

Abstract Aluminum phosphate-sulfate (APS) minerals are present as small, disseminated crystals in the upper Cretaceous shallow marine ooidal ironstones, E-NE Aswan area, southern Egypt. Their association with the ironstones is considered as a proxy of subaerial weathering and post-diagenetic meteoric water alteration. The mineralogical composition of the ooidal ironstones was investigated by optical and scanning electron microscopes, X-ray diffraction, Fourier transform infrared and Raman spectroscopy. The ooidal ironstones are composed mainly of ooids and groundmass, both of which consist of a mixture of detrital (quartz) and diagenetic (fluorapatite, chamosite and pyrite) mineral assemblages. These mineral assemblages are destabilized under acidic and oxidizing, continental conditions. These conditions resulted from the oxidation of pyrite and probably organic matter under warm and humid, tropical climate followed the Santonian Sea regression and subaerial exposure. These pedogenic conditions promoted corrosion of quartz, dissolution of chamosite and apatite and hydrolysis of feldspars of the nearby exposed granitoids. The released Si, Al and Sr from quartz, chamosite and feldspars; Fe and S from pyrite and P, Ca and light rare earth elements (LREE) from apatite are reprecipitated as hematite, kaolinite, apatite and APS minerals from the pore fluids or along fractures. The paragenetic sequence and textural relationships of this post-diagenetic mineral assemblage indicate that hematite was formed by replacement of chamosite followed by formation of a secondary generation of pore filling chlorapatite and APS minerals and finally the precipitation of kaolinite in the remaining pore spaces. The formation of APS minerals and chlorapatite is simultaneous, but APS minerals are stable at shallow depths under acidic to neutral pH conditions, whereas chlorapatite is stable under alkaline pH conditions. Alkaline conditions were maintained at greater depths when the infiltrated acidic fluids reacted with chamosite. The APS minerals display a homogeneous chemical composition in all ironstone locations in Aswan area, corresponding to a solid solution between crandallite ($\text{CaAl}_3(\text{PO}_4)_2(\text{OH})_5 \cdot \text{H}_2\text{O}$), goyazite ($\text{SrAl}_3(\text{PO}_4)_2(\text{OH})_5 \cdot \text{H}_2\text{O}$), svanbergite ($\text{SrAl}_3(\text{PO}_4)(\text{SO}_4)(\text{OH})_6$) and woodhouseite ($\text{CaAl}_3(\text{PO}_4)(\text{SO}_4)(\text{OH})_6$) end-members. The variations in the APS mineral chemistry ($\text{AB}_3(\text{XO}_4)_2(\text{OH})_6$) are essentially due to variable substitutions of Sr and LREE for Ca at the A site and limited S for P at the X site. The spatial distribution of APS minerals and their composition in the ooidal ironstones of Aswan area permitted to consider them as good tracers of physicochemical and paleoenvironmental changes, in particular those associated with subaerial exposure and pedogenesis. The post-diagenetic phosphatization and kaolinization of the Aswan ironstones decrease their economic potentiality; thus, understanding paragenetic sequence and textural relationships is essential for the iron ore beneficiation.

Keywords Aluminum phosphate-sulfate minerals · Paleoenvironment · Ooidal ironstones · Aswan · Egypt