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## HERSCHELITE—A VALID SPECIES?

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In 1825 Levy described two new minerals, both zeolites, occurring in cavities in lava at Aci Reale (actually Aci Castello) on the flanks of Mt. Etna, Sicily. One of these minerals, phillipsite, has retained its status as an independent species; the other, herschelite, was later identified with chabazite and has been relegated to the synonymy. The correctness of the latter procedure was apparently confirmed when it was found that herschelite and chabazite give essentially identical x-ray powder patterns (Strunz, 1956). Nevertheless, other evidence suggests that these minerals, while closely related, are chemically distinct and are separated from each other by a composition gap.

The ideal formula for chabazite can be written  $\text{Ca}_2\text{Al}_4\text{Si}_8\text{O}_{24} \cdot 12\text{H}_2\text{O}$ , there being three such formula units in the unit cell. Wyart (1933), who worked out the structure of chabazite, demonstrated that chemical analyses of chabazite showed the following variability in the numbers of atoms in the above formula (omitting one analysis which shows a high MgO content):

Ca:	0.93– 1.91
Na:	0 – 2.27
K:	0 – 1.46
$\Sigma\text{Ca} + \text{Na} + \text{K}$ :	1.97– 3.46
Al:	3.59– 4.52
Si:	7.35– 8.20
$\Sigma\text{Al} + \text{Si}$ :	11.76–12.19

The principal variation in composition is clearly in the amounts of calcium, sodium and potassium. Evidently the chabazite structure can accommodate more than two of these atoms per formula unit. However, Ca never exceeds two, and the low Ca is compensated by high (Na+K); the principal variations in chabazite composition can be explained by the substitution of ( $\text{Na}_2$ ,  $\text{K}_2$ ) for Ca.

Most chabazite is calcium-rich. This is clearly demonstrated in Fig. 1, in which the relative amounts of Ca, Na, K in Wyart's selected analyses of chabazite are plotted, along with analyses of herschelite from the literature. However the five analyses of herschelite from Sicily form a small group clustered close to the Na apex, and are separated by a wide composition gap from the "normal" calcium-rich chabazites. Also in the sodium-rich field are a pair of analyses (nos. 3 and 4) which are of "chabazite" from Richmond, Victoria, Australia, and one (no. 2), also from Sicily.

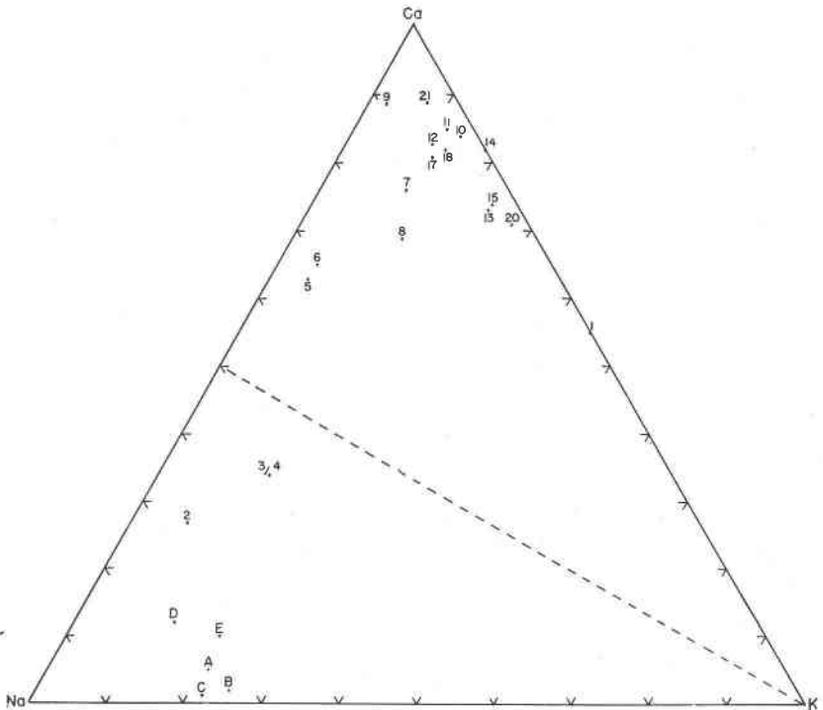


FIG. 1. Atomic percentages of Ca, Na, and K in analyses of chabazite and herschelite; the numbered points are the analyses listed by Wyart (1933), the lettered points are analyses of herschelite from Aci Castello, Sicily, as follows: A, *Zeit Deutsch. geol. Gesell.*, **28**, 547, 1876; B and C, *Ann. Chem. phys.*, **14**, 99; 1845; D and E, *Mineral. Abstr.*, **11**, 292, 1951.

Herschelite differs from "normal" chabazite in other respects. The crystal habit is quite distinct—whereas chabazite occurs in a variety of forms, usually simple rhombohedral crystals or penetration twins, herschelite is always found as aggregates of hexagonal plates, evidently a combination of base and rhombohedron faces. Walker (1951), in his study of crystal habit in many hundreds of chabazite crystals from the Antrim basalts, did not find a single example of the herschelite habit, and it seems to be recorded only in the material from Sicily and that from Richmond, Victoria. Herschelite has a distinctly lower refractive index—in specimens I have measured the mean refractive index is about 1.472 (birefringence low, 0.002–0.004), whereas the mean refractive index of chabazite is about 1.485.

On the above evidence it appears that herschelite should be recognized as a valid species, isostructural with, but distinct from, chabazite. Its

ideal formula is  $\text{Na}_2\text{Al}_2\text{Si}_4\text{O}_{12} \cdot 6\text{H}_2\text{O}$ , but natural herschelite shows substitution of calcium and potassium for sodium. There is probably a composition gap between chabazite and herschelite which will be more closely defined by additional analyses, but for the present an arbitrary boundary, as shown by the dashed line on Fig. 1, from the potassium apex to the mid-point on the Ca-Na join, can be suggested. The relationship between chabazite and herschelite is exactly analogous to that between heulandite and clinoptilolite, as described by Mason and Sand (1960).

It should be noted that the composition of herschelite is very similar to that of gmelinite, and that these two species are not distinguishable on the basis of chemical analyses, although they are different structurally and in x-ray powder photographs. They may be dimorphs of  $\text{Na}_2\text{Al}_2\text{Si}_4\text{O}_{12} \cdot 6\text{H}_2\text{O}$ , but the conditions favoring the formation of one or the other remain to be elucidated.

I am indebted to Mr. John Albanese for drawing my attention to this problem, and for providing me with specimens of herschelite from the original locality in Sicily.

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BAOTITE (PAO-T'OU-K'UANG) FROM RAVALLI COUNTY, MONTANA<sup>1</sup>

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## INTRODUCTION

The carbonatic RE-Nb deposits of southern Ravalli County, Montana, have been studied systematically by Crowley (1960) and by Heinrich and

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