A new occurrence of xitieshanite \([\text{Fe}^{3+}\text{(SO}_4\text{)}\text{Cl}\cdot6\text{H}_2\text{O}]\) crystals in acid-mine seepways, Green Valley, Vigo County, Indiana, U.S.A.

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**ABSTRACT**

A new occurrence of the rare efflorescent sulfate mineral xitieshanite \([\text{Fe}^{3+}\text{(SO}_4\text{)}\text{Cl}\cdot6\text{H}_2\text{O}]\) has been documented from acid mine drainage (AMD) flows at Green Valley, Vigo County, Indiana, U.S.A. This represents only the second documented occurrence of the mineral, and is a new environment of deposition. Previously, xitieshanite had been documented only within the oxidation zone at the Xiteshan Mine, Quinghai Province, China. The presence of xitieshanite at Green Valley was confirmed through X-ray powder diffraction and chemical analyses. The mineral forms botryoidal semi-gelatinous lumps, as well as radiating clusters of light-green bladed and rod-like acicular crystals up to 1 mm long, in some cases pseudomorphically replacing melanterite. This is the only documented occurrence of the mineral as distinct observable crystals that indicate pseudomorphism. The xitieshanite forms following large summer storms that provide oxygenated waters in the AMD seepways, and a warm, humid environment of deposition. The chlorine in the mineral may originate from coal waste or anthropogenic sources related to de-icing operations at the mine plant.

**INTRODUCTION**

Xitieshanite, a hydrous iron sulfate mineral, has previously only been reported in the oxidation zone of a lead-zinc deposit in Quinghai Province, China. Xitieshanite is present in minor quantities at the Xiteshan mine, where it occurs as rhombic rectangular crystals or massive aggregates up to 2 cm in length. The xitieshanite crystals occur within the lower portion of the oxidation zone along with the iron sulfate phases copiapite, romerite, coquimbite, amarillite, sideronatrite, and melanterite (Li et al. 1983). Originally assigned a formula of \(\text{Fe}^{3+}\text{SO}_4\text{(OH)}\cdot7\text{H}_2\text{O}\) by Li and others (1983), further work documented the presence of 10.05 wt% Cl resulting in a new published formula \([\text{Fe}^{3+}\text{(SO}_4\text{)}\text{Cl}\cdot6\text{H}_2\text{O}]\) (Zhou et al. 1988).

A new occurrence of xitieshanite is documented here based on X-ray powder diffraction and wet chemical data obtained from samples collected from several seeps of acid mine drainage (AMD) at Green Valley, Vigo County, Indiana, U.S.A. (Fig. 1). Small quantities of xitieshanite have precipitated onto iron oxide-coated glacial limestone cobbles and modern organic debris along the seeps.

Three AMD seeps at Green Valley occur along the southern margin of a 2.1 million m\(^3\) gob pile of coarse-grained coal waste, fine coal slurry, and minor shale, limestone, sandstone, and pyrite. This material occupies the former coal processing plant of the Snow Hill Coal Corporation. The Indiana Department of Natural Resources Reclamation Division has capped and revegetated the gob pile, and lined all AMD seeps with limestone cobbled riprap in an ongoing remediation effort to neutralize the highly acidic (pH ~ 1 to 4) water before it discharges into Sugar Creek. The limestone cobbles quickly become coated with dark brown to yellow iron oxides; melanterite (FeSO\(_4\)\cdot7H\(_2\)O) is ubiquitous on these cobbles at seeps 1, 2, and 3.

Seep 3 is a site where AMD was first documented in 2001. It was lined with limestone riprap in 2002 after the samples for this study were collected. At the time of this study, the seep had flowed over glacial cobbles (including some glacial limestone cobbles) and till that were used to cap the gob pile. Xitieshanite is observed here in close association with melanterite and rozenite on limestone cobbles and organic material.

**METHODS, DATA, AND INTERPRETATION**

**Methods**

Samples of efflorescent minerals were collected in the field and sealed in 1 oz borosilicate glass bottles with airtight poly-seal cone closures. Water samples were collected in acidified borosilicate glass bottles with airtight poly-seal cone closures and stored on ice until elemental analysis was performed using a Finnegan MAT “Element” Sector Field (HR) ICP-MS at Washington University. Field measurements of specific conductance and temperature were performed using a YSI 30 conductivity meter, and pH was measured in the field using a Corning-Hanna 98/07 pH meter. For XRD analyses, both General Electric XRD-700 and Philips X-Pert diffractometers were used. An α-quartz sample from Hot Springs, Arkansas and General Electric Corporation “permaquartz” samples were used as XRD standards. Centroid peak errors for the standards were ± 0.002° 2θ.

**Physical properties and observation of crystals**

The xitieshanite at Green Valley is light green in color and occurs both as botryoidal semi-gelatinous aggregates on limestone cobbles and as clusters of acicular crystals on organic material.