Reprinted from *SHOCK METAMORPHISM OF NATURAL MATERIALS*

(Bevan M. French and Nicholas M. Short, Editors)

MONO BOOK CORP., 6747 Whitestone Road, Baltimore, Maryland 21207

Printed in the United States of America

IMPACT METAMORPHISM AT CLEARWATER LAKE, QUEBEC[1]

DONALD B. McINTYRE

Geology Department, Seaver Laboratory, Pomona College, Claremont, California

In 1958, the Dominion Observatory of Canada made an extensive gravity survey east of Hudson Bay. Unusual metamorphic rocks were collected at stations on islands in Clearwater Lake (74° 30′ W; 56° 10′ N). The lake consists of two circular bodies of water, 30 km and 20 km in diameter. The smaller is over 450 feet deep and is probably floored by arkose and Paleozoic limestone. The larger contains a ring of islands with topographic indication of gentle dip towards the center where recrystallized diorite is exposed. The crudely layered rocks are probably megabreccias and are interpreted as resulting from a meteorite impact. Locally there are abundant boulders of fossiliferous Paleozoic limestone (submitted to the Geological Survey of Canada). No evidence of volcanic activity was observed.

The predominant rock is hematite-stained breccia, with a glassy vesicular matrix, containing fragments of altered granite. Feldspars are recrystallized in sheaf-like aggregates, amphibole and biotite are converted to pyroxene, and quartz is granular. Quartz paramorphs after tridymite are conspicuous. Shattered granite passes into micro-breccias with numerous deformation lamellae in the quartz. Veins of vesicular glass, with feathery feldspars, traverse the breccia. Recrystallization of feldspar separating the quartz crystals may have prevented the formation of coesite.

During the summer of 1958, while a field party from the Gravity Division of the Dominion Observatory of Canada was occupying stations in the Clearwater Lake area, I had a brief opportunity to examine the surrounding country rocks and to collect some specimens from the islands in the western lake. Although Dr. C. S. Beals, who joined us at Clearwater Lake, had suggested that the feature might be a meteorite crater, my impression in the field was that I had collected from a suite of andesitic volcanic rocks with unusually abundant xenoliths derived from the granitic basement. But subsequent petrographic study showed that no normal volcanic rocks had been collected, and that the specimens were quite unlike any rocks that I knew to have previously been described.

Some rocks are granitic microbreccias in which the stages of progressive brecciation *in situ* are strikingly displayed, and in which the angular quartz fragments show an extraordinary richness of various planar deformation features. Some of the microbreccias are intimately veined with glass that carries prolific microlites of feldspar. Other rocks, which appeared in hand specimen to be slightly weathered granite, were seen under the microscope to be completely reconstituted while preserving the general shape of the original minerals; the quartz has been converted to polycrystalline mosaics and the feldspar to sheaf-like aggregates and feathery masses. As a result of these observations, I adopted the hypothesis of impact metamorphism and presented the evidence in 1961

[1]*Editor's Note*: Prof. McIntyre was prevented at the last moment from attending the Conference and presenting his scheduled paper. However, because his work involves the first recognition and description of some spectacular shock metamorphic features (McIntyre, 1962) from a large structure which has been the subject of considerable subsequent study, we invited him to submit a short note and a group of selected photomicrographs for inclusion in the Proceedings Volume. We are very grateful to Prof. McIntyre for having taken the trouble to supply a set of excellent photomicrographs and the accompanying text.

Fig. 1. Margin of a clast of hornblende quartz-diorite in microbreccia. Hornblende grain near bottom right. A large quartz crystal is seen in the process of breaking into angular fragments. The fractures, which have opened and filled with shards of quartz and feldspar, are in this case approximately parallel to the *c*-axis. Crossed polarizers. Long dimension of field is 6.3 mm.

at the 1st Western National Meeting of the American Geophysical Union (Tectonophysics), in Los Angeles. The abstract printed above was published at that time (McIntyre, 1962).

In 1961 I learned that field parties of the Geological Survey of Canada had studied the Clearwater Lake area and had concluded the origin of the feature to be volcanic. Many geologists have

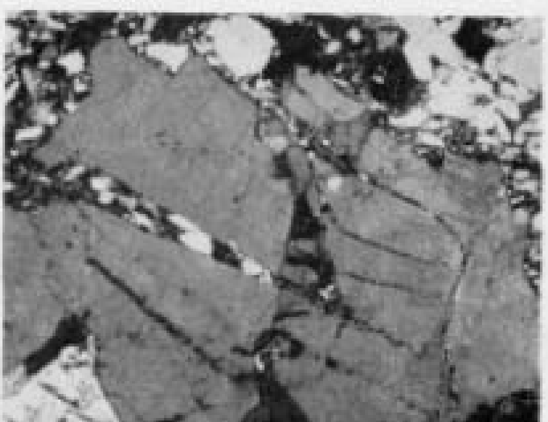

Fig. 2. Detail from part of the same field as shown in Figure 1. The microbreccia seems to have formed nearly *in situ*. Pieces of a single crystal of quartz have rotated away from one another and, becoming detached, were incorporated into the matrix. Crossed polarizers. Long dimension of field is 2.7 mm.

Fig. 3.

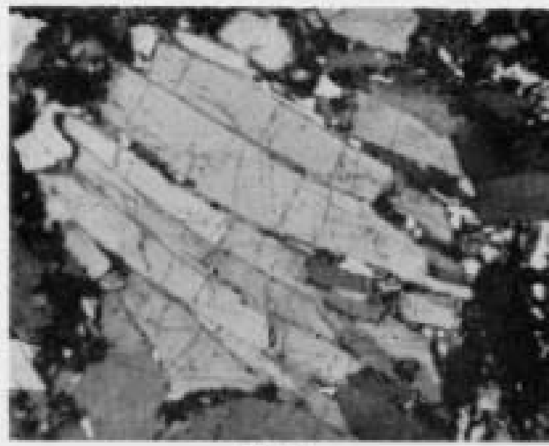

Fig. 4.

Fig. 5.

Figs. 3, 4, and 5. Three stages in the progressive disintegration of quartz crystals in granite into increasingly more separated fragments. Crossed polarizers: Long dimensions of fields are 3.2, 1.9, and 3.8 mm, respectively.

Fig. 6. Clastic quartz with development of planar features showing the appearance of kink banding, as described by Carter (1965). There is no change in optical orientation in the crystal. Plane polarized light. Long dimension of field is 1.3 mm.

Fig. 8. The polycrystalline quartz mosaics in this specimen (light areas) appear to be relics of large quartz crystals from the original granite. Feldspar is completely reconstituted into fine fibrous aggregates and occasionally into nests of more distinct crystals. The dark material seems to be hematite-stained glass. Plane polarized light. Long dimension of field is 6.1 mm.

Fig. 7. In hand specimen, this rock appears to be a slightly decomposed granite, but it is completely reconstituted. The ovoid cloudy areas shown here are quartz, which under crossed polarizers is seen to be recrystallized into a polycrystalline mosaic. The feldspars are partly aggregates of fine fibers and sheaf-like bundles, and partly recrystallized into decussate masses of distinct individuals. The patterns of distortion within the original feldspar crystals are clearly visible where the new microlites are small, but are lost when the new crystals grow larger. The feldspars evidently flowed around and between the quartz areas, which seem to have preserved their unity. This field, under crossed polarizers, is illustrated in N. M. Short (1966, Fig. 11; the magnification given there should be 18×). Plane polarized light. Long dimension of the field is 4.9 mm.

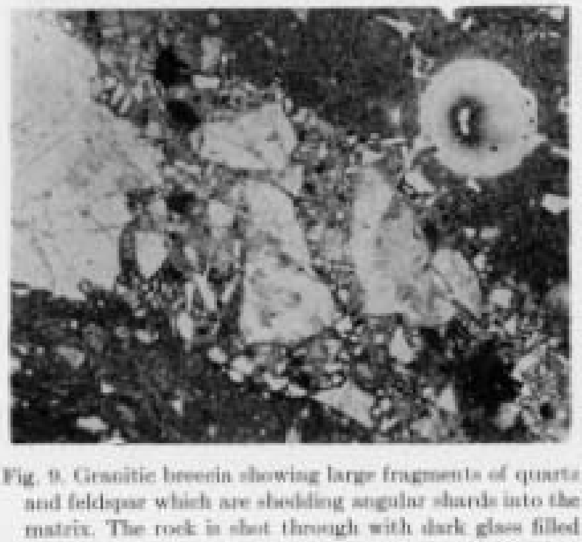

Fig. 9. Granitic breccia showing large fragments of quartz and feldspar which are shedding angular shards into the matrix. The rock is shot through with dark glass filled with feldspar microlites. The large circular feature is a vesicle in the glass. (The small black circles are air bubbles in the mount.) Plane polarized light. Long dimension of field is 5.7 mm.

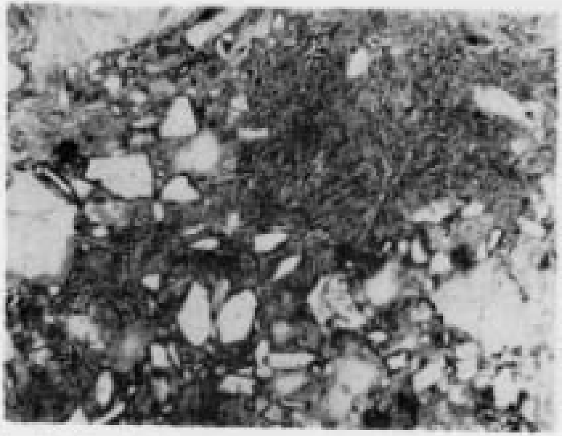

Fig. 10. Detail of the intimate relationship between microbreccia and the glass with microlites in the specimen shown in Figure 9. Many of the fragments have alteration rims and appear to have been partially fused. New microlites sprout in optical continuity from some of the feldspar shards. Plane polarized light. Long dimension of field is 2.0 mm.

Fig. 12. Margin of a granitic clast (upper) against the glassy matrix. The quartz forms a polycrystalline mosaic while the feldspar has recrystallized into stellate and sheaf-like bundles. Plane polarized light. Long dimension of field is 1.1 mm.

Fig. 11. Detail of part of an old feldspar crystal, showing regeneration of new feldspar crystals within it and sprouting of skeletal microlites from its surface into the surrounding glass, in the specimen shown in Figure 9. Plane polarized light. Long dimension of field is 0.33 mm.

now visited Clearwater Lake for much longer periods of time than I did in 1958, and there exist collections that doubtless are more extensive and representative than mine. But I welcome the invitation to publish some of the photomicrographs that show the evidence which impressed me with the case for impact metamorphism at Clearwater Lake.

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