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The shear-wave splitting in the crust and the upper mantle around the Bohai Sea, North China

Shi Yutao *, Gao Yuan, Tai Lingxue, Fu Yuanyuan

Institute of Earthquake Science, China Earthquake Administration, Beijing 100036, PR China

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ABSTRACT

In order to infer the distribution of local stress and the deep geodynamic process in North China, this study detects seismic anisotropy in the crust and upper mantle beneath the Bohai Sea area. A total of 535 local shear-wave and 721 XKS (including SKS, PKS and SKKS phases) splitting measurements were obtained from stations in permanent regional seismograph networks and a temporary seismic network called ZBnet-E. The dominant fast polarization orientation of local shear-waves in the crust is nearly East-West, suggesting an East-West direction of local maximum compressive stress in the area. Nearly North-South fast orientation was obtained at some stations in the Tan-Lu fault belt and the Zhang-Bo seismic belt. The average fast orientation from XKS splitting analysis is 87.4° measured clockwise from the North. The average time-delays of XKS splitting are range from 0.54 s to 1.92 s, corresponding to a 60–210 km thick layer of anisotropy. The measured results indicate that upper mantle anisotropy beneath Bohai Sea area, even the eastern part of North China, is mainly from asthenospheric mantle flow from the subduction of the Pacific plate. From the complicated anisotropic characteristics in this study, we infer that there might be multiple mechanisms in the crust and upper mantle around the Bohai Sea area that led to the observed anisotropy.

1. Introduction

Seismic anisotropy describes the directional dependence of seismic velocity as an important characteristic feature in the Earth's interior structure. It widely exists at different depth ranges in the crust, mantle and inner core. Crustal anisotropy is most likely the result of aligned micro-cracks referred to Extensive-dilatancy Anisotropy (EDA) or layer fabric (Crampin et al., 1980; Crampin, 1994; Crampin and Peacock, 2005; Crampin and Peacock, 2008). The dominant polarization of the fast shear-wave splitting equates with the orientation of aligned crack by in situ tectonic stress, and the time-delay equate with the degree of crack density for each source-receiver path (e.g., Crampin and Zatsepin, 1997; Boness and Zoback, 2004; Gao et al., 1998, 1999; Cochran et al., 2003; Shi et al., 2009). Alternately, if anisotropy is due to layered fabric, the anisotropic parameters relate to direction of fabric and degree of layering (e.g., Cochran et al., 2006; Margheriti et al., 2006; Peng and Ben-Zion, 2004; Shi et al., 2009, 2013).

Upper mantle anisotropy is a consequence of the strain-induced lattice preferred orientation (LPO) of intrinsically anisotropic mantle minerals (principally olivine). In principle, the observations of shear-wave splitting in the upper mantle can be used to constrain the lithospheric and sublithospheric mantle deformation (Silver and Chan, 1991; Vinnik et al., 1992; Savage, 1999). The polarization orientation of the fast shear-wave can characterize the orientation of asthenospheric flow, and the time-delay can characterize depth extent of mantle strain fields (e.g., Silver, 1996; Savage, 1999; Conrad et al., 2007).

The Bohai Sea area is situated in the eastern North China Craton, which experienced thermotectonic reactivation and destruction during the Late Mesozoic–Cenozoic. Since then, it has been tectonically active with high heat flow values (e.g., Ai and Zheng, 2003; Kusky and Li, 2003), thinned lithospheric mantle (e.g., Griffin et al., 1998; Chen et al., 2008; Chen et al., 2010), and frequent strong earthquakes such as the Ms7.3 Haicheng earthquake and the Ms7.8 Tangshan earthquake (Fig. 1). The Tan-Lu fault belt, which is a giant rift-slip fault belt across the Bohai Sea area, was formed by the continent–continent collision between the North China block and the Yangtze block probably began in the Middle Triassic (e.g., Xu et al., 1987; Li, 1994; Menzies et al., 2007). As an important asthenospheric upwelling channel (Chen, 2010; Zhu and Zheng, 2009), the Tan-Lu fault belt separates the Bohai Sea area into two lithospheric blocks with different velocity structure in the crust and mantle (Wang et al., 2000; Ai and Zheng, 2003;

* Corresponding author.
E-mail address: shiyutao3995@126.com (S. Yutao).

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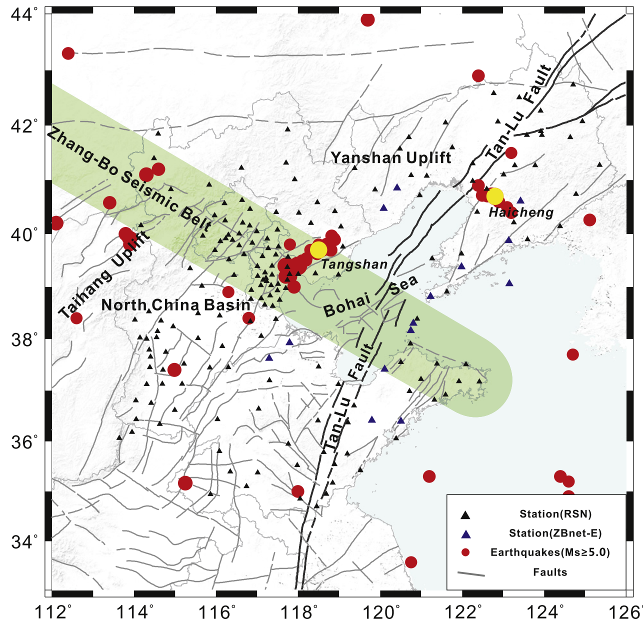

Fig. 1. Distribution of seismic stations and active faults around the Bohai Sea area and its vicinity. The black and blue triangles are the seismic stations from regional seismograph networks (RSN) and ZBnet-E operated by Institute of Earthquake Science (IES) of China Earthquake Administration. The red dots indicate earthquakes with Ms ≧ 5.0 in this region, and the two yellow dots indicate the Ms7.8 Tangshan Earthquake on July 28, 1976 and Ms7.3 Haicheng earthquake on February 04, 1975, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

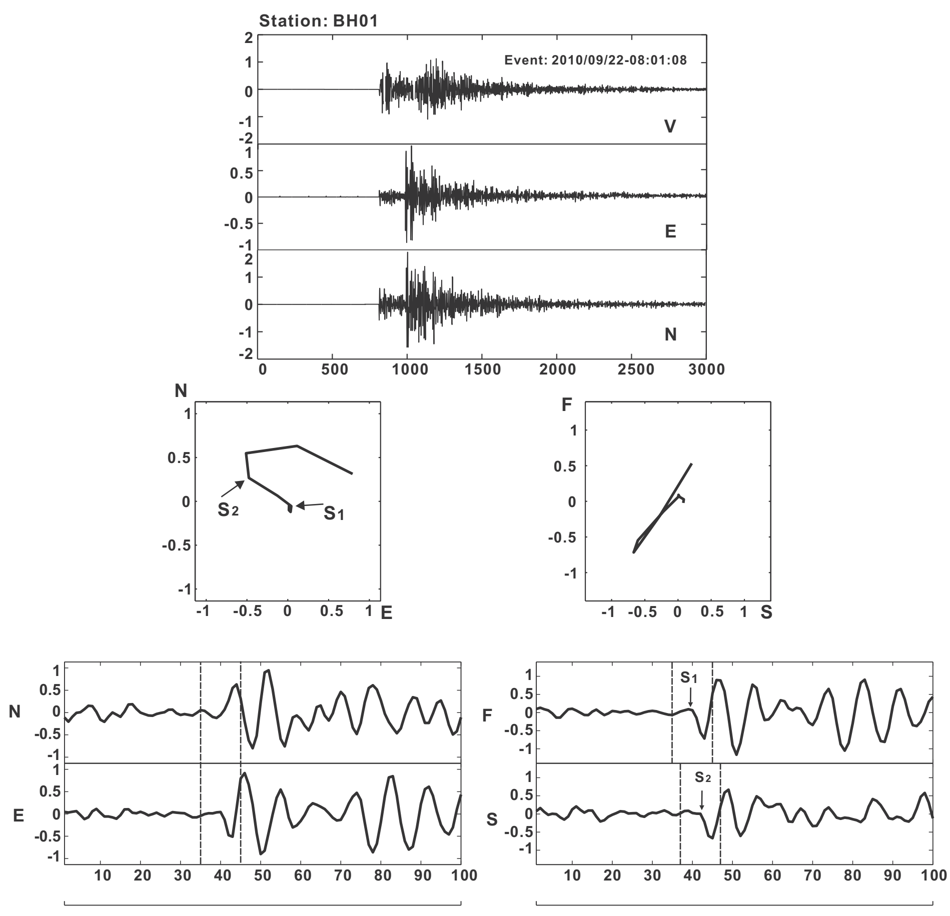

Fig. 2. Shear-wave splitting analysis of seismic event (20100922080108) recorded by station BH01. The depth of this event is 5.0 km with ML3.6. The upper panel shows the original vertical, north-south and east-west waveforms. The lower-left is particle movement of shear-wave of original record and shear waveforms at north-south (NS) and east-west (EW) direction. S1 and S2 indicate the start position of fast shear-wave and slow shear-waves respectively. The lower-left is fast shear-wave (F) and slow shear-wave (S) and the trail of particle movement of fast shear-wave and slow shear-wave, which have eliminated the effect of time delay. The ordinate is the count value of amplitude. The abscissa is the number of sampling points. The two vertical lines mark the segment of shear waveforms showed in the polarization diagrams.

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