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BIAXIAL CALCITE

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Walker and Parsons[1] have called attention to the anomalous properties shown by some calcites probably formed at high temperatures, and they have ascribed these properties to the molecular rearrangement which would take place at the inversion from alpha calcite at 970°. Among these anomalous properties described by them is a biaxial character, and a value of 15° for 2 E. Moreover the calcite does not exhibit complete extinction, possibly, they thought, due to some molecular disturbance.

In examining some marbles and calcareous schists the writer and several of his students have found examples of calcite, and of dolomite, showing the biaxial character. The marbles in which such grains were found are coarsely crystalline rocks from contact metamorphic zones. The other rocks also show evidence of intense soaking by hot solutions. After some experience it has become a simple manner to select in a thin section those grains in an aggregate which will show the biaxial figure. These grains do not become entirely extinct on rotation of the stage, but rather take on a mottled blue appearance in the extinction position. In working with grains mounted in viscous Canada balsam, such grains when turned into the proper position, give the biaxial figure.

There is no possibility that the grains giving the biaxial figure are grains of aragonite mixed with the calcite. The grains possess the rhombohedral cleavage and twinning of the members of the calcite group, and moreover the size of the optic angle varies among the grains in a single specimen. Furthermore, it is very improbable that aragonite would be found in a pre-Cambrian or early Paleozoic rock.

[1] Walker, T. L. and Parsons, A. L.; The characteristics of primary calcite: *Univ. Toronto Studies, Geol. Ser.*, No. **20**, Contributions to Canadian Mineralogy, 1925, pp. 14–17.

The examples listed below were found in the Technology collection. They will show that this feature is not limited to any geological horizon, nor any geographical location.

Contact metamorphosed limestone from the Shamrock Mine, Garnet, Montana. Specimen collected by W. O. Crosby from near the contact with the granite. Maximum optic angle noted, 2V=13°.

Grenville limestone,[2] from Cascade Lake, Mount Marcy quadrangle, Essex County, New York. Maximum angle noted, 2V=about 5°.

The Number Two Paleozoic limestone,[3] above the orebody, magnetite iron mine of Bethlehem Steel Company, Cornwall, Pa. Maximum angle noted, 2V=5.8°.

Cambrian limestone,[4] from the vicinity of the abandoned iron mines, north of Manhattan Gap, Highland quadrangle, Lincoln County, Nevada. Maximum angle noted, 2V=11.3°. An adjacent grain to this one gave a reading of 4.5°.

Dolomite zone in same area as previous sample. Maximum angle noted, 2V=8.7°. Another grain in the same thin section gave 4.5°.

Cambrian limestone bed in Cambrian shale, near contact with quartz monzonite, in the central part of the same quadrangle as last samples. Maximum angle noted, 2V=4.0°.

Cambrian limestone[5] from east shore of Pend Oreille Lake, south of South Gold Creek, Bonner County, Idaho. Maximum angle noted, 2V=10.0°.

Grenville limestone,[6] Tilly Foster Iron Mine, Putnam County, New York. Maximum angle noted, 2V=14.0°. A doubtful reading of 20° was made.

Quartz-biotite-epidote-calcite schist[7] from the west dump of No. 3 tunnel driven in the building of the Weston, Mass., aqueduct. Maximum angle noted about 5°.

Calcite in Iron Ore of the Andover Iron Mine, Andover, N. J.[8] Maximum angle noted about 5°.

[2] Described by Lary, H. N.; Some phases of contact metamorphism in the southeastern Adirondacks. (Thesis presented to the faculty of the Mass. Inst. Technology in partial fulfillment of the requirements of the degree of Master of Science, 1927.)

[3] Described by Callahan, W. H.; The magnetite deposit at Cornwall, Pa. (Thesis presented to the faculty of the Mass. Inst. Technology in partial fulfillment of the requirements of the degree of Master of Science, 1927.)

[4] Gillson, J. L.; Contact metamorphism near Pioche, Nevada. In preparation.

[5] Samson, Edward and Gillson, J. L.; The geology and ore deposits of the Pend Oreille Mining District of northern Idaho. To be published as a bulletin of the U. S. Geological Survey.

[6] Colony, R. J.; Magnetite iron deposits of southeastern New York. *New York State Mus. Bull.* **249–250**, pp. 121–124 (1923).

[7] Warren, C. H.; Petrographical notes on the rocks of the Weston aqueduct, Mass. *Technology Quarterly*, **17**, pp. 117–123 (1904).

[8] Rexford, E. P.; The mineralization of the Andover and Sulphur Hill Mines near Andover, N. J. (Thesis presented to the faculty of the Mass. Inst. Technology in partial fulfillment of the requirements of the degree of Master of Science, 1927.)

Calcite replacement in quartzite of the Coos group, near Chandler Mills, N. H. The rock there was apparently metamorphosed by the Concord, N. H., granite.

Some of the biaxial figures obtained are so clear and sharp that there can be absolutely no doubt of the anomalous optical character of the grains. Moreover, all such grains show the incomplete extinction mentioned by Walker and Parsons.

A discussion of the probable transition from beta calcite (the low temperature modification) to the higher alpha form is given by Grubenmann and Niggli.[9] The quadruple point is only established thermally, but is given by them as 970° and 40 atmospheres pressure. From the quadruple point the boundary curve between the two solid modifications rises nearly perpendicularly, since in a condensed system the pressure has but little influence. These authors further state that the transition from the alpha to the beta form is unrecognizable in the end products, although they imply the importance of such recognition were it possible. This importance has been stressed by Walker and Parsons, and in fact it can not be overestimated. If by the recognition of optical anomalies in a contact limestone, a temperature as high as 970° can be established, the intrusive temperature of the igneous body must have been well above 1,000°. Grubenmann and Niggli[10] state that even near the contact a difference in temperature between wall rock and intrusive of 300° is probable in many cases.

Smyth and Adams[11] have lately shown, however, that no high temperature modification of calcite exists. Thus the anomalous properties of calcite can not be connected with the supposed inversion at 970°. From this proof there is no need for alarm that an intrusive temperature as high as 1,000° or higher is indicated by all contact metamorphosed limestones showing biaxial calcite.

If the anomalous properties are not due to an inversion, to what are they do? Some experiments recently undertaken in this laboratory would indicate that the anomalously biaxial character of the rhombohedral carbonates above described may be due to deformation disturbances. Mr. M. J. Buerger of this laboratory has been experimentally able to produce biaxial calcite by sec-

[9] Grubenmann, U. and Niggli, P.; Die Gesteinsmetamorphose, Bd. **I**, pp. 121–122, *Berlin* (1924).

[10] *Idem*, p. 251.

[11] Smyth, F. H., and Adams, L. H.; The system, calcium oxide-carbon dioxide. *Jour. Am. Chem. Soc.*, **XLV**, pp. 1182–1184 (1923).

ondary twinning on $(01\bar{1}2)$. Microscopically homogeneous fragments of the twins mounted in viscous Canada balsam gave the optical anomalies similar to those observed on the natural material. The artificially twinned portion of one specimen of calcite gave a value for 2V of about 30°. A twin produced from another piece of calcite gave 2V of about 5°, with an extreme dispersion $\rho > \nu$. The dispersion was so strong that three sets of isogyres were observed; orange, red and blue, from the acute bisectrix outward. In all cases the fragments showed incomplete extinction with anomalous colors near the extinction positions.

A more complete discussion of the experimental work will be published by Mr. Buerger in the near future.

A biaxial character in quartz as a result of strain caused by differential stresses has been described[12] as have other deformation structures in quartz.[13]

Although a biaxial character was found on artificially twinned calcite grains, many naturally twinned grains do not show it. A section of the Grenville limestone from a locality on the east shore of the Hudson River near the south end of the North Creek quadrangle in the Adirondacks contains calcite so mashed that its gliding planes are curved. The grains are not biaxial. The grains from the contact metamorphosed limestones that do show a biaxial character usually exhibit little or no other visible evidence of strain.

It is hoped that further experimentation will fully explain the cause of the biaxial character of the members of the calcite group.

STELLERITE FROM NEAR JUNEAU, ALASKA

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In the spring of 1925 while at Juneau, Alaska, the writer collected in the upper part of the Granite Creek basin, several miles west of the town, several crystals forming an incrustation on the rock surface. These crystals were later determined as stellerite, and as the literature on this mineral is rather meager the occurrence was considered worthy of description.

[12] Grubenmann, U. and Niggli, P., Der Gesteinsmetamorphose, Bd. I, p. 220 (1924).

[13] Holmquist, P. J.; Deformationsstrukturen der Gesteinsquarze. *Geol. För. Förh.*, Bd. 48, pp. 410–428 (1926).