ON THE COLOUR OF BLACK AND GREY QUARTZ FROM YELLOWKNIFE, NORTHWEST TERRITORIES, CANADA[1]

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Abstract

Heating tests, chemical tests, and x-ray analysis have shown that the colour of black and grey quartz, occurring in veins and lenses in the greenstones and sediments of the Yellowknife gold belt, is primarily due to disseminated carbon and graphite. Finely divided sulphides or other dark minerals may be responsible for a partial darkening of the quartz, but these impurities are secondary in effect to those of carbon or graphite.

Introduction

The colour of quartz has engaged the attention of many investigators, and satisfactory hypotheses have been given for the cause of the colouring in amethyst, rose, and smoky varieties. Some work has been done on the nature of the colouring medium of black and grey quartz, but in general the hypotheses advanced have received little rigorous investigation.

The research work outlined in this paper completes one portion of a general investigation of the colour of quartz from Yellowknife and other Canadian localities. The work described here was started in the Geochemical Laboratory at the University of Toronto under the supervision of Professor F. G. Smith, and completed in the laboratories of the Geological Survey of Canada.

Geological Occurrence and Description of the Black and Grey Quartz

The gold quartz veins of the Yellowknife region occur in folded and faulted greenstones and sediments of Archaean age. Two periods of faulting are clearly represented in the greenstones of the region. The first period produced an extensive series of shear zones which contain the economic gold quartz veins and lenses; the second is represented by narrow breccia faults containing a few quartz lenses which have no economic interest. In the highly folded sediments quartz veins and lenses occur in small faults, along broken axial planes of isoclinal folds, in drag folds, and along bedding planes. Narrow breccia faults belonging to the same age and structural pattern as those noted above in the greenstones are widespread. For a more detailed account of the geology of the area the

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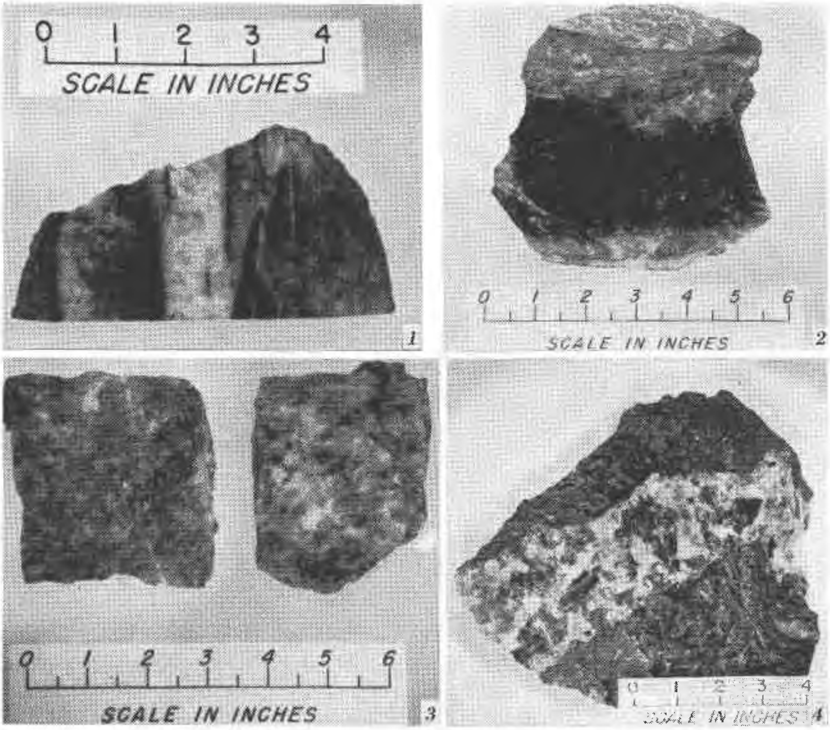

FIG. 1. Black quartz cut by veinlets of white quartz. Rycon mine Yellowknife, N.W.T.

FIG. 2. Black quartz occuping the central portion of a quartz vein. Specimen shown was taken across width of quartz vein. Negus mine, Yellowknife, N.W.T.

FIG. 3. Mottled quartz. Rycon Mine, Yellowknife, N.W.T.

FIG. 4. Black calcite enclosed in white quartz with adjacent walls of chlorite-sericite schist. Giant mine, Yellowknife, N.W.T.

reader is referred to the published accounts of Henderson and Brown (1950), and Jolliffe (1938).

In the greenstones the early shear zones contain two main types of quartz, an early, grey to black variety and a later, white to light flesh-coloured variety. Locally, the two types contain pyrite, arsenopyrite, stibnite, boulangerite, jamesonite, several other sulphosalts, and gold.

Black quartz is characteristic of a set of parallel shear zones on the properties of the Negus and Rycon gold mines, but has been noted in many other localities, especially in some of the underground workings of the Giant mine. It occurs in narrow lenses and veins within the shear zones and appears to have formed both by open space filling and replacement.

In the veins and lenses the black quartz is distinctly early and is cut by the later generation of white quartz (Fig. 1). In some lenses black quartz or grey quartz is adjacent to the vein walls with the white variety occupying a medial position; in other veins the reverse may be true (Fig. 2). Many veins and lenses contain a mottled variety which consists of small nuclei of black quartz in a matrix of white quartz (Fig. 3). Mottled varieties grade by degrees into dark grey to light grey varieties. In general, a wall rock alteration accompanies the black, grey, and mottled varieties of quartz. The minerals present in the altered zone are ankerite, chlorite, sericite, arsenopyrite, and pyrite. Locally, grey to black ankerite, calcite, and dolomite (Fig. 4) occur in association with the black and grey quartz. The age relationship of this carbonate is difficult to determine since many ages are usually present. In some cases the carbonate is early, and probably originated in part by a recrystallization of the carbonate formed in the wall-rock alteration zones; in other cases the black carbonate fills vugs containing euhedral quartz crystals.

In hand specimens the black quartz may grade to grey quartz in a single specimen. Other specimens are common in which the quartz is a dense coal black colour that, in appearance, resembles anthracite coal. In many veins and lenses the black and grey quartz has undergone severe crushing and brecciation and subsequent healing by white calcite.

Thin sections of the black quartz reveal a groundmass of medium-grained quartz intersected and surrounded by a ramifying system of veinlets and patches of fine-grained quartz. Inclusions and strain extinctions are notable in the medium-grained quartz, whereas, the fine-grained variety is usually clear and possesses sharp extinction. The black colouring material lies along an intersecting gridwork of pronounced inclusion planes that are restricted to the medium-grained quartz. These inclusion planes appear to be secondary features that may have formed after the consolidation of the quartz, but another origin is possible since these planes of colouring matter may be residuals after replacement of the black carbonate described below.

Thick sections studied under the binocular microscope give a better idea of the nature of the colouring material. In these sections the colouring material is seen to lie along a network of wavy planes that intersect the medium-grained quartz at many angles and are terminated against the clear veinlets and patches of fine-grained quartz. The density of the colour is dependent upon the quantity of these intersecting planes.

The black ankerite, calcite, and dolomite are found locally in many of the shear zones of the region. In some localities the carbonate exhibits good euhedral crystals which have a marked depositional banding due to the alternation of colourless or white bands with grey or black bands. The majority of the carbonate is, however, intersected by a mesh of

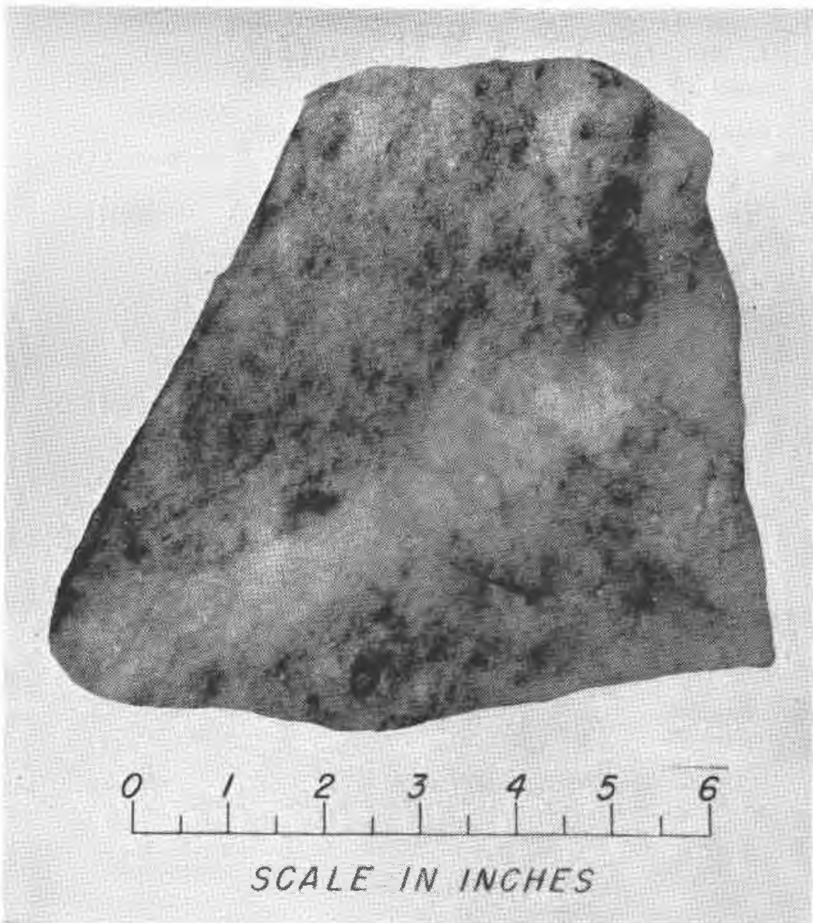

Fig. 5. Early grey quartz cut by later white quartz. Ptarmigan mine, Yellowknife, N.W.T.

dark grey or black seams and planes of colouring material. Again, the density of the black colouring is dependent on the quantity of the seams and planes. As noted above, this carbonate is apparently replaced by both grey and black quartz, but in some localities white quartz appears to replace the carbonate.

The veins and lenses in the sediments exhibit two distinct ages of quartz. The first age is a grey quartz, and the second cutting age is a white quartz (Fig. 5).

In hand specimens the quartz is relatively pure and contains only minor quantities of pyrite, sphalerite, and galena. In thin sections the grey quartz exhibits a ground mass of medium sized grains cut by ramifying areas of small quartz grains. The medium sized grains of the grey quartz contain innumerable microscopic black ovoid specks which show no preferred orientation or location.

Identification of the Colouring Matter

It was thought at first that the black and grey colour was due to electronic darkening produced by radioactivity similar to that suggested by Holden (1925) and others as the cause of the colour of smoky quartz. To test this hypothesis specimens of black and grey quartz were heated with a specimen of smoky quartz made available by Dr. F. G. Smith. The tests were conducted in a small electric furnace, and the temperatures were recorded by a thermocouple. The results of this experiment are given in Table 1.

Table 1. Heating Test on Black and Smoky Quartz

Temperature ° C.	Colour of Smoky Quartz	Colour of Black & Grey Quartz
100	Dark brown to smoky brown	Black, grey
200	No change	No change, grey
300	Slight bleaching	No change, grey
350	Almost completely bleached	No change, grey
400	Completely bleached, colourless, many factures	No change, many fractures
500	Completely bleached, colourless, many fractures	No change, many fractures
600	Completely bleached, colourless, many fractures	Slight bleaching on edges, many fractures
700	Completely bleached, colourless, many fractures	Slight bleaching on edges, many fractures
800	Completely bleached, colourless, many fractures	Slight bleaching on edges, many fractures
1,000	Completely bleached, colourless, many fractures	Slight bleaching on edges, many fractures

Heating rate—10° C. per minute.

Specimens were allowed to cool after attaining each temperature indicated in the table and comparisons of the two types were made.

After cooling the specimens from 1,000° C. to room temperature the smokly variety remained clear and colourless, but the black and grey varieties presented only a slightly bleached appearance on thin edges, and the interior remained relatively unaffected. Heating the black and grey quartz at 1,000° for four hours had little effect in removing the body colour.

Since these experiments failed to give a clue to the nature of the colouring medium, it was decided to dissolve specimens of the black and grey quartz in hydrofluoric acid and examine the residues. For these experiments 500 grams of black and grey quartz were prepared in chip form, dissolved, and the residues examined. They were seen to consist of fine grey sulphides, some pyrite, gold, a few unidentified, colourless euhedral crystals, and an abundant black substance in the case of the samples of black and grey quartz from the greenstone area, and of some pyrite and an abundant black substance in the case of the samples of grey quartz from the sedimentary area. These residues were then successively leached with hydrochloric acid, nitric acid, and aqua regia for one hour. The solutions after this tréatment were visibly darkened by extremely fine black material. After settling, decantation, and thorough washing, the black material was caught on watch glasses, and x-ray photographs were taken.

In the majority of cases of the quartz from the greenstones the black material failed to give an x-ray powder pattern for graphite due probably to the finely divided state of the material. In two separations, however, x-ray patterns for graphite were obtained. Ignition tests carried out on platinum foil showed that the finely divided black material burned leaving no residue. Preliminary tests conducted on this material to determine the presence of hydrocarbons proved negative. It was concluded in view of this evidence that the colouring medium in most cases was finely divided carbon and in some cases graphite. Further work is proceeding on the material which failed to give the graphite pattern.

In all separations of the black material from the quartz of the sedimentary area, x-ray powder photographs gave consistent graphite patterns and further chemical tests were not necessary.

Similar experiments were carried out on the grey and black carbonate from the main occurrences at Yellowknife. In all cases the colouring matter was carbon and failed to give x-ray powder patterns of graphite.

To test the general validity of carbon and graphite being the colouring medium in black quartz, specimens from other regions of the Precambrian in the Northwest Territories, from the Red Lake region in Ontario, and from the O'Brien Mine in Quebec were tested with the same results as those obtained from the Yellowknife quartz. Further work is proposed on the quartz from other areas when samples become available.

Samples of white quartz, milky quartz, and light flesh-coloured quartz from the Yellowknife veins were treated in a similar manner to that of the black quartz, but carbon or graphite was not present in any of the samples.

Discussion

Two general ideas have been prevalent in the minds of those who have examined the problem of the colouring of black and grey quartz. The colour has been attributed to: (I) Electronic darkening due to the action of radioactive emanations—the view advanced by Bruce (1934). (II) Impurities: these may be finely disseminated sulphides, tourmaline needles, various dark minerals, carbonaceous matter, graphite, etc.—in general, the colour is attributed to impurities, and usually some mineral is suggested, but few qualifications are made.

In the cases studied by the author the first postulate does not apply because it has been shown that a heating comparison of black and grey quartz and smoky quartz has proved conclusively that the phenomenon cannot be attributed to the action of radioactivity. There are several other arguments against the radioactivity postulate. At Yellowknife the veins and wall-rocks are very low in radioactivity, and hence, no actuating mechanism is present to produce radioactive darkening. Black coloration in carbonate is not produced by radioactive processes; the colour produced is generally some combination of red. Finally, where black, grey and white quartz occur in an intimate relationship there is no reason to suspect that one age of quartz would be affected by radioactivity and not the other.

The second cause, that attributed to impurities, probably is responsible for most of the black and grey quartz that is so common a feature of the gold-quartz veins of the Precambrian Shield. Disseminated sulphides may act as a colouring agent since in the experiments described in this paper finely divided sulphides were isolated from the residue after leaching with hydrofluoric acid. In several experiments, however, sulphides were not present yet the quartz presented a coal black colour. It is, therefore, considered that the sulphides may make a slight contribution toward the darkening of the quartz. The effect, however, appears to be a rather minor one unless the sulphides are extremely abundant. The same conclusions can be cited for the presence of tourmaline or other similar dark minerals.

Carbon and graphite have been proved to be present in the quartz from Yellowknife and other localities in the Precambrian of Canada, and since carbon and graphite absorb light strongly there is little difficulty in explaining the black or grey colour of the quartz. During the experiments it was noted that the colour varies from light grey to dark grey to black depending upon the quantity of carbon or graphite present in the quartz.

No special attempt was made in this investigation to determine whether or not small amounts of hydrocarbons were present in the samples. It may well be that a certain proportion of the black material in some black quartz is a hydrocarbon, but preliminary chemical experiments indicate that hydrocarbons are either rare or absent in the Yellowknife quartz.

It should be noted here that a distinction should be made between so called "smoky quartz," which is due to radioactivity or other electronic causes, and black or grey quartz due to other causes. The writer would restrict the term "smoky quartz" to quartz that can be proved to have derived its colour from radioactive or electronic processes, and the terms "black or grey quartz" to those varieties that owe their colour to some strongly absorbing impurity.

Conclusions

The black and grey quartz found in the veins and lenses of the Yellowknife greenstone and sedimentary areas owes its colour primarily to carbon or graphite distributed along planes or disseminated in the medium-grained quartz. Grey sulphides may serve to deepen the colour, but the effect is not notable unless the sulphides are present in large amounts. The variation in colour, grey to black, is a function of the amount of carbon or graphite present in the quartz.

A preliminary investigation of samples from other Canadian Precambrian areas suggests that carbon or graphite may be the most important colouring medium in grey and black quartz. Sulphides, tourmaline, and other dark minerals may be partly responsible for the dark colour of some quartz.

It is suggested that the term "smoky quartz" be restricted to the dark brown smoky variety that results from long exposure to radioactive emanations or other electronic causes, and that "black quartz and grey quartz" be applied to that variety which derives its dark colour from light absorbing impurities.

Acknowledgments

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