

TOMOGRAPHY AND LOCATION PROBLEMS IN CHINA USING REGIONAL TRAVEL-TIME DATA

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ABSTRACT

Phase data from the Annual Bulletin of Chinese Earthquakes (ABCE) are being collected and used for tomographic inversion and event location problems within China. So far, we have seven years of data in computer form and six more in catalog form. Current efforts focus on regional tomography of China, comparing locations between the ABCE and other earthquake catalogs, and developing station corrections for IMS stations in and around China.

We used the Pn phase data from the ABCE catalog to image the uppermost mantle velocity and anisotropy structure beneath China. Raypaths cover most of central and eastern China; coverage in western China and Tibet is poor. The data quality is exceptional, with Pn phases routinely identified and picked for distances from 1.5 to 9 degrees. Over 25,000 arrivals have been used in the Pn tomography algorithm. The average uppermost mantle velocity beneath China is 8.0 km/s. The Tarim, Junggar, Tsaidam, and Sichuan basins have the highest Pn velocities (over 8.2 km/s). These places are cratonic terrains that were accreted to southern Asia before the Indian-Asian collision. The high velocities imply higher density mantle that may have aided in the development of these basins. The eastern Tien Shan has normal Pn velocities of 8.0 to 8.1 km/s. Pn velocity beneath Tibet decreases from south to north as previous studies have also found. Late station delays in and around Tibet attest to its 70 km thick crust. Along the southeastern Tibet margin, low Pn velocities are found suggesting that high temperatures and possible partial melt exist in the uppermost mantle there. A region of high anisotropy surrounds Tibet. Eastern China has lower Pn velocities and thinner crust as a result of Cenozoic extension of eastern China. A very low Pn velocity (<7.7 km/s) is found north of Hainan Island. This feature may be related to the opening of the South China Sea.

We compared event locations between the ABCE and the PIDC catalogs for our only year of overlap, 1995. The ABCE locations are located with many local stations and can be expected to be better than the teleseismic locations. On average, ABCE and PIDC locations differ by 0.95 degrees. For the same events, estimated errors from the PIDC locations average 0.76 degrees. Several events were mislocated in excess of 4 degrees due to a lack of reporting stations and poor azimuthal coverage. The 1995 location capability of the PIDC was not sufficient to locate Chinese events within the 1000 sq-km region required by the CTBT. Better station coverage and calibration are needed to achieve this goal.

Key Words: China, Tomography, Pn

OBJECTIVE

NMSU seismologists, in conjunction with seismologists from the Institute of Geophysics of the China Seismological Bureau (IG/CSB), seek to collect seismic data to calibrate International Monitoring System stations in China and to document regional phase propagation characteristics in China. We are approaching these problems through regional tomography, characterization of regional wave propagation, station calibration, and an analysis of current location capabilities in China (Figure 1).

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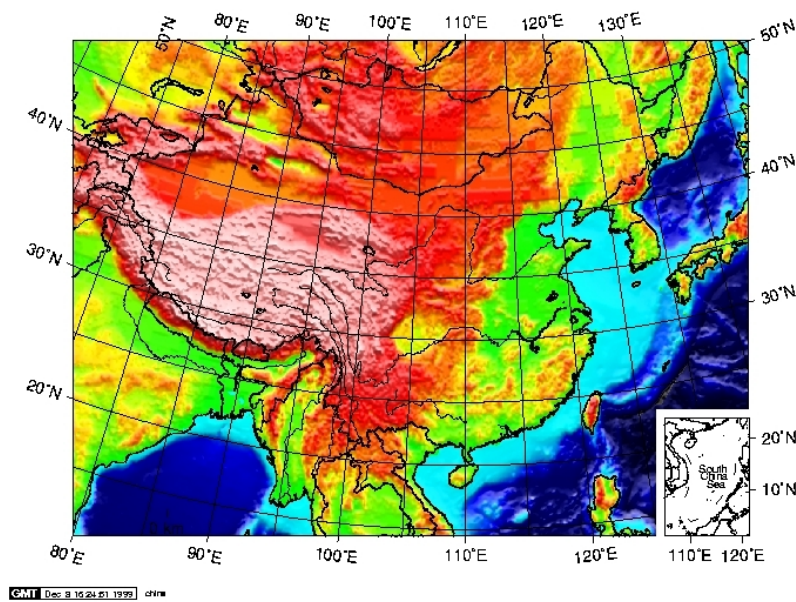


Figure 1 - Shaded topography of China.

RESEARCH ACCOMPLISHED

Data collection

Our data set of the Annual Bulletin of Chinese Earthquakes (ABCE) consists of both paper catalogs and digital data sets provided by our colleagues from the China Seismological Bureau (CSB). Paper catalogs span 1983 to 1995; 1991 to 1995 were also given to us in digital form. The 1986 and 1987 catalogs were typed into the computer and work on other catalogs proceeding. The data quality from the ABCE is exceptional, with Pn phases routinely identified and picked for distances of up to 9 degrees [Figure 2]. Pn arrivals form the linear first-arrival portion of the travel-time curve between distances of 200 to past 1500 km.

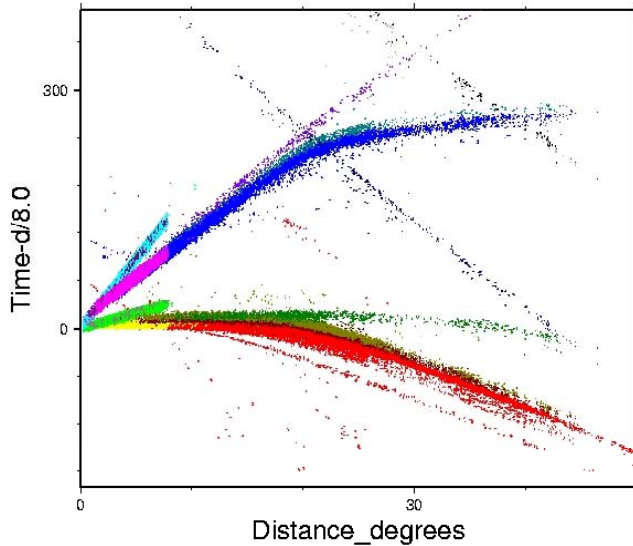


Figure 2 - P-wave first arrival travel times from the Chinese bulletins (ABCE) for 1991 through 1995. Pg, Pn and a distant P branch are clearly visible. The ABCE routinely identifies arrivals as Pg, Pn, P, PP, pP, Sg, Sn, S, SS, sS, sP, PcP, S11, ScS, P11, ScP, PcS.

Pn tomography beneath China

We have applied the Pn tomography algorithm of Hearn [1999] to Pn data from the ABCE to image the P-wave velocity and anisotropy at the surface of the mantle. Raypaths for these data cover most of central and eastern China; coverage in western China and Tibet is poorer, but we are now beginning to include data from other sources to remedy this. We used raypaths between 1.8 and 15 degrees distance and only stations and events with more than 9 arrivals at them. The final Pn data contains over 115,000 arrivals that span most of China [Figure 3].

The inversion yields an average Pn velocity of 8.05 km/s for all of China. Additional travel time studies have also been made by plotting out travel time curves for three different regions of China. We found the apparent velocities for these regions to be:

Region	Pg velocity	Pn velocity
Huabei	6.19	7.94
Tianshan	6.28	8.02
Sichuan	6.08	7.86

Figure 4 shows the regionally varying Pn velocities and anisotropy from the inversion. The Tarim, Tsidam, and western Sichuan basins have the highest Pn velocities. These places may be cratonic terrains that were accreted to southern Asia before the Indian-Asian collision. The high velocities also represent higher density mantle that may have aided in the development of these basins. Pn velocity beneath Tibet decreases from south to north as has been found in previous Tibet studies [McNamara, 1997]. This suggests that the subducted Indian plate ends somewhere beneath central Tibet. Eastern China has much lower Pn velocities. Along the southeastern Tibet margin, low Pn velocities are found suggesting that high temperatures and possible partial melt exists in the mantle there. Anisotropy is shown in Figure 5 by short line segments oriented along the fast anisotropy direction. Major regions of anisotropy are beneath the eastern Himalayan syntaxis, Sichuan Basin and Taiwan. Our resolution in the velocity and anisotropy is between two and three degrees. Because anisotropy can vary on shorter distance scales, much of it remains unresolved.

Both station and event delays represent the combined effect of crustal velocity and thickness [Figures 6 and 7]. Event delays, however, are also susceptible to errors in origin time or depth in the event location. In most Pn tomography studies [e.g. Hearn, 1999], these errors create such scatter in the event

delays that they are of little use. This is not the case for the ABCE data, and it indicates that events in China are exceptionally well located.

The delays can be interpreted as a rough map of crustal thickness in China. For a constant velocity crust, 1 second of delay time represents approximately 10 km of crustal thickening. Late station and event delays in Tibet then imply that the crust there is 30 to 40 km thicker than the crust in eastern China. Events north of the Tarim Basin and in the Tien Shan also show late delays indicating crust that is 10 to 20 km thicker than eastern China. A thin crust is also apparent on the southeast margin of Tibet where extension is occurring.

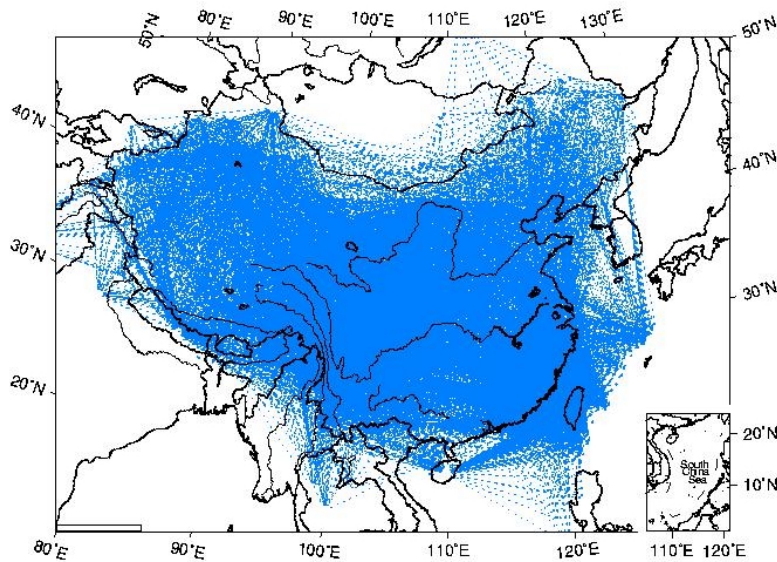


Figure 3 - Pn raypaths used in the tomography. Distances were restricted to 1.8 to 15 degrees. About 25,000 raypaths are shown.

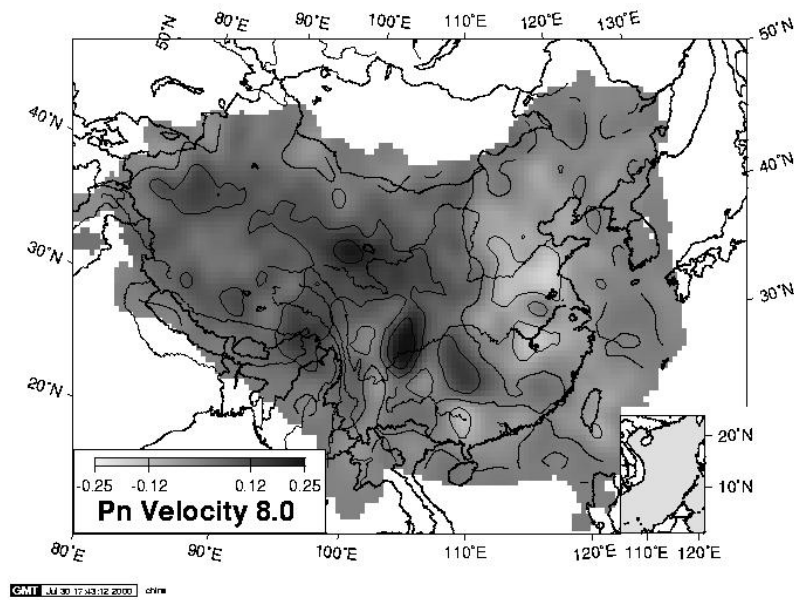


Figure 4 - Pn velocity beneath China. Shades represent variations from a mean Pn velocity of 8.0 km/s. The Tarim, Tsaidam, and western Sichuan basins have the highest Pn velocities. These places may be cratonic terrains that were accreted to southern Asia before the Indian-Asian collision. Eastern China has lower Pn velocities.

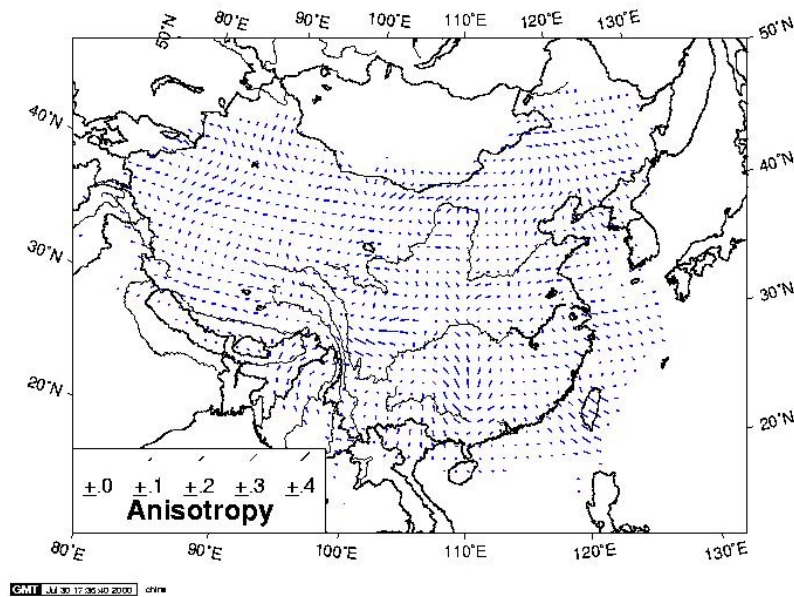


Figure 5 - Pn anisotropy beneath China. Line segments show the orientation of the anisotropic fast direction; line lengths show the magnitude of the anisotropy.

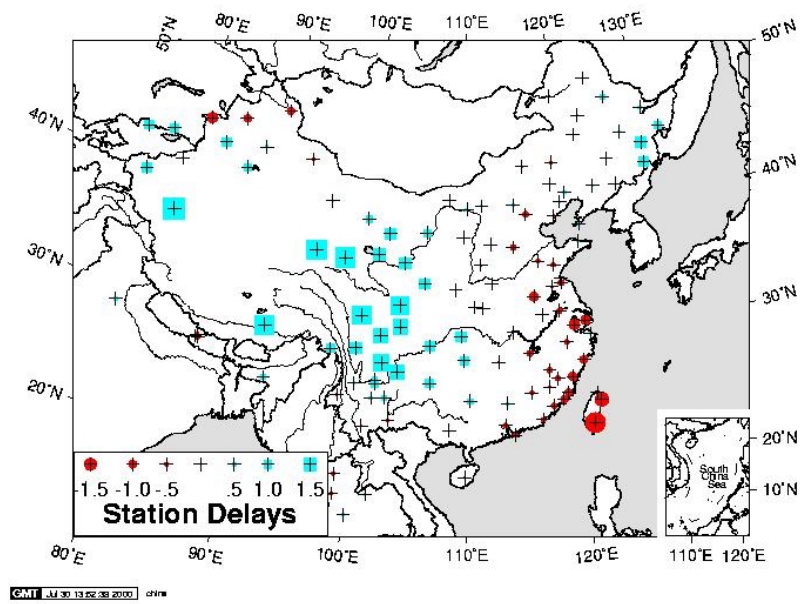


Figure 6 - Station delays beneath China (zero-mean). These delays depend on both crustal thickness and crustal velocity. For a constant velocity crust, one second of delay corresponds to about 10 km of crustal thickening. Late arrivals in Lhasa, Tibet, and around the edges of the Tibetan Plateau result from the 70 km thick crust. Early delays in the east and in Taiwan are the result of thinner crust.