Windy Knoll, Derbyshire

[SK 127 829]

Introduction

Windy Knoll forms a small culmination on a ridge crest composed of the Carboniferous (Vsean) Bee Low Limestone Formation, that was previously a reef completely top- and side-sealed by the Namurian Bowland Shale Formation (formerly the 'Wale Shales'. The quarry is on National Trust land, to the west of Castleton, in Derbyshire (see (Figure 4.20)).

At Windy Knoll, a small, disused limestone quarry is famed for its bitumen deposits (see (Figure 4.22)). The quarry face displays 'neptunian dykes' (or fossil grikes) at the contact of the eroded Carboniferous limestones and the overlying shales. These neptunian dykes are variously filled with mixtures of limestone boulders and shales, and include heavy hydrocarbons, including elaterite (a rubbery bituminous material).

The bitumen deposits of Windy Knoll are regarded as a heavy residue of a former oil accumulation. Inorganic minerals are present within the bituminous materials and can be released through the use of solvents. They include galena, sphalerite, marcasite, bravoite, fluorite, barite, calcite and quartz, and typically form small, euhedral, perfectly formed crystals. Marcasite coats rod-like nodules of a hard, green waxy hydrocarbon.

Description

The stratigraphical position of the mineralization at Windy Knoll is almost identical to that at the nearby Odin Mine. A substantial boulder bed occurs between a reef knoll and the overlying Bowland Shale Formation. Quarrying in the mid-19th century opened this up, although the quarries are now mainly ladled and overgrown. The main area of exposure is in the south-west face of the quarry, which is mapped as a boulder bed. However, the limestone appears to be fairly solid, although broken up into large units by neptunian dykes filled with limestone and shale, and containing solidified hydrocarbons and metalliferous minerals. There appears to be a transition from south-east to north-west, from solid limestone, to limestone with increasing neptunian dykes, to boulder bed. This implies a passage through a regolith zone, which is in keeping with the northerly regional dip of the strata. Stromatolite mats, crinoids and corals are among the fossils found in this exposure.

At the south-eastern end of the quarry there is a small cavern, in the walls of which the 'oily and rubbery' hydrocarbons are clearly visible, seeping out of the limestone (Ford, 2002). Some hydrocarbons may be observed occurring as shiny, black nodules, while others are present in 'sticky, brown' seepages. Polymerization on exposure to air causes these seepages to become elastic and rubbery; as such they are described under the general name 'elaterite'. Pering and Ponnamperuma (1969) described the hydrocarbons as ranging from 'brittle, black chunks and brown chunks and brown rods showing concoidal features, to dark grey-green elastic gums'. Nooner *et al.* (1973) classified the hydrocarbons at the Windy Knoll deposit into four main types based on their aliphatic, aromatic, and asphaltic distributions, termed 'Types A-D'.

In addition to occurrences in neptunian dykes and in joints in the limestone, bitumens also occur within hydrothermal veins in the Lower Carboniferous (Visean) Bee Low Limestone Formation (Mueller, 1954, 1970). These hydrothermal veins within the Windy Knoll area terminate along the boundary of the overlying impermeable Namurian Bowland Shale Formation. The bitumens are in some cases associated with fluorite-rich veins.

Interpretation

The abundance and variety of bitumens in the Castleton area suggest that before the removal of the Namurian cover the shelf-margin crest and the northwardly-inclined shelf margin of the Visean limestone succession could have hosted a

significant oil accumulation.

It has been hypothesized that the boulder-bed formation resulted from either (1) the widening of solution joints into neptunian dykes in a karstic environment, and then a break-up of the karst in the zone of wave action during Bowland Shale Formation deposition; or (2) the neptunian dykes represent the collapse of overlying strata into voids during replacement of limestone by mineralization, beneath a cap-rock of shale, i.e. collapse into a replacement flat of Northern Pennine-type.

The role of hydrocarbons in the process of orefield paragenesis at Windy Knoll has been the topic of extensive research (for example Mueller, 1954; Pering and Ponnamperuma, 1969; Worley and Ford, 1977). Polymerization causes the brown hydrocarbon seepages to become elastic and rubbery. Dunham (1967) noted the intimate association between the hydrocarbons and gangue minerals such as pyrite, marcasite, quartz, calcite and fluorite. This association implies that hydrocarbon deposition may be related to the genesis of once economically important lead, zinc and barite deposits in the area. A similar link between hydrocarbons and mineralization is seen at the Castle Hill Quarry GCR site, in Leicestershire.

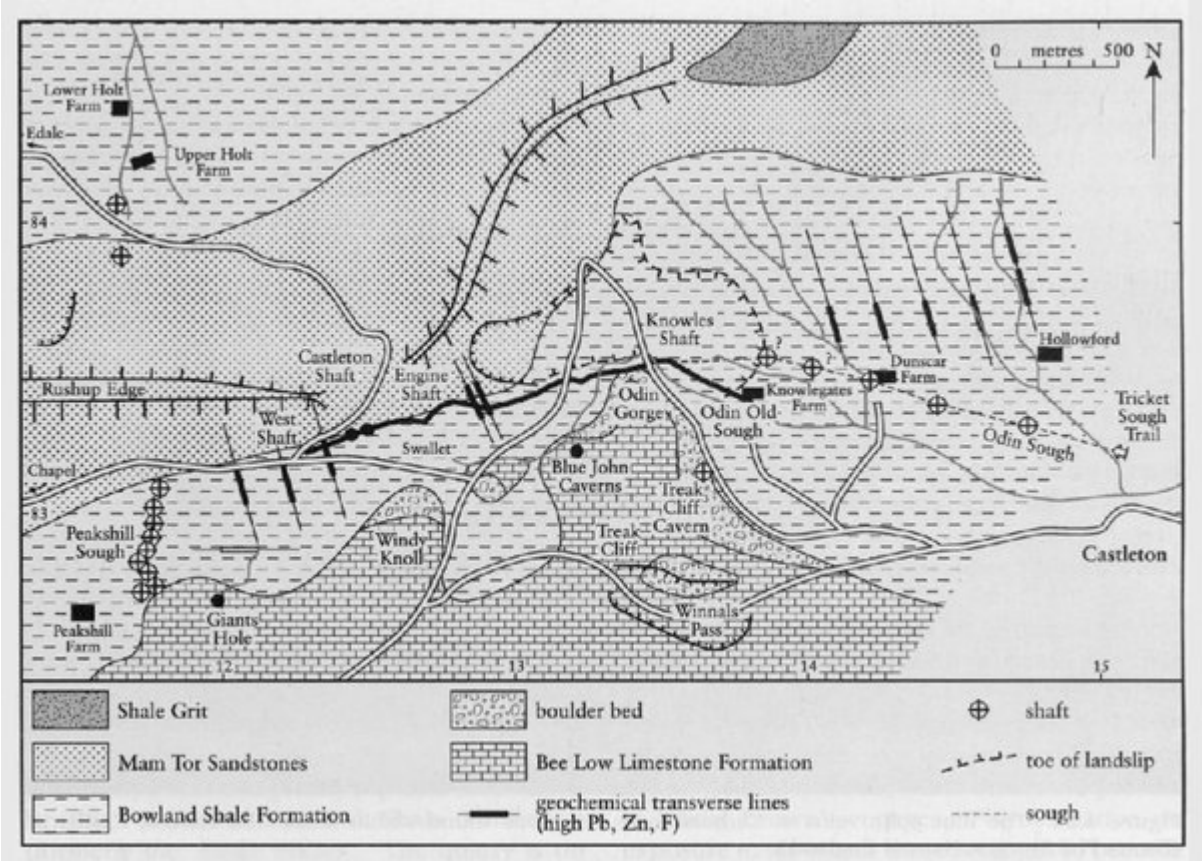
Mueller (1951, 1954, 1969, 1970) suggested the bitumens were derived from biogenic organic matter distilled from surrounding sediments by hot (250°–350°C) ore-bearing fluids. Sylvester-Bradley and King (1963) reported evidence that these may be either biogenic or abiogenic in origin. Pering (1971) proposed that the bitumens formed from organic material collected in a topographical high during two-stage migration from parent sediments. Pering and Ponnamperuma (1969), and Pering (1971, 1973) detected isoprenoid hydrocarbons in the bitumens, again supporting evidence of a biogenic origin. Nooner *et al.* (1973) identified four distinct bitumen types (Types A-D) in the Windy Knoll deposit, and Khavari-Khorosani and Murchison (1978) concluded that the bitumen forming the base of the Windy Knoll deposit (a Type-D 'black bitumen') is a product of thermal metamorphism. More modern work (Xuemin *et al.,* 1987; Ewbank *et al.,* 1993, 1995) has shown that the bitumens at Windy Knoll represent the biodegraded residue of an oil accumulation. Moser *et al.* (1992) determined a direct link between the fluid-inclusion populations in fluorite at Windy Knoll, the outcropping bitumens, and fluorite deposition. A two-stage deposition of the fluorite was determined from the fluid-inclusion data, with an early, high-salinity fluid at a temperature of 69°–100°C, and a later, lower-salinity fluid at a temperature of 112°–150°C (Moser *et al.,* 1992).

The base of the elaterite may define a residual oil-water contact. Bitumen impregnation in limestone breccias below the oil-water contact may indicate the charge pathway. These breccias were found by Peacock and Taylor (1966) to contain uraniferous collophane. If the bitumen and uranium are genetically associated, an indication of the area formerly open to oil migration is provided by Peacock and Taylor's map of surface uranium anomalies. Radioactive anomalies occupy the entire 6000 m-long, 500 m-wide and 150 m-high exposed portion of the slope to the south of Windy Knoll.

Conclusions

The Windy Knoll GCR site provides an excellent location to study the inter-relationship between lead-zinc-fluorite mineralization and hydrocarbons in the South Pennine Orefield. In contrast to most of the mineralized sites in the orefield it contains a large bitumen deposit which contains both solid and liquid hydrocarbons. Prior to the erosion of the overlying Bowland Shale Formation, the Windy Knoll area would have formed an ideal structural-trap for a significant hydrocarbon deposit. The site also contains a very good example of a palaeokarst surface.

References



(Figure 4.20) 'Freak Cliff location and geological map. After Ford and Rieuwarts (1976).

(Figure 4.22) The limestone quarry face (left) at Windy Knoll with the residual petroleum 'elaterite' deposits in the foreground. The black tarry material forms the matrix to pale fragmented limestone. (Photo: J. Poll, Natural England.)