TWO OCCURRENCES OF CHLORITOID AS A HYDROTHERMAL MINERAL IN IGNEOUS ROCKS

J. K. GUSTAFSON, *Boulder, Colorado.*

ABSTRACT

Chloritoid occurs as a hydrothermal alteration mineral in pre-Cambrian lavas in the Porcupine district, Ontario, and Kalgoorlie district, Western Australia, and as a vein mineral in occasional quartz veins in the Porcupine district. These occurrences contradict geologic texts describing ottrelite and chloritoid solely as stress minerals resulting from the dynamic metamorphism of sedimentary rocks.

INTRODUCTION

The brittle micas chloritoid and ottrelite appear to be generally fixed in the geologic mind as stress minerals produced only in sedimentary rocks by dynamic metamorphism. For example, Dana's *Textbook of Mineralogy*, 4th edition (1),[a] on pp. 667–668 describes the occurrence of these minerals thus, "Chloritoid (ottrelite, etc.) is characteristic of sedimentary rocks which have suffered dynamic metamorphism, especially in the earlier stages; it is thus found in phyllites, quartzites, mica schists, etc." Harker (2) and Grubenmann and Niggli (3) in their texts on metamorphism similarly discuss chloritoid only in connection with sedimentary rocks. Harker remarks (pp. 213–214), "The formation of chloritoid is probably dependent in the early stage of regional metamorphism upon the presence of kaolin." On page 149 he mentions, "other *distinctively stress-minerals** such as chloritoid, ottrelite, and staurolite." Winchell (4, p. 886) states that chloritoid occurs "only in crystalline schists where it may be abundant." This paper describes the occurrence of chloritoid as a hydrothermal alteration mineral in pre-Cambrian lavas at Porcupine, Ontario, and Kalgoorlie, Western Australia, and as a vein mineral in quartz-ankerite veins at the Hollinger mine in the Porcupine district.**

GEOLOGIC ENVIRONMENT OF CHLORITOID OCCURRENCES

The Porcupine and Kalgoorlie districts are among the most important gold mining districts in the world. Their geology is remarkably similar.

[a] References are at the end of the paper.

* The italics are mine.

** This paper originated from observations made by the author in 1930–1932 while on L. C. Graton's staff during a study of the Hollinger Mine and during 1934–1936 while geologist for Western Mining Corporation Limited. The manuscript was written in 1937 and revised slightly in 1942. L. C. Graton suspected the hydrothermal origin of "chloritoid" in the Rand conglomerate (Hydrothermal origin of Rand gold deposits, p. 170, *Econ. Geol.*, **25,** supplement, May 1930), and possibly other mining geologists have presented evidence elsewhere for the hydrothermal origin of chloritoid and ottrelite. Nevertheless a recent scanning of new texts on mineralogy suggests that this paper is still timely.

Porcupine District (5, 6)

The rocks of the Hollinger mine in which chloritoid is conspicuously developed are folded, sheared Keewatin lava flows ranging from albite dacite to albite andesite in composition. Fine-grained portions of the flows are frequently pillowed. All have been somewhat altered, and a number of distinct types of alteration can be recognized. The regional rock alteration that accompanied folding was slight. There was, however, a fairly widespread hydrothermal type of alteration that preceded vein emplacement and the development of alteration haloes around vein zones. This early alteration, where operative, generally turned the lavas of intermediate composition into ankeritic and sericitic or chloritic rocks. It also turned intrusive quartz porphyries into sericitic rocks and turned intrusive basic rocks into talcose or serpentine rocks.

The veins of the Hollinger mine are hypothermal gold-quartz veins containing subordinate carbonate, albite, tourmaline, and other minerals. The productive veins have strongly pyritized, sericitized, and ankeritized walls.

Kalgoorlie District (7, 8)

The foregoing description of the Porcupine rocks and of their metamorphism and hydrothermal alteration serves almost equally well for their Kalgoorlie counterparts. About the only modification required is that the pre-Cambrian lava flows in which the chloritoid is best developed at Kalgoorlie are basalts rather than andesites, and that the Kalgoorlie rocks include a thick diorite sill infolded with the flows.

The Kalgoorlie ore deposits, however, differ markedly from the Porcupine ore deposits. The primary Kalgoorlie ores are gold-pyrite-telluride replacement lodes occupying shear zones. Mineralogically they are somewhat similar to the Kirkland Lake ores of Ontario. Although generally classed as hydrothermal, they have many mesothermal characteristics.

Chloritoid in Porcupine District

Chloritoid in Altered Lavas

In the eastern part of the Hollinger mine is an irregular pipe-like zone of extreme rock alteration. The zone is several hundred feet across and extends vertically downward for more than 4,000 feet. Within this zone the lava flows are strongly sericitized and ankeritized. Locally the rocks are flecked with small plates of chloritoid. Both pillow lavas and the coarser "greenstones" have been found to grade into the altered rock of this zone. Generally flow contacts can be traced through the zone with fair accuracy, and pillow outlines can often be recognized even where the

rock is thoroughly impregnated with ankerite, sericite, and chloritoid.

The microscope reveals a rock composed of 50% or more of ankerite. The remainder is chiefly a fine-grained crystallized quartz and sericite with subordinate chloritoid, chlorite, and occasionally a little pyrite.

The sericite appears in minute flakes scattered more or less randomly between ankerite and quartz grains or as wisps composed of parallel plates (up to 4 mm. in long diameter) which mark the schistosity. There is not the high degree of mineral parallelism suggestive of rock flowage that is found in true schists. Rather the textures suggest a later sericitization and ankeritization of a rock previously laminated by mechanical shearing.

Chloritoid occurs as small green plates (commonly 1 to 5 mm. across) which are readily detected in hand specimen. They are randomly oriented with regard to the rock cleavage. In thin section the plates appear to be rectangular with multiple twinning parallel to their length. The peculiar "hour-glass" pattern of the mineral is fairly common. The edges, especially the ends of the plates, are usually frayed, and the interiors of the plates are filled with inclusions of ankerite and occasionally quartz. These included grains are aligned in the plane of the rock cleavage, so that the schistose texture of the rock can be seen through the chloritoid grains. In several instances the mineral was concentrated about pyrite and tourmaline grains in intensely altered rock as if the mineral was recrystallized, if not introduced, at the time pyrite and tourmaline were formed. (Pyrite and tourmaline were clearly introduced by vein solutions.)

The following indices of refraction were obtained from one specimen: $\gamma = 1.724 \pm .003$, $\beta = 1.720 \pm .003$, $\alpha = 1.714 \pm .003$. These closely approximate the values for chloritoid. The other optical properties concur with those of either chloritoid or ottrelite.

Chloritoid in Quartz Veins

Some barren quartz-ankerite veins in the east end of the mine contain conspicuous quantities of chloritoid, only those veins, however, that occur within the previously described areas of chloritoid-bearing lavas.

The vein mineral chloritoid occurs in irregular patches several inches in diameter surrounded by quartz or as a narrow selvage separating quartz from wallrock. The patches probably represent replaced wallrock inclusions; the selvage may be the result of reaction between vein solutions and enclosing rock walls. Both patches and selvage consist of numerous rosettes of radiating chloritoid plates. Individual plates measure 2 mm. across.

The mineral possesses the following optical properties: optically (+); $\gamma = 1.723 \pm .003$, $\beta = 1.719 \pm .003$, $\alpha = 1.713 \pm .003$, $\gamma - \alpha = .010$; moder-

ately pleochroic, X = bluish green, Y = yellowish green, Z = greenish yellow; absorption X = Y > Z; 2V = 55°–65° (visually approximated); Z makes an angle of 11° ± with a normal to (001). The mineral has a highly perfect basal cleavage (001) and probably a poor prismatic cleavage.

Chloritoid in Kalgoorlie District

Chloritoid* is best developed in the altered pillow lavas of the "Older Greenstone" in the vicinity of Lake View Townsite on the east fringe of the "Golden Mile." Because of poor exposures, less is known about the shape and dimensions of this alteration zone than is known about the similar one at Porcupine. It is known, however, to be very local in its extent. Unoxidized rock from drill cores is indistinguishable to the naked eye from similar chloritoid-bearing rock from the Hollinger mine. The lava flows within the Kalgoorlie alteration zone have also been heavily impregnated with ankerite and sericite and flecked with chloritoid. I did not study the Kalgoorlie chloritoid rock microscopically. I do not doubt however, that the Porcupine rock and the Kalgoorlie rock are similar both as to composition and origin.

Conclusions

The occurrence of chloritoid as a vein mineral and as a product of hydrothermal alteration in lavas makes it necessary to revise the common impression that chloritoid is a stress mineral, that it is necessarily indicative of dynamic metamorphism, and that it forms only in altered sediments.

References

1. Dana, E. S., *Textbook of Mineralogy*, 4th Ed. (Ed. by W. E. Ford.) John Wiley and Sons, Inc., N. Y. **(1932).**
2. Harker, Alfred, *Metamorphism*. Menthurn & Co., Ltd., London **(1932).**
3. Grubenmann, V., and Niggli, P., *Die Gesteins Metamorphose*. Gebrüder Borntraeger, Berlin **(1924).**
4. Winchell, N. H., and Winchell, A. N., *Elements of Optical Mineralogy*, Part II, 2nd Ed., John Wiley & Sons, N. Y. **(1927).**
5. Graton, L. C., McKinstry, H. E., and others, Outstanding features of Hollinger geology: *Can. Inst. Min. and Met.* **(1933).**
6. Burrows, A. G., The Porcupine gold area: *Ont. Dept. Mines*, 33rd Ann. Rept., Vol. **23,** Part II (1924).
7. Gustafson, J. K., and Miller, F. S., Kalgoorlie geology re-interpreted: *Ec. Geol.*, **32,** 285–317 (1937), and *Aust. Inst. Min. & Met., Proc.*, New Series, **106** (1937).
8. Stillwell, F. L., Geology and ore deposits of the Boulder Belt, Kalgoorlie: *Geol. Surv. Western Australia, Bull.* **94** (1929).

* The mineral might be ottrelite. Stillwell (8) refers to it as chloritoid although on Finucane's map accompanying Stillwell's bulletin, the mineral is indicated as ottrelite.