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TILLEYITE, A NEW MINERAL FROM THE CONTACT ZONE AT CRESTMORE, CALIFORNIA

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INTRODUCTION

The contact metamorphic zone at Crestmore, California, where granodiorite and quartz monzonite have invaded limestone, has already yielded seven new mineral species, and in addition some fifty-three other previously known species. An examination of blocks of the material from the Wet Weather quarry, collected by the senior author during 1932, has revealed the presence of a new lime silicate-carbonate mineral, with distinctive optical and chemical properties. For the new mineral the name tilleyite is proposed in honor of Professor C. E. Tilley of Cambridge University, England, in recognition of the contributions he has made to the study of metamorphism.

ASSOCIATED MINERALS

A summary of the minerals already recorded from Crestmore has been given in a paper by A. F. Rogers (1929). It will therefore suffice here to mention only those minerals which have been found in intimate association with the tilleyite. The rock in which the new mineral was discovered is a hard green material, the color being imparted by the presence of abundant merwinite. The grain size, though not fine, is such that individual grains cannot be distinguished with the naked eye. Brown streaks of vesuvianite traverse the rock, and with these a light colored grossularite is associated. Tilleyite appears to be most abundant in white patches, where it is associated with wollastonite. Spurrite is present in limited amounts, as well as a mineral which corresponds in all its optical properties with gehlenite, but shows "microcline" twinning in basal sections. This assemblage appears to represent the more

intensely metamorphosed part of the contact zone, and calcite is present in insignificant amount only. Veinlets of thaumasite traverse the rock, and there is also a white powdery alteration product coating the surface of the blocks, part of this is hydromagnesite.

An examination of the collection of material from Crestmore in the Mineralogical Museum of Harvard University showed that tilleyite is present in a number of specimens. In these, the mineral assemblage is similar to that described above. On the other hand, tilleyite was not detected in specimens which contained large amounts of recrystallised calcite, as do those in which wilkeite, brucite and diopside are important constituents.

OPTICAL PROPERTIES

Tilleyite is biaxial, with refractive indices, determined by the immersion method, as follows: $\alpha=1.617$, $\beta=1.635$, $\gamma=1.652$; all

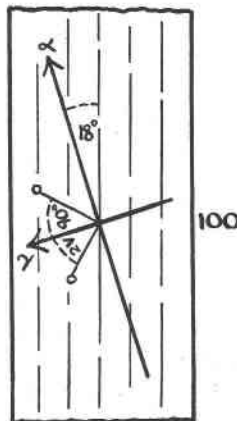


FIG. 1. Optical orientation of tilleyite.

$\pm .003$. Inspection of the interference figures exhibited made it evident that the optic axial angle is large, approaching 90° . This was confirmed by means of the Fedorov stage. An optical sign cannot therefore be assigned with complete certainty, but the mineral is probably positive. If this is so, the dispersion of the optic axes, which is fairly conspicuous, is $r < v$ (perceptible). The optical orientation was obtained by the use of the Fedorov stage. Within the limits of experimental error, the β -index direction was found to lie in the plane of the perfect cleavage. The α - and γ -directions are

both inclined to this plane. It is therefore suggested that the mineral is monoclinic; that the *b*-crystal axis be taken as parallel to the β index direction, and that the plane of the cleavage be assumed to be parallel to (100). The *c*-crystal axis then also lies in the cleavage plane, and the angle $X \wedge c$ is 18° . The accompanying diagram summarises the proposed orientation.

Twinning has not been detected in tilleyite, but in addition to the perfect cleavage discussed above there is another ill defined cleavage which was detected in only one thin section. This makes an angle of about 42° with the perfect cleavage, and is inclined at 18° to the proposed *b*-crystal axis.

PHYSICAL PROPERTIES

In powder, tilleyite is white without lustre. There is one perfect cleavage, and in addition one ill-defined cleavage. The presence of the perfect cleavage causes abundant cleavage fragments to appear in the powder. Calculation of the specific gravity by Gladstone and Dale's law gave as a result Gr. = 2.90; while determination by means of the quartz pycnometer showed that the density is 2.838. The hardness has not been determined owing to lack of sufficiently large grains.

CHEMICAL PROPERTIES

A sample was separated for analysis from the original rock by means of heavy liquids, bromoform-methylene iodide mixtures being used. It became apparent in the process of separation that the amount of tilleyite in the rock was small, being of the order of 0.5 to 1.0%. The impurities remaining in the analyzed powder were estimated as follows: wollastonite 2%, spurrite 1.5%. Preliminary tests showed that the mineral effervesces vigorously with cold dilute hydrochloric acid, and gelatinizes. The results of an analysis are given below:

SiO ₂	24.09
Al ₂ O ₃	0.61
Fe ₂ O ₃	0.12
MgO.....	0.43
CaO.....	57.75
H ₂ O.....	1.09
CO ₂	15.82

The analysis shows the mineral to be composed essentially of lime, silica and carbon dioxide. Correction for the estimated impurities, and recalculation of the principal constituents to 100% gave the results in column I below:

	I	II	III	IV
SiO ₂	24.00	0.399	22.1	0.376
CaO	59.60	1.063	61.8	1.180
CO ₂	16.40	0.372	16.1	0.376

The molecular ratios (column II) suggest an empirical formula $3\text{CaO}\cdot\text{SiO}_2\cdot\text{CO}_2$; the theoretical percentage weights are given in column III, and the molecular proportions of these in column IV. Examination of other possible formulae showed that only a very complex one would fit the analysis better than the one assigned, and we have decided, pending the availability of purer material for analytical purposes, to present the formula in its simple form.

Thin sections cut from the blocks in which the mineral was first found show that while it is homogeneous, some grains show borders having a lower birefringence than the rest of the grain. The zoned texture does not appear to be due to alteration, but more probably represents variation in composition. It was not found possible to take any account of this effect, but it is suggested that the slight divergence of the analysis from the theoretical composition proposed may perhaps be due in part to the presence of these borders.

THE SCAWTITE-TILLEYITE-SPURRITE GROUP

Three naturally occurring minerals in which carbon dioxide has combined with calcium silicate are known. These are spurrite, originally described by F. E. Wright (1908), scawtite, described by C. E. Tilley (1929B) and tilleyite. Tilleyite and spurrite may be expressed in structural formulae showing a molecule of calcium carbonate combining with one and two molecules of calcium-olivine, respectively. Scawtite is not capable of being expressed in a simple structural formula of this type.

The table which follows summarizes some of the properties of the group. Those of larnite, the calcium-olivine first discovered in the Scawt Hill contact-zone by C. E. Tilley (1929A) have also been inserted for reference:

	SCAWTITE	TILLEYITE	SPURRITE	LARNITE
SiO ₂	34.2	24.1	26.9	31.0
CaO	46.4	59.5	62.3	64.9
CO ₂	18.0	16.4	9.7	0.0
Formulae:	2CaCO ₃ · Ca ₂ Si ₃ O ₈	CaCO ₃ · Ca ₂ SiO ₄	CaCO ₃ · 2Ca ₂ SiO ₄	Ca ₂ SiO ₄
α =	1.597	1.617	1.640	1.707
β =	1.606	1.635	1.674	1.715
γ =	1.621	1.652	1.679	1.730
Birefringence =	0.024	0.035	0.039	0.023
Sp. Gr. =	2.77	2.838	3.014	

There is thus a gradation in properties within the group. Increasing refractive index may be correlated with increasing lime percentage, and decreasing carbon dioxide. Similarly, the specific gravity increases with the decrease of carbon dioxide.

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