Complexity in 15- and 30-sectors polygonal serpentine: Longitudinal sections, intrasector stacking faults and XRPD satellites

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ABSTRACT

Pale-green massive serpentine veins cutting the Yugoslavian serpentinites consist of 15- and 30-sectors polygonal serpentine in random orientation but becoming stress-oriented close to the vein walls. [100] cross-sections show ordered one-layer and two-layer projected polytype sequences, as well as disordered multilayer sequences. From sector to sector, these sections have systematically alternating polytypes that obey the O-L-R and O-R-L alternation rules in 15- and 30-sectors polygonal serpentine, respectively. Furthermore, [010] longitudinal sections systematically show a unique two-layer sequence. By combining the two projections, we reconstruct the basic 3D polytype assemblage that from sector to sector consists of alternating M5-M15-M15 or M5-M16-M16 polytypes. The individual fibers may be described as cyclical pseudo-twins, based upon continuous 1:1 layers, with possible octahedral rotation from one sector to the other. Continuous curved sector boundaries join adjacent sectors, with no tetrahedral sheet inversion; the curved boundaries behave as similar folds and have variable interplanar spacings. Simulated electron diffraction patterns reproduce all the observed diffraction geometries, even for faulted stacking sequences, and explain numbers of diffraction cusps and chords. Additional XRPD reflections are indexed based on polytypes present in 15- and 30-sectors polygonal serpentines.

Keywords: Polygonal serpentine, polytypism, twinning, stacking faults, electron diffraction, HRTEM

INTRODUCTION

Pale-green splintery serpentine veins are common within massive serpentinites. Some consist of fibrous antigorite (e.g., Viti and Mellini 1996), others of fibrous serpentine with X-ray diffraction patterns akin to chrysotile. Eckhardt (1956) and Zussman and Brindley (1957) noticed rotational disorder lower than in chrysotile, as indicated by sharp X-ray diffraction spots in the even layers (h = 2n) of [100] fiber patterns, or by additional X-ray powder diffraction (XRPD) lines. This serpentine variety was initially named “Povlen-type” chrysotile (Kristanović 1967; Kristanović and Pavlović 1964). The names “schweizerite” (Eckhardt 1956; Zussman and Brindley 1957) or “chrysotiloid” (Varlakov and Guriev 1985; Podvysotskiy 1985) have also been used. Transmission electron microscopy (TEM) microstructural studies finally led to the name “polygonal serpentine” (PS), as [100] cross-sections showed polygonally arranged sectors, formed by flat 1:1 serpentine layers (Cressey and Zussman 1976; Middleton and Whittaker 1976; Cressey 1979; Jiang and Liu 1984; Mellini 1986; Yada and Wei 1987; Mitchell and Putnis 1988; Papp 1990).

The number of sectors matches the “magic numbers” 15 or 30 (hereafter PS-15 and PS-30, respectively), with sectors rotated by 24° or 12°. These values arise because, from the core to the rim, five b repeats are added each 1:1 layer; sectors will be 15 or 30, depending on the addition of b/3 or b/6 components at every intersector junction (Baronnet and Mellini 1992; Chisholm 1992; Baronnet et al. 1994; Cressey et al. 1994; Baronnet and Devouard 1996; Logar and Viti 1996; Dódony 1997a). Baronnet and Devouard (2005) showed that PS is made of laterally continuous 1:1 layers, with no tetrahedral inversion at the curved sector boundaries. Although different, this model is similar to those of Chisholm (sharp boundaries with no inversion) and Dódony (sharp boundaries with inversion). The basic features of the Baronnet and Devouard’s model are the local, non-crystallographic fivefold axial symmetry and the concerted presence of specific polytypes in adjacent sectors. This model agrees with the Dódony’s observations, as far as the alternation of three different oblique two-dimensional (2D) cells is concerned. From sector to sector, in [100] projections there is a one-layer orthogonal (O) cell, an oblique right-slanting (R) cell, and an oblique left-slanting (L) cell (being O-R-L and O-L-R the counterclockwise alternations in 30- and 15-sectors fibers, respectively).

In addition, we report [100] TEM data on nanostructure and polytypism in PS-15 and PS-30, comparing our results with the previous models. We also focus on complex [100] diffraction patterns, characterized by “wings,” “cusp points,” and “chords” (Baronnet and Devouard 2005), which we interpret as due to intrasector radial stacking faults.

Finally, we deal with [010] longitudinal sections, to understand the three-dimensional (3D) polytype arrangements. The resulting 3D polytype model is used to index additional reflections in the XRPD patterns.