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BAVENO-TWINNED ALBITE FROM MONT SAINT-HILAIRE, QUEBEC

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ABSTRACT

Baveno-twinned albite (An_0) crystals were found in considerable numbers in a large pocket opened in May 1988 at the Poudrette Quarry, Mont Saint-Hilaire, Quebec. They are associated with aegirine, microcline, two earlier generations of albite, serandite, leifite, and other less abundant constituents, but grew directly only on microcline and earlier albite crystals. The twins do not exceed 2 mm in size, but are morphologically complex and well suited for goniometric study. The habit of these Baveno twins is different from that of Baveno-twinned orthoclase, and from that of untwinned albite from the same pocket. All of the sixteen twinned crystals measured are Baveno-R (021) twins. Baveno twins found in a separate pocket in May 1990 are of a larger size, but morphologically similar to those from the earlier find. These twins occur with quartz, microcline, sphalerite, epididymite, elpidite, catapleiite, dolomite and behoite. Baveno-twinned albite also has been found in smaller quantities at Mont Saint-Hilaire in association with siderite, pyrite and synchysite, and with biotite, zircon, astrophyllite, aegirine, calcite and ancylite.

Keywords: plagioclase, albite, twinning, Baveno twin, Mont Saint-Hilaire, Quebec.

SOMMAIRE

Nous avons découvert plusieurs cristaux d'albite (An_0) maclés selon la loi de Baveno dans une large géode ouverte en mai, 1988 dans la carrière Poudrette, au mont Saint-Hilaire (Québec). Ces cristaux sont associés à aegyrine, microcline, deux générations antérieures d'albite, sérandite, leifite, et autres phases accessoires, mais seuls les cristaux de microcline et d'albite précoce ont servi de substrat. La taille des individus maclés ne dépasse pas 2 mm; leur morphologie est complexe et propice à une étude goniométrique. Ils diffèrent morphologiquement des macles de Baveno que l'on trouve dans les cristaux d'orthoclase, et des cristaux non maclés d'albite de la même géode. Les seize cristaux qui ont fait l'objet de mesures sont des macles de Baveno-R (021). Les individus maclés qui ont été découverts dans la géode de mai, 1990 sont plus gros, mais semblables dans leur morphologie. Ils montrent une association avec quartz, microcline, sphalérite, épididymite, elpidite, catapléiite, dolomite et béhoïte. On trouve aussi à Saint-Hilaire, mais moins couramment, l'abite maclée selon la loi de Baveno en association avec sidérite, pyrite et synchysite, et avec biotite, zircon, astrophyllite, aegyrine, calcite et ancylite.

Mots-clés: plagioclase, albite, macle, Baveno, mont Saint-Hilaire, Québec.

INTRODUCTION

In May, 1988, a large crystal-filled pocket was opened in the wall of the Poudrette Quarry at Mont Saint-Hilaire, Quebec. This pocket produced outstanding specimens of serandite and leifite, together with a rich assemblage of other minerals, which included some small, colorless heart-shaped twinned crystals that collectors did not recall having seen before. These crystals turned out to be albite twinned on the Baveno law. In May 1990, a second pocket containing Baveno twins was encountered. These are an order of magnitude larger than those from the first pocket, and are a distinct pink color. This paper describes the paragenesis and the morphology of these Baveno twins, which are quite different from the usual Baveno twins displayed by K-feldspar.

GEOLOGICAL SETTING AND PARAGENESIS

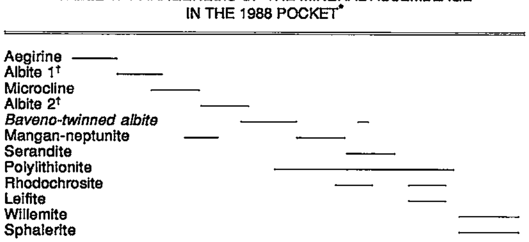
Mont Saint-Hilaire lies about 40 km east of Montreal, and is one of the Monteregian Hills, a series of igneous stocks of Cretaceous age that lie along a west-to-east trend, and have been interpreted as a series of static vents of mantle-derived materials and heat sources (Currie *et al.* 1986) associated with the St. Lawrence rift system (Currie 1970). Descriptions of the geology of the Monteregian Hills and of Mont Saint-Hilaire in particular can be found in Currie (1970, 1983), Greenwood & Edgar (1984), and Currie *et al.* (1986).

The Poudrette Quarry is excavated in rocks primarily of the East Hill suite, which represents the last intrusive event, and consists of a pipe of nepheline and sodalite syenites, phonolites, and intrusive breccias, with many xenoliths of the older igneous and sedimentary rocks. Well-formed crystals of a wide variety of minerals have been recovered from pockets in these rocks, at the Poudrette Quarry and the adjacent DeMix Quarry. More than 250 species have been identified at the quarries, many of them rare. The minerals of Mont Saint-Hilaire are described by Mandarino & Anderson (1989), Horváth & Gault (1990), in many papers referenced therein, and by Fisher & Glenn (1989).

The pocket opened in May 1988 was encountered in the southeastern wall of the quarry, at the contact between hornfels and nepheline syenite. The pocket was a pipe-like structure, as much as 60 cm in diameter, rising steeply into the wall of the quarry for at least 4 meters. The pocket contained large crystals of aegirine, serandite and leifite (Robinson & King 1989), twinned mangan-neptunite, willemite, rhodochrosite, sphalerite, polylithionite, microcline, and albite, including abundant Baveno twins to 2 mm across. A preliminary report on these Baveno twins was given by Richards (1989). Most of the research for this paper was performed on specimens from this pocket, *i.e.*, on approximately 200 Baveno twins. Much more material from the pocket is in the hands of collectors who visited Mont Saint-Hilaire around this time. In all probability, thousands of Baveno-twinned albite crystals were recovered. The sequence of mineral deposition in this pocket, based on overgrowth relationships, is shown in Table 1.

The pocket encountered in May 1990 was hosted by a microcline-rich pegmatitic phase of the nepheline syenite, near its contact with a sodalite syenite (M. Picard, pers. comm.). The pocket contained abundant albite and microcline, with lesser amounts of quartz, and uncommon accessory species. Baveno-twinned albite constituted much less than 1% of the euhedral albite crystals; however, crystals were typically in the range of 2 to 5 mm across, with a maximum of 8 mm. Materials available to us from this pocket comprise about 10–20 Baveno twins, collected by M. Picard and J. van Velthuisen of the Canadian Museum of Nature. Material from this pocket obtained by other collectors may also contain Baveno twins.

TABLE 1. PARAGENESIS OF THE MINERAL ASSEMBLAGE IN THE 1988 POCKET*



* Paragenesis is based on overgrowth relationships observed in samples from the pocket.
† Albite 1 consists of large platy crystals, usually Carlsbad twinned. Albite 2 consists of crusts of microcrystalline crystals.

The paragenesis of the 1990 pocket is relatively simple, with early large microcline crystals followed by smoky quartz and pink albite. The earliest albite crystals are platy albite-Carlsbad twins, and the Baveno twins are of the epitactic type described below. Later mineralization included sphalerite and galena, elpidite, platy twinned epididymite, micaceous catapleiite, dolomite and, rarely, behoite.

Baveno-twinned albite also occurs on a specimen of twinned siderite purchased by RPR from a specimen dealer. The data on the locality do not indicate which quarry the specimen came from. On this specimen, the crystals are of the auto-epitactic type, are relatively crudely formed, and lack the infilling faces seen on other examples. Their appearance is similar to Figure 2F. They are associated with siderite and minor pyrite and synchysite.

A single Baveno-twinned albite occurs in auto-epitactic orientation on a platy crystal of albite collected by RPR from the Poudrette Quarry in June 1990. Associated minerals are zircon, biotite, acicular astrophyllite, and late-stage aegirine, calcite, and ancylite. This crystal is very similar morphologically to those from the 1988 pocket.

Baveno Twinning in Plagioclase

Baveno twins are normal twins, *i.e.*, twins by reflection, with twin plane and usually composition plane {021}. In orthoclase, the two planes (021) and (0$\bar{2}$1) are equivalent and produce twins with identical interfacial angles. In plagioclase, these two planes are not equivalent because of the triclinic symmetry, and twins on (021) have different interfacial angles across the twin plane than twins on (0$\bar{2}$1). Twins on (021) are designated as right Baveno twins, or Baveno-R twins, and those on (0$\bar{2}$1) are designated left Baveno twins, or Baveno-L twins.

Baveno twins of plagioclase occur sparingly among the phenocrysts seen in thin sections of igneous rocks, and even more rarely among albite crystals in veins and pockets in igneous and metamorphic rocks. Smith (1974) reviewed many earlier studies, and presented summary tables to indicate that Baveno twins generally constitute less than 10% of the twinned plagioclase crystals observed. Vinczéné Szeberényi (1977) and Vincze-Szeberényi (1972) reported that Baveno twins comprise from 3 to 15% of all twinned phenocrysts (An_{60} to An_{85}) in some andesites in Hungary. Both Baveno-R and Baveno-L twinning were observed, with Baveno-R invariably more common.

Baveno twinning appears to be more common in plagioclase with a substantial An content than in albite. However, Donnelly (1963) reported infrequent Baveno-L-twinned albite in felsites from Wales and quartz keratophyres from the Virgin Islands. Talapatra (1966) found complexly twinned albite containing Baveno-R twinning in sodic granites from Bihar, India. Most of these twins consist of two units related by the Carlsbad law. Baveno twinning is contained within these units, as is lamellar Albite-Ala B twinning.

Morphological descriptions cannot be made with any great precision using thin sections, but require crystals that either grew in a void in the rock, or have weathered out of the enclosing matrix. Baveno-twinned albite of this sort is apparently very rare. Baveno twinning in albite was first described by Neumann (1832), in a specimen from Tirol, Austria. Goldschmidt (1916) illustrated six Baveno twins in his section on albite. However, two of these show albite epitactic on a Baveno-twinned orthoclase crystal; thus the Baveno twinning of the albite is merely inherited from the twinned substrate. Two figures illustrate Neumann's crystal, and the other two are drawings of a second twin (Baveno-R) from Schirm in Tirol (Brezina 1873). None of the authors cited above mention any other examples of Baveno-twinned albite, and Brezina implied that no other crystals were known to him. A literature search (GEOREF, GEOBASE) produced only two references to Baveno twinning in albite; these references contained no further morphological descriptions of Baveno-twinned albite. Thus, previous morphological descriptions of Baveno-twinned albite seem to be based on only two crystals.

X-Ray Crystallography

Twinning in the albite from Mont Saint-Hilaire was studied by the precession method. All photographs were taken with Zr-filtered Mo$K\alpha$ X radiation using a Supper precession camera. A small fragment of one twin that includes material from both twin members, spanning the twin plane, was used in the study. This fragment was mounted on a goniometer head with the twin plane normal to the fiber axis and, therefore, parallel to the incident X-ray beam. This arrangement allowed for a comparative study of the complete twin *versus* one component without changing the crystal orientation.

Orientation photographs were taken on one twin member until the reciprocal axes Y^* and X^* were identified, and the orientation could thereby be deduced. At this stage, both twin members were exposed to the X-ray beam, and by taking a number of photographs at various settings of the drum, the diffraction pattern of the second twin component could be indexed. The twin plane was deduced as being {021}. Unit-cell parameters were measured from the precession photographs; these are a 8.13, b 12.77, c 7.14 Å, α 94.0°, β 116.5°, γ 87.8°, and are indicative of low albite. Estimates of precision for axis lengths are ± 0.01 Å, for angles ± 0.1°.

Chemistry

Electron-microprobe analyses were carried out with a JEOL 733 electron microprobe equipped with Tracor–Northern TN 5500 and TN 5600 automation. Operating conditions were 15 kV, 20 nA, 25-s count time, 40-μm defocussed beam. Data reduction was done with a conventional ZAF routine in the Tracor-Northern TASK series of programs. No elements with Z greater than 10 other than Na, K, Al and Si were detected in the energy-dispersion spectra; Fe and Ca were sought with wavelength-dispersion spectrometers during data collection, but were not detected. Albite (Na, Al, Si) and sanidine (K) were used as standards.

Compositions of three albite crystals are given in Table 2. Minor differences in potassium content are noted between crystals from the 1988 and 1990 pockets, but not between Baveno twins and non-Baveno twins from the same pocket. The anorthite content is negligible in all cases: the detection limit for calcium was 0.02 wt.% CaO

TABLE 2. ELECTRON-MICROPROBE DATA ON THREE ALBITE TWINS*

	1	2	3
	Weight %		
Na_2O	11.44	11.64	11.50
K_2O	0.12	0.03	0.05
Al_2O_3	19.08	19.42	19.33
SiO_2	68.07	68.21	68.33
Fe_2O_3	ND	ND	ND
CaO	ND	ND	ND
	98.71	99.30	99.21
	Cations per 32 atoms of Oxygen		
Na	3.92	3.97	3.92
K	0.03	0.01	0.01
Al	3.98	4.02	4.01
Si	12.03	11.99	12.01
	19.95	19.99	19.95

* Each result represents the average of two analyses.
1. Baveno-twinned albite from 1988 pocket.
2. Baveno-twinned albite from 1990 pocket.
3. Albite-twinned albite associated with sample 2.
ND: not detected.

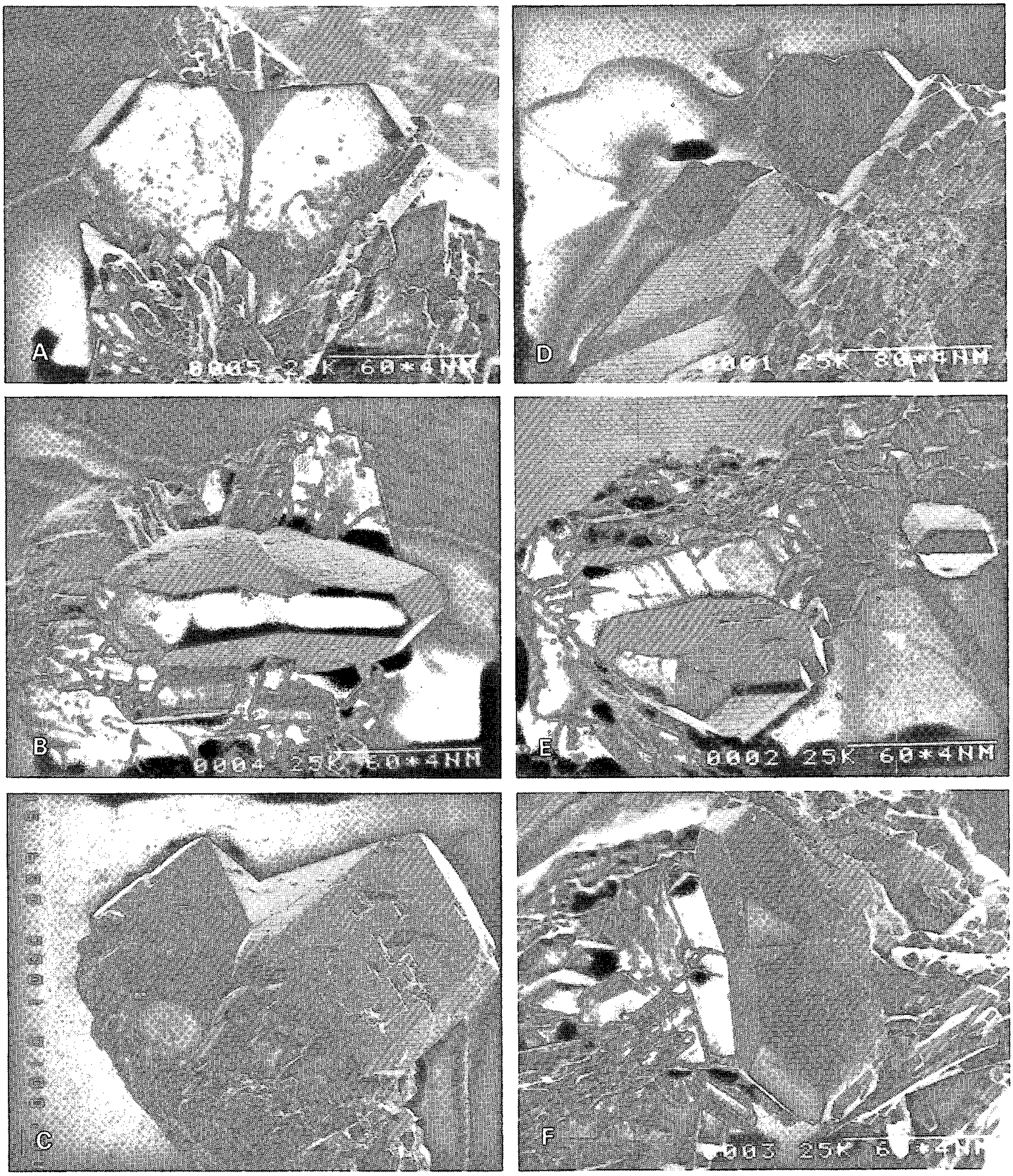


FIG. 1. Scanning electron-microscope images of representative Baveno-twinned albite crystals from the 1988 pocket. Unless otherwise noted, the scale bar is 0.6 mm long. A. A twin viewed from a position similar to that of Figure 2C, right side. Note the platy "flanges" along the lower extremes of the twin. B. The same crystal, viewed from the end, and comparable to Figure 2B, but rotated through 180°. C. Another crystal, viewed from the same orientation as Figure 1A, showing large π faces and different-sized twin halves. The twin is about 1 mm in horizontal dimension. D. A large platy crystal of albite with three auto-epitactic Baveno-twinned albite crystals, viewed in the same orientation as Figure 1A. Note the small auto-epitactic twin with simple rhomboidal morphology, comparable to Figure 2E. The scale bar is 0.8 mm. E. The same specimen viewed with the "host" albite, and (001) of the outer half of the twin, nearly parallel to the plane of the page. F. Another view of the twin shown in Figures 1A and 1B, with the twin plane nearly horizontal.

under the operating conditions stated above, and calcium was not detected in any crystal. No evidence of zoning was detected when spots near the core of the crystals were compared with those near the margin.

Morphology

The suite of twins from the 1988 pocket was studied with a binocular microscope to determine the range of their morphological expression. Three crystals that spanned the range of morphology were selected for goniometric study. These were measured on a Stowe two-circle goniometer, and indexed by comparison of their stereographic projections with theoretical projections produced by the program SHAPE (Dowty 1980, King 1990), and by use of observed zonal relationships. The positions of the (001) cleavage and of faces in the [001] zone were used as absolute reference-points. Uncertain forms were verified by comparison of their interfacial angles to well-established faces with those calculated from the cell constants derived from the X-ray studies. Idealized drawings of crystals representing the range of observed morphologies were prepared using SHAPE, and compared to actual specimens to verify the accuracy of the morphological interpretation. The twin plane (0$\bar{2}$1) was used in preference to (021), because it produced positive indices for most of the faces present on the crystals.

The range of morphology of the Baveno twins from the 1988 pocket is illustrated in Figures 1 and 2. Table 3 gives the correspondence between Miller indices and face symbols used in the drawings in Figure 2. The crystals share a consistent morphology, characterized by the development of **o** and **y** as major faces. The major zones are [001], with the faces **z**, **M**, **a**, **m**, **f**, and **b**, and [101], with the faces π, **o**, and **P**. The faces **o**, **M**, and **y** lie in the zone [112]. The crystals from the 1990 pocket are morphologically similar to those from the 1988

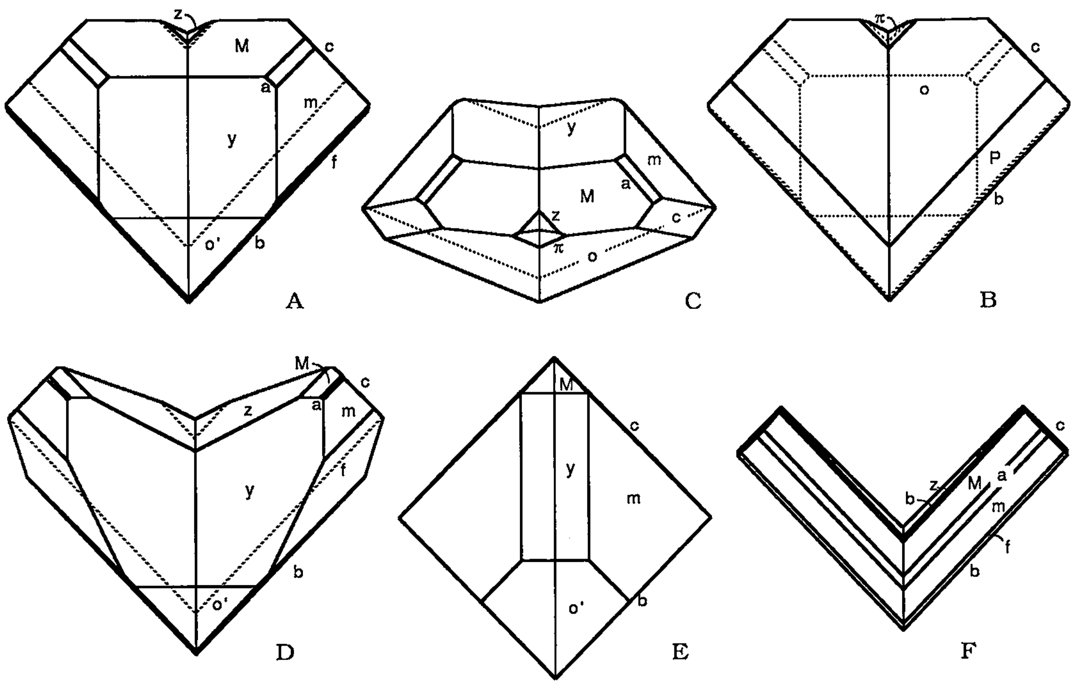


FIG. 2. Drawing of representative crystals of Baveno-twinned albite from the 1988 pocket. A. A crystal with large **c** (001) and **m** (110) faces. B. The same crystal, rotated 180° about the vertical axis in the plane of the paper. C. The same crystal rotated 120° relative to 2B, about the horizontal axis in the plane of the paper. D. A crystal of less blocky aspect, due to the development of large **z** (1$\bar{3}$0) and **f** (130) faces and incomplete filling of the re-entrant angle. E. A crystal with a diamond-shaped cross-section, a result of large **c** (001) and **m** (110) faces, small **y** (20$\bar{1}$) and **M** (1$\bar{1}$0) faces, and missing **z** (1$\bar{3}$0) and **f** (130) faces. F. A Baveno-twinned platy albite crystal, with no twinning-related distortion of habit. Crystals of this habit have been found in the siderite–synchysite association. Figures 2D–F are in the same orientation as Figure 2A.

TABLE 3. FACES OBSERVED ON BAVENO-TWINNED ALBITE*

Face Symbol	Miller indices
y	$20\bar{1}$
o	$\bar{1}\bar{1}1$
a	100
b	010
c	001
z	$1\bar{3}0$
M	$1\bar{1}0$
m	110
f	130
o'	$11\bar{1}$
π	$\bar{1}\bar{3}1$
p	$\bar{1}11$
y'	$\bar{2}01$
M'	$\bar{1}10$

* Separate letters are assigned to (hkl) and $(\bar{h}\bar{k}\bar{l})$, if both occur, because of characteristic differences in size and position introduced by twinning.

pocket, but usually simpler, lacking some of the modifying faces.

Baveno-R twinning cannot be reliably distinguished from Baveno-L twinning by eye, because the interfacial angles across the twin plane are too similar. For certain pairs of faces, however, the difference in interfacial angles is large enough that the distinction can easily be made by goniometric measurement. Sixteen twins were selected from the 1988 pocket materials, and at least one diagnostic pair of faces was measured for each twin. All of the measured twins are Baveno-R twins; data are available upon request from the senior author. The probability of this result arising by chance, assuming that Baveno-L and Baveno-R twinning are equally likely to occur, is vanishingly small (<0.00002). This indicates that some combination of structural and environmental factors strongly favored the development of Baveno-R twins in this pocket.

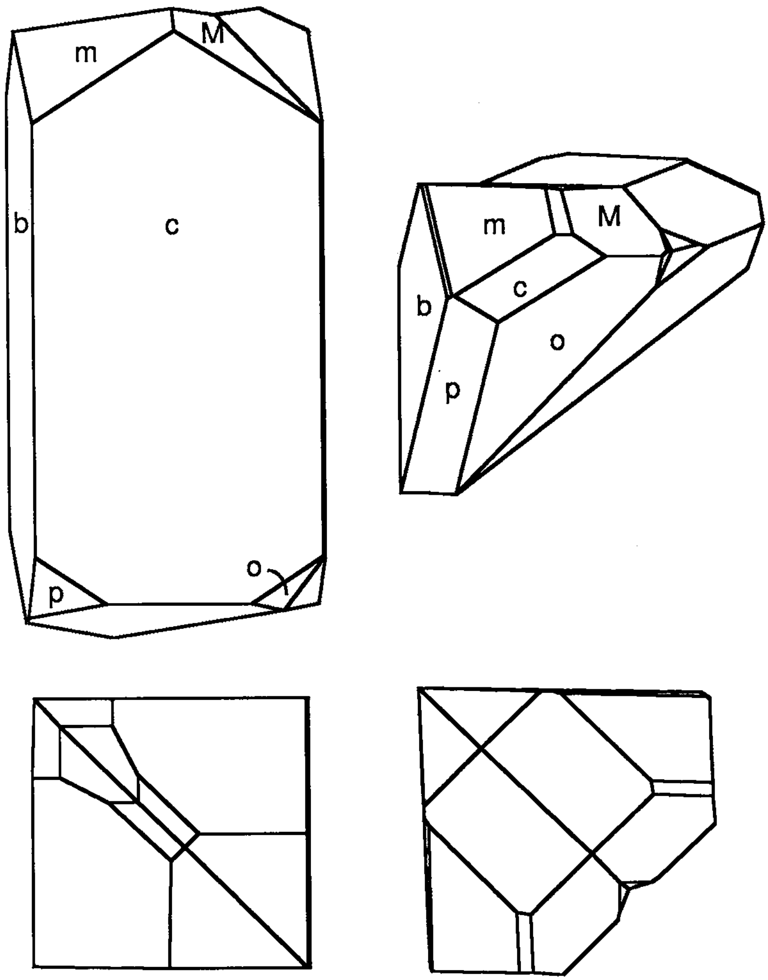
The habit of these Baveno-twinned albite crystals is quite different from that of typical Baveno twins of orthoclase, which are usually of a somewhat elongate prismatic habit. The nearly square prism of orthoclase Baveno twins is composed of **c** and **b** faces belonging to each half of the twin. In the Baveno-twinned albite from Mont Saint-Hilaire, the axis of this prism is a short dimension, and the prism is interrupted by other faces, particularly **o**. The relationship between the two habits is shown in Figure 3. The Baveno-twinned albite shown by Goldschmidt (1916) is intermediate in habit between these two, with a short but easily identified prism.

The habit of the albite Baveno twins from both the 1988 and 1990 pockets also is different from that of associated crystals of albite that lack Baveno twinning. These are of a platy habit, with large {010} faces, generally contain lamellar albite twinning, and commonly are contact Carlsbad twins. Figure 2F illustrates the appearance expected of an otherwise untwinned crystal of this habit if twinned on the Baveno law. The Baveno-twinned albite associated with siderite, pyrite, and synchysite (described above) has this habit. Some of the more typical Baveno-twinned crystals have segments of this general appearance as an outer sheath (*e.g.*, Fig. 1A).

The blocky habits of the typical crystals appear to be a result of enhanced growth, which fills in the re-entrant caused by twinning, a pattern familiar from Japan-law twins of quartz and "butterfly" twins of calcite, among other minerals. Many of these Baveno twins have lamellar albite twinning along the outer margins of the crystals, but albite twinning has not been observed in the central region. The central region also is usually the most transparent, free of both solid and fluid inclusions.

Typically, Baveno twins from both pockets are developed on finely crystalline masses of albite. In some instances, twins are found in (auto)epitactic orientation on earlier-formed, large platy crystals of albite or microcline (Figs. 1D–F). Single hosts commonly have many twins on one crystal surface. The (010) face of the lower twinned individual is in contact with the (010) face of the host crystal, bringing the (001) face of the upper individual essentially parallel to the (010) face of the host. Both the nucleation of the new crystal and the twinning occurred nearly simultaneously. A few of these epitactic twins have orientations, relative to the rest, which are suggestive of albite or Carlsbad twinning. However, it is not clear whether these are twinned relative to the host crystal, or are in alignment with segments of the host crystal that are themselves twinned.

In no instance has Baveno-twinned albite been observed growing on a non-feldspar substrate. The Baveno twins oriented on pre-existing albite crystals clearly represent a separate nucleation event. Apparently, the nucleation advantage presented by



A **B**

FIG. 3. A typical Baveno twin in orthoclase (A), and a Baveno twin in albite from Mont Saint-Hilaire (B). Forms are identified in Table 3. In orthoclase, **M** and **m** belong to the same form, as do **o** and **p**.

these abundant substrates prevented the development of sufficient supersaturation to allow nucleation on other substrates. This observation suggests that the twins observed on fine-grained albite substrates also are epitactic, but on hosts too small to detect in most cases.

CONCLUSIONS

Although Baveno-twinned albite appears to be rare in hydrothermal settings elsewhere, it must be regarded as moderately common at Mont Saint-Hilaire. Crystals from Mont Saint-Hilaire are well-formed Baveno-R twins, which differ in morphology from Baveno twins of K-feldspar and from rare Baveno twins of albite elsewhere. It seems probable that further, as yet unrecognized examples of Baveno-twinned albite exist in the many collections from Mont Saint-Hilaire. These may include crystals from additional pockets, with different parageneses. We would welcome the opportunity to examine any materials of this sort.

ACKNOWLEDGEMENTS

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