

Colour Alteration of Reworked Devonian and Carboniferous Conodont Elements from the Upper Permian of Nottinghamshire

A. Swift

Abstract: The majority of reworked Devonian conodont elements recovered from the Permian Lower Marl (late Permian) of the Brough borehole, Nottinghamshire, have a colour alteration index (CAI) value of 1.0, but a few have a higher value of 1.5-2.0. Similarly, elements of Carboniferous age from surface exposures of the Cadeby Formation (late Permian) around Mansfield, Nottinghamshire, yield a value of 1.0 overall, with occasional elements having a higher value of 1.5-2.0. The admixture of more thermally mature elements at both localities indicates that in each case the conodont material was derived from more than one area and/or horizon.

The reworked conodont elements on which this report is based were first reported, without colour determinations, by Swift and Aldridge (1982). Specimens of Devonian age were recovered from the Permian Lower Marl (Marl Slate, late Permian) at a depth of 557m in a borehole sunk at Brough, between Nottingham and Lincoln. The Cadeby Formation (late Permian) at three localities around Mansfield yielded several collections of Carboniferous conodont elements. Full locality details and CAI determinations are given in the Appendix. The Carboniferous collections were thought to be locally derived, but it was concluded that

the Devonian elements were probably transported over several tens of kilometres to the Brough site, probably via fluvial agency; a remarkable and very rarely recorded example of this process (Swift and Aldridge, 1982). Reconstructions of Devonian palaeogeography published since 1982 have confirmed this conclusion, the East Midlands area being interpreted as land or, in the late Devonian, marginally marine in its southern part (Bluck *et al.* in Cope *et al.*, 1992). The conodont elements recovered are from fully marine species, so a local source is ruled out.

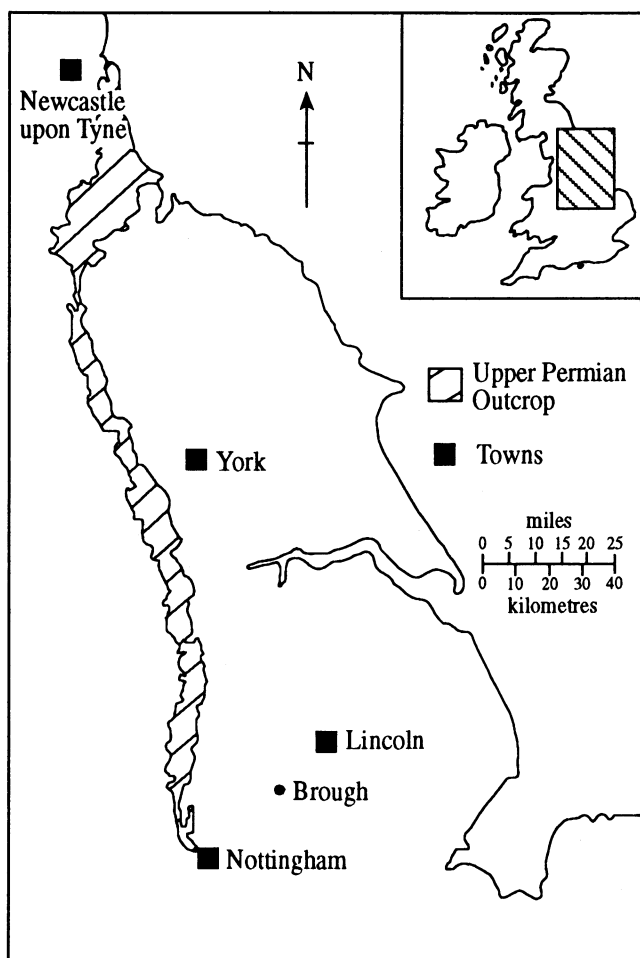


Fig. 1. Map of Upper Permian outcrop and site of the Brough Borehole.

The CAI concept

Conodont elements are composed mainly of calcium phosphate (apatite), but small percentages of organic compounds have also been identified (Ellison, 1944; Pietzner *et al.*, 1968). Laboratory experiments conducted by Epstein *et al.* (1977) demonstrated that the composition of these organic compounds is modified by heat, which in turn causes a darkening of element colour. Over a temperature range from 60-375°C the colour changes from pale yellow through pale brown to brown to dark brown to black (Epstein *et al.*, 1977, fig. 5). Each colour correlates with a specific temperature band and the degree of maturation is embodied in a colour alteration index (CAI) scale from 1-5. Above 375°C the apatite itself is crystallographically altered, creating further colour changes from black through grey to white to colourless at temperatures exceeding 600°C; the CAI scale extends from 6-8 to accommodate these higher levels of heating.

The heat required to alter conodont element colouration may be generated beneath a cover of later sediments or tectonically overthrust strata, by the thermal halo around igneous intrusions, or alternatively, mantle-derived heat channelled through highly-conductive igneous bodies may be responsible (e.g. Burnett, 1987). Hydrothermal solutions have also been identified as causing colour changes (Wardlaw and Harris, 1984) and other non-thermal causes of colour alteration may be influential, such as leaching or staining.

CAI has proved a useful tool in hydrocarbon exploration and it has been established that oil generation is constrained below a level of CAI 2 and gas below CAI 3.5 (Epstein *et al.*, 1977).

Material

Ninety broken and abraded elements were recovered from the Brough borehole core and 127 mostly broken elements from 12 samples taken in the Mansfield area. Differences between the two sites are apparent both in the type of element present and the degree of abrasion suffered. The Brough Devonian collection is dominated by sub-rounded fragments of robust platform elements, whereas the Carboniferous specimens consist mainly of portions of smaller delicate ramiform elements. Differences in the type of element recovered from each area may be related to the constitution of the faunas at their original point of deposition, but differences in preservation are probably due to the disparity in distance transported.

The great majority of specimens from both the Brough borehole and the Mansfield area have a very low CAI value of 1.0: however, a few elements in both cases are darker in colour and are assessed at 1.5-2.0.

Discussion

The overall low CAI value of 1.0 for elements from both areas indicates that they received very little heating after being incorporated into the sediment, either at the original site of deposition in Devonian and Carboniferous strata, or at the site of redeposition in late Permian rocks. CAI enhancement above 1.0 begins when temperature exceeds 50-80°C (Epstein *et al.*, 1977). Examples from the Appalachian Basin of North America have shown that such a temperature can be generated beneath a thickness of sedimentary overburden exceeding 1200m (Epstein *et al.*, 1977). Thus the majority of conodont elements from both sites were at no time covered by great thicknesses of younger rocks or tectonically overthrust strata. In addition, the low figure points to minimal influence from mantle-heat channelled through igneous bodies or heat carried by mineralizing solutions. It is unclear why some elements from both the Brough borehole and the Mansfield area are more thermally mature, but it is possible that they were derived from different sources, perhaps originating from locations where the thickness of overburden was greater. On the other hand, it cannot be discounted that they came from older (and therefore more deeply buried) horizons at the same localities as the low-CAI specimens.

The low levels of maturation recorded by the conodont elements from Nottinghamshire are within the limits for both oil and gas generation.

Appendix: Sample localities, horizons and CAI values

1. Reworked Devonian elements. Borehole sunk at Brough, near Collingham, depth 557m, SK 8335 5840. Permian Lower Marl, late Permian. CAI 1.0/1.5-2.0.
2. Reworked Carboniferous elements. Old railway cutting west of Studfold, near Kirkby in Ashfield, SK 499 556. Cadeby Formation, late Permian. CAI 1.0/1.5-2.0 (6 samples).
3. Reworked Carboniferous elements. Road cutting in Teversal, SK 480 618. Cadeby Formation, late Permian. CAI 1.0/1.5-2.0 (2 samples).
4. Reworked Carboniferous elements. Small exposure in Stony Houghton, SK 4925 6623. Cadeby Formation, late Permian. CAI 1.0/1.5-2.0 (4 samples).

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Andrew Swift
Department of Geology
The University
Leicester
LE1 7RH