

**EXCEPTIONAL CHIAVENNITE ASSOCIATED WITH PEZZOTTAITE  
FROM THE SAKAVALANA PEGMATITE,  
AMBATOVITA, MADAGASCAR**

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*Abstract: exceptional specimens of chiavennite were recently found, associated with the new mineral pezzottaite, in the Sakavalana pegmatite at Ambatovita, in central-western Madagascar. Chiavennite at Ambatovita formed as a late-stage mineral, after quartz, amazonite, albite, spodumene, Cs-bearing beryl and pezzottaite, liddicoatite, Cs-rich muscovite-lepidolite, danburite and other accessories such as zircon, pyrochlore-group minerals and cassiterite. Chiavennite formed together with hambergite, a late generation of pezzottaite, and some masses of Mn-hydroxides (mainly cryptomelane). Chalcedony formed together and after chiavennite.*

## INTRODUCTION

In November 2002, in a wild area in central-western Madagascar close to the village of Ambatovita, 22 km south of Mandrosonoro, local miners discovered in the Sakavalana pegmatite a spectacular, large miarolitic cavity containing large crystals of citrine quartz, green amazonite, albite, green-to pink spodumene, multicolored liddicoatite and raspberry “Cs-rich beryl”, the recently approved new mineral pezzottaite (Laurs et al., 2003). This discovery, documented during the last year by several publications, has been described also in *Le Règne Mineral* by Warin and Jacques (2003).

One of the authors (H.F.), in February 2003, examining some samples collected at Ambatovita, first observed a 5 cm specimen mainly consisting of a brownish-red mineral forming small aggregates of radial crystals, associated with Mn-hydroxides and cementing large fragments of quartz and pezzottaite crystals. In the small cavities of the specimen, this mineral formed globular aggregates 1-2 mm across, covered by a thin crust of colorless to pale blue chalcedony.

During a field trip to Ambatovita in July 2003 the senior author (F.P.) obtained from a local miner a large specimen (over 7 kg in weight) containing groups of pezzottaite crystals, liddicoatite, green amazonite, quartz, Mn-hydroxides and large masses of the brownish-red mineral mentioned above, together with chalcedony and a colorless to white mineral forming flat, elongated prisms up to 1 cm. Breaking the specimen into smaller pieces, a few cavities up to 5 cm across were found inside the masses of the brownish-red mineral. These cavities were

covered by globules and aggregates of tabular crystals of the unknown mineral, together with pezzottaite crystals.

In October 2003, EDS microprobe analyses performed in the laboratory of the Museo di Storia Naturale of Milano, and X-ray powder diffraction analyses performed at the Dipartimento di Chimica Strutturale e Stereochimica Inorganica of the University of Milano, allowed to identify the brownish-red mineral as chiavennite, and the colorless to white prismatic crystals as hambergite.

## PREVIOUS LOCALITIES FOR CHIAVENNITE

Chiavennite,  $\text{CaMnBe}_2\text{Si}_5\text{O}_{13}(\text{OH})_2 \cdot 2\text{H}_2\text{O}$ , is a rare Be-bearing zeolite with an interrupted framework of four-connected  $[\text{SiO}_4]$  and three-connected  $[\text{BeO}_4]$  tetrahedral (Coombs et al., 1998). The structure was solved by Tazzoli et al. 1995.

The mineral was discovered in 1981 in a granitic pegmatite outcrop close to the Tanno village, in the Chiavenna Valley, Central Alps, Italy (Bondi et al., 1983). At the Italian type locality chiavennite forms tiny lamellar aggregates of reddish or orange-yellow color up to 1-2 mm across, occurring in small vugs or fissures in feldspars. Associated minerals include, beside feldspars, muscovite, spessartine, manganocolumbite, bavenite, milarite and apatite. Occasionally the mineral occurs also as partial pseudomorphs of small beryl crystals.

Contemporary with the Italian discovery, chiavennite was identified in Norway in the nepheline-syenitic pegmatites at Heia and Langangen, in the Oslo region (Raade, 1983). Associated minerals were aegirine, K-feldspar, albite, biotite, thorite, zircon, thomsonite, chlorite, hambergite, arsenopyrite, lollingite, galena, apatite, analcime, eudidymite, natrolite and fluorite. A few other occurrences of this rare Be-zeolite were observed later in syenitic pegmatites of the nearby area (e.g. Bakkane, Vevja). Beautiful specimens of chiavennite are illustrated by Andersen et al. (1996).

At Tvedalen, a new significant discovery of chiavennite was recently made (April 2000) in another syenitic pegmatite mined in the Tuften quarry (Larsen, 2000). At this locality the mineral is associated with analcime, hambergite, aegirine, natrolite, calcite and chlorite (Nordrum 2004).

Today there are approximately 20 nearby locations of chiavennite (Larsen, 2001), all on the mainland in the extensive larvikite quarries in Tvedalen near Larvik. There is only one locality on the islands in Langesundsfjord, *viz.* Vesle Arøya (Svein Arne Berge, pers. Comm.. 1993).

In 2000 a boron-rich chiavennite, associated with genthelvite-helvite, was also described from (Li-Cs-Ta rich) pegmatites at Utö, Stockholm, Sweden (Langhof and Holtstam, 1994, Langhof et al. 2000), where it occurs as up to 5 mm single crystals of golden brown color, often together with milarite.

Close to the type locality in the Chiavenna valley, a second occurrence of the mineral was made in 2001 in a pegmatitic dike located at Pra della Munega (Pietro Vignola 2004, personal communication).

In all granitic pegmatite localities chiavennite is a late-stage mineral forming small tabular crystals, radiated aggregates covering feldspars and other minerals in vugs or fractures, and partial or complete pseudomorphs of beryl crystals.

In the nepheline-syenitic pegmatites, however, chiavennite is most probably formed as a result of hydrothermal alteration of meliphanite or leucophanite as the source of beryllium (Larsen, 2001).

Typically in the Norwegian locations chiavennite is often associated with hambergite, which is sometimes altered and probably another source of Be (Engvoldsen et al., 1991).

#### MALAGASY CHIAVENNITE

Chiavennite at Ambatovita was found in the two samples described above and in a few other specimens, very rich in the mineral and always showing the same paragenesis. All such samples probably originated from a restricted portion of the large cavity (or system of cavities) of the original pezzottaite find in November 2002.

Because of the abundance of chiavennite, the freshness of the crystals and the association with other rare species, the Ambatovita occurrence is absolutely exceptional. The large specimen acquired in July 2003 at Ambatovita contained some kilograms of the mineral (more or less “mixed” with chalcedony). On the surface of the specimen, chiavennite appears to be more or less altered, with an orange color. Washing and brushing the outer coating reveals the hambergite and the pezzottaite crystals. Breaking such masses, chiavennite appears very fresh and the crystals (up to 2 mm) in the cavities are well formed and transparent.

The EDS microprobe analyses indicated Ca, Mn and Si contents in the range of the published data for the mineral obtained in the other localities. Some significant Fe content is present in the Y site. No study has been performed since now to know the boron content of the mineral.

The X-ray powder diffraction data (Tab.1) confirmed the mineral identification. Cell parameters resulted:  $a = 8.722(4)$ ;  $b = 31.21(1)$ ;  $c = 4.892(1)$ , in agreement with those reported in literature (compare with table 2 in Langhof et al., 2000).

#### ASSOCIATED MINERALS AND GENETIC CONSIDERATIONS

The Ambatovita chiavennite formed as a late-stage mineral, after quartz, amazonite, albite, spodumene, Cs-bearing beryl and pezzottaite, liddicoatite, Cs-rich muscovite-lepidolite, danburite and other species such as zircon, pyrochlore-group minerals and cassiterite. Chiavennite formed together with hambergite, a late generation of pezzottaite and some masses of Mn-hydroxides (mainly cryptomelane). Chalcedony was deposited together with and after chiavennite. Some other phases associated with chiavennite are still under study.

Chiavennite in the large miarolitic cavity at Ambatovita formed after a significant pocket rupture, as suggested by the large fragments of crystals of the previously formed minerals cemented by this zeolite. Corroded pezzottaite, as well as non-corroded pezzottaite crystals are cemented by chiavennite; also a late generation of pezzottaite formed inside the cavities of the zeolite. This indicates that multiple generations of pezzottaite occurred and that chiavennite formed over a significant span of time during the latest stages of evolution of the cavity. These late minerals formed very probably in low-temperature hydrothermal B-rich solutions, with a strong activity of Be, Mn, Cs and Ca.

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FIGURE CAPTIONS



Fig. 1 – The Sakavalana mine in July 2003. Photo F. Pezzotta.



Fig. 2 – Frontal view of the Sakavalana mine photographed in April 2004, after the strong cyclone of March 2004 which destroyed much of the cabins at the place. Photo F. Pezzotta.



Fig. 3 – Chiavennite, aggregate of crystals 2-3 mm across. L. Caserini collection. Photo R. Appiani.



Fig. 4 – Chiavennite aggregates (2-3 mm across) with pezzottaite crystals. L. Bertelli collection. Photo R. Appiani.



Fig. 5 – Chiavennite aggregates 2 mm across, partially covered by chalcedony. Collection Natural History Museum, Milan. Photo R. Appiani.



Fig. 6 – Hambergite, crystal 7 mm long with chiavennite. Collection Natural History Museum, Milan. Photo R. Appiani.

Table 1. X-ray powder diffraction data for Chiavennite  
 From Ambatovita. Cu-K<sub>α</sub> radiation, orthorhombic cell  
 With parameters:  $a$  8.722 (4),  $b$  31.21 (1),  $c$  4.892 (1) Å

I/I <sub>0</sub>	$d_{\text{obs}}$	h	k	l
52	15.608	2	0	0
6	7.612	2	1	0
24	5.808	4	1	0
22	4.114	2	1	1
8	3.295	7	0	1
26	3.258	0	2	1
12	3.187	2	2	1
24	3.118	7	2	0
23	2.939	10	1	0
37	2.887	5	2	1
12	2.827	9	0	1
7	2.692	9	1	1
12	2.633	10	0	1
5	2.599	12	0	0
10	2.515	10	1	1
11	2.499	0	3	1
9	2.378	11	2	0
6	2.335	4	0	2
10	2.254	4	1	2
11	2.222	12	1	1
6	2.181	0	4	0
13	2.157	13	0	1
7	1.977	14	1	1
7	1.951	10	3	1
10	1.929	4	4	1
6	1.770	14	3	0
6	1.702	4	5	0
6	1.631	0	0	3
7	1.613	13	4	0
6	1.608	3	4	2
8	1.601	1	1	3
7	1.420	0	5	2