

# FURTHER DATA ON THE STILPNOMELANE MINERAL GROUP

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## ABSTRACT

Three new stilpnomelane analyses are reported together with their physical data. One of the minerals was separated from quartzose schists and the other two, which exhibited zonary relationship, had crystallized in a glaucophanic mineral assemblage. Using unit cell dimensions determined by Gruner, tentative empirical cell contents for these stilpnomelanes have been calculated, and a figure of 30 oxygens per unit cell appears most probable. The compositions of the minerals are intermediate to those previously recorded and the optical and chemical data determined allow preparation of somewhat better composition/refractive index curves than those recorded earlier (Hutton, 1938, 1945). The modes of occurrence in both instances in plumose aggregates and vein-fillings that uninterruptedly traverse foliation, microfolds, and other structural features, point to a very late period of crystallization.

## OCCURRENCE AND PETROGRAPHY

*San Juan Bautista Mine, California.*\* So far as the writer is aware stilpnomelane has not been recorded as such in rocks from the Oak Hill environment by earlier workers, among whom are Carey and Miller (1907), Templeton (1912), and Crittenden (1949, 1951), but it should be made clear that Carey and Miller (1907, pp 167–168) did note the presence of what they believed to be mica—some of which was pale brown in color—in glaucophane schists at this locality, whereas Templeton (1912, pp. 17–18) recorded an abundance of mica but did not mention the color thereof. Although members of the stilpnomelane group of minerals have often been incorrectly identified as biotite—and correct diagnosis may be difficult if grain-size is small—it is not possible to say that this may have been the case so far as Carey and Miller and others are concerned because of the paucity of mineralogical description.

Although Crittenden (1949, pp. 94–95) did not find stilpnomelane in the mineral assemblage of schists from Oak Hill, he (1949, pp. 99, 103) does record it in a metachert and a glaucophane-bearing rock from the nearby Los Buellis Hills area. However, the properties recorded by him for stilpnomelane in the metachert are quite anomalous since although refractive indices are very high, *viz.*  $\alpha=1.75$  and  $\gamma=1.78$ , birefringence is abnormally low, *viz.* 0.03. Crittenden considers that his data, although they differ notably from any previously published by the present writer (Hutton, 1938), are similar to those determined by Larsen and recorded by Winchell (1933, p. 435) for a stilpnomelane from New York. Actually Winchell records no such data!

\* Also known as the Hillsdale Mine, 3–4 miles south-east of San Jose, Santa Clara County, California.

Stilpnomelane occurs as a major constituent of both quartzose and albitic glaucophanic schists at the San Juan Bautista Mine. Garnet and sphene are minor accessories whereas clinozoisite, apatite, muscovite, and chlorite are only occasional constituents. Water-clear quartz and often patchily twinned plagioclase occur in cataclastically deformed xenoblastic grains, 1.0 mm. in diameter, and the latter mineral consistently has a composition of  $An_{9-10}$ .

Amphibole forms about 15–20% of the rocks and might best be described as a member of the glaucophane-riebeckite series rather closer to glaucophane than to the alkali and iron-rich varieties, on account of pleochroism, small optic axial angles, and medium birefringence. The dominant glaucophanic phase is strongly zoned, especially in the albite-rich rocks, by a second member of the series which differs from the first in two ways, *viz.* (1) more intense absorption but similar pleochroism, and (2) smaller optic axial angle. This suggests that the composition is rather close to that of crossite, but no instance of a transverse optic axial plane was observed.

Stilpnomelane forms plumose and closely interlaminated aggregates with no obvious orientation, and platelets are found to lie at any angle with respect to foliation and schistosity; instances can be found where the radiating crystals stab through albite in more or less continuous fashion (Fig. 1). From a survey of many thin sections it is clear that the color of the stilpnomelane exhibits a distinct range from brown to intense red-brown for the *Z*-vibration direction of the ellipsoid, and in a few instances a range of color was evident within a single sheaf-like aggregate of platelets. Accordingly an attempt was made to determine the compositional range therein by chemical analysis.

*Frankton Road.* † A narrow zone of quartzose rocks exceedingly rich in stilpnomelane is associated with a thick lens of albite-epidote-chlorite schists three-quarters of a mile from Queenstown Post Office along the road to Frankton. The stilpnomelane schists at this new locality are similar to those described earlier (Hutton, 1938, pp. 178–179) that outcrop some 300–400 yards further to the east.

Stilpnomelane makes up about 90% of the particular schist from which that mineral was separated for analysis, and quartz, very minute euhedra of manganiferous garnet, usually segregated into dense semi-translucent laminae, clusters of large xenoblastic crystals of hydroxy-apatite, sphene, and yellow ferruginous epidote complete the mineralogical assemblage. However, among the thirty specimens examined the ratios of stilpnomelane to quartz show a wide range with as little as 20%

† Lake Wakatipu, Western Otago, New Zealand.

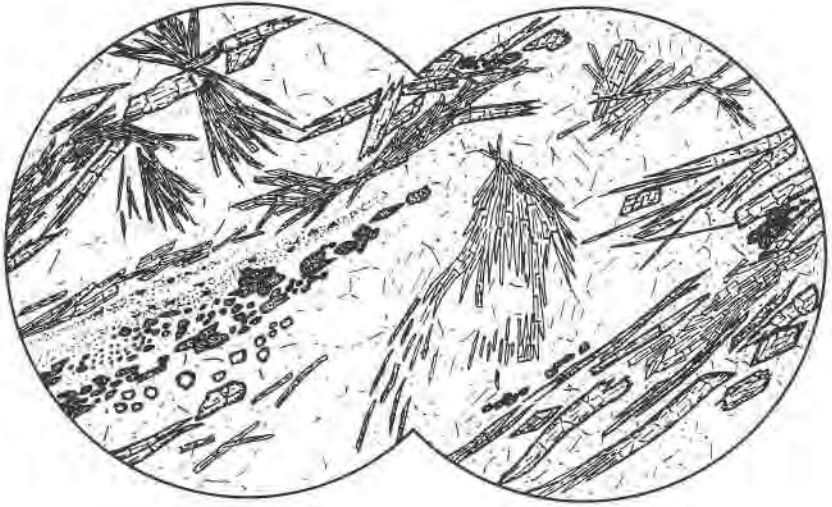


FIG. 1. Sheaf-like aggregates of stilpnomelane lie within or across the planes of schistosity in glaucophane schist. Albite, glaucophane, sphene, garnet, and quartz are associated minerals. San Juan Bautista Mine, near San Jose, California. Magnification  $\times 11$ .

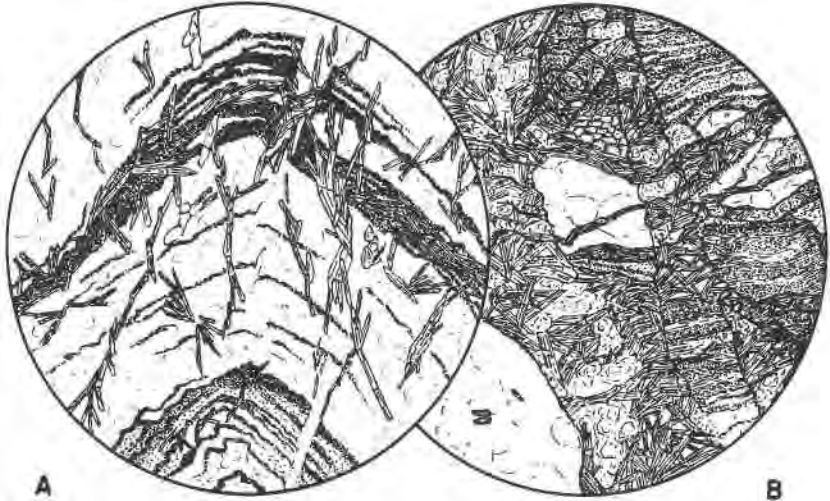


FIG. 2A. Crystallization of coarse plates of stilpnomelane has been guided to some extent either by tension during the very last phase of development of micro-folds, or by tension cracks that resulted from earlier flexure. Frankton Road, three-quarters of a mile from Queenstown Post Office, Lake Wakatipu, Western Otago, New Zealand. Magnification  $\times 11$ .

FIG. 2B. Late veinlets composed almost exclusively of stilpnomelane in quartz-garnet schist. Locality as for Fig. 2A. Magnification  $\times 11$ . Res. Coll. No. 21924.

of the former mineral in one instance. Albite was not observed in any specimen.

Stilpnomelane forms radiating sheaf-like aggregates and anastomosing networks of platelets (Fig. 2 *A* and *B*) that average about 0.2–0.3 mm. in length although a considerably coarser grain size is apparent in those schists in which stilpnomelane is less dominant—the more quartzose types. These rocks have undergone a considerable amount of deformation that would seem to have been largely, if not entirely, completed before crystallization of the bulk of the stilpnomelane occurred. Accordingly undeformed platelets and plumose aggregates are found in veinlets and tension cracks that cut across micro-folds and schistosity, and are also found to penetrate both post-deformation quartz veining and adjacent schist without interruption (Fig. 2 *A*). There appears to be little doubt that at least the major portion of the stilpnomelane crystallized after all movement had ceased.

TABLE 1. ANALYSES OF STILPNOMELANE

	<i>A</i>	<i>B</i>	<i>C</i>
SiO <sub>2</sub>	44.51	44.89	45.24
Al <sub>2</sub> O <sub>3</sub>	7.20	6.98	5.27
TiO <sub>2</sub>	0.19	0.15	0.15
Fe <sub>2</sub> O <sub>3</sub>	19.42	28.80	26.87
FeO	8.92	1.02	2.96
MnO	2.93	2.74	2.74
MgO	6.24	5.23	5.97
CaO	0.47	0.65	0.85
K <sub>2</sub> O	0.86	1.30	0.57
Na <sub>2</sub> O	0.37	0.42	0.75
H <sub>2</sub> O <sup>+</sup>	6.92	6.59	7.11
H <sub>2</sub> O <sup>-</sup>	2.28	1.58	1.92
	100.33	100.35	100.40
$\alpha$	1.584 ± 0.003	1.620 ± 0.003	1.605 ± 0.003
$\gamma$	1.661	1.718	1.691–1.696 1.694 for majority
$\gamma$ - $\alpha$	0.077	0.098	0.089
X	golden yellow	golden yellow	golden yellow
Y=Z	deep brown	deep red-brown	deep red-brown
S.G.	2.80 ± 0.02	2.85 ± 0.02	2.78 ± 0.02

Analyses *A* and *B*: San Juan Bautista Mine, 3–4 miles south-east of San Jose, Santa Clara County, California. Analyst: C. Osborne Hutton.

Analysis *C*: Frankton Road, three-quarters of a mile from Queenstown Post Office, Western Otago, New Zealand. Analyst: R. Klemens.

## MINERALOGY

The stilpnomelanes were prepared for analysis by the methods used in an earlier study (Hutton, 1938, p. 183) and preliminary fractionation was greatly facilitated by the highly brittle character of the minerals concerned since this allowed preferential reduction in grain-size with consequent concentration of the mineral concerned. The final pure fractions were secured by repeatedly centrifuging the nearly pure powders after they had been reduced in grain-size by careful grinding under acetone.

In the case of the Otago stilpnomelane a specific gravity of  $2.78 \pm 0.02$  was found, but for the San Juan Bautista mineral, where a range of composition was evident from optical study alone, fractionation was found to be continuous over a density range of 2.79–2.86. Accordingly two fractions were separated in the latter instance, *viz.* one at 2.80 and a second at 2.85, but insufficient material of intermediate densities was obtained for analysis.

These analyses with their physical data are set out in Table 1. It will be noted that analyses *A* and *B* are similar except for the degree of oxidation of iron, and slightly lower magnesia and water content in the more highly oxidized mineral; total iron in these two analyses, expressed as  $\text{Fe}_2\text{O}_3$ , is 29.36% and 29.93%. The similarity of the composition of stilpnomelanes *A* and *B* suggests that the change in ratio between  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  might be attributed to a very slow increase in pH of pore solutions (or oxidation potential) during crystallization of stilpnomelane

TABLE 2. STILPNOMELANE ANALYSES CALCULATED ON THE BASIS OF 30(O, OH) ATOMS TO THE UNIT CELL

	A Metals			B Metals			C Metals			
$\text{SiO}_2$	44.51	7.92	}8.00	44.89	7.93	}8.00	$\text{SiO}_2$	45.24	7.99	}8.00
$\text{Al}_2\text{O}_3$	7.20	1.41		{0.08	6.98		1.45	{0.07	$\text{Al}_2\text{O}_3$	
$\text{TiO}_2$	0.19	.02	}1.33	0.15	.02	}1.38	$\text{TiO}_2$	0.15	.02	}1.08
$\text{Fe}_2\text{O}_3$	19.42	2.60		}7.37	28.80		3.83	}7.14	$\text{Fe}_2\text{O}_3$	
$\text{FeO}$	8.94	1.33	}0.38		1.02	.14	}0.55		$\text{FeO}$	2.96
$\text{MnO}$	2.93	.44		}0.42	2.74	.40		}0.42	$\text{MnO}$	2.74
$\text{MgO}$	6.24	1.65	}0.38		5.23	1.37	}0.38		$\text{MgO}$	5.97
$\text{CaO}$	0.47	.08		}0.38	0.65	.12		}0.38	$\text{CaO}$	0.85
$\text{K}_2\text{O}$	0.86	.18	}0.38		1.30	.29	}0.38		$\text{K}_2\text{O}$	0.57
$\text{Na}_2\text{O}$	0.37	.12		}0.38	0.42	.14		}0.38	$\text{Na}_2\text{O}$	0.75
$\text{H}_2\text{O}$	6.92	8.21	}0.38		6.59	7.76	}0.38		$\text{H}_2\text{O}$	7.11

Formulae thus derived are:

- A.  $(\text{O, OH})_{10}(\text{Na, K, Ca})_{.36}(\text{Fe}^{2+}, \text{Fe}^{3+}, \text{Mg, Mn, Ti, Al})_{7.37}[(\text{Si, Al})_6\text{O}_{20}]$   
 B.  $(\text{O, OH})_{10}(\text{Na, K, Ca})_{.35}(\text{Fe}^{2+}, \text{Fe}^{3+}, \text{Mg, Mn, Ti, Al})_{7.14}[(\text{Si, Al})_6\text{O}_{20}]$   
 C.  $(\text{O, OH})_{10}(\text{Na, K, Ca})_{.33}(\text{Fe}^{2+}, \text{Fe}^{3+}, \text{Mg, Mn, Ti, Al})_{7.08}[(\text{Si, Al})_6\text{O}_{20}]$

rather than to weathering processes. In this connection it is possibly significant that the stilpnomelane with the higher percentage of  $\text{Fe}^{3+}$  also has a lower total water-content, and calculation of empirical cell

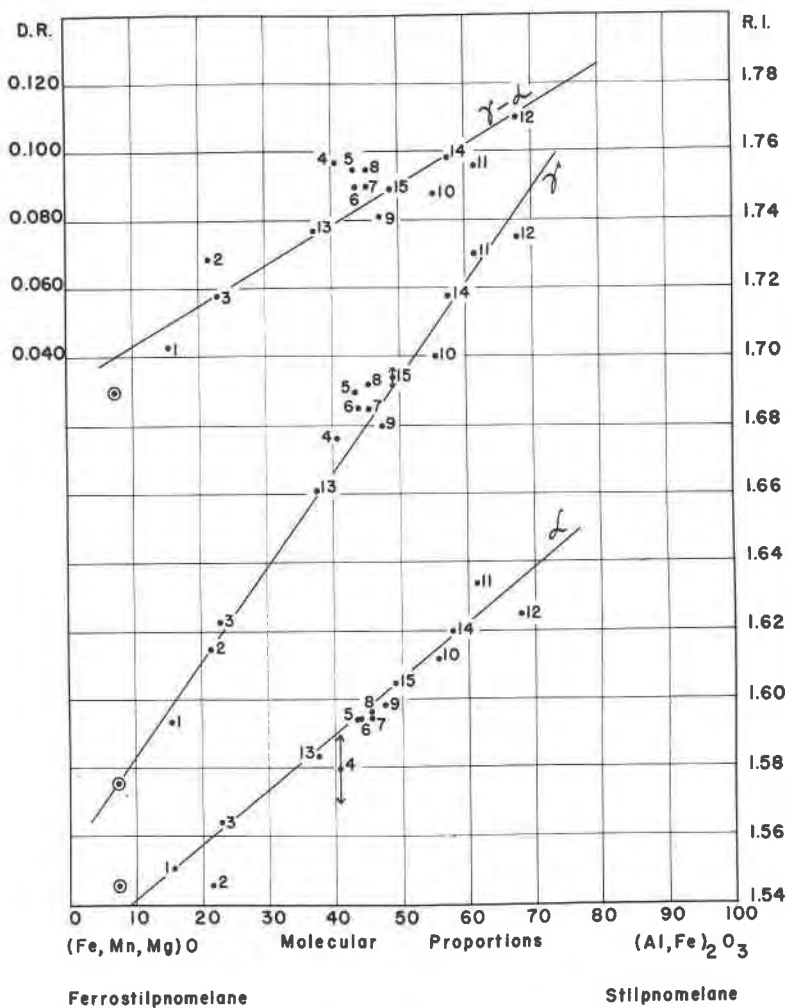


FIG. 3

- 1-12. These numbers correspond to those employed in Fig. 1 of Hutton (1945, p. 716).  
 13. Less oxidized fraction, San Juan Bautista Mine, San Jose, California.  
 14. Oxidized fraction, San Juan Bautista Mine, San Jose, California.  
 15. Three-quarters of a mile along Frankton Road from Queenstown Post Office, Lake Wakatipu, Western Otago, New Zealand.  
 Circled dot. Parsettensite (J. Jakob, 1923).

contents suggests that the lower water-content may be compensated for by increase in oxygen replacing hydroxyl.

The question of a formula for stilpnomelane cannot be satisfactorily settled until a structure analysis is made (Table 2). However, one can derive empirical cell contents if density and cell dimensions are known and at the same time make no assumptions as to the numbers of (O, OH) ions that might be present (Hey, 1954). Complete measurements of cell size have not been made by the writer for the three minerals described herein, although *c*-spacings were determined to be 12.14 Å., 12.10 Å., and 12.12 Å. for stilpnomelanes *A*, *B*, and *C* respectively. These data correspond closely with those secured by Gruner (1944, p. 294), *viz.* 12.07–12.18 Å. Thus for approximation purposes only it may be assumed that the stilpnomelanes described herein have comparable cell sizes to those already recorded by Gruner.

If we employ Gruner's cell volume and specific gravities of 2.80 and 2.82 for mineral *A* (Table 1) and a stilpnomelane previously studied (Hutton, 1945, p. 717, anal. 1) we arrive at cell weights of 1719.2 and  $1731.5 \times 10^{-24}$  gms., respectively. From these data an empirical oxygen content of 29.91 and 29.27 is obtained in each instance, figures that may be considered to have an accuracy of  $\pm 0.75$ , if a very generous margin for error in physical constants is allowed, since cell volumes have been used that have not been determined for material actually analyzed. No account is taken here of water given off below 105° C., but it is believed that a large part of this must be present as water molecules absorbed between the sheets. Certainly a previous experiment (Hutton, 1938, p. 191) clearly demonstrated that at least the greater portion of this water was not present as closely bonded hydroxyl ions.

Refractive indices have been plotted against the ratio (Fe, Mn, Mg)O : (Fe, Al)<sub>2</sub>O<sub>3</sub> for fifteen analyses of members of the stilpnomelane group (Fig. 3), and the curves previously recorded by the writer (1945) are here slightly modified, and it is hoped, more correctly drawn.

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#### REFERENCES

- CAREY, E. P., AND MILLER, W. J. (1907), The crystalline rocks of the Oak Hill Area near San Jose, California: *Jour. Geol.*, **15**, 152–169.
- CRITTENDEN, MAX D., JR. (1949), Geology of the San Jose-Mount Hamilton area, California: Ph.D. thesis, University of California, Berkeley, California.
- (1951), Geology of the San Jose-Mount Hamilton area, California: *Calif. Div. Mines, Bull.* **157**, 7–74.
- GRUNER, J. W. (1944), The structure of stilpnomelane reexamined: *Am. Mineral.*, **29**, 7–8, 291–298.

- HEY, MAX H. (1954), A further note on the presentation of chemical analyses of minerals: *Mineral. Mag.*, **30**, 227, 481-497.
- HUTTON, C. O. (1938), The stilpnomelane group of minerals: *Mineral. Mag.*, **25**, 163, 172-206.
- (1945), Additional optical and chemical data on the stilpnomelane group of minerals: *Am. Mineral.*, **30**, 714-718.
- JAKOB, J. (1923), Vier Mangansilikate aus dem Val d'Err (Kt. Graubunden): *Schweiz. Min. Petr. Mitt.*, **3**, 227-237.
- TEMPLETON, E. C. (1912), The geology and stratigraphy of the San Jose Quadrangle, California: M.A. thesis, Stanford University Library, Stanford, California.
- WINCHELL, A. N. (1933), Elements of optical mineralogy, pt. 2, 3rd ed. John Wiley and Sons, Inc., New York.

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