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WHEWELLITE AND CELESTITE FROM A FAULT OPENING IN SAN JUAN COUNTY, UTAH*

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ABSTRACT

Whewellite ($CaC_2O_4 \cdot H_2O$) in two large crystals, yellow celestite, and several other minerals were found in vuggy openings along a fault in the Radon mine near Moab, San Juan County, Utah. This is the second reported occurrence of whewellite from North America, the first being from limestone concretions in Montana. Paragenetically whewellite is later than the celestite and its origin is believed related to associated carbonaceous material.

INTRODUCTION

In April 1958 one of the writers, Vance C. Kennedy, found two large crystals of whewellite in a uranium mine in eastern Utah. This is the second occurrence of whewellite reported from North America, the first having been described by Pecora and Kerr (1954) from a septarian limestone concretion in marine shale near Havre, Montana. The two crystals here described are much larger and are from a considerably different geological environment. They were collected from the Radon mine located on the southwest flank of the Lisbon Valley anticline, about 35 miles southeast of Moab in sec. 28, T. 29 S., R. 24 E., Salt Lake Meridian, San Juan County, Utah. The crystals were found in celestite-lined vuggy openings along the "Radon" fault where it cuts high grade uranium ore on the 280 level. Near the sampling site the Radon fault is normal, strikes about N55 W, dips 67° SW, and has a vertical displacement of about 3.5 feet (C. L. Dodson and T. Botinelly, written communication). Wall rock of the vugs consisted of the lower few feet of the Triassic Chinle formation, just above its contact with the Permian Cutler formation. Here the Chinle is composed of interbedded lenses of medium-grained sandstone, fine-grained sandstone, mudstone, and claystone.

DESCRIPTIVE MINERALOGY

The larger of the two whewellite crystals weighs 8.6 gms. and measures roughly $2\frac{1}{2}$ by 2 by $1\frac{1}{2}$ cm. A small part of the crystal is intergrown with yellow celestite and very minor amounts of pyrite, marcasite, calcite, and black asphaltic material. When found, parts of the crystal were covered by very thin gray coatings of loosely-adhering micro-crystalline calcite, most of which were gradually rubbed off by handling. The crystal is milky white in color, but where broken on an edge, the interior appears blue-gray and more translucent. One good cleavage, parallel to the form

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($\bar{1}01$), is evident. A stereographic photograph and the morphology of this crystal are shown in Fig. 1. Crystallographic data were obtained by A. J. Gude, 3rd., and are described below, under Crystallography and *x*-ray data.

The smaller of the two crystals of whewellite, 2 by 1 by 0.7 cm., is attached to the matrix of a large piece of buff-colored medium to coarse-grained sandstone which is coated with small crystals of celestite and calcite. A third, or satellitic, whewellite crystal 3 mm. in diameter and about 5 mm. from the one in place was removed with an ultrasonic needle and all physical, spectrographic and *x*-ray work was performed on it. Table 1 records the physical properties of whewellite from Utah and compares them with those of the whewellite specimen from Montana as given by Pecora and Kerr (1954).

TABLE 1. PHYSICAL PROPERTIES OF WHEWELLITE

	San Juan County, Utah	Havre, Montana
α	1.491 ±0.002	1.491 ±0.002
β	1.556 ±0.002	1.555 ±0.002
γ	1.650 ±0.002	1.654 ±0.002
2V (+)	84°±2°	82°
Specific gravity	2.21±0.05 Berman balance 2.19±0.01 Suspension method	2.21±0.01
Hardness	~2.5	3

Measurement of the indices of refraction was greatly facilitated by the use of a rotating needle stage devised by Wilcox (1959). Measurement of the optic angle was made on a universal stage and represents the average of two readings taken from the acute bisectrix to an optic axis. The specific gravity as determined by a Berman balance represents an average of four determinations on two grains. The specific gravity was also determined on two grains by the suspension method, but the lighter of the two grains was strongly suspected of having air voids due to skeletal structure in the whewellite fragment. Hence the average value by this method, 2.19, is probably low.

SPECTROGRAPHIC DATA

Semiquantitative spectrographic analyses (Table 2) were made on both the whewellite from Utah and from Montana. The latter sample was kindly furnished by W. T. Pecora.

Although both samples are extremely pure calcium oxalate monohydrates, it is noted that the whewellite from Utah, which is intimately

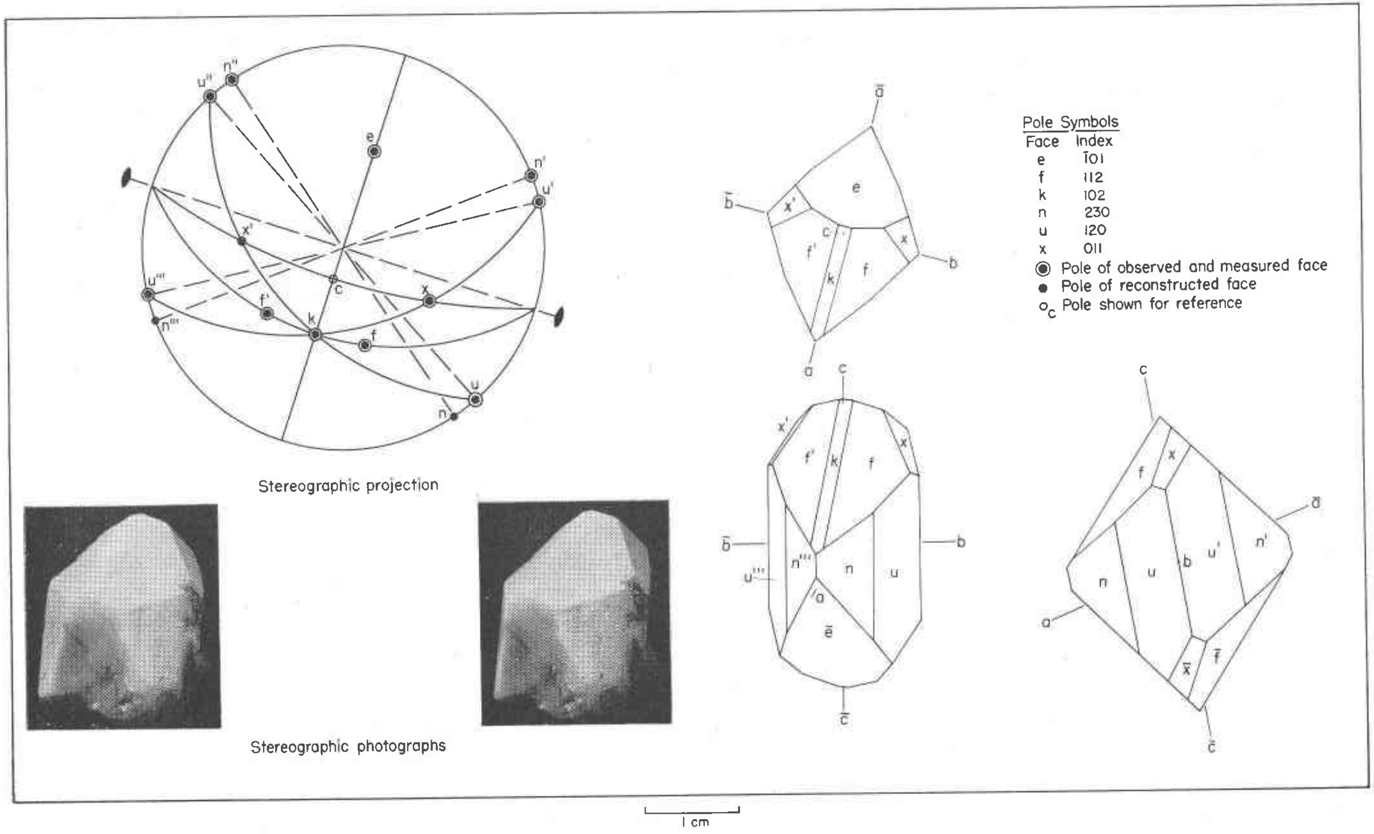

FIG. 1. Crystal morphology of whewellite from Lisbon Valley, Utah.

associated with celestite, contains considerably more strontium than the whewellite from Montana.

TABLE 2. SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES OF WHEWELLITE
(J. C. Hamilton, Analyst)

	San Juan County, Utah	Havre, Montana
Si	0.015%	0.03%
Al	0.0015	0.007
Fe	~0.0008*	~0.0008*
Mg	<0.0005	<0.0005
Ca	M	M
Mn	<0.0002*	0.0003
Na	0.07	0.07
Ba	0.0007	0.0003
Sr	0.007	0.0007
Cr	0.00015	0.00015
Cu	<0.0001*	0.0007

Notes: Figures are reported to the nearest group in the series 7, 3, 1.5, 0.7, 0.3, 0.15, etc., in per cent. The numbers represent midpoints of group data on a geometric scale. Comparisons of this type of semiquantitative results with data obtained by quantitative methods, either chemical or spectrographic, show that the assigned group includes the quantitative value about 60 per cent of the time.

M = major constituent—greater than 10 per cent.

* Limit of detection.

The following elements were looked for and not found: K, Ti, P, Ag, As, Au, B, Be, Bi, Cd, Ce, Co, Dy, Er, Eu, Ga, Gd, Ge, Hf, Hg, Ho, In, Ir, La, Li, Lu, Mo, Nb, Nd, Ni, Os, Pb, Pd, Pr, Pt, Rb, Re, Rh, Ru, Sb, Sc, Sn, Sm, Ta, Tb, Te, Th, Tl, Tm, U, V, W, Y, Yb, Zn, Zr.

CRYSTALLOGRAPHY AND *X*-RAY DATA

The largest crystal of whewellite was used to determine its morphology (Fig. 1). *X*-ray data are shown and compared in Table 3 with similar data by Pecora and Kerr (1954).

Both large crystals show the same morphology. Neither is twinned although casual preliminary inspection and comparison with the figures given by Palache, Berman and Frondel (1951) caused some delay in interpreting the goniometric data before the correct orientation shown in Fig. 1 was determined. The upper domatic faces and the two prisms are partially developed. None of the lower terminations are present.

The crystal has poorly reflecting faces and is somewhat oversize for ordinary optical goniometry. Attached fragments of the matrix minerals, facial overgrowths that formed step-like apparent curvatures, shallow and flat obtuse angles, and combinations of these and similar imperfections, made contact goniometer measurements generally unreliable. Accordingly, the crystallographic data were obtained by using a spectrometer adapted as a one-circle goniometer. Four sets of each of the interfacial angle measurements were made from independent resettings of the crystal and goniometer.

A well-developed prism zone was proved to be present. From the stereographic plot of face poles *e* ($\bar{1}01$) was found to be the prominent face on the crystal. Careful examinations of the lower fractured areas then revealed a parallel cleavage surface which agrees well with the published descriptive data of Palache, Berman and Frondel (1951). A face pole for *c* (001) is shown in Fig. 1 for convenience of reference although no development of this face was found. The flat obtuse angle between *n*(230) and *u*(120) can be seen on the crystal only in oblique illumination and then only with difficulty. However, these two faces were easily and distinctly resolved when measured on the goniometer. Face *k*(102) was found and verified by measurement after plotting a preliminary stereogram and reexamining the crystal. Axial angle β is not easily determined from the sets of faces found on this particular specimen.

Celestite and Other Associated Minerals

The celestite that is intimately associated with the whewellite occurs in clear yellow blade-shaped crystals which attain several millimeters in length and several tenths of a millimeter in thickness. Practically all the celestite contains abundant inclusions of pyrite and marcasite which occur as cubes and bladed crystals up to about 0.3 mm. in size. The iron sulfide inclusions were segregated into cube-like and lath-like fractions and *x*-rayed separately. The cube-like fraction proved to be only pyrite; the lath-like forms consisted of both pyrite and marcasite, with pyrite predominant. The celestite has the following optical properties and specific gravity:

$\alpha = 1.622$ (by calculation)
$\beta = 1.624 \pm 0.002$
$\gamma = 1.632 \pm 0.002$
$2V(+) = 55° \pm 2°$
Pleochroism $\alpha = \gamma =$ almost colorless
$\beta =$ pale yellow
Absorption $\beta > \alpha = \gamma$
Sp. gr. $= 4.03 \pm 0.05$

A noteworthy feature of some of the celestite crystals is that the yellow coloration is not equal through all the parts of a single crystal when β is being viewed. Contact between the yellow tints is generally curved, but

TABLE 3. *X*-RAY POWDER DIFFRACTION DATA FOR WHEWELLITE FROM UTAH AND MONTANA

Diffractometer[1]		Film	
Utah		Montana (Pecora and Kerr, 1954, p. 210)	
d(Å, meas.)	I	*d*(Å, meas.)	I
14.3	13		
10.0	5		
8.42	5		
5.95	75	5.95	100
5.79	27	5.81	5
4.52	8	4.53	5
4.33	5		
4.15	5		
4.09	8		
3.860	8		
3.770	11	3.773	5
3.633	100	3.652	90
3.480	7		
3.401	7	3.414	1
		3.321	1
3.278	7		
3.110	14	3.105	5
2.998	14	3.002	1
2.969	100	2.971	50
2.903	18	2.906	10
2.840	14	2.842	10
2.754	7		
2.706	6		
2.637	8	2.639	1
2.607	7		
2.578	7		
2.529	8		
2.494	35	2.497	20
2.448	9	2.455	1
2.411	10	2.422	1
2.380	9	2.388	1
2.356	68	2.357	80
2.293	7		
2.253	25	2.262	20
2.212	10	2.213	5
2.127	8	2.135	1
2.103	6		
2.094	10		
2.070	21	2.076	10
2.045	5		
1.977	20	1.978	5
1.949	16	1.955	5

[1] CuKα (Ni filter), $\lambda = 1.5418$ Å.

TABLE 3 (*Continued*)

Diffractometer[1]		Film	
Utah		Montana (Pecora and Kerr, 1954, p. 210)	
d(Å, meas.)	I	*d*(Å, meas.)	I
1.933	22	1.930	5
1.892	16	1.891	5
1.859	7	1.859	1
		1.848	1
1.841	10		
		1.826	1
1.814	13	1.818	1
1.791	15	1.794	1
1.774	4		
1.759	5		
1.734	15	1.737	1
1.707	4		
1.689	6	1.693	1
1.639	3	1.644	1
1.583	8	1.588	1
		1.522	1
1.547	10		
1.526	8	1.528	1
1.499	6	1.505	1
1.484	9	1.480	1
		1.458	1
1.406	6		
1.397	5		
1.379	6		
1.375	7		
1.331	10		
1.304	4		
1.282	5		
1.248	4		
1.214	4		
1.185	9		
1.152	7		
1.130	4		
1.108	3		
1.097	6		

sharp. The optic angle was measured by using a universal stage and represents the average of four direct measurements. Specific gravity was measured on a Berman balance and represents an average on nine determinations on several grains. Extreme measurements were 3.95 and 4.09.

A semiquantitative spectroscopic analysis of the celestite, was made by John C. Hamilton of the U. S. Geological Survey and showed the following impurities in per cent: Al 0.07, Fe 0.03, Ca 0.15 and Ba 3.0. The sample submitted for this analysis still contained some iron sulfide inclusions even after careful handpicking; these inclusions although estimated at less than 0.1 per cent by volume, based on a micrometer ocular measurement, probably account for most or all of the iron found. Part or all of the aluminum may be due to clay impurity, although none could be seen with a microscope. The specific gravity and indices of refraction of this celestite are slightly higher than those of pure celestite ($SrSO_4$), no doubt due to the 3.0 per cent Ba.

It is the optic angle of 55°, however, which poses a problem since the barytocelestite series is reported to vary in 2V from 50° to 37° 30′ according to Winchell (1951). This is not an isolated instance of 2V anomaly for celestite, for earlier unpublished work by one of us has shown that celestite from the Cripple Creek District, Colorado, had a 2V of $51° \pm 3°$ (by universal stage) and thus the 2V reported for pure celestite. Yet this had a composition of 64 per cent $SrSO_4$ and 36 per cent $BaSO_4$ estimated from the indices of refraction and confirmed by spectrographic analysis.

Black lustrous conchoidally-fracturing asphaltic material occurs intergrown with the celestite and very thin coatings of iridescent iron sulfides cover some of the celestite crystals. Colorless calcite caps some of the celestite and also is found free as small dogtooth spar crystals. It was checked optically and found to be uniaxial negative with ω about 1.657. Finally strontianite occurs sparsely as tiny tufts of acicular crystals capping both calcite and celestite. These needles show parallel extinction and are length fast; their optic sign is negative and their 2V is very small. α is approximately equal to 1.516 and β and γ are both close to 1.666.

PARAGENESIS

Paragenesis is rather clear in this whewellite occurrence, and the minerals are listed from first-formed to last-formed:

celestite
pyrite and marcasite
asphaltic material
whewellite
calcite
strontianite

None of the crystals in this sequence show corrosion. The iron sulfides and celestite are mainly contemporaneous, but thin iridescent coats of sulfides on celestite indicate the sulfides to be later also. The occurrence of both pyrite, marcasite and marcasite altered to pyrite suggests changing conditions during the iron sulphide deposition. Asphaltic material, partially intergrown with celestite, and also covering it, indicates its early formation. Whewellite clearly shows evidence of enclosing and crystallizing around the celestite. Calcite was found capping celestite, asphaltic matter, and whewellite. Finally, strontianite caps both calcite and celestite.

The association of whewellite with asphaltic material strongly suggests that the oxalate part of the whewellite is of organic origin and is either derived from the asphaltic material or from the same source as the asphaltic material. This source is most probably the carbonaceous detritus ("carbonaceous trash") known to be present in the lower part of the Chinle formation.

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