High velocity layer beneath seismic Reflector 'X' in the Bristol Channel may be Carboniferous Limestone: Implications for a possible Exmoor-Cannington Park thrust: Reply to Brooks and Miliorizos 2001

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We made an interpretation of offshore seismic reflection profiles which considered all the evidence of the geology surrounding the Bristol Channel and concluded that Reflector 'X' was more likely to represent top Dinantian limestones rather than metamorphic basement. There is no direct evidence available to prove or disprove this interpretation. In the absence of deep boreholes within the inner Bristol Channel the most relevant area comprises the small outcrops of Dinantian and Silesian rocks at Cannington Park, near Bridgwater in Somerset.

The Cannington Park inliers and Knap Farm borehole lie only about 30 km along strike from the main area in question, about as far as South Wales lies, across strike, to the north. In a seismic reflection study of the concealed Variscan structure of the adjacent Vale of Glamorgan Brooks *et al*. (1994) pointed out that the information 'derived from the Mendip Hills area about 30 km east along the strike of the orogenic belt' was useful in making interpretations. We agree with this approach. In areas like the outer Variscides with rapidly varying outcrop geology, caused by E-W anticlines and thrusts we strongly recommend using along-strike correlation in seismic reflection interpretation.

High velocity Dinantian rocks are present in the Knap Farm borehole in the main Cannington Park inlier (Whittaker and Scrivener, 1982), where they are mostly represented by a dolomitised Waulsortian reef facies. A similar facies also crops out in south Pembrokeshire. The upper part of the Dinantian succession at Cannington Park has been eroded (the surface rocks are Arundian in age) but the preserved strata are demonstrably thicker than those in South Wales. In South Wales there is also spectacular thickening from the north and east crops to the south crop confirming a general southerly thickening. The only area onshore lacking Carboniferous rocks is the Exmoor-Quantocks Devonian outcrop, south of the Cannington inliers. It is preferable to draw analogies between the Bristol Channel and Cannington Park, *along-strike*, rather than across-strike between the Channel and Exmoor-Quantocks.

We did not mention other boreholes in southern England (as suggested in discussion by Brooks and Miliorizos, 2001) which also contain high sonic velocity Dinantian rocks, but take the opportunity to tabulate these (Table 1), together with their distance from the Bristol Channel. The high sonic velocities (final column of table) are dependent on, *inter alia,* facies and burial. These comfortably exceed the sonic velocities of, for example, Precambrian igneous rocks in Heath Farm and Withycombe Farm (English Midlands boreholes). Precambrian rocks in the Kempsey borehole have a comparable sonic velocity of 5.57 km/s, but from a mid point depth of 2658 m below OD. The velocity of Dinantian rocks is therefore frequently greater than Precambrian rocks. The interval velocity of Dinantian rocks (first column of table) is often lower than Dinantian limestones *sensu stricto* because the basal Dinantian Lower Limestone Shales is everywhere of significantly lower velocity than the rest of the section. Bruton, Farley South and Netherhampton boreholes do not reach these shales.

Average velocity km/s	Mid point depth below OD (m)	Distance (km) from Bristol Channel	Well	Thickness (m)	Interval (m) with sonic velocity > 6.1 km/s
5.78	1074	20	Maesteg	471	320
5.59	475	10	Knap Farm	950	650
5.33	1078	70	Fifehead Magdalen	373	208
5.64	339	55	Bruton	92	35
6.13	1834	100	Farley South	282	160
6.19	1511	90	Netherhampton	167	152

Table 1. *Average sonic log velocity and other properties of Dinantian rocks in SW England and Wales.*

The relationship between sonic velocity and refraction velocity is not clear to us either but is only relevant in connecting the 6.2 km/s refractor from onshore north Devon (Mechie and Brooks, 1984) and Reflector 'X'. We have followed Brooks *et al*. (1993) in making this connection. If this connection were to prove erroneous the seismic reflection interpretation of Reflector 'X' as top Dinantian would still remain the most likely with Devonian rocks underlain by an unknown rock with a seismic refraction velocity of 6.2 km/s.

Our paper resurrects an earlier hypothesis of thrusting because it best fits the observations if Reflector 'X' represents the top of the Dinantian. By interpreting Reflector 'X' as top metamorphic basement (probably Precambrian) Brooks *et al*. (1993) and Brooks and Miliorizos (2001) model a southern Bristol Channel which lacks Dinantian, with Lower Palaeozoic and possibly Devonian thin or absent. There is no evidence for inversion on this scale removing such a large thickness of rocks. In fact late Devonian rocks are present in the Mendips and South Wales, where they unconformably overlie older rocks. They were unbottomed at Cannington Park borehole and are also probably present beneath the Bristol Channel.

The Cannington Park Dinantian and Silesian inliers and the Steep Holm island outcrop indicate that it is more likely that Carboniferous rocks are present beneath the whole of the Bristol Channel (Smith, 1985). Brooks and Miliorizos (2001) state that Reflector 'X' has only been observed in the hangingwall of the Watchet-Cothelstone-Hatch Fault. In our interpretation the top of the Dinantian (=Reflector 'X') is observed elsewhere, on the northern parts of all N-S reflection profiles and is interpreted to lie beneath the base (Permo)-Triassic unconformity at the ends of two E-W profiles.

The southern of these two profiles, shown by Miliorizos and Ruffell (1998, their figure 9) terminates about 10 km NW of Cannington Park. It shows high amplitude reflectors, interpreted by us as top Dinantian, about 100 milliseconds (ms) beneath the Permo-Triassic unconformity at about 700 ms. The authors interpret 1200 ms of Mesozoic and Permian rocks here instead. Using the Burton Row borehole velocities their Permo-Triassic basin depocentre would lie at about 2400 m. This is considered to be too deep because Permian rocks would have to be over 1 km thick. The northern profile has not been published and terminates about 5 km SW of Steep Holm island, comprising an Arundian-Chadian age outcrop (Whittaker and Green, 1983). It is unlikely therefore that Dinantian rocks are absent from the Bristol Channel in the area of these profiles.

Velocities derived from refraction profiles cannot be used unambiguously to detect the presence or absence of rock groups in preference to the above reasoning. Brooks and co-workers, over three decades, have attributed to Dinantian rocks seismic refraction velocities ranging from 4.2 km/s to 6.0 km/s. Brooks and Miliorizos (2001) appear to concede now that 5.77 km/s might represent Dinantian rocks on refraction profile 74/3 and we merely follow Brooks and Al-Saadi (1977) in correlating this refractor to the *apparent* 5.95 km/s refractor on refraction profile 74/6.

A N-S section across the Bristol Channel resembles that of section 3 of the 1:250000 Bristol Channel geological map (BGS, 1988) and, for the southern part only, figure 2 of Miliorizos and Ruffell (1998) is relevant. The latter section shows a Mesozoic normal fault between the Devonian of the Quantocks and Carboniferous of Cannington, which restored to its pre-Triassic displacement would necessitate the presence of the Exmoor-Cannington Park Thrust (ECPT). Similarly restoring the Variscan surface across the Central Bristol Channel Fault Zone (CBCFZ) indicates that this thrust probably emplaced Dinantian rocks over Silesian (Smith *et al*., 1998, figures 3 and 4).

The NW-trending strike-slip faults are relatively minor structures, which offset the major Variscan ESE-WNW structures but do not appear to be associated with significant inversion. In summary our interpretations feature Carboniferous reflectors, extrapolate along the Variscan strike and emphasize the major structures and the Cannington Park inliers. Brooks and Miliorizos (2001) recognise no Carboniferous reflectors south of the CBCFZ, extrapolate across strike and emphasize the strike-slip faults, dismissing the Cannington Park evidence.

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