Crystallographic preferred orientations of talc and chloritoid and implications for seismic anisotropy in subduction zones

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Abstract

Introduction

Hydrous minerals are elastically very anisotropic and the crystallopgraphic preferred orientations (CPOs) of those minerals can cause a large seismic anisotropy and long delay time observed in subduction zones. Talc and chloritoid are representative hydrous minerals in subduction zones. However, CPOs of both talc and chloritoid are lack of study. We measured CPOs of polycrystalline talc and chloritoid by SEM-EBSD analysis, and calculated the CPO-induced seismic anisotropies considering the subduction zone geometry.

Geological setting and sample description

CPOs of talc and chloritoid were measured in Grt-Clr-Tlc schists collected from Makbal complex. Samples contained 20 - 40 vol.% of talc and 10 - 23 vol.% of chloritoid. Previous studies have reported that the Makbal Grt-Cld-Tlc schist was originated from subduction-related oceanic crust and its peak metamorphism as P = 2.9 GPa and T = 550 °C.

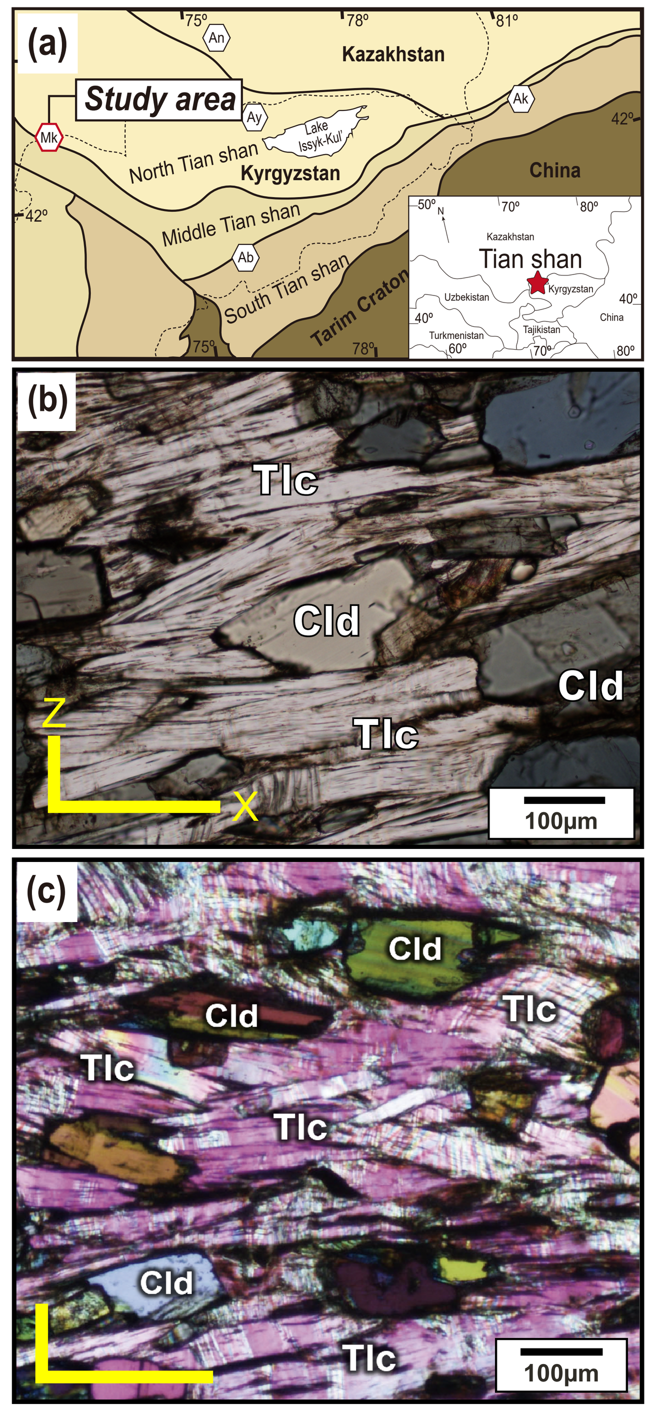


Figure 1. (a) Sample locations of Makbal UHP talc schists. (b and c) Optical microphotographs of Grt-Cld-Tlc schist samples under (b) open-nicole (sample 12-52) and (c) cross-polarized light (sample 10-16) with gamma plate. The horizontal direction (X-direction) and the vertical direction (Z-direction) correspond to the lineation of the schist and the direction normal to the foliation, respectively (yellow line). Well-elongated talc and chloritoid grains are preferentially aligned subparallel to the lineation. Cld; chloritoid, Tlc; talc.

CPOs of talc and chloritoid

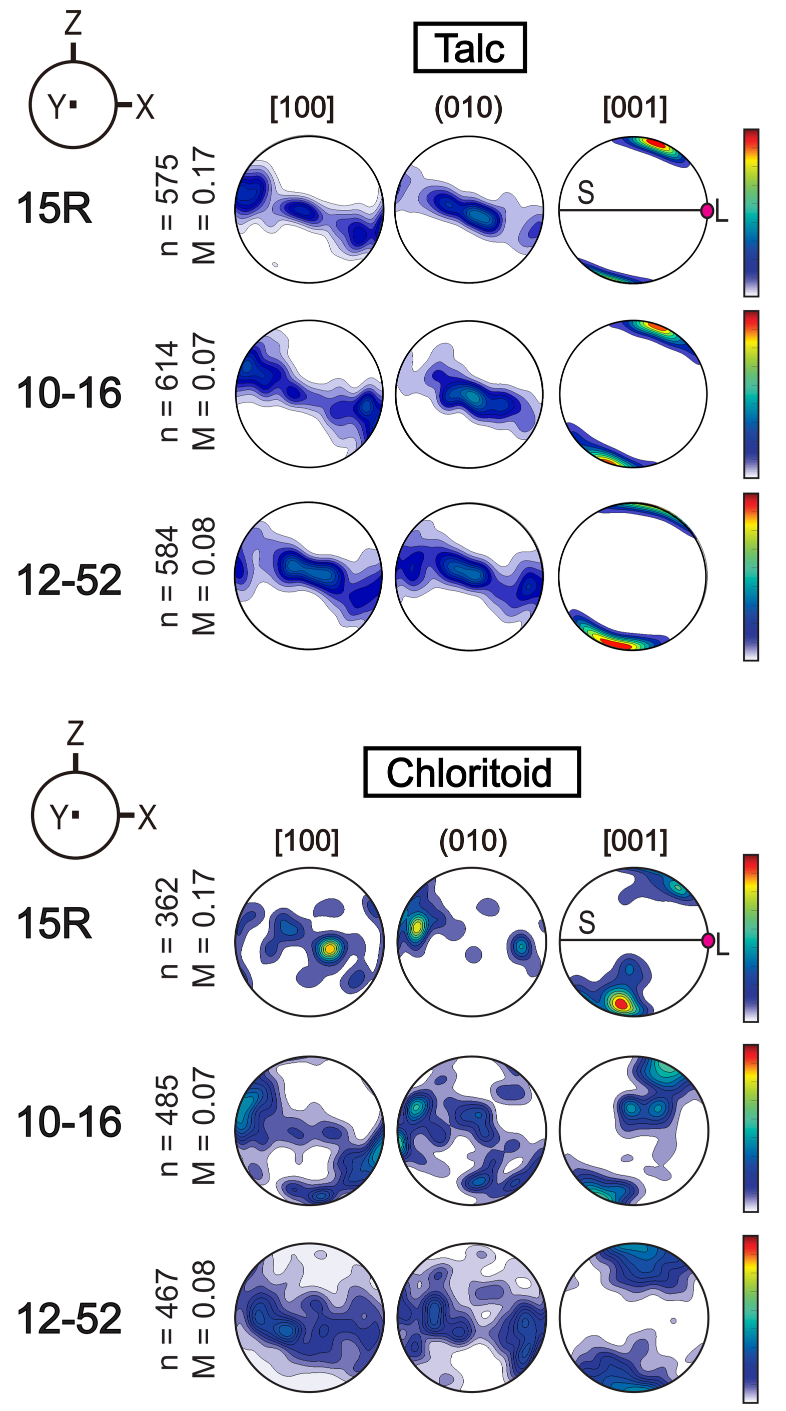


Figure 2. Pole figures of polycrystalline talc and chloritoid in the three Grt-Cld-Tlc schist samples, presented in lower hemisphere using an equal-area projection. Color bars show CPO strengths in units of multiples of random distribution (m.r.d.). n; the number of analyzed grains. M; M-index indicating the CPO strength. X-direction is parallel to the lineation (L), Z–direction normal to the foliation (S) and Y-direction orthogonal to the X-Z plane. Notice that polycrystalline talc and chloritoid showed the strong alignment of [001] axes subnormal to the foliation (Lee et al., 2021).

Method

LPOs of talc were measured by using JEOL JSM-6380 SEM with HKL EBSD at Seoul National University. Seismic anisotropy and P-wave radial anisotropy were calculated as:

$$AVp\ (\%) = \frac{Vp_{max} - Vp_{min}}{(Vp_{max} + Vp_{min})/2} \times 100, \quad AVs\ (\%) = \frac{Vs_1 - Vs_2}{(Vs_1 + Vs_2)/2} \times 100,$$

$$RA = (Vph - Vpv) / \{(Vph + Vpv)/2\}$$

where Vph is the average velocity of horizontally propagating P–waves and Vpv is the vertically propagating P–wave velocity.

References

J. Lee et al. (2020), Lattice preferred orientation of talc and implications for seismic anisotropy in subduction zones, *Earth and Planetary Science Letters*, 537, p.116178., J. Lee et al. (2021), Seismic anisotropy in subduction zones: evaluating the role of chloritoid, *Frontiers in Earth Science*, 9, pp.1-16.

Seismic anisotropies of talc and chloritoid

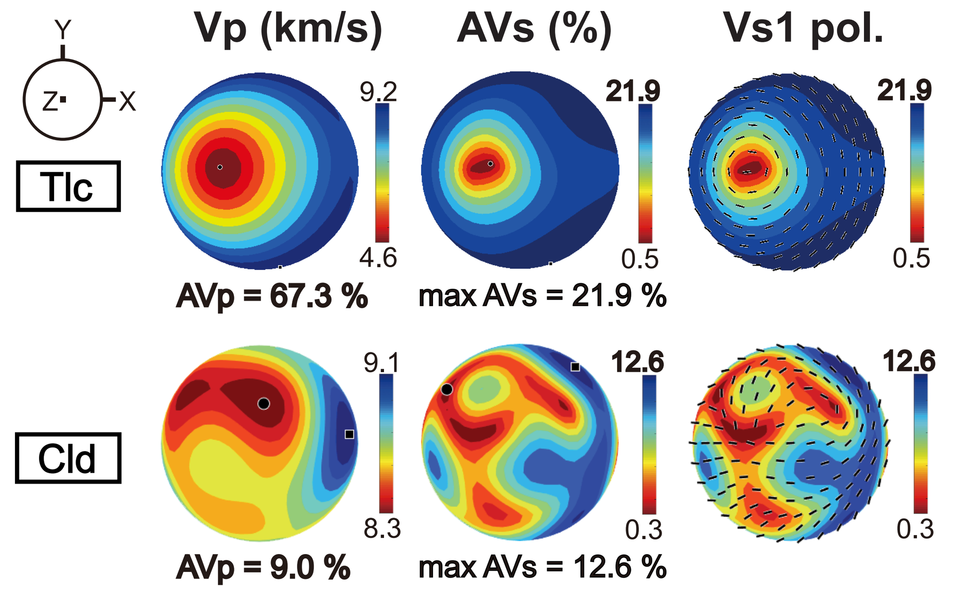
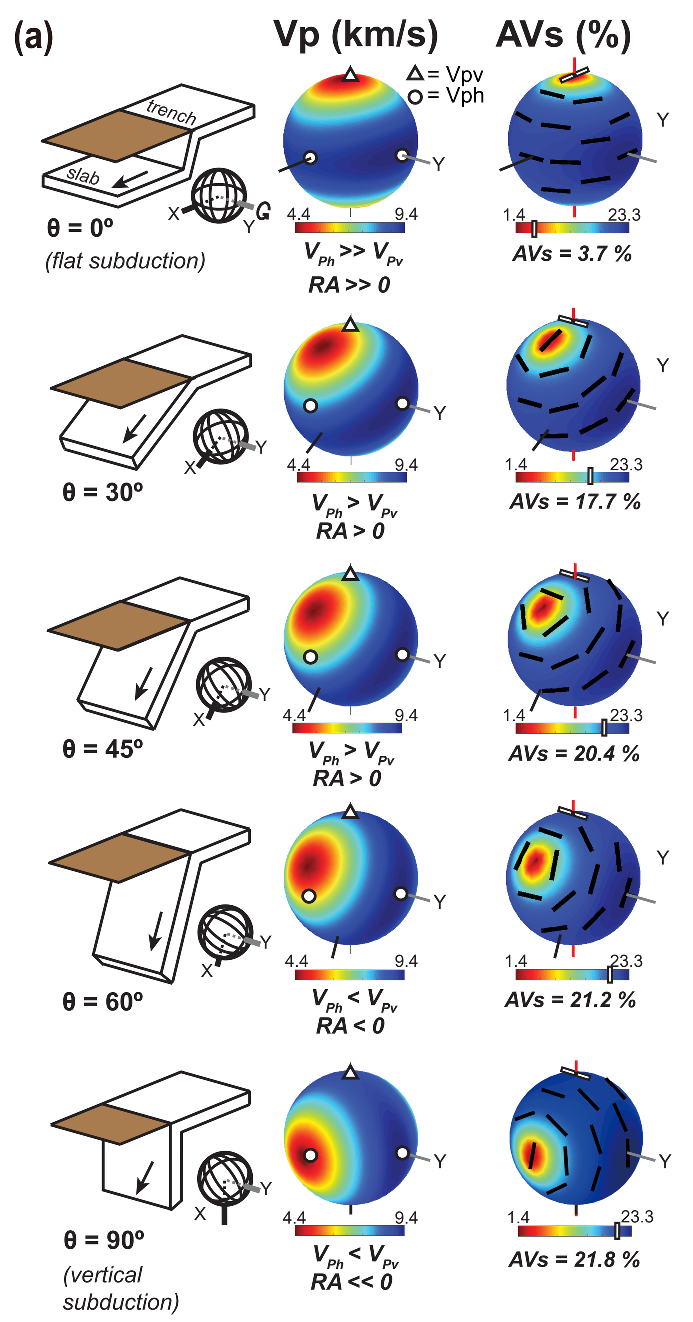


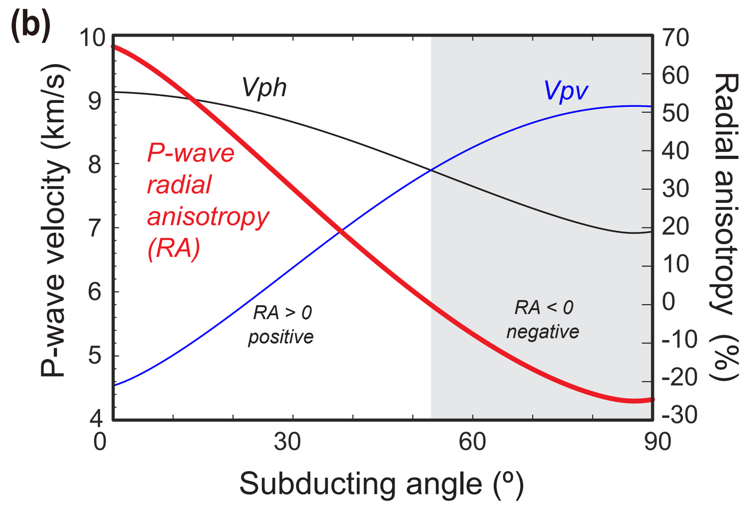
Figure 3. Representative plot of P-wave velocities (Vp), S-wave anisotropies (AVs) and fast S-wave polarization directions (Vs1 pol.) of talc and chloritoid polycrystals in the Grt-Cld-Tlc schists (sample 10-16). Notice the very high P-wave anisotropy (AVp) of talc and high AVs of both talc and chloritoid.

Table 1. Summary of seismic anisotropies of polycrystalline talc and chloritoid in the schist samples.

Sample	Talc		Chloritoid	
	AVp (%)	max AVs (%)	AVp (%)	max AVs (%)
15R	72.3	23.3	10.3	18.1
10-16	67.3	21.9	9.0	12.6
12-52	69.3	21.5	5.3	9.7

Implications for seismic anisotropy in subduction zones





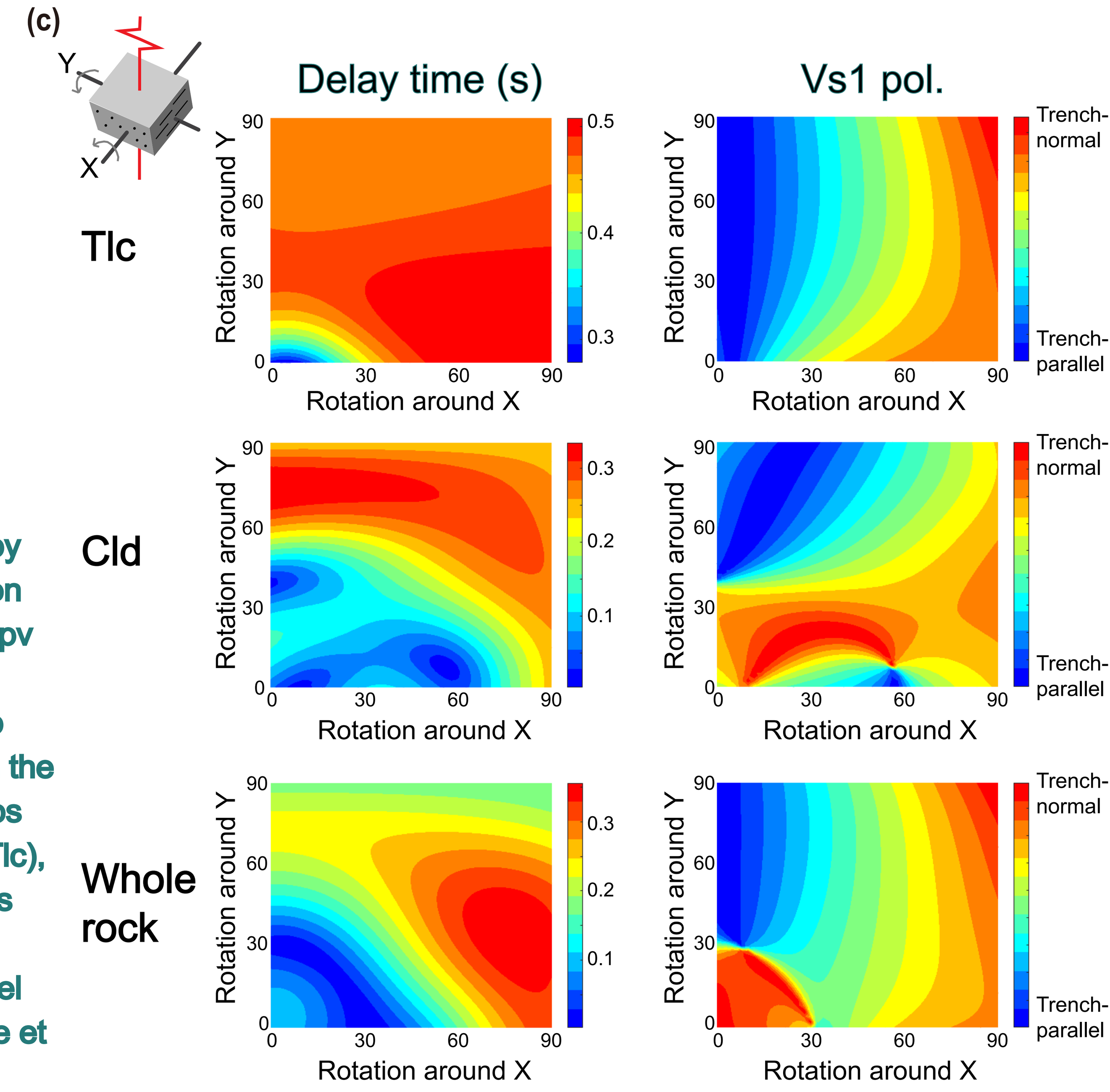


Figure 4. (a) Seismic anisotropies of talc polycrystal. P-wave velocity (Vp), radial P-wave anisotropy (RA), S-wave anisotropy (AVs) plotted in 3-D geometry of subduction zone (Lee et al., 2020). (b) RA, Vph and Vpv of talc polycrystal according to subducting angles. Notice that RA is negative at steep subducting angles which is consistent with the observations in high-angle subducting slabs (ex. Ryukyu, Alps). (c) 3–D effect of talc (Tlc), chloritoid (Cld) and the whole rock samples on a vertically incident S-wave. Notice the long S-wave delay times and trench-parallel anisotropies of both talc and chloritoid (Lee et al., 2021).

Summary

CPOs of polycrystalline talc and chloritoid were measured in Makbal UHP schist samples by EBSD analysis. We found strong CPOs of both talc and chloritoid showing a strong alignment of [001] axes subnormal to the foliation and a girdle distribution of [100] axes and (010) poles subparallel to the foliation. Results of seismic anisotropies of those minerals suggest that strong CPOs of talc can contribute to the production of strong P-wave anisotropy, and CPOs of both chloritoid and talc can influence strong trench-parallel S-wave anisotropies in subduction zones.