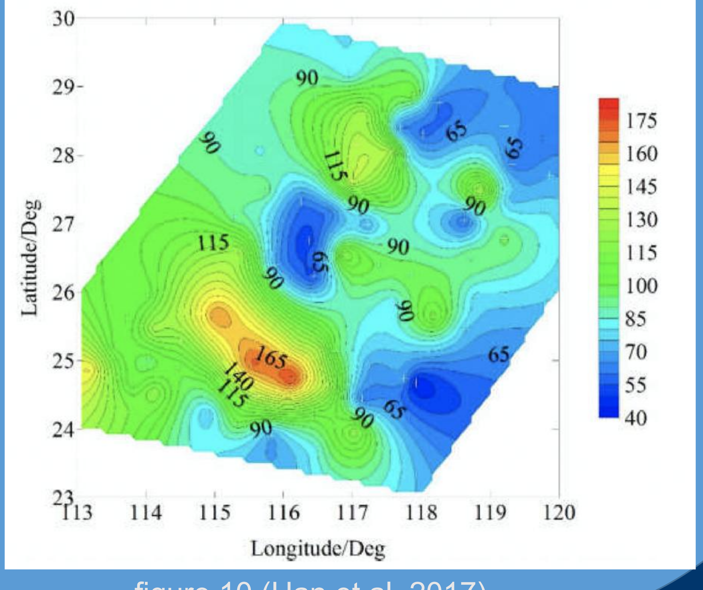

figure 10 (Han et al.,2017)

Conclusion

In this study, using the data from the mobile station, the distant seismic tomography was carried out with the nanling tectonic belt as the center. The following conclusions can be drawn:

(1) these low-Vp anomalies, which are widely distributed in the upper mantle, may be caused by the mantle material brought by the subduction of the Pacific and Philippine sea plates, which has extensive bottom transgression on the lithosphere of the cathaysia plate. low-Vp anomalies at deeper depths in southeastern China may represent the deep source of late Mesozoic igneous rocks.

(2) the high-speed mantle anomaly in the coastal area of fujian province may be caused by the cooled Mesozoic igneous rocks.

(3) the high-speed anomaly under the shaowu-heyuan fault zone may be the lithosphere where mantle source material has not penetrated sufficiently.