Clay Structures revealed by TEM

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Clay minerals are a representative layered material, ubiquitously existing as the key inorganic substance for the terrestrial surface environments and possessing many industrial applications. However, it is also recognized that their structures are still not well-understood owing to the complexity characteristic to the layered structures, small particle size, and possible inhomogeneity in a sample. For instance, X-ray diffraction commonly applied to clay minerals often does not characterize them thoroughly, which may bother people utilizing clay minerals in their researches.

On the other hand, transmission electron microscopy (TEM) can analyze individual clay particles to derive information for their crystal structure, chemical composition, bonding state, etc. Hence TEM analyses are generally irreplaceable and often essential for the understanding of the clay minerals. Of course TEM is not omnipotent. Especially the number of particles examined by TEM is so limited that the obtained results may not represent the sample. This problem should be complemented with other "bulk analysis" techniques. Moreover, amorphization by beam radiation often prevents the atomic scale high-resolution TEM (HRTEM) imaging of clay structures.

Since 1996 when the author started investigation of clay minerals and related materials using HRTEM, he has reported the atomic structures of a number of clay minerals, which were obscure or only speculations from other techniques. Among them, elucidations of the stacking structure of kaolinite and halloysite [1, 2] deserve specific mention. These results give new insights for the formation scheme of kaolin group minerals as well as the correct interpretation of XRD and IR spectroscopy from the minerals. Unfortunately similar HRTEM studies have not appeared from other research groups in the recent decade, probably due to difficulty to overcome radiation damage. However, the situation will be improved, for instance, by the development of new cameras with a higher detection efficiency, image processing techniques, and more "intelligent" electron microscope systems.

[1] Kogure and Inoue (2005) Am. Mineral., 90, 85-89.
[2] Kogure et al. (2013) Am. Mineral., 96, 1776-1780.