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# ETTRINGITE ("WOODFORDITE") FROM CRESTMORE, CALIFORNIA

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## INTRODUCTION AND OCCURRENCE

In the process of studying minerals from Crestmore, California, A. O. Woodford and his associates, Woodford *et al.* (1941), Woodford (1943), observed veins of a hexagonal mineral which they could not identify, and provisionally called Mineral "K." This was later, in part at least, determined to be thaumasite, Switzer and Bailey (1953). Very similar material from their specimen, and from other specimens collected by Col. Clarence Jenni from the same general locality, was not thaumasite. This was submitted to the authors for identification. Its properties were found to be very close to those of ettringite (from published descriptions), but *x*-ray study showed the unit cell to have twice the dimension of ettringite in the $a_0$ direction. A chemical analysis also showed the presence of 3.15 $SiO_2$ and 3.35 $CO_2$, and a perceptibly smaller amount of $H_2O$ than called for in ettringite.* Further, the indices of refraction were somewhat lower, and accordingly the mineral was considered to be new, and given the name "woodfordite." After presentation of a report on this mineral, Murdoch and Chalmers (1958), it became possible to obtain crystals of type material, from Ettringen, and *x*-ray measurements were made on them for comparison. This study showed that the determination of the unit cell is in error, and that the *a* axis is really twice the published value, Bannister (1936). This finding has been confirmed by Hurlbut (see page 1141 in this issue) on crystals from Scawt Hill, and the authors are forced to the conclusion that "woodfordite" is ettringite. The difference in composition, although important, and the slight variation in indices of refraction, cannot be considered enough to warrant giving this material a new species name. The name "woodfordite" thus must be considered withdrawn.

Ettringite occurs as a vein filling in the massive contact rock of the 910′ level of the Commercial quarry at Crestmore, and is locally rather abundant in some of the veins. The matrix rock is rather variable, and is made up of varying proportions of a merwinite, spurrite, gehlenite mixture, with associated diopside, idocrase, wollastonite and rarer small bright yellow grains of garnet. In the veins ettringite occurs as an open

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* This determination was made on material which appeared to be fresh, but which apparently was somewhat de-hydrated, perhaps during the rather considerable time lapse between collecting and analyzing.

space filling of small (maximum length 1 mm.) hexagonal crystals associated with calcite and afwillite, and as somewhat larger grains showing few crystal faces, usually penetrated by afwillite prisms. The well-formed crystals are stout prismatic in habit, terminated, sometimes doubly, by the base and a series of pyramid forms which are not usually well-developed. The prism faces are sometimes perfectly smooth, but not uncommonly striated parallel to *c*. This is in part due to incipient alteration, and serves as an easy criterion for distinction of the mineral from thaumasite, which is invariably very smooth-faced and much more glassy in luster than ettringite. The accompanying calcite is usually in small very steep rhombohedral crystals, and the afwillite is normally in slender bladed prisms.

## PHYSICAL PROPERTIES

The Crestmore ettringite is colorless when fresh, but often coated, or completely replaced by a white, powdery alteration product. Its hardness is 2.5; specific gravity 1.78 (measured in bromoform-acetone mixture); cleavage $\{10\bar{1}0\}$ perfect; soluble with moderate to slight effervescence in cold dilute acid, leaving a visible residue of silica. The crystals show

TABLE I. *X*-RAY POWDER DATA FOR ETTRINGITE
Cu radiation, Ni filter, $\lambda = 1.5418$

| Crestmore | | Synthetic | | Crestmore | | Synthetic | |
|---|---|---|---|---|---|---|---|
| *d* | I | *d* | I | *d* | I | *d* | I |
| 10.53 | ½ | — | | 2.81 | ½ | 2.806 | ½ |
| 9.72 | 10 | 9.73 | 10 | 2.773 | 5 | 2.773 | 4 |
| 8.88 | ½ | 8.86 | 1 | — | | 2.714 | ½ |
| 5.60 | 7 | 5.61 | 8 | 2.69 | ½ | 2.697 | 1 |
| 4.97 | 2 | 4.98 | 2 | 2.68 | ½ | 2.680 | ½ |
| — | | 4.86 | ½ | 2.618 | 1 | 2.616 | 2 |
| 4.68 | 3 | 4.69 | 4 | 2.568 | 5 | 2.564 | 4 |
| 4.55 | ½ | — | | 2.525 | ½ | 2.524 | ½ |
| — | | 4.41 | ½ | 2.490 | ½ | 2.487 | ½ |
| 4.025 | ½ | 4.02 | 1 | — | | 2.434 | ½ |
| 3.88 | 4 | 3.88 | 5 | 2.427 | ½ | 2.422 | ½ |
| 3.67 | ½ | 3.67 | ½ | 2.410 | ½ | — | |
| 3.59 | ½ | 3.60 | 1 | 2.403 | ½ | 2.401 | 1 |
| 3.476 | 2 | 3.48 | 3 | 2.356 | ½ | 2.347 | ½ |
| — | | 3.27 | ½ | — | | 2.230 | 2 |
| 3.24 | 1 | 3.24 | 2 | 2.208 | 5 | 2.209 | 4 |
| 3.03 | ½ | 3.016 | ½ | 2.180 | ½ | 2.185 | 1 |
| 2.93 | ½ | — | | 2.154 | 2 | 2.154 | 2 |
| | | | | plus additional lines | | | |

$\{10\bar{1}0\}$ with occasionally only $\{0001\}$, but more commonly one or more pyramids rather poorly developed. The commoner of these approach $\{10\bar{1}2\}$ and $\{10\bar{1}1\}$ (or $\{70\bar{7}8\}$), but are in such poor position that an axial ratio derived from them would be quite unreliable. The indices of refraction appear to be somewhat variable from specimen to specimen, common observed values being from 1.450 to 1.455 for $\epsilon$, and from 1.465 to 1.470 for $\omega$. One specimen, showing good crystals terminated by $\{0001\}$ only, gave values of $\epsilon = 1.470$, $\omega = 1.485$.

The white alteration product is found to be largely a mixture of calcite and gypsum. Residual needles of ettringite in this mixture usually give a higher index than normal.

## *X*-RAY STUDY

*X*-ray powder photographs of the Crestmore ettringite match almost exactly that of synthetic ettringite, Bur. Standards (1959), (Table I). Single crystal *x*-ray photographs were taken about [0001], $[10\bar{1}0]$ and $[11\bar{2}0]$. From these the cell-dimensions were derived (Table II). In this table are given published values for ettringite from other localities, and also of thaumasite, for comparison as a similar mineral. The space group, $P6_3/mmc$ was determined from the observed systematic extinctions, and agrees with the findings of Bannister (1936) and Hurlbut (1960).

TABLE II. UNIT CELL DIMENSIONS

| | $a_0$ | $c_0$ |
|---|---|---|
| Ettringite 1 | 22.48 Å | 21.31 Å |
| Ettringite 2 | 22.33 Å | 21.35 Å |
| Ettringite 3 | 22.28 Å | 21.29 Å |
| Ettringite 4 | 11.26 Å<br>x2 = 22.52 | 21.48 Å |
| Ettringite 5 | 22.47 Å | 21.46 Å |
| Thaumasite 1 | 10.95 Å<br>x2 = 21.90 | 10.30 Å |
| Thaumasite 2 | 22.12 Å | 10.54 Å |

*Ettringite* 1. Ettringen, Germany (Murdoch, this study)
2. Crestmore, California (Murdoch, this study)
3. Franklin, N. J. (Hurlbut, 1960)
4. Scawt Hill, Co. Antrim (Bannister, 1936)
5. Scawt Hill, Co. Antrim (Hurlbut, 1960)
*Thaumasite* 1. Långban, Sweden (Welin, 1957)
2. Paterson, N. J. (Murdoch, this study)

The revised value for *a* for thaumasite was derived from a rotation photograph about $[10\bar{1}0]$, on a good single crystal.

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# N,N-DIMETHYLFORMAMIDE, A NEW DILUENT FOR METHYLENE IODIDE HEAVY LIQUID*

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Dimethyl sulfoxide (DMSO), $(CH_3)_2SO$, has been recommended as a diluent for methylene iodide (diiodomethane) in heavy liquid separations (Cuttitta, Meyrowitz, and Levin, 1960). Dimethyl sulfoxide-methylene iodide liquids of low density (approximately 2.92) become blood red on long standing. Storing the liquids in contact with copper wire or shavings reduces markedly the rate at which the red color deepens.

N,N-Dimethylformamide (DMF), $HCON(CH_3)_2$, is recommended as a diluent for methylene iodide. Its physical properties are similar to dimethyl sulfoxide. Its vapor pressure is low; its boiling point is high and it is completely miscible with water and acetone. The advantage of the dimethylformamide liquids over the dimethyl sulfoxide liquids is that they remain transparent for a longer time. Mixtures of dimethylformamide and methylene iodide stored in contact with copper wire or shavings do not become red on long standing (seven months). They remain light yellow. They do become red when not stored in contact with copper wire or shavings. Table 1 compares the salient properties of dimethylformamide, dimethyl sulfoxide, acetone, ethyl alcohol, and methylene iodide.

In order to test the constancy of the dimethylformamide-methylene iodide solutions during use, a series of solutions, each having a 90 ml. volume, was prepared. The specific gravities of the liquids were 2.85,

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