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Mica-dominated seismic properties of mid-crust beneath west Yunnan (China) and geodynamic implications

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ABSTRACT

Measurements of crystallographic preferred orientations (CPO) and calculations of P- and S-wave velocities (V_p and V_s) and anisotropy were conducted on three quartz–mica schists and one felsic mylonite, which are representative of typical metamorphic rocks deformed in the middle crust beneath the southeastern Tibetan plateau. Results show that the schists have V_p anisotropy (AV_p) ranging from 16.4% to 25.5% and maximum V_s anisotropy [AV_s(max)] between 21.6% and 37.8%. The mylonite has lower AV_p and AV_s(max) but slightly higher foliation anisotropy, which are 13.2%, 18.5%, and 3.07%, respectively, due to the lower content and CPO strength of mica. With increasing mica content, the deformed rocks tend to form transverse isotropy (TI) with fast velocities in the foliation plane and slow velocities normal to the foliation. However, the presence of prismatic minerals (e.g., amphibole and sillimanite) forces the overall symmetry to deviate from TI. An increase in feldspar content reduces the bulk anisotropy caused by mica or quartz because the fast-axis of feldspar aligns parallel to the slow-axis of mica and/or quartz. The effect of quartz on seismic properties of mica-bearing rocks is complex, depending on its content and prevailing slip system. The greatest shear-wave splitting and fastest V_p both occur for propagation directions within the foliation plane, consistent with the fast Pms (S-wave converted from P-wave at the Moho) polarization directions in the west Yunnan where mica/amphibole-bearing rocks have developed pervasive subvertical foliation and subhorizontal lineation. The fast Pms directions are perpendicular to the approximately E-W orienting fast SKS (S-wave traversing the core as P-wave) directions, indicating a decoupling at the Moho interface between the crust and mantle beneath the region. The seismic data are inconsistent with the model of crustal channel flow as the latter should produce a subhorizontal foliation where vertically incident shear waves suffer little splitting.

1. Introduction

Understanding of the seismic properties (i.e., P- and S-wave velocities, anisotropy, shear wave splitting) of dominant lithologies is a key to assess and interpret the style and magnitude of deformation in the crust and mantle from geophysical data (Barruol and Mainprice, 1993; Brownlee et al., 2011; Christensen and Okaya, 2007; Ji et al., 2013a, 2013b; Shao et al., 2014). Among these properties, seismic anisotropy is an extremely important proxy of ductile deformation behavior of earth materials (e.g., Ji et al., 2002; Meissner et al., 2006; Moschetti et al., 2010). Seismic anisotropy of rocks is generally attributed to the combined effect of compositional layering, CPO and aligned fractures in the upper crust (Crampin and Peacock, 2008), and predominantly to the CPO of mica in the mid-crust (e.g., Cossette et al., 2015; Dempsey et al., 2011; Erdman et al., 2013; Lloyd et al., 2009, 2011a, 2011b; Meltzer and Christensen, 2001; Ward et al., 2012), amphibole in the lower crust (Ji et al., 2013b; Tatham et al., 2008), and olivine in the upper mantle (Ji et al., 1994; Karato et al., 2008; Mainprice, 2007; Saruwatari et al., 2001). Teleseismic shear wave splitting results measured worldwide (e.g., Savage, 1999; Silver, 1996), however, are influenced by both crustal and mantle anisotropy (e.g., Godfrey et al., 2000; Mainprice, 2007; Okaya and Christensen, 2002; Vergne et al., 2003). These non-unique sources of elastic anisotropy will impose ambiguity on geological interpretation of observed seismic properties (e.g., Rasolofosaon et al., 2000; Werner and Shapiro, 1998, 1999). Thus it is crucially important to constrain the contribution of crustal deformation (e.g., style and magnitude of strain) to shear wave splitting data measured from teleseismic observations, and to explore the implications for the degree of crust–mantle coupling during orogeny.

The collision between the Indian and Eurasian plates resulted in formation of a transpressional boundary around the east Himalayan Syntaxis (EHS), which is accompanied by a series of highly strained crustal shear zones (e.g., Gaoligong shear zone, Lancangjiang shear zone, and Red River shear zone in west Yunnan, Fig. 1), which are characterized by shortening and strike-slip shear (e.g., Leloup et al., 1995;

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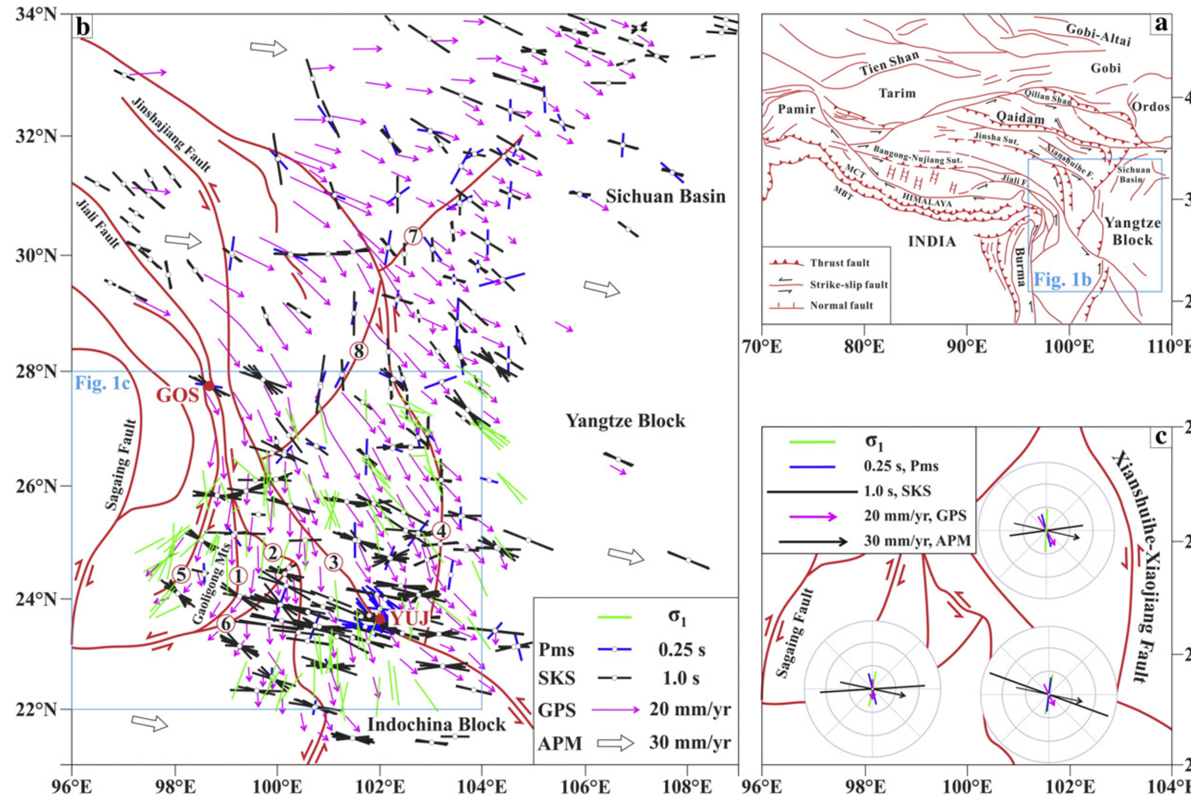

Fig. 1. (a) Simplified geological map of the Tibetan plateau and surrounding regions. Blue rectangle refers to Fig. 1b. (b) Tectonic map of the east Tibetan plateau and surrounding regions with the vectors of GPS, Pms- and XKS-wave splitting, the maximum principal stress σ_1, and the APM (see the text for explanation). (c) Average orientations of GPS, Pms- and XKS-wave splitting, σ_1, and APM in three tectonic blocks. Red lines show main shear zones or fault zones: (1) Gaoligong shear zone; (2) Lancangjiang shear zone; (3) Red River shear zone; (4) Xianshuihe fault zone; (5) Nabang fault; (6) Nanting fault; (7) Longmen Shan fault; (8) Lijiang-Xiaojinhe fault. Half arrows refer to Tertiary shear sense.

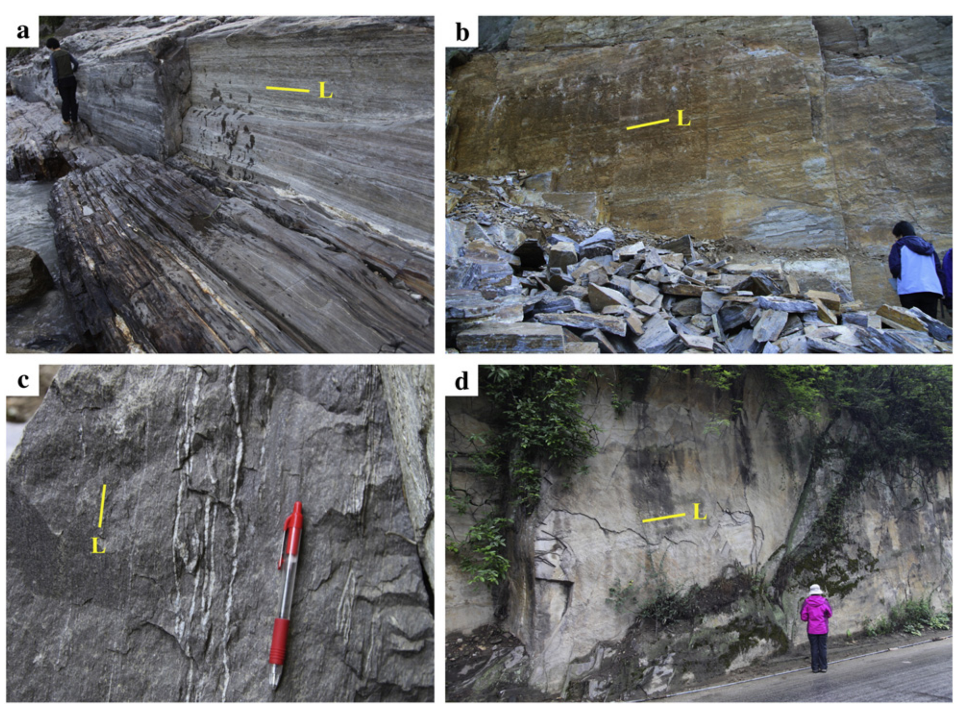

Fig. 2. Field photographs showing typical mica-bearing rocks in the Lancangjiang (a, c–d), and Gaoligong (b) shear zones, west Yunnan, China, where foliation is nearly vertical and stretching lineation is almost horizontal. (a) Qtz–Bt–Ms schist at site GLG132 (26.9848°N, 98.8641°E, altitude 1204 m). (b) Dioritic mylonite at site GLG133 (26.8271°N, 98.8840°E, altitude 1180 m). (c) Qtz–Bt schist at site GLG257 (26.3537°N, 98.8272°E, altitude 1840 m) in which quartz veins have been intensively folded. (d) Qtz–Bt–Ms schist at site YN1389 (26.8587°N, 98.8760°E, altitude 1153 m). Lineation is indicated by L.