Quartz replaced anhydrite nodules ('Bristol Diamonds') from the Triassic of the Bristol District

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Quartz replaced anhydrite nodules ('Bristol Diamonds') from the Triassic of the Bristol District

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(Plates 1–2)

Summary. Quartz nodules and geodes, known as Bristol Diamonds, occur in the Triassic Dolomitic Conglomerate of the Bristol district of England. They are composed of either, megaquartz, milky in the outer part and clear towards the centre, or fibrous quartz, chalcedony and lutecite. Much of the quartz, particularly in the outer parts, is full of anhydrite inclusions which are relics of larger lath-shaped anhydrite crystals. The Bristol Diamonds formed by silica replacement of anhydrite nodules, with replacement proceeding from the outside inwards. In many cases anhydrite solution was faster than silica replacement, so that a central void developed into which grew crystals with fine terminations. The anhydrite formed by precipitation of sulphate from hypersaline sediment-porewaters, probably in a marginal playa situation.

1. Introduction

Quartz nodules (potato stones, Bristol Diamonds or Bristol Stones) occurring in and associated with the Triassic Dolomitic Conglomerate in the Bristol district have been known for several centuries. They are commonly geodes lined with well-formed sparkling quartz crystals which in the sixteenth-century were mistaken for diamonds, although of a rather inferior quality (Bradshaw, 1968). Previously, the origin of these nodules (and many quartz geodes in general) has been ascribed to decreasing pore-water salinity and dehydration of silica gel (Bradshaw, 1968; Pettijohn, 1975). This paper reinterprets the Bristol Diamonds in terms of quartz replacement of anhydrite nodules.

2. Occurrence

The quartz nodules occur in the Dolomitic Conglomerate of Upper Triassic age and in the laterally equivalent Keuper Marl (Etheridge, 1870; Woodward, 1876; Stoddart, 1877; Bradshaw, 1968). They have been recorded from many localities including Sea Mills, Shirehampton, Westbury on Trym, Clifton and St Vincent's Rocks. The Dolomitic Conglomerate is usually regarded as a colluvial (scree) deposit since it forms a massive wedge banked up against Carboniferous Limestone and Old Red Sandstone and is composed chiefly of clasts of these Palaeozoic rocks. However, interbedded are sorted conglomerates and cross-bedded sandstones deposited by braided streams, and thin-bedded sandstones and marls of sheet-flood and playa origin.

The Dolomitic Congolomerate passes laterally into the Keuper Marl (e.g. Green & Welch, 1965) which is known to contain halite and gypsum (Whittaker, 1972). Celestine occurs as a late diagenetic sulphate in the Triassic sediments, particularly in the region of Yate (Nickless, Booth & Mosely, 1975). Quartz,

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often associated with celestine, haematite and calcite, also occurs as irregularly shaped replacement nodules and vein fillings in the Carboniferous Limestone underlying the Dolomitic Conglomerate (Bradshaw, 1968).

3. Nature of the quartz nodules

The quartz nodules in the Dolomitic Conglomerate are mainly spherical to subspherical in shape, ranging in size from 3 to 15 cm. In many cases the outer surfaces are roughly mammillated, suggesting that the nodules were originally composed of several smaller nodules. There are basically two types of quartz nodule (Plate 1). The first and most common type is a geode composed of megaquartz and lined with fine quartz crystals (Plate 1*a*). The second type (Plate 1*b*) is composed of fibrous varieties of quartz, either length-slow chalcedony (quartzine), length-fast chalcedony or lutecite (*c* axes at 30° to the fibres). Both types may have central voids (as in Plate 1*a*) or contain a later fill of calcite (as in Plate 1*b*) or celestine.

3.a. Megaquartz nodules

Geodes consisting of megaquartz commonly have a two-layer structure of milky-white quartz in the outer part of the nodules, and clear, glassy quartz with fine terminations in the innermost part. The milky quartz layer is characterized by the presence of numerous inclusions, up to 30 μm in length (Plate 2*a*), which presumably account for the milkiness. The inclusions are rectangular to elongate in section, have moderate relief and birefringence and parallel extinction. The outline of the inclusions is commonly castellated through right-angle re-entrants, indicating 90° cleavages. These optical characters show that the inclusions are composed of *anhydrite*. The inclusions are commonly aligned or form parallel/subparallel clusters. Micron-sized inclusions (of anyhdrite, carbonate, iron or clay minerals) are also present and commonly define rectangular-shaped areas particularly in the peripheral zone of the nodules and occasionally projecting into the surrounding matrix (Plate 2*b*).

The milky quartz itself consists of large equant crystals with unit or flamboyant extinction and irregular intercrystalline boundaries. There is no size increase of these milky quartz crystals from the substrate towards the cavity centre. The glassy megaquartz of the innermost part of the geodes is completely devoid of inclusions, has unit extinction and terminations. The boundary between the inclusion-rich milky megaquartz and the inclusion-free glassy megaquartz locally has crystal terminations defined by the inclusions. These terminations occur within megaquartz crystals and are directed towards the centre of the nodule.

3.b. Fibrous quartz nodules

Geodes of fibrous quartz are sometimes similar to the megaquartz nodules in having a two-layered structure, in this case of length-slow chalcedony (quartzine) or lutecite in the outer part and the more normal length-fast chalcedony in the central part. The quartz again contains inclusions but on such a fine (submicron) scale that they are indeterminable. However, the inclusions are arranged into light and dark, inclusion-poor and inclusion-rich areas which often define rectangular shapes (Plate 2*c*). Under crossed polars (Plate 2*d*) the fibrous quartz is composed of either lutecite, with curious fern-like, chevron, swinging and oblique extinction patterns, or length-slow chalcedony, with the quartz fabrics for the most part unrelated to the rectangular inclusion patterns.

4. Interpretation and discussion

The presence of anhydrite inclusions in the outer parts of the Bristol Diamonds shows that they have formed by the replacement of anhydrite nodules. The rectangular-shaped areas within the milky quartz and lutecite layers are interpreted as the original shapes of the anhydrite crystals which made up the nodules. The inclusions of anhydrite are relics of these originally larger lath-shaped crystals. In recent anhydrite nodules from the Persian Gulf sabkhas (Shearman & Fuller, 1969; Butler, 1970) and in anhydrite nodules from ancient evaporite sequences (e.g. Holliday, 1968; Maiklem, Bebout & Glaister, 1969; Llewellyn & Stabbins, 1970; Arthurton & Hemingway, 1972) rectangular or lath-shaped crystals and preferred orientations are common features.

The fabrics of the megaquartz geodes, with preservation of anhydrite inclusions in the outer part, show that replacement of the anhydrite nodules took place from the outside inwards. However, as noted earlier, the Bristol Diamonds are mostly geodes indicating that as replacement of calcium sulphate by quartz proceeded, there was an increase in sulphate solution over silica replacement and a void developed. The continued precipitation of silica resulted in growth of the glassy, inclusion-free quartz crystals with fine terminations, developed into the void left by the dissolving anhydrite. The fabrics of the milky quartz crystals – irregular intercrystalline boundaries, non-competitive growth fabrics and flamboyant extinction – are all typical replacement fabrics (cf. Kendall & Tucker (1973) for replacement calcite) and quite unlike the fabrics of void-filling, drusy precipitates (e.g. Bathurst (1971) for carbonate drusy fabrics), such as possessed by the innermost, glassy megaquartz crystals. The presence of inclusion-defined terminations between the milky quartz and glassy quartz coincides with the changeover from quartz replacement to quartz precipitation, resulting from enhanced sulphate solution, when the quartz crystals were first free to grow without any constraint imposed by the host sulphate. At the time of increasing sulphate solution the quartz crystals would be growing in a less-dense mush of sulphate and would then be able to organize the inclusions to conform with the shape of these growing crystals. Similar inclusion-defined terminations occur in calcite replacements (Kendall & Tucker, 1973; Tucker & Kendall, 1973).

The lutecite and quartzine varieties of fibrous quartz were recognized initially by Folk & Pittman (1971) as a common indication for the former presence of evaporite minerals and have since been described by other authors (e.g. Siedlecka, 1972; Schreiber, 1974). Quartz nodules similar in many respects to the Bristol Diamonds, although occurring in supratidal sediments within a marine sequence, have been described by Chowns & Elkins (1974). The growth of these peculiar varieties of fibrous quartz was related by Folk and Pittman to the alkaline nature of the replacement micro-environment and its effects on the ionization of silica, or to the presence of sulphate ions in the groundwater. However, these suggestions have been questioned by Chowns & Elkins (1974), since groundwaters in anhydrite deposits tend to be neutral or slightly acidic and length-slow chalcedony and lutecite are now known from non-evaporitic rocks. Solution and replacement of the Triassic anhydrite nodules probably reflect the passage through the sediment of fresh groundwaters, rich in silica and poor in sulphate.

At the present day, nodular anhydrite is forming within sediments by precipitation from hypersaline groundwaters (often via gypsum), in marginal marine and continental sabkha situations (Kinsman, 1969; Butler, 1970). In view of the palaeogeography for the upper part (Norian) of the British Triassic (Audley-Charles, 1970) and the characters of the sediments associated with the Bristol Diamonds, the anhydrite probably formed marginal to a continental sabkha or playa. It is likely that most Bristol Diamonds were formed within the finer-grained red dolomitic marls interbedded with the coarse scree and stream conglomerates. Quartz replaced anhydrite nodules occur in a similar situation in the Triassic sediments of South Wales (Tucker, in prep.). Bristol Diamonds occurring within the conglomerates may represent reworked anhydrite nodules or anhydrite replaced Carboniferous Limestone pebbles. The former existence of anhydrite within the Dolomitic Conglomerate, indicating high mean annual temperatures (above 22 °C), with seasonal temperatures in excess of 35 °C (Kinsman, 1969) fits in with the well-established arid or semi-arid climate of the British Triassic (e.g. Tucker, 1974).

5. Conclusion

The presence of inclusions of anhydrite within the Bristol Diamonds indicates an origin through replacement of sulphate nodules. The replacing silica is either flamboyant megaquartz without drusy fabrics or fibrous quartz (quartzine and lutecite), now well-known as a common evaporite replacement. Increased sulphate solution during the replacement resulted in the development of a central void into which grew glassy quartz crystals with fine terminations or length-fast chalcedony. The demonstration of the former presence of anhydrite nodules in the Bristol Triassic, indicating sabkha-type diagenesis, is consistent with the sedimentology and known palaeoclimatology and palaeogeography of the time.

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Geol. Mag. Vol. **113**, 1976, Tucker, Plates 1 & 2, between pp. 574 and 575.

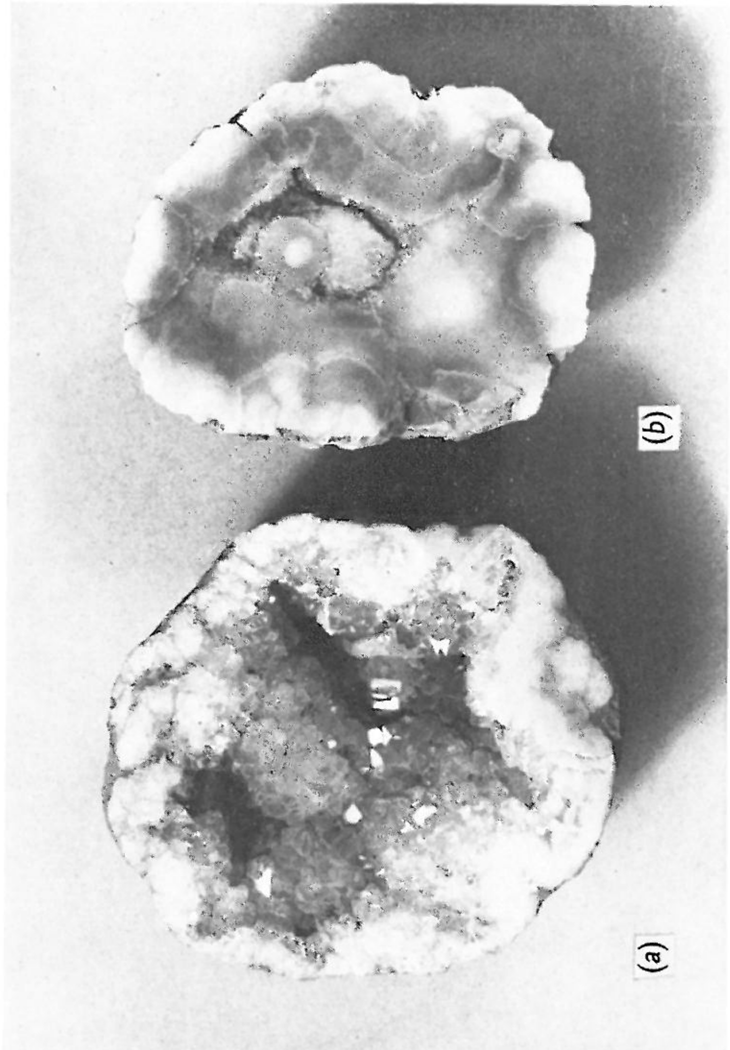

Plate 1. Quartz nodules (Bristol diamonds).

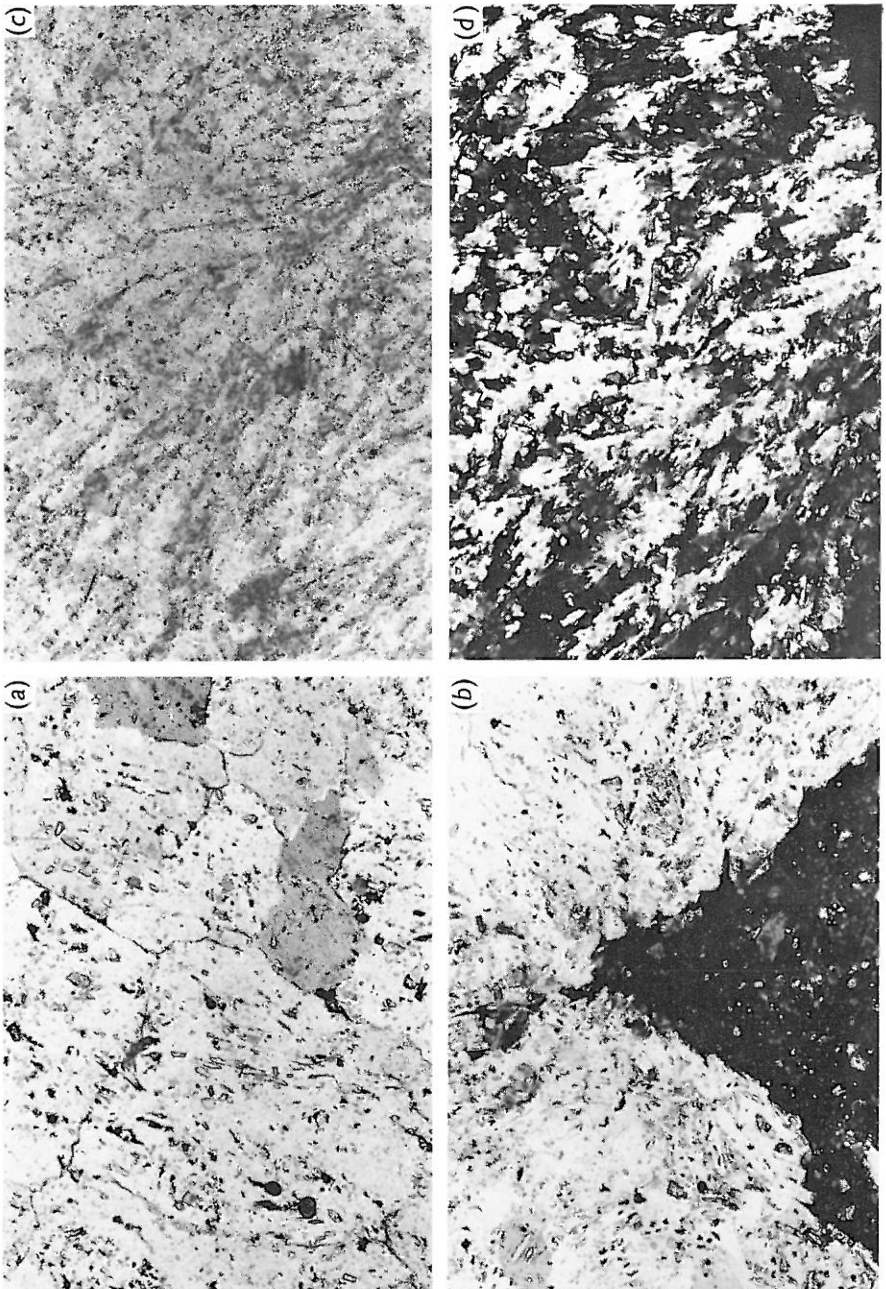

Plate 2. Fabrics of the Bristol Diamonds.

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EXPLANATION OF PLATES

Plate 1. Bristol diamonds from the Wallington Mineral Collection, now housed in the Geology Department, University of Newcastle upon Tyne.

Plate 1 (*a*). Megaquartz geode with milky quartz in the outer part, and clear, glassy quartz with sparkling crystal terminations towards the centre.

Plate 1 (*b*). Fibrous quartz nodule composed of lutecite and containing calcite in the centre.

Plate 2. Fabrics of the Bristol Diamonds, all fields of view 2×1.25 mm.

Plate 2 (*a*). Megaquartz from the outer part of a Bristol Diamond, showing the numerous relic inclusions of anhydrite. Note irregular inter-crystalline boundaries to quartz crystals.

Plate 2 (*b*). Outer part of megaquartz geode showing rectangular shapes defined by micro-sized inclusions.

Plate 2 (*c*). Fibrous quartz showing light and dark areas which define rectangular shapes – inferred to have been anhydrite laths.

Plate 2 (*d*). Fibrous quartz, the variety lutecite under crossed polarizers showing peculiar extinction patterns, unrelated to rectangular shapes seen in plane polarized light.