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HIGH VELOCITY LAYER BENEATH SEISMIC 'REFLECTOR X' IN THE BRISTOL CHANNEL MAY BE CARBONIFEROUS LIMESTONE: IMPLICATIONS FOR A POSSIBLE EXMOOR-CANNINGTON PARK THRUST

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INTRODUCTION

The Bristol Channel, lying between South Wales and southwest England, is underlain by the east-west-trending Bristol Channel Syncline which contains about 2000 m of Triassic to Upper Jurassic strata. A series of east-west-trending faults cutting the core and northern limb of this syncline comprises the Central Bristol Channel Fault Zone. The Mesozoic rocks are flanked to north and south (onshore) by upper Palaeozoic rocks which were folded during the Variscan Orogeny.

Information about the concealed geology of the Bristol Channel has, in the absence of boreholes penetrating to the concealed strata, been obtained entirely from studies of geophysical data. Of particular significance in evaluating the offshore area are commercial multichannel seismic reflection profiles that reveal details of shallow crustal structure to depths of about 5 km. The positions and numbers of seismic profiles referred to in this note are shown on Figure 1.

In the southern Bristol Channel, a prominent seismic reflector ('Reflector X') was recognised by Brooks et al. (1993) and correlated with the top of a high velocity (6.2 kms^{-1}) refractor recorded at shallow depth in north Devon (Mechie and Brooks, 1984). The interface between the shallow refractor/reflector was interpreted by Brooks *et al*. (1993) as the top of pre-Devonian schistose or gneissose basement rocks. An alternative interpretation, proposed here, is that this unit consists of Carboniferous Limestone (Dinantian). If correct, this interpretation revives the hypothesis, first postulated (Ussher, 1891) on evidence from Cannington Park, Somerset (Figure 1), that the Devonian rocks at the surface in north Devon and west Somerset could be thrust northwards over Carboniferous Limestone on a westward extension of a thrust (the Exmoor-Cannington Park Thrust, ECPT).

We suggest that Reflector X represents the top of the Carboniferous Limestone in the footwall unit of the ECPT and that the 6.2 km s^{-1} refractor under north Devon, which was correlated with Reflector X by Brooks *et al*. (1993), represents the ECPT itself where the footwall is composed of Carboniferous Limestone. The probable presence in the Bristol Channel of Upper Carboniferous (Silesian) strata overlying the Carboniferous Limestone and within the hydrocarbon generation window, combined with the possible presence of Permo-Triassic sandstone reservoir rocks, is of interest for the hydrocarbon prospectivity of the region.

PREVIOUS STUDIES OF THE DEEP STRUCTURE AND STRATIGRAPHY OF THE BRISTOL CHANNEL

No deep boreholes have been drilled in the Bristol Channel, but extensive geophysical work in the last 25 years has led to a number of interpretations of the subsurface structure and stratigraphy of the area, notably by M Brooks and his co-workers. Mechie and Brooks (1984) identified a basal refractor with a velocity of 6.0-6.2 kms^{-1} beneath much of the Bristol Channel and South Wales, and correlated it with Precambrian crystalline basement rocks. This refractor (L4 in Figure 2), lies at depths of 5.6-6.7 km beneath post-Variscan rocks in the Bristol Channel Syncline, and at a depth of about 7.5 km beneath the north Devon coast. In the same study, Mechie and Brooks (1984) interpreted east-west onshore and nearshore seismic refraction lines (F2 in Figure 1) in the north Devon area as showing a high-velocity refractor with a velocity of 6.21 km s^{-1} at much shallower depths than the basal refractor (L4) referred to above. This shallower refractor (L2 in Figure 2) was considered to be an horizon in the Devonian or Lower Palaeozoic succession; it is at a depth of about 4 km at Minehead, Somerset, and rises westwards to about 2 km near Lundy Island. Mechie and Brooks (1984) interpreted these results as evidence for a velocity inversion, with the shallow high-velocity layer (L2) overlying a lower velocity (and lower density) layer (L3 in Figure 2). This in turn was considered to rest on the deep autochthonous basement (L4) detected from the north-south refraction lines.

The results of later offshore seismic reflection surveys by Brooks *et al*. (1988) provided evidence for the existence of a major Variscan thrust (the Bristol Channel Thrust) in the Palaeozoic basement beneath the Bristol Channel Syncline. Reactivation of this thrust was considered to have been responsible for the formation of the Central Bristol Channel Fault Zone (CBCFZ). The thrust is well seen on north-south seismic reflection profile 159 (Brooks *et al*., 1988, fig. 3), where it forms a reflection event dipping southward to two-way travel times of more than 2.0 s. This profile is reproduced in Figure 2 and its location shown on Figure 1.

Recognition of 'Reflector X'

Subsequently, a prominent reflector ('Reflector X') was recognized, on some profiles, in the hanging-wall block of the Bristol Channel Thrust at two-way travel times of about 0.7-1.1 s (Brooks *et al*., 1993). This reflector separates an upper, rather featureless, unit from one characterised by irregular, laterally discontinuous reflection events (Figure 2). Brooks *et al*. (1993) considered that Reflector X and the shallow high-velocity refractor represent a single interface extending beneath north Devon and west Somerset and along the southern Bristol Channel; it is truncated to the north against the south-dipping Bristol Channel Thrust (Figure 2). Its present geometry is affected by deformation associated with the formation of the Bristol Channel Syncline.

The velocity-depth model suggested by Brooks *et al*. (1993) is summarised in Figure 2a, together with the relationship of the reflection events, as interpreted from seismic profile 159. The interface represented by Reflector X and the shallow high-velocity refractor was considered by Brooks *et al*. (1993) to be a geological boundary of major significance, but, in the absence of boreholes, the lithology and age of the layers above (L1/Unit A, Figure 2a) and below (L2) this surface are uncertain. Brooks *et al*. (1993) considered that there were no major lithological units younger than the outcropping

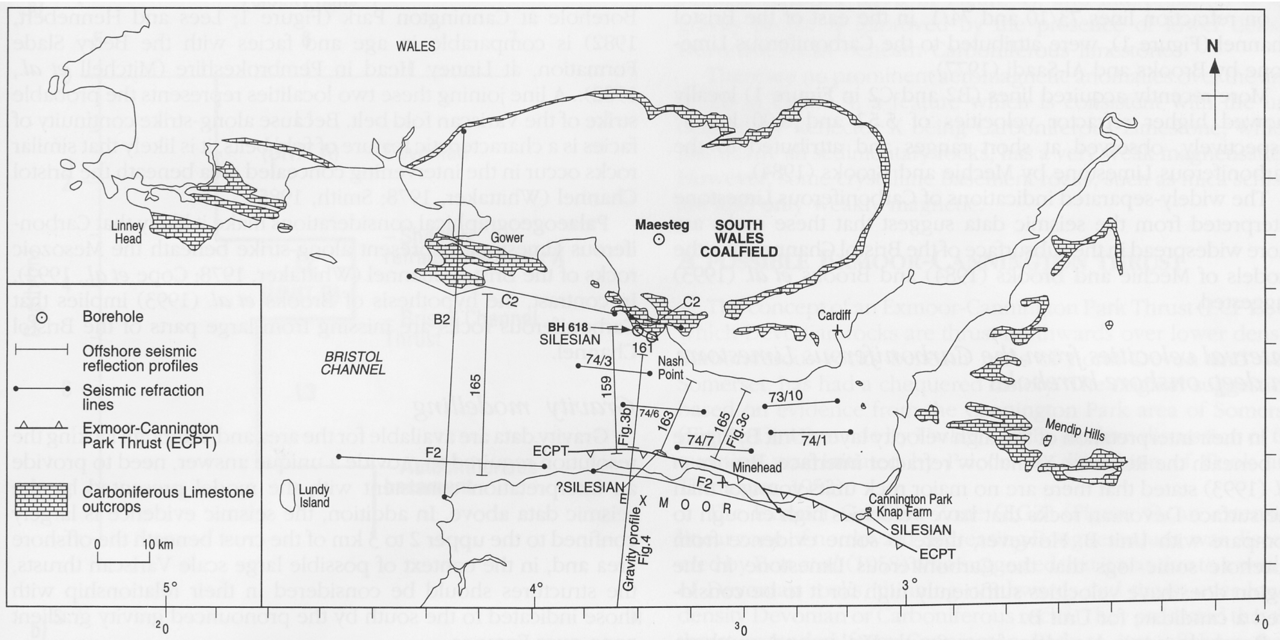

Figure 1. *Location map of Bristol Channel area, showing locations of seismic reflection and refraction profiles, and of deep boreholes referred to in the text, and the generalised outcrop of the Carboniferous Limestone. (ECPT - trace of postulated Exmoor-Cannington Park Thrust).*

Devonian rocks that could be reasonably correlated with the underlying high velocity layer (L2/ Unit B, Figure 2a). They therefore proposed that Unit B represented a major lithostratigraphical division older than the outcropping Devonian succession and in normal stratigraphical contact with it, and suggested that it could be pre-Devonian basement schists or gneisses. A tectonic (thrust) origin for the interface was not ruled out, but thought unlikely.

ALTERNATIVE INTERPRETATION OF THE HIGH VELOCITY UNIT

The high velocity unit (Unit B in Figure 2) is here interpreted as comprising Carboniferous Limestone. This interpretation is based on evidence from the following:

1. Seismic reflection and refraction data.
2. Interval velocities from the Carboniferous Limestone in deep onshore boreholes.
3. Onshore outcrops and structure.

A cross-section (Figure 4), based on interpretation of the regional gravity data illustrates the implications of the seismic model in a regional context. The gravity model covers the offshore Mesozoic basin structure, but extends southwards to include the important Exmoor gravity gradient zone (see below).

Reflection data

Our interpretation of the subsurface geology of the Bristol Channel, based on interpretation of seismic reflection profiles (Figure 1), is shown in the cross sections on Figure 3. Figure 3a shows seismic reflection profile 161 (also reproduced in Brooks *et al.,* 1988, fig. 4). Figure 3b is our interpretation of profile 161 and Figure 3c is our interpretation of profile 165, about 18 km farther east; profiles 161 and 165 have been extended southwards on to the onshore area.

Circumstantial evidence for the presence of Carboniferous Limestone beneath the Bristol Channel is provided by the character and distribution of seismic reflectors. A package of shallow sub-Mesozoic reflectors at the northern end of profile 161 (Figures 1 and 3a, b) can be tied with confidence to onshore outcrops of Carboniferous Limestone in South Wales, and a well- defined reflector at the top of this package was identified as the top of the Carboniferous Limestone by Brooks *et al.* (1988, fig. 4). A parallel, but lower and less well defined reflector, is possibly the base of the Carboniferous Limestone, indicating a thickness for that unit of about 850 m.

On seismic profile 161 there is difficulty in tracing the top Carboniferous Limestone reflector southwards across the large faults of the CBCFZ, owing to the poor quality of the reflections. However, farther east, seismic profile 165 (Figure 3c) shows a smaller throw on the CBCFZ and the top Carboniferous Limestone reflector can be picked and tied to Reflector X of Brooks *et al.* (1993) south of the CBCFZ. The evidence from seismic profiles therefore suggests that Reflector X marks the top of the Carboniferous Limestone (Figure 3a, b).

Refraction data

Brooks and James (1975) used refraction surveys to elucidate the structure of the Bristol Channel. Initially, they used velocities of 4.2-4.5 km s^{-1} for the Carboniferous Limestone; these were subsequently found to be too low (Brooks and Al-Saadi, 1977, p. 436). Brooks and Al-Saadi (1977) carried out seismic refraction studies using a velocity estimate of 5.1-5.3 km s^{-1} for the Carboniferous Limestone. Refraction line 74/3 (off Nash Point in South Wales, Figure 1) identified a refractor with a velocity of 5.77 km s^{-1}, which was considered by Brooks and Al-Saadi (1977) to be too high to be correlated with known Lower Carboniferous or Old Red Sandstone lithologies and was interpreted by them as probably indicating Lower Palaeozoic rocks (Brooks and AlSaadi, 1977). However, seismic reflection profile 161 intersects refraction line 74/3 (Figure 1) and shows a top Carboniferous Limestone reflector (Brooks *et al.,* 1988, fig. 4) dipping south from shallow depth (Figure 3a). In the light of this seismic reflection evidence, the 5.77 km s^{-1} refractor is reinterpreted as the top of the Carboniferous Limestone. Refraction line 74/6 (Figure 1) also encountered a high velocity refractor (5.95 km s^{-1}) which was correlated by Brooks and Al-Saadi (1977) with the basal layer (velocity 5.77 km s^{-1}) on line 74/3 and interpreted by them as due to Lower Palaeozoic rocks. However, this refraction line is also intersected by seismic profile 161 and the refractor is therefore also reinterpreted as the top of the Carboniferous Limestone. Refraction line 74/7 proved a refractor with a velocity of 5.54 km s^{-1} at a depth of less than 800 m which, by comparison with seismic reflection profile 165, which it crosses, is probably the top of the Carboniferous limestone

Refractors of 5.34 km s^{-1} and 5.25 km s^{-1} on refraction lines 73/10 and 74/1, in the east of the Bristol Channel (Figure 1), were attributed to the Carboniferous Limestone by Brooks and Al-Saadi (1977).

More recently acquired lines (B2 and C2 in Figure 1) locally showed higher refractor velocities of 5.52 and 6.00 km s^{-1} respectively, observed at short ranges and attributed to the Carboniferous Limestone by Mechie and Brooks (1984).

The widely-separated indications of Carboniferous Limestone interpreted from the seismic data suggest that these rocks are more widespread in the subsurface of the Bristol Channel than the models of Mechie and Brooks (1984) and Brooks *et al.* (1993) suggested.

Interval velocities from the Carboniferous Limestone in deep onshore boreholes

In their interpretation of the high velocity layer (Unit B, Figure 2) beneath the Reflector X/shallow refractor interface, Brooks *et al.* (1993) stated that there are no major rock units younger than the surface Devonian rocks that have velocities high enough to compare with Unit B. However, there is some evidence from borehole sonic logs that the Carboniferous Limestone in the region does have velocities sufficiently high for it to be considered a candidate for Unit B.

Borehole sonic log data from South Wales and southern England indicate that the Carboniferous Limestone contains substantial intervals of limestone with sonic velocities of 6.2 km s^{-1}. In the Knap Farm Borehole [ST 2479 4011] at Cannington Park, Somerset (Figure 1), the Carboniferous Limestone has an interval velocity of 6.0 km s^{-1} from 150 to 800 m below surface, with the interval between 630 and 700 m depth having velocities of 6.42 km s^{-1} (Edmonds and Williams, 1985). In the Maesteg Borehole [SS 8528 9245] in South Wales (Figure 1), the Carboniferous Limestone at 800-1300 m below surface has an average interval velocity of 5.78 km s^{-1}, with the middle 400 m of the succession averaging 6.0 km s^{-1}.

This evidence for high Carboniferous Limestone velocities in boreholes is apparently contrary to the suggestion of Brooks et al. (1993) that there are no lithological units younger than surface Devonian rocks with velocities high enough to be correlated with Unit B.

The average sonic velocity in the Carboniferous Limestone of the Maesteg Borehole (5.78 km s^{-1}) is significantly higher than refractor velocities derived from long refraction lines in South Wales (for example, Bayerley and Brooks, 1980, lines 2 and 3; Mechie and Brooks, 1984, lines B2, J and I) where velocities greater than 5.3 km s^{-1} were encountered only over very short sections of line over the Carboniferous Limestone. However, evidence from refraction lines in the Bristol Channel, noted in the section on refraction data above, indicates that refractor velocities attributable to the Carboniferous Limestone of the Bristol Channel area range between 5.25-5.95 km s^{-1}. The relationship between refractor and sonic log velocities is not precisely known. Probably sonic-derived velocities are higher than refractor velocities (M. Brooks and M. Miliorizos, personal communication). Despite the difficulties in comparing the two kinds of data, there appear to be grounds for believing that velocities of the Carboniferous Limestone may approach those in the high velocity unit beneath Reflector X (Unit B in Figure 2)

Comparison with onshore outcrops and structure

Interpretation of Unit B as Carboniferous Limestone is consistent with the location of the Bristol Channel Syncline along-strike from the islands of Flat Holm and Steep Holm, the known onshore outcrops of Carboniferous Limestone at Cannington Park and in the Mendip Hills, and with the probable presence of Silesian rocks in the Bristol Channel. Reflector X is located between the CBCFZ and the north Devon coast, along-strike from the Cannington Park inlier (Figure 1) which is critical for the interpretation of the Bristol Channel data.

The 220 m-thick Waulsortian Reef proved in the Knap Farm Borehole at Cannington Park (Figure 1; Lees and Hennebert, 1982) is comparable in age and facies with the Berry Slade Formation, at Linney Head in Pembrokeshire (Mitchell *et al*., 1982). A line joining these two localities represents the probable strike of the Variscan fold belt. Because along-strike continuity of facies is a characteristic feature of fold belts, it is likely that similar rocks occur in the intervening concealed area beneath the Bristol Channel (Whittaker, 1978; Smith, 1985).

Palaeogeographical considerations make it likely that Carboniferous Limestone is present along-strike beneath the Mesozoic rocks of the Bristol Channel (Whittaker, 1978; Cope *et al*., 1992). In contrast, the hypothesis of Brooks *et al*. (1993) implies that Carboniferous rocks are missing from large parts of the Bristol Channel.

Gravity modelling

Gravity data are available for the area and, although lacking the resolution required to provide a unique answer, need to provide an interpretation consistent with the model presented by the seismic data above. In addition, the seismic evidence is largely confined to the upper 2 to 3 km of the crust beneath the offshore area and, in the context of possible large scale Variscan thrusts, the structures should be considered in their relationship with those indicated to the south by the pronounced gravity gradient zone over Exmoor.

A gravity profile (Figure 4) has been modelled along, and as a southerly continuation of, profile 161 (Figures 1, 3), using constraints imposed by the geological and seismic evidence, and densities derived from other surveys (summarised in Whittaker and Green (1983), and Edmonds and Williams (1985)). There is an overlap in density values between the Mesozoic and Carboniferous rocks, both of which have relatively high values, and the Devonian sequence. Density contrasts are also present between different Devonian lithologies on Exmoor.

The model suggests that the main cause of the Exmoor Gradient Zone (EGZ) (discussed below) does not lie within the upper few kilometres of the crust, but is a more deep-seated density change, probably associated with the underlying Lower Palaeozoic and Precambrian rocks. This change is modelled as the juxtaposition of two basement types along a structure related to the thrusts and reverse faults in the upper part of the crust. Basement 1 (B1), occurring to the south, has a higher density than Basement 2 (B2), found to the north (Figure 4). The high density basement beneath Exmoor probably extends across much of south-west England, giving rise to the high Bouguer anomaly values characteristic of the region. This conclusion is supported by the observation that density contrasts of 0.15 Mgm^{-3} are needed between the pre-Devonian basement and the Variscan granites (density typically 2.60 Mgm^{-3}) to explain satisfactorily the observed gravity lows (Bott *et al*., 1958).

A southward thinning of Devonian strata (D in Figure 4) is likely, but cannot be constrained closely by the gravity evidence; increasing the thickness of the lower density Devonian rocks necessitates compensation, for example in the calculated profile, by increasing the thickness or density of the higher density basement.

Although the Mesozoic rocks in the Bristol Channel Basin produce a gravity low, its amplitude is not very great because of the relatively high density of these rocks. It was necessary to introduce a wedge of low density (2.60 Mgm^{-3}) material (Figure 4) beneath the southern part of the Bristol Channel which could represent a sequence of lower/pre-Devonian rocks thickened beneath the CBCFZ.

It can be seen that, owing to its location near the minimum gravity anomaly, the thrust block (TB in Figure 4) needs to be of relatively low density, in addition to having high velocity and low magnetisation. Among the alternative explanations, it is difficult to correlate TB with pre-Devonian basement; to the south, for example, the basement needs to have a high density to explain the increase of gravity values observed across Exmoor. The block cannot be part of the

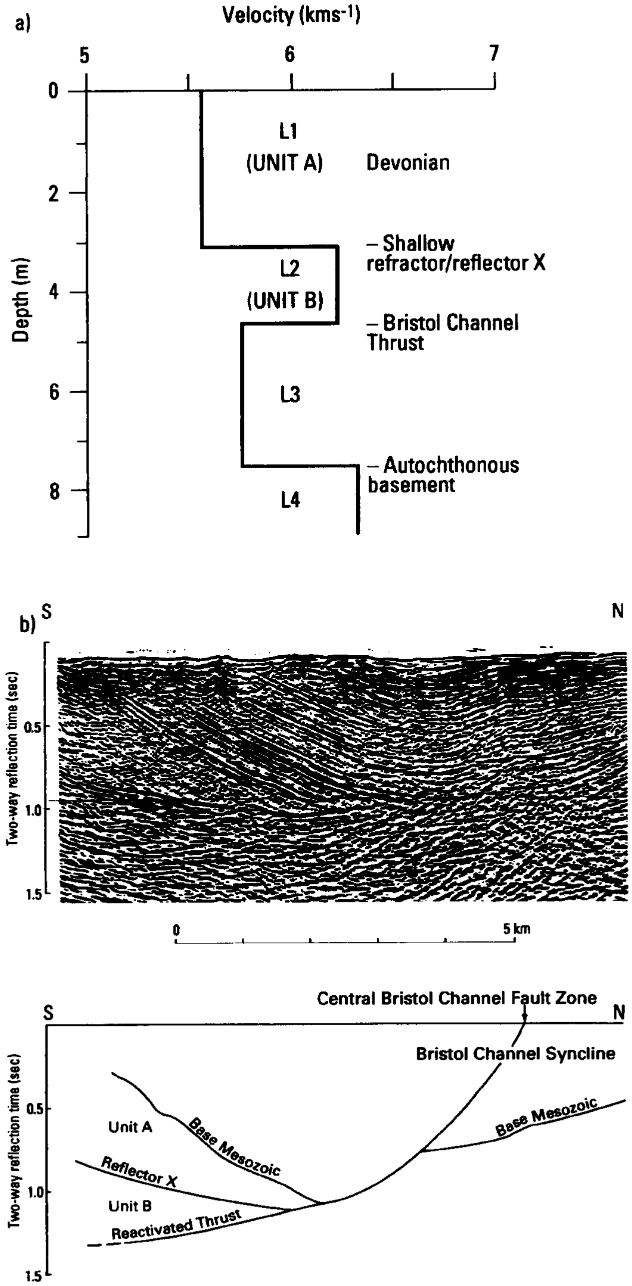

Figure 2. *(a) Velocity-depth model for west Somerset, north Devon and the Southern Bristol Channel, with interpretation after Brooks et al. (1993); L1 - L4 correspond to seismically defined layers recognised by Mechie and Brooks (1984). (b) Seismic reflection profile 159 with geological interpretation, after Brooks et al. (1993); the location of the profile is shown on Figure 1. Seismic data used by courtesy of Geco-Prakla.*

basement to the north, mainly because of the opposed direction of thrusting, which would be required to emplace it, but also because tapering of TB southwards from less than 2 km at the coast to zero will not, itself, explain the observed gravity change over Exmoor. In addition, the seismic refraction evidence, summarised by Mechie and Brooks (1984), shows that the deeper high velocity basement (probably equivalent to the lower density basement B2 in Figure 4) is not connected to TB beneath the Bristol Channel. In the interpretation (Figure 4), the density ascribed to TB (2.70 Mgm^{-3}) is consistent with the presence of a Carboniferous Limestone sequence. This unit has been continued southwards beneath the coast to form the high velocity refractor (HVR in Figure 4), and interpretation of the gravity profile is improved by the presence of lower density Devonian rocks beneath Carboniferous limestones.

There are no prominent aeromagnetic anomalies over the area of TB in Figure 4, a feature which is consistent with the unit defined by Reflector X being Carboniferous Limestone, which, like nearly all sedimentary rocks, has a very weak magnetisation. However, some crystalline basement rocks, such as mica schists, are also only weakly magnetic.

A POSSIBLE EXMOOR-CANNINGTON THRUST

The concept of an Exmoor-Cannington Park Thrust (ECPT), on which Devonian rocks are thrust northwards over lower density Carboniferous rocks beneath parts of north Devon and west Somerset, has had a chequered history. The original suggestion, based on evidence from the Cannington Park area of Somerset (Figure 1), was made by Ussher (1891). Modern discussion of the question was initiated by Falcon (in discussion of Cook and Thirlaway, 1952).

The Exmoor Gradient Zone (EGZ) (Figure 4), an extensive linear zone of northward-decreasing Bouguer values, was discovered by Bott *et al*. (1958) who suggested that it was due to a wedge of Devonian rocks, thinning northwards and thrust over lower density Devonian or Carboniferous rocks. They predicted that the thrust extended from Cannington Park to just offshore from Porlock, and westwards of there diverged from the coast. The acquisition of offshore gravity data for the Bristol Channel area (Brooks and Thompson, 1973) led to the recognition of the pronounced gravity low associated with the low density Mesozoic rocks in the Bristol Channel Syncline. Reinterpretation of the EGZ in the light of these new gravity data produced some modification to the thrust model (Brooks and Thompson, 1973).

The discovery by Brooks *et al*. (1977) of a high velocity refractor, identified as the top of the Lower Palaeozoic/Precambrian, at a depth of only about 2 km beneath the north Devon coast, resulted in an alternative model in which the EGZ was explained, without invoking thrusting, by assuming that Lower Palaeozoic/ late Precambrian rocks had a low density and formed the core of the west-north-west-trending Lynton Anticline. However, this was subsequently modified by the discovery that the high velocity refractor was underlain by lower velocity material (Brooks *et al*., 1993) (Figure 2a).

Structural relationships at Cannington Park

The structural relationships between the various inliers of Palaeozoic rocks in the Cannington Park area of Somerset (Figure 1) have been a significant factor in discussions of the thrust hypothesis. The Cannington Park inlier [ST 245 405] of Carboniferous Limestone (Dinantian) is separated by only 200 m from a west-south-west trending inlier [ST 244 398] of Rodway Siltstone (Namurian). Boreholes drilled in the area showed that the contact between the Rodway Siltstone and the Cannington limestone is a normal fault, with a throw of at least several hundred metres. Whittaker (1975) noted that the simplest structural explanation of the relationship between the Namurian and the Dinantian rocks was high angle normal faulting; however, he noted that the low angle (10°) contact proved in one of the boreholes might be a lag fault, subsequently affected by high-angle normal faulting.

South of the Cannington Park area, Rodway Siltstone is also present in another inlier [ST 232 392] at Swang Farm. A major fault, downthrowing several thousands of metres to the north, may be present between the Swang Farm inlier and an inlier [ST 226 387] of Middle-Upper Devonian rocks near Currypool Farm. Whittaker (1975) noted that the fault could be normal and dip to the north or could be the near-surface trace of the Exmoor-Cannington Park Thrust and dip to the south.

The evidence from Cannington Park is therefore equivocal, but is sufficient to suggest the possibility of a south-dipping thrust between the Devonian and Carboniferous strata. A thrust interpretation is shown on cross section 3 of the BGS Bristol Channel

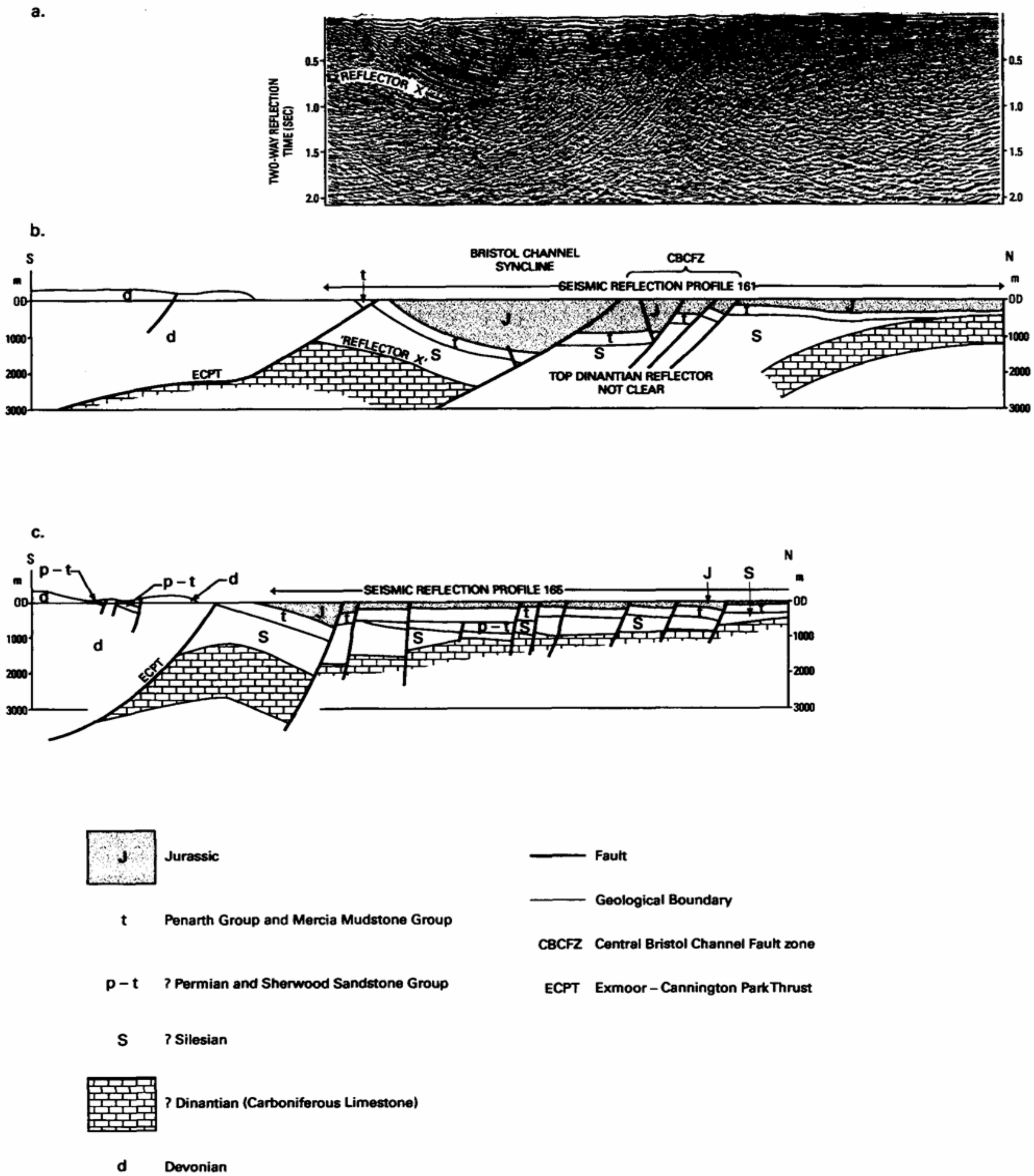

Figure 3. *(a) Seismic reflection profile 161. Geological interpretations of seismic reflection profiles 161 (b) and 165 (c), with extensions southwards beneath contiguous onshore areas. Location of profiles indicated on Figure 1. Seismic data used by courtesy of Geco-Prakla.*

1:250 000 Solid Geology sheet (BGS, 1988).

Proposal for an Exmoor-Cannington Park Thrust

If the interpretation of Reflector X as the top of the Carboniferous Limestone is correct, then the close proximity of Devonian rocks above, both onshore and offshore, suggests that a thrust separates them from Reflector X. The trace of the proposed thrust is considered to pass offshore south of seismic profile 165 (Figures 1, 3). It may subcrop beneath Triassic strata between the southern end of profile 165 and the Devonian outcrop which is interpreted to be in the hanging-wall of the thrust, at the sea bed near the coast. Farther west, a fault at the southern ends of seismic profiles 163, 161, 159 (Brooks *et al*., 1993, fig. 3) and 149 (Brooks *et al*., 1988, fig. 2) is possibly the Mesozoic reactivation of the proposed thrust. This interpretation results in the Devonian and Carboniferous strata having the same relationship in the offshore area as that at Cannington Park. The trace of the proposed thrust is probably offset by strike-slip faults such as the Watchet Fault (Dart *et al*., 1995).

As noted above, Mechie and Brooks (1984) identified a 6.2 km s^{-1} refractor beneath north Devon, and attributed it to an horizon in the Devonian or Lower Palaeozoic succession. Brooks *et al*. (1993) depth converted Reflector X, in a way which we have not been able to replicate, resulting in it being near-horizontal or dipping south (Brooks *et al*., 1993, fig. 5a), and merging Reflector X and the 6.2 km s^{-1} refractor as one interface. Using their interval velocities on seismic

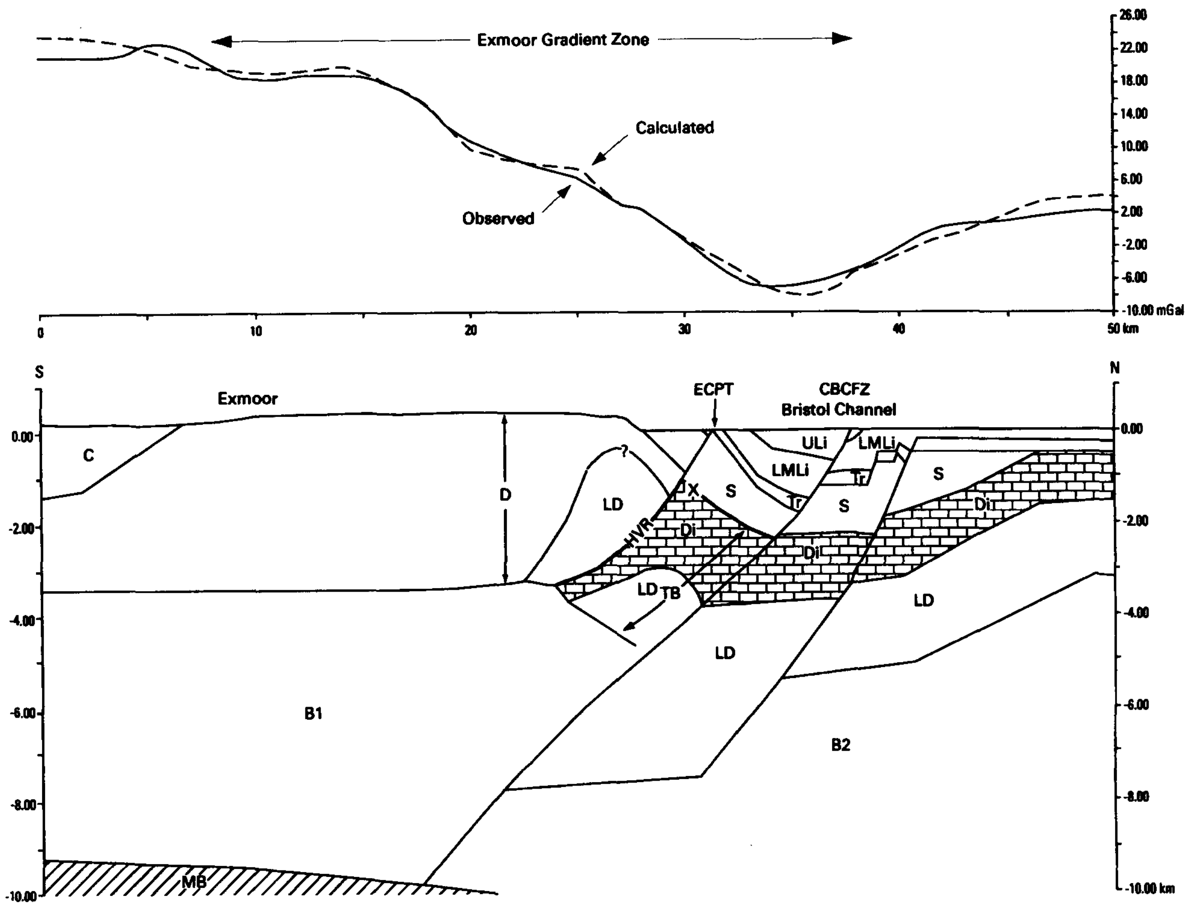

Figure 4. *Bouguer gravity anomaly profile acreoss Exmoor and the Bristol Channel, with interpretation of geology. Location of profile, which is partly coincident with the line of seismic reflection profile 161, is shown on Figure 1.*
Density ranges (in Mgm^{-3}) for componenbts of model: M - Mesozoic rocks (2.45-2.55), Carboniferous: Di - Dinantian (2.72). S - Silesian (2.50), D - Devonian (undifferentiated) (2.55-2.70), LD - lower/pre-Devonian low density rocks (2.60), BI - basement 1 (2.78), B2 - basement 2 (2.70), MB - magnetic basement (2.78, magnetic susceptibility 0.03 SI units). Other abbreviations: C: Lower Carboniferous (non-Carboniferous Limestone facies), Tr: Triassic rocks, LMLi: Lower and Middle Lias, Upper Lias.
X - seismic Reflector X, HVR - high velocity refractor, TB - thrust block (shallow high velocity layer).
Background field 0 mGal, background and Bouguer correction density 2.70 Mgm^{-3}.

profile 159, we calculate that Reflector X dips north from a depth of about 1800 m to a depth of 1925 m, where it is truncated by the CBCFZ (Figure 3). We interpret the 6.2 km s^{-1} refractor of Mechie and Brooks (1984) as the Exmoor-Cannington Park Thrust, which thus juxtaposes relatively low velocity Devonian strata above, against a high velocity refractor below, possibly representing Carboniferous Limestone. The postulated top of the Carboniferous Limestone (Reflector X) lies in the footwall of the ECPT. Its relationship to the 6.2 km s^{-1} refractor can be accommodated, without invoking any further structural complication, if the total thickness of the complete Carboniferous Limestone section was about 1500 m. The Knap Farm Borehole [ST 2479 4011] at Cannington Park proved 1100 m of Carboniferous Limestone, so that such a thickness is not improbable.

AGE OF THE SEQUENCE BETWEEN REFLECTOR X AND THE BASE OF THE MERCIA MUDSTONE GROUP: IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Our interpretation of seismic profiles suggests that Silesian and Dinantian strata form the subcrop beneath the Mesozoic Bristol Channel Basin (Figure 3). Silesian, probably Westphalian rocks, were proved offshore near Porthcawl, close to the northern end of seismic reflection profile 161 (Figure 1) (BGS, 1988, shallow core samples 616 and 618). Seismic profile 163 (Figure 1) indicates that possible Upper Carboniferous strata, lying above Reflector X, may have a small seabed exposure [SS 847 514] about 3 km offshore and 6 km north-west of Porlock (Figure 1).

Permian and Sherwood Sandstone Group (Triassic) rocks may be present locally (Tappin *et al.*, 1994, figs. 24a and b), but their thicknesses are not great in boreholes to the east and west, and they are overlapped by the Mercia Mudstone Group (Triassic).

The Mesozoic hydrocarbon potential of the Bristol Channel Basin has been discussed by Kamerling (1979) and Nemcok *et al.* (1995). No hydrocarbon shows have so far been reported from wells drilled in the western part of the basin, owing, firstly, to insufficient hydrocarbon generation from the patchily-developed, rather low quality Lias Group source rocks, and, secondly, to the lack of suitable traps existing at the time of hydrocarbon generation. In addition, there is an almost complete lack of suitable reservoir rocks. Near-mature Lias Group crops out in South Wales and Somerset (Cornford, 1986). At Kilve on the Somerset coast, a 'Lower Lias' bituminous shale was worked as a source of oil, yielding 40 gallons (182 litres) per volumetric ton (1.15 cubic metres) (Whittaker and Green, 1983).

The possible presence of Silesian rocks beneath the offshore area could offer older source rocks. Maturities are variable (Smith, 1993); south of the proposed Exmoor - Cannington Park Thrust, the rocks are overmature, but between that thrust and South Wales, Silesian rocks are likely to lie within the gas window, although the effects of Mesozoic burial, which was substantial, are not known from actual measurements (Maddox *et al.,* 1995). The presence of Silesian rocks, combined with the possible existence of potential Permo-Triassic sandstone reservoirs (Figure 3c) capped by the Mercia Mudstone Group, is significant for the hydrocarbon prospectivity of the area. Waulsortian reefs. productive in the Williston Basin, USA (Mitchell, 1995), and so far disappointing as a reservoir in Europe, offer a higher risk target.

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