Crystal chemistry and defect structure of ekmanite: 
new data from transmission electron microscopy 
and Mössbauer spectroscopy

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Abstract: Ekmanite is a member of the 2:1 type modulated layer silicates such as ganophyllite and bannisterite. 
Its chemical composition can be represented by \( \text{K(M}_2\text{O)}[\text{Si}_8\text{O}_{26}](\text{OH})_{16} \) \( (\text{M} = \text{Fe}^{2+}, \text{Mg}^{2+}, \text{Mn}^{2+}) \) where three 
of eight Si-tetrahedra are inverted across the interlayer sharing an apical oxygen with similarly inverted 
tetrahedra from the adjacent layers. The arrangement of the regular, D, and inverted, R, tetrahedra has the 
configuration 4D2R1D1R4D... along the \( b \)-axis. In local regions of possibly high \( \text{Mg/(Mn+Fe)} \) ratio, this 
configuration is interrupted by the absence of inverted tetrahedra. Ekmanite typically contains a multitude of 
defects; twinning and both regular and irregular stacking arrangements are the most common ones.

Ekmanite is sensitive to oxidation and an unidentified phase, chemically related to it, is always found 
lining its grain boundaries. This texture results in intergrown rods defining polygons where the central parts 
do not contain ekmanite. The Mössbauer spectrum consists of \( \text{Fe}^{2+} \) and \( \text{Fe}^{3+} \) absorption doublets with the 
\( \text{Fe}^{2+} \) absorption composed of two Gaussian line pairs and the \( \text{Fe}^{3+} \) absorption of a single but broad line 
pair.

Key-words: ekmanite, HRTEM, Mössbauer spectroscopy, modulated structure, defects, image processing.

1. Introduction

Ekmanite from the mine Brunnsvjöruvan in Hällefors, Örebro, Sweden, was first described as an 
Fe- and Mn-rich hydrous silicate mineral by Igelström (1865). On the basis of optical data and 
chemical analysis, ekmanite was considered to be related to the friedelite-pyrosomalite group by 
Hamberg (1889). From single-crystal X-ray data, 
Nagy (1954) identified ekmanite as a layer silicate, structurally related to stilpnomelane. He suggested that the structure of the orthorhombic subunit, with \( a_0 = 5.54 \), \( b_0 = 9.60 \) and \( c_0 = 12.08 \) Å, 
was composed of talc-like layers and interleaved cations. However, the reflections were so heavily 
streaked that the structure could not be determined from X-ray diffraction data.

The extraction of phases and amplitudes and the subsequent refinement of the origin from experimental HRTEM images has been exploited by 
image processing techniques to determine the structure of both organic and inorganic compounds (De Rosier & Klug, 1968; Wenk et al., 1992; Zou et al., 1993). This technique has also 
been used to enhance structural details in minerals (Ferrow & Hovmöller, 1993). Nevertheless, the 
technique has previously only been used in studies of periodic features. Using the Fourier 
transform filtering methods provided by CRISP, a commercially available system running on PC