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Exomorphism of Jacobsite Precipitates in Bixbyite Single Crystals from the Thomas Range in Utah

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Naturally occurring single crystals of bixbyite, (Fe,Mn)2O3, from the Thomas Mountain Range in Utah, USA were studied via (scanning) transmission electron microscopy (S)TEM. With up to 5 cm edge length, these mineral specimens are the largest bixbyite crystals found worldwide. Their hexahedral shapes are often modified by {211} facets at the corners and small {211} truncations along their cube edges. Characteristic lamellar defects running parallel to the {100} planes can be observed via TEM imaging, which are, according to EDS analyses, attributed to the tetragonal manganese silicate braunite, Mn7[SiO12]. In the present study, electron nano-diffraction and atomic resolution (S)TEM were employed to verify the presence of braunite lamellae and to investigate their orientation relationship with bixbyite. The analysis confirmed an epitaxial intergrowth of both phases, with their main axes being parallel and the unique c axis of braunite always aligned perpendicularly to the lamellar plane. Moreover, small rectangular shaped precipitates, which had been, due to their almost identical chemical composition, previously interpreted as small bixbyite inclusions within the host crystal, were often observed in contact with the braunite lamellae. Electron nano-diffraction and atomic resolution (S)TEM imaging revealed these crystallites not to be bixbyite but jacobsite, a cubic iron-manganese spinel with the stoichiometric formula MnFe2O4, whose occurrence in this unique context had not been reported before. Moreover, due to the higher temperatures needed for spinel crystallization, the occurrence of jacobsite may serve as a geo-thermometer. (S)TEM in conjunction with automated crystal orientation mapping (ACOM)-TEM showed that no orientation relationship exists between the jacobsite inclusions and the bixbyite/braunite matrix. Nevertheless, their characteristic rectangular shape is typically aligned concordantly with the (001) plane of the braunite lamellae. The resulting crystal shape of jacobsite is determined by the presence of the braunite lamellae, while the respective crystallites maintain their freedom of rotation. To the authors'knowledge, this is a novel observation of exomorphosis of jacobsite, i.e. the change in habitus of the spinel crystallites due to external conditions. Note that the term exomorphosis is used here in the mineralogical sense in contrast to the often used petrological aspect. Based on the TEM results, the formation of the jacobsite precipitates is discussed and a growth model suggested.

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