ZOISITE-PREHNITE ALTERATION OF GABBRO*

KENNETH DEP. WATSON,
Princeton University, Princeton, New Jersey.

ABSTRACT

Metagabbro in the vicinity of Baie Verte, Newfoundland, has been altered to an aggregate of zoisite and prehnite. Microscopic study shows zoisite intimately penetrated by a network of prehnite veinlets. Chemical analyses indicate a large increase in lime and decrease in silica, iron, magnesium and alkali content. The alteration is attributed to hydrothermal solutions probably related to the nearby granitic rocks.

INTRODUCTION

Baie Verte is an indentation in the large peninsula situated between White Bay and Notre Dame Bay on the northern coast of Newfoundland

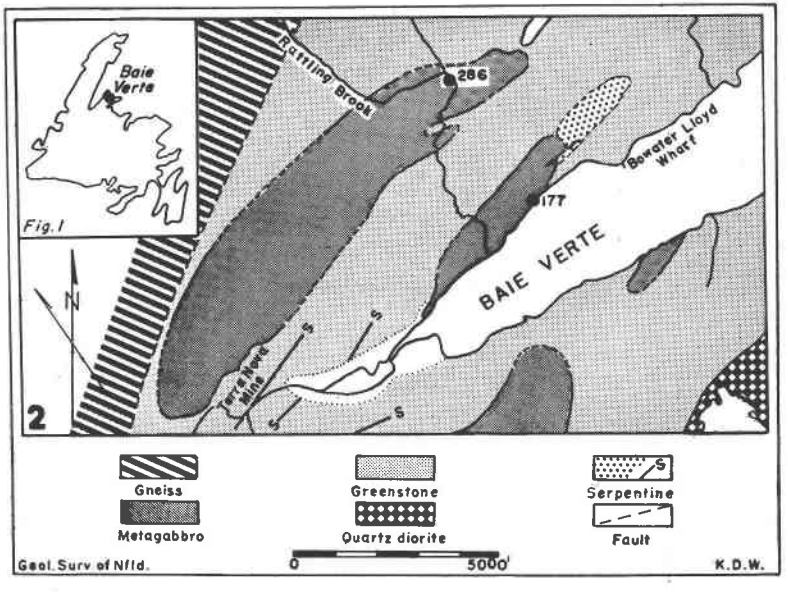

FIG. 1. Map of Newfoundland showing position of Baie Verte.
FIG. 2. Geological map of southwestern part of Baie Verte.

(Fig. 1). In the vicinity of the bay, a thick, highly folded section of rocks consisting principally of greenstones has been intruded by large, dominantly concordant bodies of ultramafics and gabbro (11).

The ultramafics have undergone serpentinization and steatitization.

* Published with the permission of the Government Geologist of Newfoundland.

The gabbro has suffered saussuritization, uralitization, silicification, carbonatization and locally, alteration to a zoisite-prehnite assemblage. Large masses of quartz diorite and granite have intruded and metamorphosed the other rocks of the area.

METAGABBRO

The metagabbro is composed principally of saussuritized plagioclase and uralitized pyroxene in varying proportions. For the most part, it is a light greenish-gray, medium grained, massive rock although local phases are highly sheared and, therefore, difficult to distinguish from the greenstone of the area. Irregular masses of a pegmatitic facies, ranging from a fraction of an inch to several feet in thickness, are of common occurrence within the large bodies.

None of the thin sections which were examined showed unaltered plagioclase and a relatively small proportion of them contained any unaltered pyroxene. A study of fresh-appearing specimens from the intrusive to the northwest of the Terra Nova mine (Fig. 2), revealed that the pyroxene, occurring as anhedral grains averaging about 0.25 mm. in diameter is augite (7, p. 520) with the following diagnostic optical properties: $2V = 47\frac{1}{2}°$ $N_p = 1.690$, $N_g = 1.718 \pm .003$; ($En_{40}Fs_{20}$ Wo_{40}).[1] Many of the grains are twinned. Most of the augite shows a peripheral alteration to actinolite or colorless tremolite. Some, however, are altered to actinolitic hornblende characterized by a fairly deep green color and distinctive pleochroism.

Plagioclase occurs as irregular polysynthetically-twinned laths, 0.75 mm. in average length, which are highly altered. They consist of albite throughout which numerous small prisms of clinozoisite and grains of epidote are disseminated. Clinozoisite also occurs as clusters of euhedral prisms in areas interstitial to the plagioclase laths. Leucoxene is present in abundance as pseudomorphs of subhedral skeletal crystals of ilmenite about 0.3 mm. in diameter.

A specimen of massive rock consisting of saussuritized plagioclase and partially altered pyroxene (Fig. 3, Plate I) from the southwest shore of Baie Verte, 2300 feet south of the Bowater Lloyd Company's wharf (Fig. 2), gave the following analysis (Table 1). Although the minerals are highly altered, the texture of the rock is well preserved and the following proportions were determined by Rosiwal analysis:

MODE

Altered plagioclase	53% by weight
Pyroxene and altered pyroxene	47% by weight

The specific gravity and porosity of the analyzed rock were determined as 3.01 and 0.3 per cent, respectively.

[1] Hess, H. H., Oral communication (cf. 7, Fig. 10, p. 585).

TABLE 1

Metagabbro No. 177					Zoisite-Prehnite No. 286	
Chemical Analysis		Norm			Chemical Analysis	
SiO_2	48.74	Or.	0.56		SiO_2	44.15
Al_2O_3	18.26	Ab.	15.72	57.42 Pc.	Al_2O_3	19.07
Fe_2O_3	1.23	An.	41.14	$Ab_{30}An_{70}$	Fe_2O_3	1.03
FeO	4.08	En.	8.90		FeO	2.49
MgO	8.76	Fs.	2.64	24.18 Di.	MgO	5.37
CaO	14.40	Wo.	12.64		CaO	25.22
Na_2O	1.87	En.	5.43	6.97 Hy.	Na_2O	.14
K_2O	.10	Fs.	1.54		K_2O	.00
H_2O+	2.25	Fo.	5.30	6.96 Ol.	H_2O+	2.46
H_2O-	.02	Fa.	1.66		H_2O-	.03
CO_2	.05	Mt.	1.86		CO_2	.03
TiO_2	.18	Ilm.	0.30		TiO_2	.14
P_2O_5	.01	H_2O+	2.25		P_2O_5	.02
MnO	.10	H_2O-	.02		MnO	.08
Total	100.05	Total	100.06		Total	100.23

Analyses by G. Kahan.

	Metagabbro 177		Zoisite-Prehnite 286	
Mode	Altered plagioclase	53%	Zoisite	83%
	Pyroxene and alterations	47%	Prehnite	15%
			Actinolite	2%
Specific Gravity	3.01		3.18	
Porosity	0.3 %		0.1 %	

Zoisite-Prehnite Alteration

Near the northern end of the sill-like body of metagabbro which extends from the vicinity of the Terra Nova mine to a short distance beyond Rattling Brook (Fig. 2), the rock has been altered to an aggregate consisting principally of zoisite and prehnite. The zoisite-prehnite rock is white or faintly greenish in color, due to the presence of actinolite and varies in grain size from extremely fine to fairly coarse. Although outcrops are not abundant, it appears that the alteration extends over an area of several hundred square feet and grades into the normal metagabbro.

Under the microscope it is seen that the zoisite ($N_p = 1.695+$, $N_g = 1.710$; positive elongation; $2V = 50° \pm$) is intimately penetrated by an intricate network of minute prehnite ($N_p = 1.617$, $N_g = 1.645$; positive elongation; $2V = 65° \pm$) veinlets (Fig. 4, Plate I). The zoisite, characterized by dark gray or anomalous deep blue interference colors, is readily distinguishable from the prehnite because of its higher relief and lower birefringence. In many places, it shows a common orientation over areas 1 to 2 mm. in diameter. A few of the grains show poor polysynthetic twinning. Commonly there is a distinct variation in the interference color within an individual crystal of zoisite. This has been interpreted by Winchell (12, p. 311) as the result of a variable Fe_2O_3 content. According to Rogers and Kerr (10, p. 320) the anomalous deep blue interference color is characteristic of the nonferrian variety of zoisite.

Winchell (12, p. 430) has presented data which show that the indices of refraction of prehnite increase and the birefringence decreases with progressive replacement of Al_2O_3 by Fe_2O_3. The indices of the prehnite examined by the writer correspond very closely to those given by Laitakari (12, p. 430. $N_p = 1.615$, $N_m = 1.624$, $N_g = 1.645$) for prehnite with a Fe_2O_3 content of 0.95%.

Some of the sections are traversed by veinlets consisting of euhedral and subhedral zoisite crystals projecting from the borders into a central portion filled with prehnite (Fig. 5, Plate I). Many of the zoisite crystals of the veinlets have been fractured and replaced by prehnite. Other veinlets consist of transversely arranged lamellar grains and plumose aggregates of prehnite (Fig. 6, Plate I).

Zoisite-prehnite rock from the south bank of Rattling Brook at a point 4600 feet N. 15° W. from its mouth (Fig. 2), was analyzed with the results given in Table 1. The mode of the analyzed rock is as follows:

Zoisite = 83% by weight
Prehnite = 15% by weight
Actinolite = 2% by weight

The specific gravity and porosity of the rock are 3.18 and 0.1%, respectively.

Similar Occurrences

The saussuritization of plagioclase and uralitization of pyroxene in gabbroic rocks is very common (9, pp. 210–214). Harker (6, p. 174) who attributes these alterations to deuteric action, states that the usual lime-aluminosilicates in saussurite are zoisite and epidote, but that prehnite is also found. In discussing metasomatism, however, he attributes the extreme prehnitization of various lime-aluminosilicates to the action of heated water of magmatic origin.

"In some localities, always in the near neighbourhood of a plutonic contact, this destructive action has been carried far, even in the extreme case to the reduction of the whole rock to an aggregate essentially of prehnite and quartz. Any lime-felspar present is first converted" (6, p. 134).

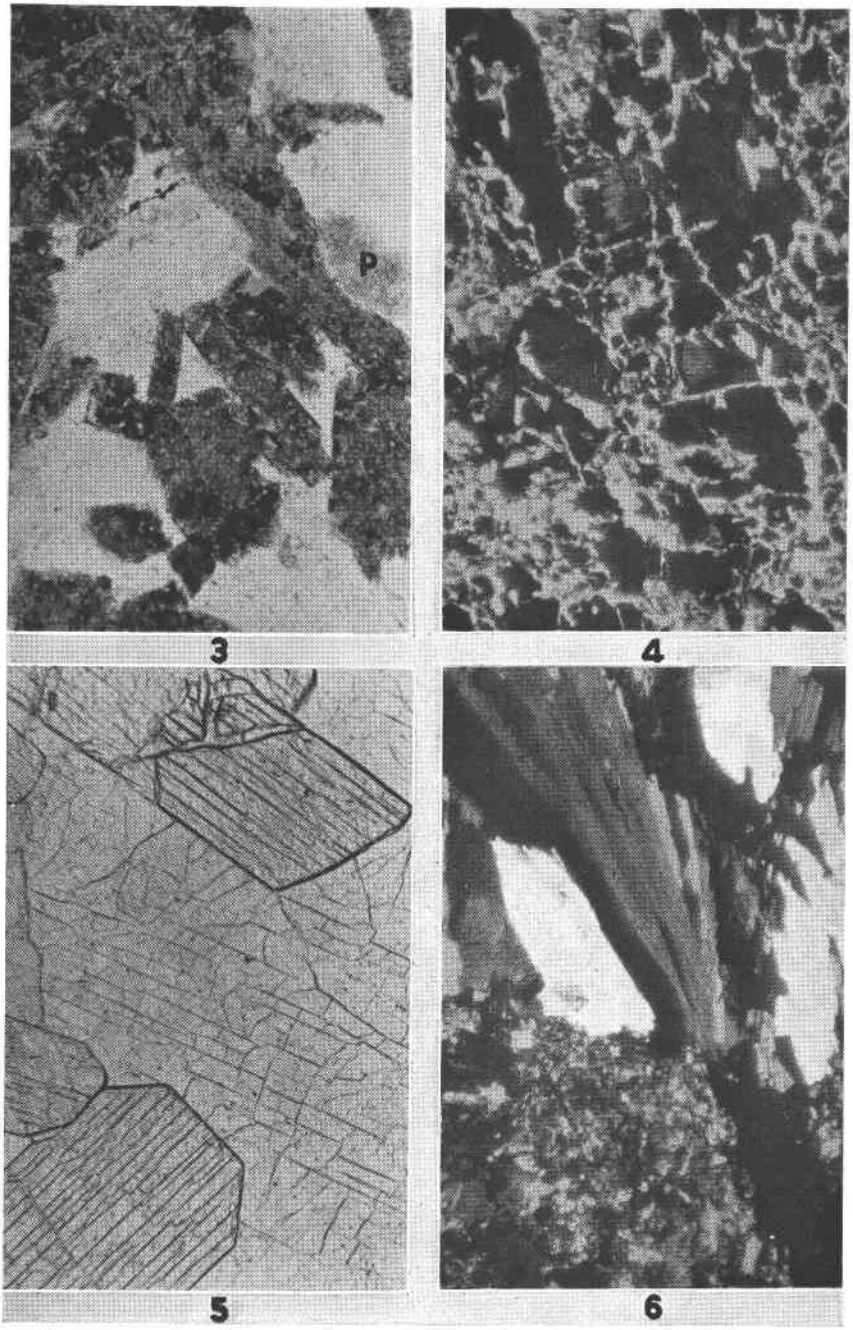

PLATE I

Benson (1, pp. 682–688) has described the occurrence of prehnite and zoisite in the altered eucrites of the Great Serpentine Belt of New South Wales. The usual altered rock consists of

"dusty diallage more or less completely changed to tremolite, and dull grey-white saussurite traversed by small veins of clinozoisite. . . . Occasionally, the saussurite would be flaked with lighter spaces, which consist of optically continuous prehnite" (1, p. 684).

At one locality, the feldspar has been entirely altered to coarsely granular zoisite. Another modification is characterized by the presence of abundant prehnite.

"This striking mineral forms in veins; the individual grains are rarely as much as 1 mm. in diameter. . . . The saussurite, on either side, is seen to have passed almost entirely into a fine mosaic of prehnite grains. The diallage in this rock is being altered, partly to tremolite, but chiefly to antigorite and pale pink garnet" (1, pp. 684–685).

Flett and Hill (5) have discussed the occurrence and origin of prehnite in the altered gabbro associated with the serpentine of the Lizard area. The saussurite alteration of the primary labradorite

"where more coarsely crystalline than usual . . . can be ascertained to contain certain minerals such as prehnite, garnet, zoisite, chlorite and alkali feldspar mixed with a variable amount of actinolite. Prehnite is very frequent, and in some cases occurs in masses and nodules several inches in diameter."

The writers attribute the alteration to the action of solutions, derived from the granitic gneisses of the area, after percolating through the serpentine.

Cooper (4) has also observed that "proximity to serpentine has favored the prehnite type of alteration" (4, p. 34) in the gabbroic rocks of the southern part of the Bay of Islands complex of western Newfoundland. In one area, the feldspars of anorthositic gabbros and troctolites which are interbanded with serpentinized dunite are completely altered to saussurite containing thick veins and blebs of prehnite.

FIG. 3. Photomicrograph of metagabbro showing saussuritized plagioclase (dark) and highly uralitized pyroxene. (Relict pyroxene (p) high relief.) Magnification: 40×.

FIG. 4. Zoisite (dark) partially replaced by prehnite (light). Magnification: 120×. Crossed nicols.

FIG. 5. Crystals of zoisite (high relief) projecting from borders of veinlet into central filling of prehnite. Note replacement of zoisite by prehnite. Magnification: 120×.

FIG. 6. Transversely arranged prehnite grains in veinlet. Magnification: 120×. Crossed nicols.

"Unquestionably the original rock was an anorthositic gabbro or troctolite. What then has caused the extreme saussurite-prehnite alteration here? Regional metamorphism, elsewhere in the region, has produced an amphibole or chlorite type of alteration with only rarely a little prehnite and some zeolite veins. The latter are probably always late-phase, low or intermediate temperature, hydrothermal effects since they are controlled by distinct fractures in the rocks which cross the other minerals. Only in the thin anorthosite bands in feldspathic dunite is prehnite quantitatively important. Apparently proximity to serpentine has favored the prehnite type of alteration" (4, p. 34).

However, prehnite may be formed in areas in which the hydrothermal solutions have not been affected by the presence of serpentine. Buddington (2, 3) has recently described the saussuritization and prehnitization of anorthositic rocks in the eastern Adirondacks. At one locality the plagioclase of several thin sheets of gabbroic anorthosite has been almost entirely replaced by a granular white prehnite which occurs as fine fibrous to lamellar aggregates and as terminated crystals projecting into druse fillings of quartz or of quartz and prehnite.

"The local saussuritization and prehnite replacement of the anorthositic rocks is later than the deformation of the rocks and may be a product of late-stage solutions originating in the granitic magmas" (2, p. 178).

Conclusions

A comparison of the composition of the typical metagabbro with that of the zoisite-prehnite rock given in Table 1 shows that the principal change involved in the formation of the latter was the addition of lime. Decrease in the silica, iron, magnesium and alkali content is also noticeable.

The saussuritization of the plagioclase and the uralitization of the pyroxene to form the typical metagabbro is probably the result of both deuteric action and regional metamorphism.

The alteration of the serpentinized ultramafics in the area to talc-carbonate rock is believed to be attributable to the presence of hydrothermal solutions probably related to the nearby granitic rocks (8, p. 643). It seems probable that somewhat similar hydrothermal solutions from the same source could alter the metagabbro to the zoisite-prehnite rock and to a zoisite-quartz assemblage which occurs elsewhere in the same region. During the alteration, a change in conditions resulted in the replacement of zoisite by prehnite, a mineral richer in silica and water.

Acknowledgments

The field work upon which this paper is based was carried out during the summers of 1938 and 1939 while the writer was employed by the Geo-

logical Survey of Newfoundland. A large portion of the laboratory expenses was borne by the Department of Geology of Princeton University.

Professor H. H. Hess gave the writer considerable aid in the optical work. The writer also wishes to thank Professor A. K. Snelgrove for help in the field, and Professor A. F. Buddington for advice and criticism in the preparation of the manuscript.

References

1. Benson, W. N., The geology and petrology of the great serpentine belt of New South Wales (Part iii): *Proc. Linn. Soc. N. S. W.*, **38,** Part 4, 662–724 (1914).
2. Buddington, A. F., Adirondack Igneous Rocks and Their Metamorphism: *Geol. Soc. Am.*, Mem. **7** (1939).
3. Buddington, A. F., and Whitcomb, Lawrence, Geology of the Willsboro Quadrangle, New York: *New York State Museum, Bull.* **325** (1941).
4. Cooper, John R., Geology of the southern half of the Bay of Islands igneous complex: *Nfld. Dept. Nat. Res., Bull.* **4** (1936).
5. Flett, F. S., and Hill, J. B., The geology of the Lizard and Meneage: *Mem. Geol. Surv. England and Wales, Expl. Sheet* **359** (1912).
6. Harker, Alfred, Metamorphism. Methuen and Co. London (**1932**).
7. Hess, H. H., Pyroxenes of common mafic magmas: *Am. Mineral*, **26,** 515–535; 573–594. (1941).
8. Hess, H. H., The problem of serpentinization and the origin of certain chrysotile asbestos, talc and soapstone deposits: *Econ. Geol.*, **28,** 634–657 (1933).
9. Johannsen, Albert., A Descriptive Petrography of the Igneous Rocks. Vol. III. The Intermediate Rocks. *The University of Chicago Press* (**1937**).
10. Rogers, Austin F., and Kerr, Paul F., Optical Mineralogy. McGraw Hill Book Co., New York (**1942**).
11. Watson, Kenneth DeP., Geology and mineral deposits of the Baie Verte-Mings Bight area; *Nfld. Geol. Surv. Bull.* To be published.
12. Winchell, Alexander N., Elements of Optical Mineralogy (Part II). Description of Minerals. John Wiley and Sons. New York (**1933**).