Harmotome from Korsnäs, Finland

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Summary. This paper describes a harmotome from the Korsnäs mine in Finland, which occurs in the same open cavity as the yellow apophyllite previously reported in this journal. The harmotome is always twinned according to the morvenite and Marburg laws. Chemical composition, optical properties, X-ray powder pattern, and single crystal data are given.

IN 1965 the senior author published a paper on the yellow apophyllite found in a large open cavity in the Korsnäs lead mine in western Finland (Sahama, 1965). As was mentioned in that paper, the same cavity contains also white to greyish harmotome in considerable quantities. This paper reports the properties of that harmotome, of which no earlier descriptions exist in the literature.

Morphology. The harmotome from Korsnäs occurs as well-developed crystals ranging up to 1 cm in the direction of the *b*-axis, often with this axis roughly at right angles to the surface of the matrix. Exceptionally, crystals up to *c.* $2\frac{1}{2}$ cm in length have been collected. The crystals, which show good cleavage parallel to {010} and slightly less good parallel to {001}, are always penetration twins; no untwinned individuals have been collected. The nomenclature of the twin laws used in this paper follows that used by Lacroix (1896) for phillipsite ('christianite') and harmotome.

The habit of a simple penetration twin of the Korsnäs harmotome is illustrated in fig. 1 and is known as the morvenite type twin. The setting used in the figure and the indices assigned to the crystal faces are based on the unit cell deduced from X-ray data to be given below. The distinction between the faces {001} and {100} was made on a *b*-axis zero-level precession photograph of a plate cut parallel to {010} in which the edges [100/010] and [001/010] were visible. The setting agrees with the crystal drawings given, e.g. by Sekanina *et al.* (1937) and by Meier (1939). No other crystal faces except those indicated in the figure have been observed. The main variation in the habit is in the predominance of {100} over {110} or vice versa: in some twins {100} is

large and {110} narrow as in fig. 1, in others {110} predominates strongly
and {100} is narrow. All crystal faces are more or less striated; the stria-
tion on {001} is parallel to the common b-axis of the twin and on {100}
and {110} parallel to the c-axis. On {010} the visible striation discloses
the twinning in the way drawn in fig. 1.
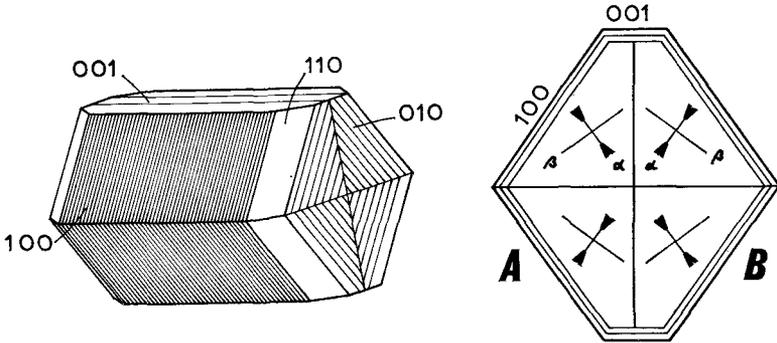
FIGS. 1 and 2: FIG. 1 (left). Habit of a simple penetration twin (morvenite). FIG. 2
(right). Section (010) of a simple penetration twin (morvenite) showing the optical
orientation

A section of the simple penetration twin parallel to {010} is illustrated
schematically in fig. 2, which also indicates the optical orientation.
The figure shows the two interpenetrating individuals A and B with the
apparent composition planes (001) and (20$\bar{1}$) perpendicular to each
other. In actual crystals the texture exhibited under the microscope in
section (010) is less regular, patches of the individual A being enclosed
in the individual B and vice versa. The existence of the two apparent
composition planes mentioned is, however, characteristic of the twin
pattern. The plane (001) represents a twin plane; twinning on {001}
is well known for harmotome and is easily understood on the basis of
the crystal structure of the mineral worked out by Sadanaga *et al.*
(1961). For the plane (20$\bar{1}$) the matter is different. The monoclinic sym-
metry of harmotome is known to be pseudo-orthorhombic (Černý, 1964),
the transformation from a primitive monoclinic cell to a base-centred
pseudo-orthorhombic cell being: $a_m \rightarrow a_o$, $b_m \rightarrow b_o$ and $2c_m + a_m \rightarrow c_o$.
As has been pointed out by Sadanaga *et al.* (op. cit.), the β-angle of
this pseudo-orthorhombic cell is not exactly 90° but is 90° 23′. Accord-
ingly, (20$\bar{1}$) does not represent a twin plane, and the ideal shape of
the simple penetration twin would be as in fig. 3, in which, however,

the angle between the $(20\bar{1})$ planes of the two individuals has been strongly exaggerated. Because this angle is small, the boundary between the two individuals, which is quasi-perpendicular to (001), appears in the twin as if it represented a regular composition plane, thus producing the texture of fig. 2.
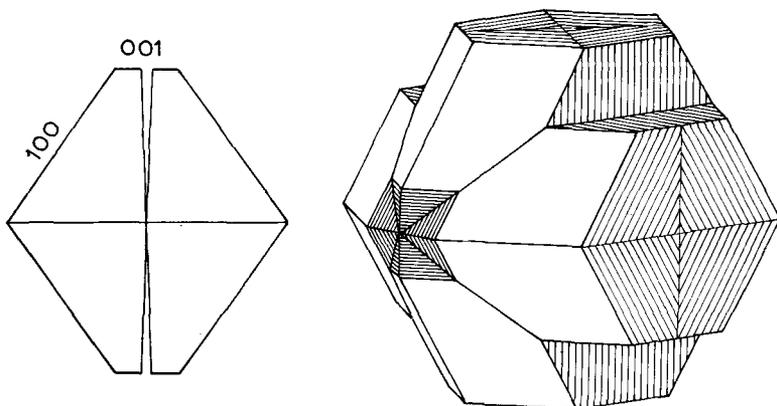
FIGS. 3 and 4: FIG. 3 (left). Idealized section (010) of a simple penetration twin. Angle between the two individuals strongly exaggerated. FIG. 4 (right). Habit of an interpenetrant cruciform twin of the Marburg type

In addition to the simple morvenite twinning, complex cruciform twinning of the Marburg type is common in the Korsnäs locality and is illustrated in fig. 4. The b-axes of the two simple morvenite twins are perpendicular to each other and the twin plane of the complex cruciform is (021). The Périer, Bowling, and Stempel type twins have not been found in Korsnäs.

Chemical composition. For chemical analysis, hand-picked crystals were used. Most of the crystals were clear, only some of them showed a slight turbidity. The total amount of impurities in the analysed material was considered virtually negligible. The chemical analysis was kindly made by Dr. H. B. Wiik, of the Geological Survey of Finland, with the following result: SiO_2 45·21, Al_2O_3 15·26, Fe_2O_3 (total iron) 0·74, MnO 0·01, MgO 0·48, CaO 0·09, BaO 20·66, Na_2O 1·81, K_2O 0·24, H_2O+ 15·57, H_2O- 0·27, total 100·34. Ti was not found. Based on the specific gravity of the mineral, $D = 2\cdot442$ (heavy liquid and Mohr balance, with better than $\pm0\cdot006$), and the unit-cell parameters to be given below, the unit-cell content is calculated as: Si 11·05, Al 4·39,

Fe 0·14, Mg 0·17, Ca 0·02, Ba 1·98, Na 0·86, K 0·07, H_2O+ 12·69, O 31·53. These values lead to the formula: $(Na, K)_{0·93}(Ba, Ca)_{2·00}$ $(Al, Fe, Mg)_{4·70}Si_{11·05}O_{31·53}.12·69 H_2O$. The Korsnäs harmotome is remarkably rich in Na, Fe, and Mg and poor in K. Compared with the formula $(Na, K)_x Ba_2 Al_{4+x} Si_{12-x} O_{32}.12H_2O$ proposed by Sekanina et al. (1937) and adopted by Černý et al. (1965), the mineral shows a slight deficiency in (Al, Fe, Mg) and a noticeable excess in H_2O. The deficiency in Al, etc., could be balanced by a part of H_2O occurring as OH in substitution for O.

TABLE I. Powder pattern of harmotome from Korsnäs, Finland. Indexing uncertain beyond 3 Å

Probable hkl	I	$d_{meas.}$ Å	$d_{calc.}$ Å	I	$d_{meas.}$ Å
100	4	8·10	8·10	2	2·920
001	5	7·16	7·16	2	2·847
011	10	6·38	6·38	2	2·751
021	4	5·03	5·03	6	2·730
$\overline{1}02$	4	4·297	{ 4·307	6	2·698
101			{ 4·285	7	2·670
				2	2·630
Line group	6	4·075		2	2·527
$\overline{2}12$	3	3·902	{ 3·915	1	2·470
210			{ 3·893	2	2·374
012	1	3·473	3·469	2	2·315
140	6	3·239	3·240	2	2·148
$\overline{3}01$	1	3·201	3·202	2	2·058
131	6	3·170	{ 3·171	1	1·953
041			{ 3·170	2	1·713
$\overline{3}12$	8	3·129	{ 3·131	2	1·675
$\overline{3}11$			{ 3·123		
$\overline{2}32$	4	3·076	{ 3·083		
230			{ 3·072		

Optical properties. The optical orientation in relation to twinning is illustrated in fig. 2, and may be summarized: $\gamma \parallel$ [010], β:[001] 27° in the acute angle β. The conoscopic method developed by Rittmann et al. (1960) and universal stage work yielded for $2V_\gamma$ the value of 82°±3°. Refractive indices, determined by the immersion method in sodium light are: α 1·505, β 1·508, γ 1·512, all ±0·001. From these values $2V_\gamma$ may be calculated as 82°.

The optical properties found for the Korsnäs harmotome lie well within the limits known for the mineral (Lacroix, 1896; Meier, 1939; Waterston, 1953; Kostov, 1962; Černý et al., 1965). The optical orientation on (010), however, varies according to these authors in the range β:[001] = 28° to 34°. As has been found by Meier (op. cit.), the

value of this angle is very sensitive to the temperature and may even be affected by the slight heating necessary in making a thin section.

X-ray crystallography. Table I summarizes the X-ray powder pattern of the Korsnäs harmotome (Philips Norelco diffractometer, filtered copper radiation, internal silicon standard). The d-values calculated on the basis of the unit-cell parameters given for harmotome by Sadanaga *et al.* (1961) are virtually identical with those measured for the Korsnäs mineral. The unit cell parameters of the Korsnäs mineral, obtained from a series of rotation, Weissenberg, and precession photographs, are in agreement with those calculable from the powder pattern: a 9.87 ± 0.02 Å (Sadanaga *et al.*: 9.87 ± 0.01 Å), b 14.14 ± 0.04 Å (14.14 ± 0.01 Å), c 8.71 ± 0.02 Å (8.72 ± 0.01 Å), β $124° 45' \pm 10'$ ($124° 50' \pm 10'$). The only systematic extinction in the single crystal photographs of the Korsnäs harmotome was found for the $0k0$ type reflections with k odd. Accordingly, the space group is $P2_1$ or $P2_1/m$ as is known for the mineral. Sadanaga *et al.* have shown the harmotome from Andreasberg to be rather strongly piezoelectric indicating that the true space group is $P2_1$.

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