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ZIRCON, A CONTACT METAMORPHIC MINERAL IN THE PEND OREILLE DISTRICT, IDAHO[1]

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INTRODUCTION

The purpose of this paper is to call attention to a rather widespread transfer of zirconium from some intrusive rocks into invaded sedimentary rocks in the Pend Oreille mining district, Idaho. This district, an area 15 by 20 miles, was recently studied by a party of the U. S. Geological Survey under Dr. Edward Sampson. The contact metamorphism was investigated in detail, and in the course of this work the prevalence of very minute zircon crystals in the most metamorphosed rocks turned the attention of the writer to a special study of this problem. Conclusions were reached only after a study of over a hundred thin sections and the examination of the heavy residues of more than thirty rock samples. In addition, Professor R. A. Daly of Harvard University very kindly loaned a number of thin sections of similar rocks from the Cana-

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dian boundary which were entirely unaffected by igneous metamorphism, and served as an interesting comparison with the rocks from the locality in northern Idaho.

The rocks affected by contact metamorphism contain very numerous microscopic zircon crystals which are shown to be of other than detrital origin. As the bulk of the rocks containing the mineral is great, the aggregate transfer of material was very considerable. Descriptions of typical occurrences of zircon in these rocks, are followed by a review of the literature on zircon in contact metamorphic zones, in some of which the zircon is definitely shown to be of pneumatolytic origin.

Occurrence in the Pend Oreille District

The sedimentary rocks of the district belong to the Belt series (Algonkian) and the Cambrian. Except for one calcareous member, the Belt rocks consist of a great thickness of thoroughly indurated sandstones and shales, and the Cambrian rocks consist of quartzite, shale and limestone. A very large batholith extends from the west side of the district westward for many miles, and three stocks, each from two to three miles across, outcrop within the area. These igneous bodies are so large and are so near to each other even at the surface that a widespread effect of igneous metamorphism would be expected in the invaded sedimentary rocks. In fact, no locality in the quadrangle was found where the sedimentary rocks did not show at least some microscopic evidence of igneous metamorphism.

Detrital zircon is commonly present in the non-calcareous rocks; but little or none is present in the calcareous rocks. For this reason the occurrences of zircon in the metamorphosed facies of these two classes of rocks is considered separately.

In Non-calcareous Rocks

To distinguish metamorphic from detrital zircon in the non-calcareous rocks it was necessary to establish the following criteria:

1. Size. The detrital zircon grains are of a size more or less in proportion to the size of the accompanying quartz grains. They are seldom less than .02 mm in diameter. A very few tiny grains less than .01 mm in diameter were noted as inclusions in detrital quartz grains.

The metamorphic zircon grains are commonly not as large as .02 mm and in many rocks very minute grains about .005 mm in diameter are very abundant. In many specimens examined both detrital and metamorphic grains are present indicating that the latter are not formed by recrystallization of the former.

2. Relative Abundance. As the detrital grains are relatively large they are easily collected by separation in heavy solutions. The quantity of detrital zircon grains separated in this way does not exceed a maximum of about 0.2 per cent by weight of the whole sample, either in the rocks of the Pend Oreille district or in those from near the Canadian boundary. This percentage is equivalent to 20 to 25 grains in the average thin section.

The metamorphic zircon grains are usually so minute that it is impossible to separate them by heavy liquids. The comparison of relative abundance, except in one or two instances, is, therefore, made on the number present in the thin sections. For example, two or three hundred of the tiny grains occur in each thin section of the metamorphosed quartzite found at the mouth of Falls Creek on the east side of Pend Oreille lake, a large body of water extending nearly the whole length of the area. The grains are so numerous that frequently twenty-five are visible in the field of the microscope with moderate magnification at one time. Similarly metamorphosed quartzite on the north slope of South Chilco mountain where the rock was invaded by a quartz monzonite exhibits a like abundance of the minute grains of zircon.

Further proof of the addition of zirconium is afforded by the zirconia determinations in two pairs of analyses of siliceous sediments made by Mr. J. G. Fairchild in the laboratory of the U. S. Geological Survey. The first pair are of specimens of quartzite of the Blacktail[2] formation on the north side of Chilco Mountain and the second pair are of an argillite of the Prichard formation in Kilroy Bay. According to these the quartzite of the Blacktail formation at the igneous contact contains 0.05 per cent ZrO_2 whereas the same rock 250 yards from the contact contains only 0.03 per cent. The argillite of the Prichard formation at the igneous contact contains 0.07 per cent ZrO_2 whereas the rock one half mile from the contact contains only 0.03 per cent. Mr. Fairchild stated that his accuracy on the zirconium analysis was approximately .005 per cent.

[2] A new formation name in the Pend Oreille district. The Blacktail is equivalent to the St. Regis and Revett formation of the Coeur d'Alene district, as will be set forth in the report of the U. S. G. S. on the Pend Oreille district now in preparation by Edward Sampson and J. L. Gillson.

3. Luster. The luster of the zircon grains as suggested by Trueman[3] aided in determining the origin of the zircon in some rocks. The detrital zircon is usually lusterless while the metamorphic crystals are very brilliant.

4. Position in Enlarged Quartz Grains. The position of the tiny zircon grains in those beds of the metamorphosed Blacktail quartzite that show pronounced quartz enlargements was an important criteria. If the tiny zircon crystals were confined to the portions of the quartz grains inside of the original rim they might be considered as inclusions in detrital quartz. If they were confined to the interstitial areas between the rims of the original rounded quartz grains, they might be considered as detrital zircon grains deposited contemporaneous with and interstitially between the quartz grains. A number of instances were noted where the grains lie across or in the original rim of a quartz grain and the zircon grains are as common inside of the old rims as in the interstitial areas. This distribution favors the view of a metasomatic origin of the zircon grains.

5. Association with a Pneumatolytic Mineral, Tourmaline. Metamorphic zircon is commonly associated with tourmaline Although detrital tourmaline was recognized in some of the thin sections of rocks from near the Canadian Boundary, the tourmaline in the sedimentary rocks in the Pend Oreille district occurs as subhedral crystals which very sharply crosscut the detrital grains and must be of metasomatic origin. Wherever a considerable quantity of tourmaline was found, the tiny zircons were invariably present, whereas in moderately metamorphosed rocks in which tourmaline was absent the few zircon grains present are all relatively large, and were probably of detrital origin.

In Calcareous Rocks

The calcareous formations were found to contain zircon only when metamorphosed. Six samples of the nearly unmetamorphosed calcareous rocks of the Wallace formation from different parts of the district were ground, and the powder treated with heavy liquids. Not a single grain of zircon was collected in the heavy residues. In the Cambrian limestone no zircon was found in pure carbonate beds, and only one or two grains of doubtful zircon was recovered from a shaly bed at Port Rock.

[3] Trueman, J. D., The origin of foliated crystalline rocks: *J. Geology*, **20**, 255-6, (1912).

The Wallace formation is not everywhere calcareous. In selecting samples of the metamorphosed rocks of the formation for examination, specimens were selected which contained such minerals as were known to form in the particular district only by the metamorphism of calcareous rocks. The Wallace formation on the west side of Bernard Peak contains an amphibole never found in the metamorphosed non-calcareous sediments of the Pend Oreille district. In the thin sections of this rock very minute grains of very high index and strong birefringence, principally zircon and titanite, are abundant, and those of zircon are readily distinguished with the highest magnification. A few grains are as large as .01 mm, but grains as small as .005 mm are very common. Identical observations were made on calcareous Wallace rocks from the west shore of Pend Oreille lake below the three conspicuous hills known as the "Three Sisters." In three thin sections the minute zircon crystals are very numerous, at least three hundred being present in each section.

In the Cambrian limestone the abundance of metamorphic zircon is as striking. In a rock from the lake shore south of the mouth of South Gold Creek the zircon grains are large enough to concentrate with heavy liquids. A two gram sample was ground and immersed in a liquid of sufficient density to float the diopside and scapolite. Subhedral crystals of zircon formed 20 per cent of the heavy concentrate, or 0.5 per cent of the rock.

In each of several thin sections of very strongly metamorphosed limestone beds from Vulcan Hill, east of Lakeview, there are more than 100 grains approximately .005 mm in diameter.

This evidence from the calcareous rocks, more striking than that in the non-calcareous rocks, leaves no room for doubt that zircon is a contact-metamorphic mineral. The sequence of the mineralization under the contact metamorphic conditions in the sedimentary rocks of the Pend Oreille district indicates that the zircon belongs to a second[4] or pneumatolytic stage in the metamorphism and formed contemporaneously with tourmaline, biotite, andalusite, cordierite, vesuvanite, garnet, diopside, apatite, etc. Unlike these minerals the zircon is of unrestricted occurrence and is found in both the calcareous and non-calcareous rocks.

[4] A manuscript describing the contact metamorphism in the Pend Oreille area has been prepared, and will appear as a chapter in the bulletin to be published by the U. S. Geological Survey.

Other Occurrences of Zircon in Contact Metamorphic Zones

Although zircon is not commonly referred to as a metamorphic mineral, the following review will show that this mode of occurrence is widespread.

In the nearby Coeur d'Alene district, Idaho, zircon is also very abundant in the sedimentary rocks which are almost directly correlated with the pre-Cambrian formations of the Pend Oreille district. Calkins[5] suspected that some of the zircon might be of contact origin, although he thought that the mineral was probably for the most part clastic.[6]

Zircon has been found as a contact mineral by a number of observers. Thürach[7] held the opinion that zircon could form from watery solutions and cited the example of zircon crystals in druses in the chlorite schist of Tyrol. In the crystalline limestone of Grenville, Ont., Hoffman[8] found large crystals of zircon with well developed faces, probably formed by contact metamorphism. Trueman[9] believed in the contact origin of zircon, citing the enlarged grains of zircon in a quartzite cut by granite at Rib Hill, Wausau, Wisconsin. Trueman,[10] however, stated that he did not know of a case where microscopic zircons developed in small grains throughout a contact rock.

Clarke[11] in describing the synthesis carried out by Deveille considers as possible the pneumatolytic origin of zircon and says further[12] that zircon occurs, though not commonly, in contact limestones.

Watson and Hess[13] state that zircon forms occasionally as a

[5] Calkins, F. C., informal communication.

[6] Ransome, F. L. and Calkins, F. C., The geology and ore deposits of the Coeur d'Alene district, Idaho: *U.S. Geological Survey, Prof. Paper* **62**, pp. 32 et seq. (1908).

[7] Thürach, H., Über das Vorkommen Mikroscopischer Zirkone und Titan-Mineralien in den Gesteinen: *Verhandl. Phys. Med. Gesell. Wurzburg,* **XVIII,** No. 10, (1884).

[8] Hoffman, G. I., Geol. and Nat. Hist. Survey of Canada, **IV**, p. 66T., 1888-9.

[9] Trueman, J. D., The origin of foliated crystalline rocks: *J. Geology,* **20,** p. 249, (1912).

[10] Trueman, J. D., *Op. cit.* p. 306.

[11] Clarke, F. W., Data of geochemistry: *U. S. Geol. Survey Bull.* **695,** p. 349, (1920).

[12] *Idem.*, p. 718.

[13] Watson, T. L. and Hess, F. L., Zirconiferous sandstone near Ashland, Va. with a summary of the properties, occurrence and uses of zircon in general: *Univ. of Virginia Pub., Bull. Phil. Soc., Sci. Ser.*, Vol. **1,** No. 11, pp. 283-8, (1912).

product of contact metamorphism and they list several places where it was probably formed by pneumatolytic agencies and give as further evidence for an origin by igneous emanations the common association of zircon with magnetite ores.

The zirkite deposits of Brazil contain zircon, and although not well understood, are described by Meyer[14] as probably of pneumatolytic origin.

Zircon has been found as a contact mineral by other observers. Dana[15] states that it occurs in crystalline rocks, especially granular limestones. One of the localities given is the southern base of Mount Eve, near Warwick, N. Y. Beck[16] stated that at this place the zircon was associated with scapolite in the limestone. Kemp and Hollick,[17] who studied the intrusive granite of Mount Eve, did not find any zircon in place, and were not certain whether the scapolite replaced igneous rock or limestone. The crystals described by Beck, however, are very unlike usual magmatic zircon crystals and may, therefore, be tentatively regarded as products of contact metamorphism.

Goldschmidt[18] found zircon as a contact mineral in certain rocks in the Christiana basin. He states that in the endomorphosed contact zones of eruptive rocks the number of zircon crystals was increased. The zircon crystals ranged up to 5 mm in length. In other rocks of the endomorphic zone tiny crystals of zircon were found in druses. In the hornfels of the exomorphic zone the zircon occurs in biotite and the grains are made conspicuous by pleochroic halos. He is not sure, however, that these zircons in the sedimentary rocks are of contact origin.

Tilley,[19] in describing the metamorphism of the Comrie area in England states that in the hornfelses, zircon has a uniform distri-

[14] Meyer, H. C., Brazilian zirkite deposits: Monthly prices for November, Foote Mineral Co., pp. 29-31, 1916. Quoted by Schaller, Waldemar, Zirconium and rare earth minerals: *U. S. Geol. Survey, Mineral Resources*, **1916**, Part II, pp. 378-9, **1919**.

[15] Dana, E. S., The system of mineralogy, 6th Ed., p. 485, (**1914**.).

[16] Beck, L. C., Mineralogy of New York, p. 380, (**1843**).

[17] Kemp, J. F. and Hollick, Arthur, The granite at Mounts Adam and Eve, Warwick, Orange County, New York, and its contact phenomena: *Annals New York Acad. Sci.*, **VII,** pp. 638-654, (1893).

[18] Goldschmidt, V. M., Die Kontaktmetamorphose im Kristianiagebiet: *Videnskapsselskapets Skrifter, I, Mat. naturv. Klasse,* No. 11, pp. 280-1, (**1911**).

[19] Tilley, C. E., Contact metamorphism in the Comrie area: *Quart. Jour. Geol. Soc. London*, **80,** p. 57, (1924).

bution, and is the more readily recognized when it is enclosed in biotite or cordierite, so as to give the characteristic pleochroic halos. He does not, however, discuss its pneumatolytic origin and it may be simply of residual detrital origin.

Zircon occurs in the phlogopite deposits at Renfrew, Ontario, which De Schmidt[20] thinks are contact metamorphosed limestones. Eckermann,[21] gives zircon as a contact mineral, stating that it occurs in the limestone in the neighborhood of the igneous contact, and that it was derived by pneumatolytic transport of material from the igneous source. In the limestone surrounding the essexite of Mount Royal, at Montreal, Dolan[22] found zircon to be one of the minerals resulting from the effects of pneumatolytic contact metamorphism.

These descriptions prove that zircon is known in many contact zones, in some if not all of which it has been formed under pneumatolytic or hydrothermal conditions.

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[20] De Schmidt, H. S., Mica, its occurrence, exploitation and uses: *Canada Dept. Mines, Mines Branch*, No. **118,** p. 277 (1912).

[21] Eckermann, Harry von, The rocks and contact minerals of the Mansjö Mountain: *Gecl. Fören. Förh.*, p. 343, (**1922**).

[22] Dolan, E. P., The contact metamorphic zone of Mount Royal, Montreal, P. Q.: *Trans. Royal Soc. Canada*, 3rd ser. vol. **17,** section IV, p. 131, (1923).

JAMESONITE FROM SLATE CREEK, CUSTER COUNTY, IDAHO[1]

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There has long been a tendency among geologists and, to a less extent, among mineralogists to refer to the mineral jamesonite all of the so-called "needle-ore" or "feather-ore" minerals of fibrous structure which are found by qualitative tests to be lead sulphantimonites. The name jamesonite has thus had a sort of "natural history" significance which it has in no wise earned. This has been

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