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MANGANESE CONTENT OF GARNETS FROM THE FRANCISCAN SCHISTS

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Introduction

Some years ago the writer (Pabst, 1931) described the garnets found in the Franciscan schists of California and reported that their composition could be expressed in terms of end members as being roughly 50 mole % almandite, usually with substantial proportions of pyrope, grossularite and andradite, but with only a very little spessartite. In summarizing the range of spessartite content was given as "0–1%."

Several years ago, at the suggestion of Dr. Max D. Crittenden, Jr., some of these garnets were reexamined and it was found that the manganese content previously reported was far too low. Additional analyses and spectrographic examination now permit a revised statement of the composition range of these garnets.

About two years ago, in response to an inquiry, the writer informed Dr. H. M. E. Schürmann of the Hague of the old error in a letter closing with the words "Reexamination of garnet *A* has shown that it contains about 2% MnO, equivalent to about 4½ mol % spessaritite." This was acknowledged by Dr. Schürmann in a letter dated 31 December, 1952, in these words:—"Many thanks for your letter of November 25th with your information on literature on glaucophane and on chemical analysis of spessartite." In view of this correspondence it is surprising that Dr. Schürmann (1953) nearly a year later cited my old erroneous figures (his Tabelle 7 and Tabelle 8) without comment.

Dr. Max D. Crittenden, Jr., and Dr. Iris P. Borg have kindly permitted the use of unpublished data which makes possible the corrected statement of the composition of garnets from the Franciscan schists given below.

New Data

A new analysis of garnet from eclogite associated with glaucophane schist ¼ mile north of the Junction School near Healdsburg, California, has recently been reported by Mrs. Borg (1954, II, p. 57) in an unpublished thesis. The locality is but a few hundred yards from the source of the garnet designated "*C*" by Pabst (1931). Table 1 contains the report of this analysis and its interpretation in terms of end members given by Mrs. Borg. It may be noted that the RO:R_2O_3:SiO_2 ratios depart from the ideal relation 3:1:3 in the fashion that is usual in garnets and that was commented upon earlier (Pabst, 1931).

Crittenden in an unpublished thesis (1951, p. 109) has recorded the corrected manganese content for the garnet from Hilton Gulch, Santa Clara County, California, designated "*A*" by Pabst (1931). In the same place he has reported a garnet of even higher manganese content in Franciscan schists but a few miles distant. Unfortunately in the published account of his work Crittenden (1951*a*) did not include these mineralogical details.

TABLE 1. ANALYSIS OF GARNET FROM ECLOGITE, ¼ MILE N OF JUNCTION SCHOOL, NEAR HEALDSBURG, SONOMA COUNTY, CALIFORNIA

Quoted from Borg (1954, II, p. 57)

		Molecular Quotients			
SiO_2	37.36	0.620	0.620	RO:R_2O_3:SiO_2	
Al_2O_3	20.12	0.197		2.78:1:2.82	
TiO_2	0.54	0.007	0.220		
Fe_2O_3	2.60	0.016		End-member Mole Per Cent:	
				almandite	57.4%
FeO	25.18	0.351		pyrope	11.7
MnO	0.92	0.013			
MgO	2.96	0.073	0.612	spessartite	2.0
CaO	9.83	0.175		andradite	9.8
H_2O −105° C.	0.04			grossularite	19.1
H_2O +105° C.	0.09				
					100.0%
	99.54				

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In Table 2 are given the MnO content and some physical properties of several garnets from Franciscan rocks. The specific gravity of garnet "*A*" has been newly determined by Berman balance and supersedes the value, 3.884, previously reported. The lattice constants have been newly determined for each garnet from a back-reflection powder pattern obtained with a focussing camera. The wave length for Co-$K\alpha_1$ radiation being taken as 1.78890, the results are properly given in Å units. The previously reported value of the lattice constant for garnet "*A*," "11.60 Å ± 0.03 Å," is to be considered as having been in kX units. Upon conversion this agrees within the limits of error with the newly determined value.

TABLE 2. MANGANESE CONTENT AND PHYSICAL PROPERTIES OF THREE GARNETS FROM THE FRANCISCAN ROCKS OF CALIFORNIA

Locality and reference	MnO (wt. %)	S. G.	N_{Na}	a_0§
¼ mile N. of Junction School, near Healdsburg, California, Borg (1954)	0.92*	4.08±0.02‡	1.795±0.003‡	11.62±0.01 Å
South of Calaveras Valley, San Jose Quadrangle, Calif., Crittenden (1951)	4.63†	4.00±0.03‡	1.795±0.002‡	11.61±0.01‖
Hilton Gulch, San Jose Quadrangle, Calif. "*A*" of Pabst (1931)	2.03†	3.95±0.04§	1.795±0.002‡	11.62±0.01

* From Table 1.
† Determinations by Abbot A. Hanks, Inc., San Francisco.
‡ Quoted from references cited.
§ New determinations, see text.
‖ A low "shoulder" on the low angle side of the diffraction lines indicates that a small part of this garnet has a lattice constant as high as 11.65 Å. The other two garnets showed very sharp simple peaks indicating little or no variation in lattice constant.

TABLE 3. RESULTS OF SPECTROGRAPHIC EXAMINATION OF GARNETS FROM FRANCISCAN ROCKS IN CALIFORNIA

	MnO %	TiO_2 %	Si	Al	Fe	Ca
From eclogite, ¼ mile N. of Junction School, near Healdsburg, Calif. Borg (1954)	(0.92) 0.9	(0.54) 1.1	PC	PC	PC	10%
S. of Calaveras Valley, San Jose Quad., Calif. Crittenden (1951)	(4.63) 5.0	0.6	PC	PC	PC	10
Hilton Gulch, San Jose Quad., Calif. "*A*" of Pabst (1931)	(2.03) 1.4	2.1	PC	PC	PC	10
Near Reed Station, Marin County, Calif. "*B*" of Pabst (1931)	2.2	2.0	PC	PC	PC	10
Near mouth of Russian River, Sonoma Co., Calif. "*I*" of Pabst (1931)	0.9	1.4	PC	PC	PC	10

Figures in parentheses quoted from Tables 1 and 2. Spectrographic results from report by Mr. George M. Gordon, dated July 17, 1954. PC means principal constituent.

Descriptions of the rocks in which these garnets occur may be found in the references cited.

As previously noted (Pabst, 1931, p. 332), the composition of garnets in the range of interest here cannot be closely estimated from physical properties. Similarity of physical properties of other garnets from the Franciscan schists then suggests similarity of composition but allows no conclusion as to manganese content. In order to check the garnets whose composition had been previously reported, five samples were subjected to spectrographic examination by Mr. George M. Gordon of the Division of Mineral Technology with the results given in Table 3. There is reasonable agreement between spectrographic and direct chemical determination of manganese. The manganese content of garnets "*B*" and "*I*," previously (Pabst, 1931, Tables I and II) reported to be very low, is seen to lie in the range found for the other garnets by chemical analysis. All of the garnets are shown spectrographically to have Fe as a principal constituent and to contain about 10% of Ca in agreement with their first description (Pabst, 1931). However, the spectrographic results indicate that the TiO_2 content is in all cases higher than the "trace" previously reported.

Conclusions

The range of composition of "garnets in glaucophane rocks" given in Table III by Pabst (1931) should be revised to read:

Grossularite	8–30%
Andradite	4–24
Almandite	48–56
Pyrope	16–20
Spessartite	1–10

Their spessartite content, though less than that of the other end members, may exceed the limits 0–3% or 1–2% given for eclogite garnets by Heritisch (1926) and by Eskola (1921) respectively. The TiO_2 content of garnets in the Franciscan schists may attain one or two per cent as indicated by spectrographic examination. Since these rocks generally contain sphene and rutile this result is not surprising.

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LAUMONTITE AND LEONHARDITE CEMENT IN MIOCENE SANDSTONE FROM A WELL IN SAN JOAQUIN VALLEY, CALIFORNIA

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The occurrence of a zeolite cement was noted in a feldspathic sandstone at a depth of approximately 11,000 feet in the Standard Oil Company of California Well C.C.M.O. 4, No. 35, Tejon Field, 30 miles southeast of Bakersfield, California. The zeolite mineral was identified by microscopic and x-ray powder diffraction methods as laumontite and its alteration product, leonhardite.

The occurrence of zeolites in rocks of igneous origin is a matter of common knowledge but their occurrence in rocks of sedimentary origin is less well known. Zeolites, nearly always secondary minerals formed by hydration of aluminum silicates of Ca, Na, etc., are derived chiefly from lime-bearing plagioclase feldspars.

Laumontite and leonhardite were found as an important alteration product in graywackes of New Zealand by Hutton (1949) and by Coombs (1952); laumontite as a cement in Cretaceous (?) sandstones from Anchor Bay, Mendocino County, California, is reported by Gilbert (1951). Hutton states that laumonitite and leonhardite probably have a much wider distribution than supposed; that in graywackes and similar rocks which have been subjected to low grade dynamothermal metamorphism the feldspars may be completely altered to laumontite and leonhardite instead of to albite.

The chemical composition of laumontite is given by Coombs (1952, p. 812) as:

$$Ca_x(Na, K)_yAl_{2x+y}Si_{24-(2x+y)}O_{48}\cdot 16H_2O$$

where $x+y/2$ does not exceed 4
and $x+y$ is not less than 4.

On exposure to the atmosphere or gentle heating laumontite loses approximately $\frac{1}{8}$ of its water to form leonhardite. This process is readily reversible and is accompanied by changes in the refractive index, optic angle, and extinction angle.

Optical properties as reported in the literature are listed in Table 1.