MICROSCOPIC QUARTZ CRYSTALS IN BROWN COAL, VICTORIA

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ABSTRACT

Minute, doubly-terminated crystals of quartz showing simple crystallographic forms occur in patches in the Tertiary Brown Coal at two localities in Victoria. They have crystallised from solutions derived either from the magma of the overlying basalt flows, or from vadose waters.

OCCURRENCE

Underground mining operations at the Parwan Colliery, 27 miles W. N.W. of Melbourne, have revealed that the upper 12 feet of the hard, earthy Parwan brown coal seam is impregnated with minute, doubly-terminated quartz crystals. The top of the seam is exposed in the inclined main heading leading northwards from the shaft.

The coal seam, which is Miocene in age (Parr, 1942), is about 100 feet thick, and lies at a depth of 405 feet below the surface. Immediately above the seam is a 9 foot thick bed of pyritic sands, partly cemented, but largely so unconsolidated that it rills down into the workings if the top of the seam is broken through. Above the sands are fossiliferous marine clays, which are capped by two thick flows of Newer Volcanic basalt, of a total thickness amounting to approximately 250 feet. A basaltic dyke, about 3 feet wide, has intruded the coal seam in the area impregnated with quartz crystals. The coal adjacent to the dyke developed minute shrinkage cracks which were filled with threads of basalt.

The quartz crystals are most abundantly developed at the roof of the seam, and diminish in both quantity and size with increase in depth below it, being practically absent at 12 feet below the roof. Ash determinations made at the Victorian Mines Department Laboratory show that in the top six feet of coal the ash, which consists chiefly of quartz crystals varies from 14.25% to 26.95%, while in coal from 6 to 12 feet below the top of the seam, the ash content is only 7%. The average ash content of the coal as mined (at 30 feet below the top of the seam) is 5%.

The decrease in the size of the crystals with increasing depth below the top of the seam, is shown by the following measurements:

DEPTH BELOW TOP OF SEAM	SIZE RANGE IN MM.	AVERAGE SIZE IN MM.
0 feet	0.10×0.05–2.0 ×0.75	0.50×0.20
3 feet	0.08×0.05–0.54×0.32	0.32×0.13
5 feet	0.05×0.025–0.29×0.13	0.11×0.05
7 feet	0.03×0.015–0.16×0.08	0.08×0.03
9 feet	0.03×0.015–0.11×0.05	0.06×0.02

In like manner, the decrease in quantity of quartz crystals with increase in depth, is indicated by the fact that three times as much quartz, by weight, occurred 3 feet below the top of the seam than at two feet lower.

At the top of the seam there are some patches in which the crystals are so crowded that the growing crystals obstructed one another, forming masses of interlocking quartz crystals, and giving rise locally to "quartzite" and to small veinlets. Some of the "quartzite" patches had associated rosettes of aragonite needles on their surfaces.

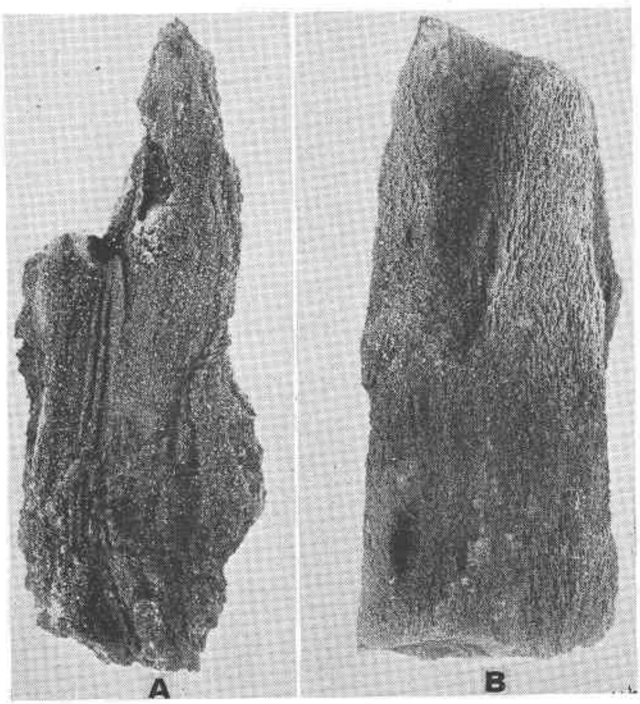

FIG. 1. Wood replaced by double-ended quartz crystals. The woody structure is still evident. Part of a log originally 12 inches long and 8 inches in diameter, from the Old Shaft mine dump, Altona. A—×0.45; B—×0.48. (A. A. Baker collection. Photo by Miss M. L. Johnston.)

A similar development of quartz crystals in Tertiary (Miocene) brown coal is known to occur at Altona, approximately 9 miles W.S.W. of Melbourne. This occurrence could not be observed underground, since the Altona brown coal mine is now closed, but specimens from the dump at the Old Shaft, differ from the Parwan specimens only in that the quartz crystals are generally somewhat larger, and have only been observed so far replacing logs of fossil wood (Figs. 1 and 2). Similar, minute quartz crystals occur on the surface of a white coloured, completely silicified fragment of a tree trunk collected on the same mine dump, but which most probably came from siliceous deposits above the coal.

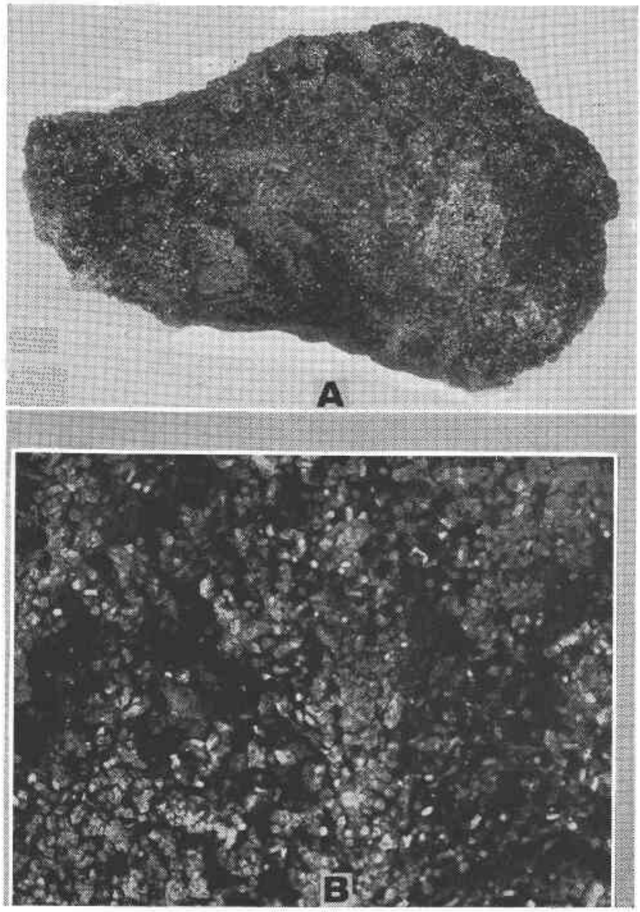

FIG. 2. A—portion broken from the interior of one of the samples depicted in Fig. 1. Woody structure not evident. ×0.49. B—enlarged portion of A, above, showing mass of minute quartz crystals. ×3. (F. S. Colliver collection. Photographs by Miss M. L. Johnston.)

These occurrences are of especial interest, not only because of the infrequent formation of quartz crystals in brown coal, but also because of the great multitude of freely-occurring, doubly-terminated quartz crystals present. Doubly-terminated quartz crystals are usually of some rarity under any conditions.

Form of Crystals

The quartz crystals in the Victorian Tertiary brown coal from Parwan and Altona are low temperature forms which crystallised below 575° C. in the hexagonal trapezohedral hemihedral symmetry group (i.e., the Trapezohedral Class, Quartz Type).

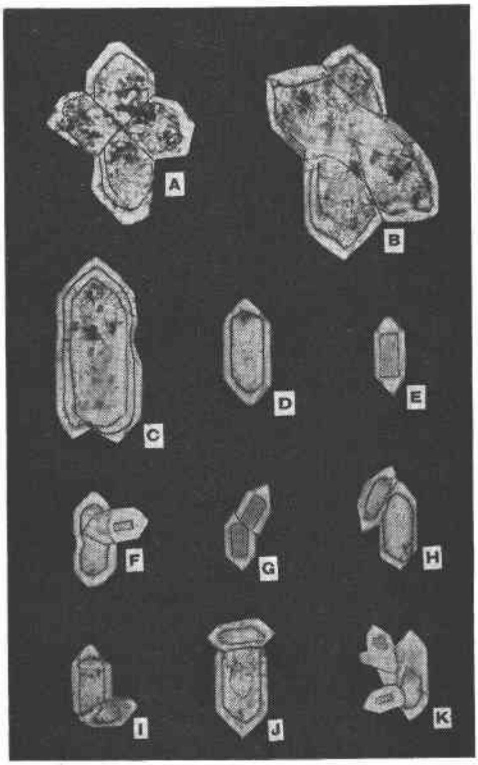

Fig. 3. Quartz crystals from brown coal, Parwan Colliery.
Photographed under crossed nicols. ×55.
A and B—interpenetration (cruciform) twins.
C, D and E—single double-ended crystals.
F, G, H and J—double-ended crystals with outgrowths.
I—contact twin.
K—irregular aggregate built up from several outgrowths. (Photographs by Miss M. L. Johnston.)

The crystals are coated to some extent with carbonaceous material, but on burning and separating the resultant greyish-white ash, the quartz crystals are seen to be principally clear and colourless, i.e., they are microscopic crystals of *rock crystal*. Of the many thousands of these quartz crystals examined under the microscope, the majority are doubly-terminated (Fig. 3; C, D and E), and many of them are almost geometrically perfect in shape (Fig. 4 No. 1).

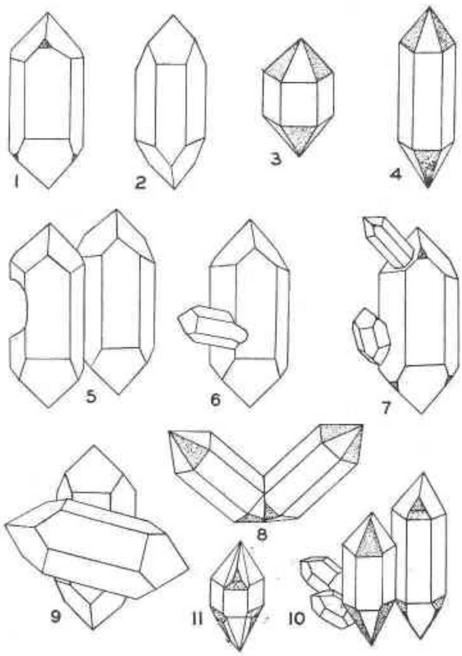

Fig. 4. Sketch diagrams of doubly-terminated, twinned and aggregated quartz crystals from the top of the Parwan Colliery brown coal.

The crystallographic faces and pecularities of habit of the quartz crystals are generally similar at both localities. Because of greater ease of separation of the quartz crystals from brown coal than from replaced wood, most of the sketches depicted in Fig. 4 represent examples from the Parwan Colliery.

The crystallographic forms are typically those of the rhombohedral-trapezohedral class. The most common form is that of the unit prism, terminated at both ends, often with equally developed faces of the positive first order rhombohedron ($h0\bar{h}1$), as shown in Fig. 4, no. 2, but occasionally with unequally developed faces of the same form. Where not doubly-terminated, the quartz crystals have broken away from clusters during preparation of the sample.

In some instances, the negative rhombohedron $(0h\bar{h}1)$ is the dominant of the rhombohedron faces possible in the quartz symmetry group, but is modified by small faces of the positive rhombohedron (Fig. 4, no. 1). In few crystals are the positive and negative rhombohedra equally developed, and in them, the long axis of the combined forms may be short compared to the length of the lateral axes (Fig. 4, no. 3), or considerably longer than the lateral axes (Fig. 4, no. 4). Seldom do crystals possess two forms of the positive rhombohedron, as in the right-hand crystal sketched in Fig. 4, no. 10.

Whereas the greater number of the quartz crystals in the brown coal are free, doubly-terminated crystals, clusters are occasionally developed, more particularly in the replaced wood from Altona and in the occasional "quartzite-like" patches at the top of the seam in the Parwan brown coal. Among the clusters are irregular aggregates of up to four and five quartz crystals (Fig. 3 (K)).

Parallel growths are occasionally present; in them, two or more doubly-terminated quartz crystals are usually attached by means of the prism faces (Fig. 4, no. 5). In some instances, smaller parallel growths are attached to larger parallel growths, but they usually grow out from the larger growths at an acute angle (Fig. 4, no. 10). Where doubly-terminated crystals occur as attached pairs, the axis of each individual crystal may vary from being parallel to that of the other, as in parallel growths, to positions where they are almost at right angles (Fig. 4, no. 9; and Fig. 3 (J)). Examples such as these have one perfect crystal embedded in the other, and when broken away, concavities are invariably left in one crystal, as indicated in the left-hand crystal of Fig. 4, no. 5. Crystals showing two, rarely three such concavities, obviously possessed two and three embedded quartz crystals.

Sometimes smaller crystals grow out from various positions on larger crystals, principally from one of the prism faces of larger, doubly-terminated crystals, as in Fig. 4, no. 6; and in Fig. 3(F). They seldom grow out from a rhombohedral face of a larger crystal, as in Fig. 4, no. 7; and in Fig. 3(G). These smaller outgrowths, which sometimes appear "chimney-like," are not doubly-terminated crystals. A few outgrowths from the larger doubly-terminated crystals, themselves occasionally possess still smaller outgrowths. The outgrowths characteristically display similar types and similar numbers of crystal faces as the host crystal.

Occasional interpretation twins of the type shown in Fig. 3 (A and B), and contact twins of the type depicted in Fig. 4, no. 8, and in Fig. 3(I) are present. In the contact twins, the vertical axes of each twin half intersect at approximately 85°.

None of the crystals showed the pyramidal habit of large doubly-terminated quartz crystals. Crystallographic faces unrepresented in these minute crystals from brown coal are those of the basal pinacoid, trapezohedra and trigonal pyramids, consequently enantiomorphous forms could not be detected.

Where siliceous solutions became concentrated in occasional patches at the top of the 100 feet thick brown coal seam at Parwan, crystallisation caused considerable crowding together, so that interference of the

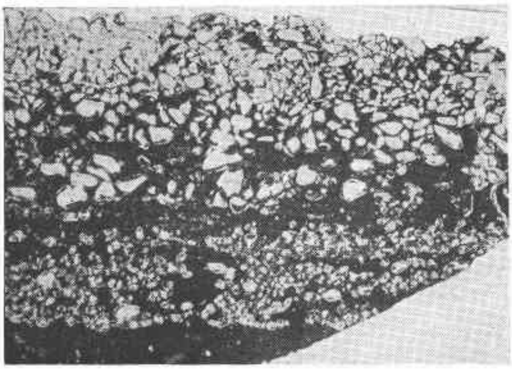

FIG. 5. Microsection of top of brown coal seam, Parwan Colliery. Ordinary light. ×3.5. Showing gradation in size of quartz crystals from above downwards. A small veinlet of silica appears in the bottom right-hand portion of the photograph. (Photo by Miss M. L. Johnston.)

growing crystals with one another prevented the growth of well-developed double-ended crystals. As a result, such patches consist mainly of masses of interlocking quartz crystals, and these are coarser in size at the top, and much smaller an inch or two lower (Fig. 5). Two small veinlets of quartz were observed in a thin section of this material; they extended to the larger crystals situated at the top of the coal seam. Carbonaceous inclusions occurred along cracks in some of the quartz crystals. In areas of somewhat lesser concentration of independent quartz crystals, small splinters of woody tissue adjacent to growing quartz crystals were bent outwards into the less resistant brown coal by the forces of crystallisation. Several fragments of wood occur where the cells have been infilled with silica, resulting in pseudomorphs by infiltration, but the cell wall tissue has not been molecularly replaced, remaining as partially coalified wood.

At the junction of the upper limit of the coal seam and the sands which form the roof of the seam, some of the quartz crystals are rounded: these examples are apparently waterworn grains which have become embedded in the topmost layer of coal. A short distance below, the quartz grains embedded in the coal are surrounded by a narrow zone of carbonaceous material, and this in turn is surrounded by a further layer of quartz forming crystal outlines, as seen in Fig. 5. Such occurrences provide examples of authigenic quartz growing in optical continuity with allothigenic quartz. They are confined to the top inch or so of the coal. All other quartz crystals in the coal below this level, are entirely authigenic in character, and they form the well-developed, doubly-terminated, clear, colourless quartz crystals which have grown in place.

Origin

The growth of introduced quartz crystals in brown coal seams is of interest in providing small scale examples of the growth of quartz veins by force of crystallisation in the manner suggested by Taber (1919), as a result of his laboratory experiments on vein formation, and advocated by Stillwell (1918, p. 27) for the development and growth of spur veins in the Bendigo goldfield, Victoria.

The distribution of the quartz crystals in the Parwan brown coal leaves little doubt that the siliceous solutions from which they crystallised migrated along the top of the coal seam, through the sand bed above the coal, cementing the sands in parts immediately above the seam, and soaking downwards into the coal. The brown coal, being relatively porous, and containing a high proportion (50% at each locality) of readily displaceable water, provided an ideal situation for the growth of perfect minute quartz crystals.

Crystallisation developed at innumerable points, the size of the resultant crystals being governed by the available supply of silica in solution. As the crystals grew, they thrust aside the relatively plastic coal, and where the supply of silica was adequate, such as along parts of the top of the seam, the crystals grew until they mutually obstructed one another and practically all the coal originally present was pushed aside. Where more porous areas, such as fragments of logs of wood, were reached by the siliceous solutions, greater amounts of infiltration and replacement took place, and the wood ultimately became transformed into a mass of quartz crystals with small amounts of entrapped carbonaceous material. Still further replacement of such areas, ultimately led to the complete expulsion of carbonaceous matter, and the wood fragments became transformed into pseudomorphs consisting entirely of silica crystals, with occasional, small, doubly-terminated quartz crystals attached to the exterior surfaces.

The source of the siliceous solutions can only be surmised. The fact that gravels and sands underlying basalt flows in Victoria and New South Wales are commonly silicified and converted to quartzites (sometimes known as "Grey Billy"), suggests that the basaltic lavas may have been the source of the solutions. The possibility cannot be dismissed, however, that the solutions may be ordinary circulating subterranean solutions saturated in silica.

Acknowledgments

The author is indebted to the Director of the Victorian Geological Survey, Mr. W. Baragwanath, for the samples of quartz-bearing brown coal from the Parwan Colliery, to Mr. F. S. Colliver and Mr. A. A. Baker for the loan of quartz-replaced fossil wood collected in 1937 from the old Altona Mine, and to Dr. A. B. Edwards for assistance with the manuscript and discussions on the problem.

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