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ART. II.—On Three Contact Minerals from Velardeña, Durango, Mexico. (*Gehlenite, Spurrite and Hillebrandite*); by FRED EUGENE WRIGHT.

DURING the summer of 1907, a geologic examination of the Velardeña mining district in Mexico was made by Mr. J. E. Spurr, assisted by Mr. G. H. Garrey. Several of the thin sections of the material there gathered were sent to the writer for examination, and in one of these a mineral with peculiar optic properties was observed. At the suggestion of the writer an adequate collection of the rock from which the thin section had been cut, was then made by Mr. Garrey, and in this collection the three minerals to be described below were found. Two of these minerals proved to be new mineral species, silicates of interesting composition, while the third, gehlenite, is apparently novel for this continent. All three are contact minerals, formed near the junction of altered limestone and intrusive basic diorite and their relations to the contact and conditions of formation have been carefully studied by Messrs. Spurr and Garrey. As the results of their extended investigation will soon be ready for publication it has not been deemed necessary to consider in detail in this present paper conditions of occurrence and formation of these minerals and their relations to the ore deposits in general.

The chemical analyses of the three minerals and their specific gravity determinations were made by Dr. E. T. Allen of the Geophysical Laboratory, and to him the writer is deeply indebted for the courtesy.

*Gehlenite.**

This mineral occurs in massive granular aggregates, usually dark gray or gray-black in color, from minute inclusions of magnetite and other particles. Rarely small pieces of gehlenite of amber-yellow color and free from magnetite inclusions were observed. The grains are rounded in outline and not suitable for crystallographic measurement. The physical and optical properties, however, are similar to those recorded for gehlenite from other localities, and the chemical composition also agrees as well with the prescribed formula as the analyses of the type material.

Crystal system, probably tetragonal, judging from the cleavage, which is imperfect after 001 and much less well marked after a prism. Fracture, uneven and irregular, conchoidal to splintery. Hardness, between 5 and 6, about 5.5. Luster,

* Type specimen from contact aureole of the Terneras intrusion, Velardeña, Durango, Mexico.

resinous to greasy. Translucent to transparent in thin flakes; in large masses, sub-transparent to opaque. Streak white to pale gray, the gray probably due to fine magnetite inclusions.

In the thin section, the gehlenite appears weakly birefracting with comparatively high refractive index. Magnetite inclusions are abundant and often show crystal outline. The magnetite also occurs, filling cleavage and fracture cracks in the gehlenite and evidently was precipitated both before, during and after the crystallization of the gehlenite. In certain of the sections the magnetite crystals showed a distinct tendency to an arrangement parallel with the first and second order prism faces. Round earthy spots also occur filled with earthy matter and are apparently of secondary origin, although they may possibly be weathered original spherulites of some mineral earlier than the gehlenite.

In the thin section the basal cleavage is well marked and after it the crystals are often developed in thick tabular form. In thick slides the interference color becomes intensely yellow, reminding one somewhat of the peculiar yellow interference tints of certain epidotes.

In convergent polarized light the interference cross is wide and uniaxial. Optically negative. On one section the birefringence was measured at $\omega - \epsilon = 0.0055$. The refractive indices were measured directly on an Abbé Pulfrich total refractometer in Na light and found to be $\omega = 1.666 \pm .003$ and $\epsilon = 1.661 \pm .003$. These values were obtained by using a polished plate of the granular material, and the refractive indices could not be determined under such conditions with an accuracy greater than $\pm .003$.

The specific gravity at 25° was determined on two samples by pycnometric methods at 3.029 and 3.049 with an average = 3.039. Part of this variability is probably the result of differences in relative amounts of inclusions.

On uncovering a thin section and treating the exposed surface with weak hydrochloric acid and then, after thorough rinsing, with a solution of fuchsin, the gehlenite was found to have gelatinized slightly. This fact was corroborated by a chemical test with powdered material, which was found to gelatinize readily.

The following chemical analysis does not agree with any simple formula and a comparison of other gehlenite analyses indicates that under the term gehlenite a solid solution series between several different end members is probably included.

Compared with the other analyses, the Velardeña gehlenite is somewhat lower in silica and magnesia, and higher in alumina and lime, but otherwise very similar, and is essentially a calcium aluminum silicate.

CHEMICAL ANALYSIS.

	1	1a	2	3	4
SiO ₂	26.33	.4359	29.78	28.59	31.40
TiO ₂ .....	.03	.0004			
Al ₂ O ₃	27.82	.2722	22.02	22.32	22.32
Fe ₂ O ₃	1.43	.0089	3.22		
FeO .....	.50	.0070	1.82	0.37	0.03
MnO .....	.01	.0001		0.50	0.96
MgO	2.44	.0605	3.88	7.78	10.02
CaO	39.55	.7050	37.90	36.76	30.92
Na ₂ O .....	.21	.0035		0.40	1.17
K ₂ O .....	.10	.0009		0.21	0.12
H ₂ O	1.85	.0103	1.28		
CaS				3.25	3.85
CO ₂	none				
	100.27	1.5047	99.90	100.18	100.79

1. Gehlenite, Velardeña, Mexico. E. T. Allen analyst.
- 1a. Molecular proportions of 1.
2. Gehlenite, Monzoni, Rammelsberg, Mineralchem., 1875, 604.
3. Gehlenite, Falkirk, Sweden. Edg. Jackson in Bauermann, Journ. Iron and Steel Inst., 1886, i, 88.
4. Gehlenite, Clarence, J. H. L. Vogt, Stud. Slagger, Stockholm, 1884, 138.

Before the blowpipe thin slivers of this mineral melt down with difficulty to dark, non-transparent beads, give a pronounced calcium flame reaction and glow intensely.

In the hand specimens, gehlenite occurs either practically alone except for magnetite inclusions, or together with spurrite, yellow garnet and calcite. Later veinlets consisting chiefly of calcite were noted occasionally, cross cutting the specimens.

So far as the writer has been able to ascertain from the available literature, this occurrence is the first recorded for gehlenite on this continent.

*Spurrite.**

This mineral, like gehlenite, occurs in granular masses which at first glance might be mistaken for crystallized marble, especially since the cleavage faces frequently glisten in the sunlight like those of calcite. No crystals were observed and the only goniometric measurements possible were made on cleavage fragments. Two cleavages were observed, the one good and the second much less perfect. The reflection signals from these faces were not of equal value and the cleavage

*Type specimen from contact aureole of Ternerás intrusion, Velardeña, Durango, Mexico.

angle could only be obtained approximately; the best average of the results is 79° with a probable error of at least $\pm \frac{1}{2}^\circ$. Fracture uneven to splintery. Brittle. Hardness, about 5. Luster, vitreous to resinous. Color, pale gray with tints of blue or yellow to colorless. Transparent to translucent. Streak, white.

On the hand specimens a weathering or alteration crust, consisting chiefly of finely divided carbonate, occurs not infrequently. In the thin section the spurrite is well defined optically and is excellent material for optical work.

From the relations of the optic properties to the crystallographic it is highly probable that spurrite is monoclinic and

FIG. 1a.

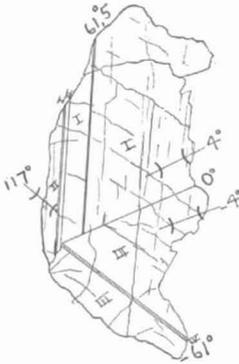
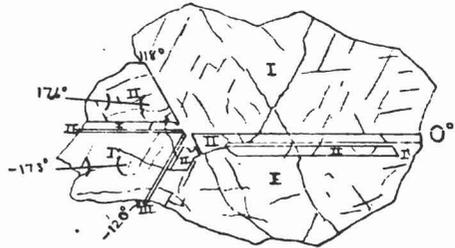


FIG. 1b.



that the cleavage faces are parallel, with the orthodiagonal (b axis). If the good cleavage plane be called the basal pinacoid, the optical orientation is apparently the following: $b = a$; $a : c$, very small and possibly zero, the cleavage cracks not being sufficiently perfect for decisive measurements.

Twinning after both 001 and polysynthetic twinning after orthodomes at angles of 56° to 58° with the twinning lines of 001 occur, and occasionally divide the field into sextants of the same birefringence and all cut approximately normal to the acute bisectrix, the plane of the optic axes in the different sextants occupying different positions, as shown in the accompanying sketches. (Figs. 1a, 1b.)

The polysynthetic lamellae are often extremely fine and resemble albite lamellae very closely. On a section almost precisely normal to the acute bisectrix the angle between the

plane of the optic axes and the fine twinning lamellae was measured at $57^{\circ}5$ in sodium light. On this thick plate crossed dispersion was unusually clearly marked, the angle between the plane of the optic axes for red lithium light being about $57^{\circ}6$, and for green thalium light $57^{\circ}1$. These measurements indicate a dispersion of the bisectrices $\epsilon_{\rho} : \epsilon_{\sigma}$ in the plane of symmetry of about 0.15° . At the same time a slight dispersion of the optic axes was noticeable with $2E_{\rho} > 2E_{\nu}$.

The optic axial angle was measured on a number of different sections by the use of the double screw micrometer ocular and also of the universal stage, the average being $2V = 39^{\circ}5, \pm 1^{\circ}$; whence $2E = 70^{\circ}$. Owing to the strong birefringence the interference figure is unusually well marked even in normal thin sections. The refractive indices were measured in sodium light on several different plates on an Abbé-Pulfrich total refractometer with reducing attachment, the different refractive index lines from the polished plates being clearly marked and easy to follow:

$$\begin{array}{ll} \gamma \text{ Na} = 1.679 \pm .002 & \gamma - \alpha = .039 \\ \beta \text{ Na} = 1.674 \pm .002 & \gamma - \beta = .005 \\ \alpha \text{ Na} = 1.640 \pm .002 & \beta - \alpha = .034 \end{array}$$

From these values the calculated optical axial angle is $2V = 41^{\circ} 12'$, which agrees fairly well with the measured value. Optical character negative.

The birefringence values were checked by direct measurements on plates in the thin section and closely accordant results obtained.*

$$\begin{array}{l} \gamma - \alpha = .040 \\ \beta - \alpha = .036 \end{array}$$

In the thin section spurrite is recognized by its high birefringence, imperfect cleavage and small optic axial angle with negative optical character and in thick sections noticeable crossed dispersion.

Still further evidence on the crystal system of spurrite was gathered from etch figures on the good cleavage face. Cleavage flakes were immersed for 10 seconds in cold 5 per cent hydrochloric acid and the etch figures of fig. 2 obtained.

Many of these figures appear asymmetrical but the upper terminal endings are so variable and influenced by adjacent cleavage cracks to such an extent that the general symmetrical aspect of the figure with respect to a vertical plane of symmetry may have thus been disturbed. It must be admitted, however, that the etch figures may be actually asymmetric, in

* For these direct measurements of birefringence in the thin section the writer is indebted to Mr. E. S. Larsen, Jr., of the Geophysical Laboratory.

which case spurrite is triclinic instead of monoclinic; the relations of the optic properties for different wave-lengths are then

FIG. 2.

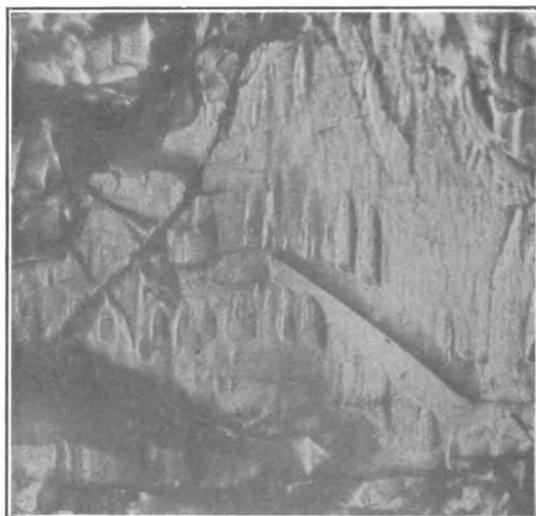


FIG. 2.—Etch figures on good cleavage face of spurrite produced by 10 sec. immersion in cold 5 per cent HCl. Magnification 150 diameters.

	1	1a	2
SiO ₂	26·96	·4467	27·13
TiO ₂	·01	·0001	
Al ₂ O ₃	·39	·0038	
Fe ₂ O ₃ }	·11	·0007*	
FeO }			
MnO	·03	·0004	
MgO	·23	·0058	
CaO	62·34	1·1114	62·98
Na ₂ O	·05	·0008	
K ₂ O	trace	-----	
H ₂ O	none	-----	
CO ₂	9·73	·2212	9·89
	<hr/> 99·85	<hr/> 1·7909	<hr/> 100·00

* Calculated as Fe₂O₃.

1. Spurrite, Velardeña, Durango, Mexico, E. T. Allen analyst.
- 1a. Molecular proportions of 1.
2. Theoretical percentage weight composition for the formula 2Ca₂SiO₄·CaCO₃.

such as to simulate very closely crossed dispersion of the monoclinic system.

Before the blowpipe spurrite shows strong calcium flame reaction, loses its glassy lustre, becomes white and porcelain-like but does not fuse even in thin splinters.

Spurrite effervesces readily with weak hydrochloric acid, dissolves completely and gelatinizes thoroughly. The chemical analysis was made on carefully selected material.

The agreement of the analyzed material with the formula $2\text{Ca}_2\text{SiO}_4 \cdot \text{CaCO}_3$ is remarkably close and in view of the purity of the material analyzed can leave no doubt that spurrite is a compound of the above formula.

The specific gravity at 25° was determined with pycnometer, both in xylene and in water, and the following results obtained:

$$\begin{array}{r} \text{Spec. gr. at } 25^\circ \text{ in xylene} = 3.013 \\ \text{“ “ “ “ water} = \left. \begin{array}{l} 3.014 \\ 3.016 \end{array} \right\} \\ \hline \text{Average spec. gr. at } 25^\circ = 3.014 \end{array}$$

Spurrite occurs in the hand specimens either in pure, unaltered state, except for minute inclusions of magnetite, or together with yellow garnet, calcite and gehlenite. Its weathering products consist chiefly of carbonates in microscopic aggregates, which appear first along cracks and cleavage planes in the altering mineral.

Through the courtesy of Mr. E. S. Shepherd of the Geophysical Laboratory, several experiments were made to reproduce spurrite artificially by heating ten per cent solutions of sodium chloride with pure Ca_2SiO_4 and CaCO_3 in finely divided state and in different proportions in silver-lined steel bombs from 6 to 9 days at temperatures of 350° to 400° . Although minute, well-shaped crystals were obtained in many of the preparations with refractive indices α and γ , practically identical with those of spurrite, the symmetry was orthorhombic and therefore not that of spurrite. Synthetic experiments on this compound are still in progress.

This mineral is named in honor of Mr. J. E. Spurr of New York, who collected the original material and who has done much to further existing knowledge of ore deposits and their accompanying minerals.

*Hillebrandite.**

Hillebrandite, unlike spurrite and gehlenite, is distinctly a fibrous mineral and occurs in aggregates often as radial spheru-

* Type specimens from the 8th level of the Terneras Mine, Velardeña, Durango, Mexico.

lites, the individual fibers of which are difficult to separate satisfactorily, and rarely measures $.5^{\text{mm}}$ in length. In the hand specimen, especially when examined with a lens, these fibers tend to produce a faint silky luster on the otherwise vitreous to porcelain-like mass. Cleavage, so far as could be observed, prismatic. Brittle. Hardness between 5 and 6, about 5.5. Color, pure porcelain white, often with faint tinge of pale green. Translucent in small chips. Streak, white.

Under the microscope the optic properties are those of aggregates of fibers, often in approximately parallel orientation, rather than of a single fiber. As a result the optical data are not easy to determine with great accuracy, although certain features of the mineral are so characteristic that its determination as such is a relatively simple matter.

The refractive indices γ and α were measured in sodium light on an Abbé-Pulfrich total refractometer on a polished plate of the mineral. It has been found by experience that even in the case of such fine-grained masses as hillebrandite, the phenomena in sodium light on the refractometer are sufficiently distinct, when reducing attachment is used, to permit a fairly accurate determination of the two limiting curves γ and α , although in the flood of light from the different grains, the medium refractive index line does not appear with sufficient distinctness to allow of its determination. On such a plate the refractive indices were found to be

$$\begin{aligned}\gamma &= 1.612 \pm .003 \\ \alpha &= 1.605 \pm .005\end{aligned}$$

The birefringence is medium to weak, but difficult to determine directly because of interweaving of overlapping fibers.

The extinction is parallel, the ellipsoidal axis (ϵ) being invariably parallel with the fiber direction which at the same time is the cleavage direction. The optic axial angle is not very large, $2E_{\rho}$ being possibly between 60° to 80° , while the dispersion of the optic axes is unusually strong and gives rise to peculiar, abnormal blue interference colors resembling those in certain epidotes and characteristic of hillebrandite. The optic character is negative with $2E_{\nu} > 2E_{\rho}$. The plane of the optic axes was found to vary, being in the one plate parallel with the fiber direction and in the next perpendicular to the same, an abnormal phenomenon which may be due in whole or in part to the disturbing influence of the interlacing fibers which tend to veil the optic phenomena and often most effectively. On a section normal to the acute bisectrix the plane of the optic axes was parallel with the cleavage and direction of elongation.

From these optical and crystallographic data, it appears that hillebrandite is orthorhombic with possibly $c=\tau$, $a=\alpha$ and cleavage after 110 (?). Its most characteristic optic features are: refractive index about 1.61, birefringence weak to medium, $2E$ medium with very strong axial dispersion $2E_r > 2E$, which in parallel light gives rise to abnormal blue interference tints which are readily recognized. Optical character, negative.

The absence of crystallographic faces of any degree of perfection precluded any attempts at etching which might have been made.

The specific gravity at 25° was determined by pycnometer with water at 2.692, and also in xylene at 2.692. The check determination in xylene was made because the analysis of hillebrandite shows it to have been slightly hydrolized.

In hydrochloric acid (1:1) hillebrandite separates some silica at once but enters otherwise into solution. Hillebrandite decomposes very slowly with cold water as the test by adding a few drops of phenolphthaline to the mixture indicates.

Before the blowpipe thin splinters of hillebrandite fuse down with difficulty to a colorless glassy bead, at the same time giving a strong calcium flame reaction and glowing briskly.

CHEMICAL ANALYSIS.

	1	1a	2
SiO ₂	32.59	.5398	31.74
TiO ₂ .....	.02	.0003	
Al ₂ O ₃ .....	.23	.0023	
Fe ₂ O ₃} } .....	.15	.0009*	
FeO }			
MnO .....	.01	.0001	
MgO .....	.04	.0010	
CaO	57.76	1.0296	58.81
Na ₂ O .....	.03	.0005	
K ₂ O .....	.05	.0005	
H ₂ O	9.36	.5019	9.45
F	none		
CO ₂	none		
	100.24	2.0769	100.00

1. Hillebrandite, Terneras Mine, Velardeña, Durango, Mexico, E. T. Allen analyst.

1a. Molecular proportions of 1.

2. Percentage weight composition of formula $H_2O.2 CaO.SiO_2$.

* Calculated as Fe_2O_3 .

This analysis agrees closely with the formula $\text{Ca}_2\text{SiO}_4 \cdot \text{H}_2\text{O}$,* it being a little higher in silica and lower in lime, a condition which is evidently due to a slight leaching of the lime. The water of the analysis was determined by loss in weight, the figure given being the average of two determinations, 9.34 and 9.39. By absorption by calcium chloride plus the little obtained at 110° the result was 9.18. The first figures, however, are more accurate.

Hillebrandite occurs usually with few inclusions and even magnetite is rare. Occasionally small grains of carbonate, yellow garnet and wollastonite occur with it and also earthy material of a secondary nature. Veinlets of wollastonite traversed several of the hand specimens and in each case the direction of elongation of the wollastonite fibers was normal to the vein walls.

Experiments to produce hillebrandite synthetically have thus far not proved successful.

The above optical and chemical data show beyond question that hillebrandite is a true chemical compound of unique chemical composition. It is with great pleasure, therefore, that the writer suggests the above name as a token of appreciation of the fundamental researches of Dr. W. F. Hillebrand of the U. S. Geological Survey in mineralogical chemistry.

Geophysical Laboratory.

Carnegie Institution of Washington,
Washington, D. C.

June, 1908.

* This formula may also be written $\text{CaSiO}_3 \cdot \text{Ca}(\text{OH})_2$ or simply $\text{H}_2\text{O} \cdot 2\text{CaO} \cdot \text{SiO}_2$.