Evidence for structural controls on the Lower Jurassic (Pliensbachian-Toarcian) succession at Chapel Cross, South Cadbury, Somerset, UK

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Temporary exposures in 1989, during improvements to the A303 trunk road near South Cadbury, Somerset, U.K. revealed a new section through part of the Dyrham Formation (formerly Pennard Sands), the Marlstone Rock Formation, the Barrington Limestone Member and the base of the Bridport Sand Formation. The Dyrham Formation contained two intraformational pebble beds that have not been observed elsewhere in south Somerset, while the Marlstone Rock Formation is anomalously thin when compared even with the condensed successions of the Yeovil region. In contrast, the Toarcian succession includes bituminous paper shales at its base, succeeded by the typical mudstone-limestone alternations of the Barrington Limestone Member, and is much more like the succession at Ilminster than the more condensed sequence, near Yeovil, that intervenes between these two areas. Tectonic structures exposed at various scales on the site provide further evidence of strike-slip faulting within the Somerset Basin.

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Introduction

The Lower Jurassic stratigraphy of the Central Somerset Basin is known in far less detail than that of the Dorset Basin to the south, where the extensive coastal sections exposing the complete Lower Jurassic succession have been the focus of research for more than two centuries (Simms *et al*., 2004). There are few natural exposures of the Lias Group in Somerset and much of our knowledge of the succession here has been dependent on artificial exposures, but the numerous quarries that once existed, described by the likes of Charles Moore (1867) or Horace Woodward (1893), have long since become overgrown or been infilled. Across much of inland Somerset recent exposures have arisen only occasionally, and often all too briefly, as a result of civil engineering projects such as road improvements or pipeline trenches. One such exposure occurred during improvements to the A303 trunk road at Chapel Cross (Figure 1), near the village of South Cadbury, in 1989 when it was documented by one of the authors (HCP). It exposed a section from the Dyrham Formation (Upper Pliensbachian) to the Bridport Sand Formation (Toarcian) of the local Lias Group succession. This part of the Lias Group is relatively well documented in the Yeovil and Ilminster area further south, albeit in many cases based on long defunct exposures (Moore, 1867; Wilson *et al*., 1958; Woodward, 1893; Simms *et al*., 2004) but more poorly known to the north of Yeovil. Indeed, Woodward (1893) stated that "*of the lower beds* [Dyrham Formation of modern terminology] *we have little information*", and commented that "*from South Cadbury northwards…to Doulting and the Mendip Hills we have no sections showing the Upper Lias*". Consequently any new information from this region can, potentially, add to our knowledge of the history of the Somerset Basin.

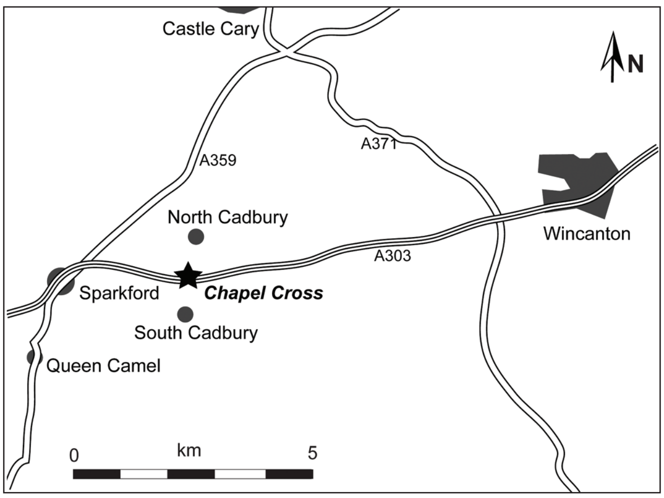

Figure 1. *Location map for the temporary exposure on the A303 at Chapel Cross, south Somerset.*

Site description and stratigraphical succession

A shallow road cutting exposed strata along a section extending roughly WSW-ENE for approximately 500 m along the A303 trunk road. Field sketches were made of the northern side of the cutting (Figure 2a) and of the strata and tectonic structures exposed in the bed of the road (Figure 2b). Representative sections were logged (Figure 3 and Tables 1 and 2) and samples were collected of some unusual sedimentological features observed within the Dyrham Formation.

The strata dip mostly eastwards at 10°-14°, with Dyrham Formation silty clays exposed at the west end of the site and a thin veneer of Bridport Sands Formation exposed at the eastern end, but locally the dip may reduce to as little as 4° with a dip to the north. A fault-bounded horst block of Dyrham Formation silty clays interrupts the general easterly dip and extends for about 40 m along the north side of the cutting, (Figure 2).

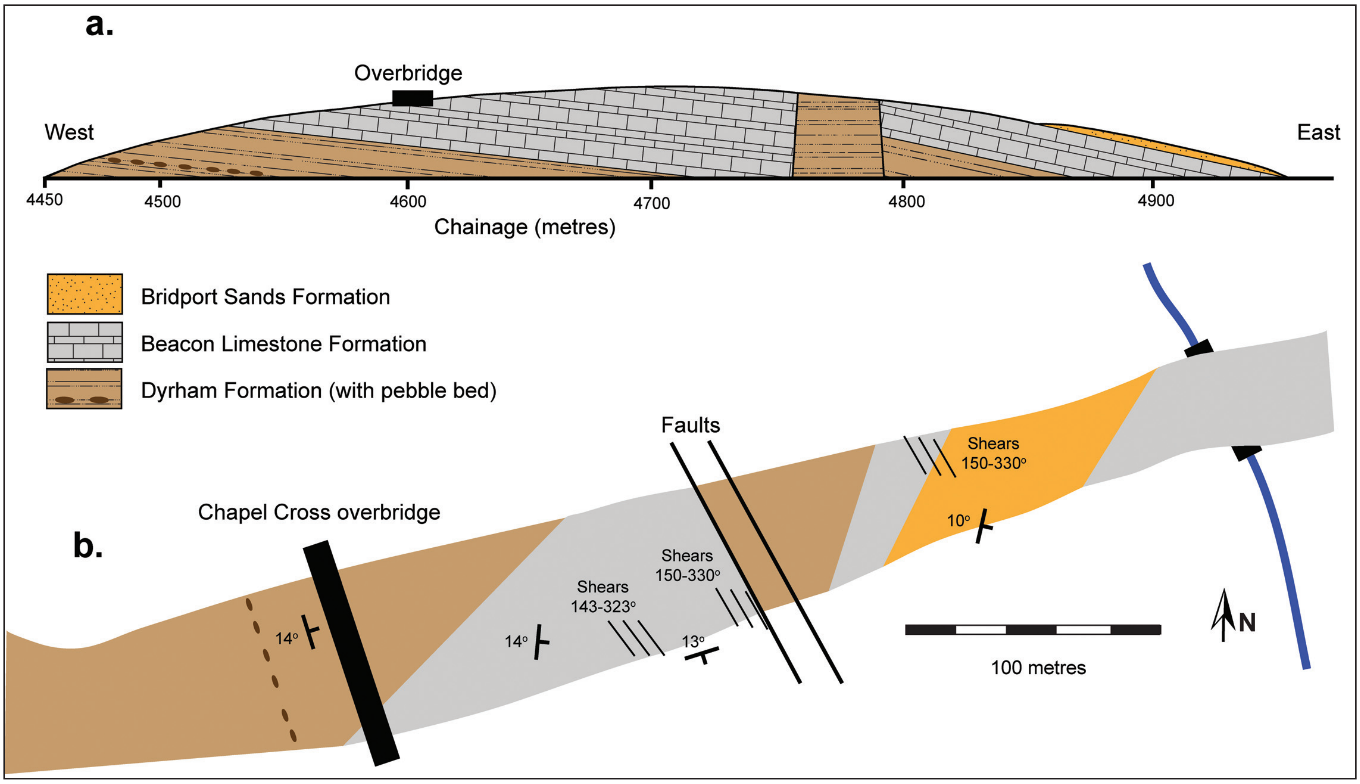

Figure 2. *(**a**) Sketch section of the exposure on the north side of the road cutting. (**b**) Sketch map of the lithostratigraphic units and tectonic structures exposed in the floor of the road cutting.*

Unit		Thickness (m)
Whitby Mudstone Formation, Barrington Limestone Member		
14	Clay	0.26
13	Rubbly limestones and clay	0.70
12	Limestone, *Dactylioceras* sp.	0.10
11	Clay *Harpoceras* cf. *subplanatum* (Oppel), *Hildoceras* sp., *Dactylioceras* sp.	0.10
10	Limestone	0.06
9	Clay	0.07
8	Limestone	0.05
7	Clay with thin impersistent limestone, *Hildoceras bifrons*	0.28
6	Ooidal limestone	0.10
5	Limestone, *Hildoceras bifrons*	0.24
4	Clay with small limestone nodules, *Hildoceras* cf. *bifrons*	0.14
3	Limestone	0.05
2	Nodular, ooidal limestone in grey clay, nautilus	0.21
1	Grey clay	0.02

Table 1. *Stratigraphical succession for section 1.*

Unit		Thickness (m)
Whitby Mudstone Formation		
13	Saurian and Fish Bed (Moore, 1867): grey-hearted, yellow coated, nodular bed (nodules up to 0.48 m across and 0.16 m thick), some with *Chondrites* in upper 10 cm	0.16
12	Black paper shales deformed below calcareous nodules, *Chondrites* in upper part between the nodules	0.74
11	Prominent tabular mudstone with planer top and bottom surfaces	0.08
10	Black and brown paper shales	0.48
Marlstone Rock Formation		
9	Grey-hearted, oolitic siltstone, broken shell fragments, crinoidal debris, bivalves, many belemnites, becomes ferruginous orange-brown where weathered near surface	0.25
Dyrham Formation		
8	Grey silty blocky clay becoming more clayey in top 0.61 m; septarian nodules (0.08 m thick) 3.35 m above base; nodules (0.16 m) 2.40 m above base; scattered grey oval nodules (0.07 m) rest on 0.8 m of grey silts at base	4.43
7	Ferruginous bed with decalcified patches, partly oolitic with crinoidal debris, bivalves, shell fragments; elsewhere hard grey-hearted nodular siltstone	0.18
6	Grey, silty, blocky clays	4.50
5	Upper pebble bed: grey nodular siltstone with rounded semi-oval flattish, bored pebbles of cross-laminated fine sandstone	0.30
4	Silty clays	0.60
3	Lower pebble bed: nodular bed with bored and oyster encrusted pebbles of reworked burrow fills	0.11
2	Hardish grey silt	0.09
1	Siltstone with planer top surface and undulating lower surface	0.13

Table 2. *Stratigraphical succession for section 2.*

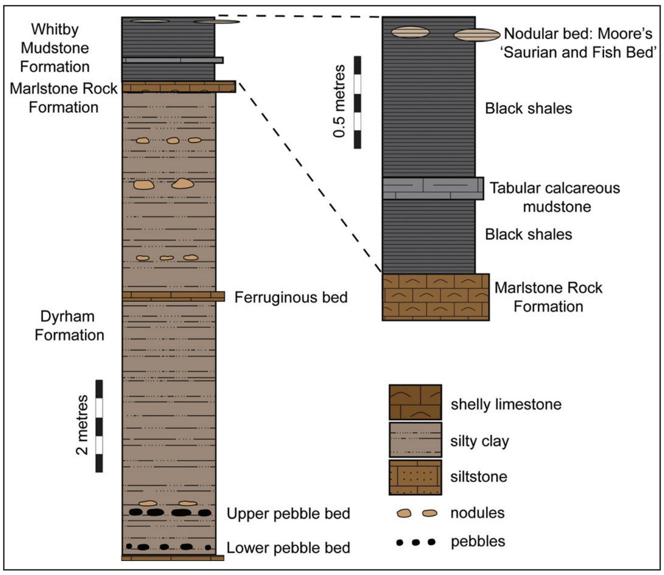

Figure 3. *Stratigraphical section from the Dyrham Formation to the Whitby Mudstone Formation exposed at the western end of the cutting. The Toarcian part of the section has been expanded in the column on the right. Note the two different scales.*

The stratigraphical succession for section 1 (Table 1) was recorded on the north side of the road cutting east of the overbridge, from ST 6323 2626 to ST 6335 2635 and had a dip of 10° to the east. The stratigraphical succession for section 2 (Table 2) was recorded at the western end of the cutting from ST 6280 2622 to the overbridge at ST 6313 2628. Beds dip at 172°/14°E at ST 6311 2627 on south side of cutting and at 072°/4°N at ST 6320 2627 on the north side of cutting.

Discussion

Stratigraphy

A conspicuous feature of the Toarcian succession at Chapel Cross is the presence of more than 1.2 m of black bituminous paper shales between the top of the Marlstone Rock Formation and the base of the typical limestone and mudstone alternations of the Barrington Limestone Member (Figure 4). Yellow-weathering, laminated, limestone nodules in the upper part of these paper shales probably represent the Saurian and Fish Bed of Moore (1867). As such the Toarcian succession here resembles the succession in the Ilminster area, to the south, as described by Moore (1867), Wilson *et al.* (1958), Howarth (1992) and Simms *et al.* (2004), and is less obviously condensed than in the intervening Yeovil area. At Stoke-Sub-Hamdon west

Figure 4. *The Whitby Mudstone Formation exposed on the south side of the road cutting east of the overbridge. The lower part of the face is in dark bituminous mudstones while the upper part is typical Barrington Limestone Member facies of rubbly limestones. The large yellow nodules at the boundary between these two facies are the Saurian and Fish Bed of Moore (1867). Total height of the face is c. 2 m.*

of Yeovil [ST 1768 4727], the Barrington Limestone Member is just 1.6 m thick, shows evidence of reduced sedimentation, synsedimentary erosion and ferruginous algal stromatolites, and rests directly on the Marlstone Rock Formation (Wilson *et al.*, 1958). However, thickness variations in the Marlstone Rock Formation do not follow the same pattern, thinning from more than 2 m in the Ilminster area (Moore, 1867; Howarth, 1992) to 0.6 m at Stoke-sub-Hamdon and, still further north at Chapel Cross, to just 0.25 m.

The underlying Dyrham Formation is similar to that found in the Yeovil area further south, being mainly silty clays with several horizons of small claystone/ironstone nodules. A ferruginous bed, partly oolitic with crinoidal debris, bivalves and shell fragments, but decalcified in places, occurred 4.43 metres below the base of the Marlstone. This may perhaps correlate with a similar, though thicker, band seen at Burrow Hill, north-east of Barrington (Wilson *et al.*, 1958). The key feature of interest in the Dyrham Formation at Chapel Cross was the presence of two pebble beds exposed near the base of the section west of the overbridge (Figures 2 and 3).

The clasts in these pebble beds are clearly intraformational, being of typical Dyrham Formation lithologies, and were derived from erosion of local pre-existing sediments rather than being extraformational and transported from further afield. As such they represent worn and bioeroded debris from erosional periods that exhumed previously lithified siltstone bands, burrow fills and nodule horizons within the Dyrham Formation. Similar reworked pebbles are present in the Dyrham and Marlstone Rock formations of the Severn Basin in Gloucestershire (Simms, 1990; Palmer, 1971) and in the Eype Nodule Bed of the Dyrham Formation on the Dorset coast (Ensom, 1985; Hesselbo and Jenkyns, 1995), but none has been observed previously in the Dyrham Formation of the Somerset Basin. Close examination of examples collected at Chapel Cross can reveal something about the extent of erosion in this region during deposition of this part of the succession. The largest pebble, from the upper pebble bed (Bed 5 of section 2), is a rounded flat slab penetrated by various lithophagid bivalve crypts on one, smooth and gently convex, face (Figure 5a) and encrusted on the other, somewhat rougher, face by a scattering of serpulid worm tubes (Figure 5b). In section it is a fine-grained, cross-laminated sandstone. This sandstone bed must have been buried sufficiently deeply to become lithified before it was exhumed and its upper surface bored into by lithophagid bivalves. The edges of the lithophagid holes are raised slightly above the surrounding surface, suggesting that this exhumed surface experienced further erosion during or after the lithophagid crypts were made. The opposite face of this slab (Figure 5b), inferred to be the lower surface, is rougher than the upper surface and encrusted with numerous small serpulid tubes. The fairly even distribution of serpulids across the surface suggests that erosion continued until the slab became detached from the underlying substrate to lie loose on the seabed, leaving sufficient gaps beneath for the serpulids to gain access. The absence of any lithophagid crypts on this surface indicates that it was not overturned during its time exposed on the sea floor and was eventually reburied as deposition resumed. The serpulids and surrounding rock surface are encrusted with a patchy thin layer of iron pyrite indicating reburial under a different, anoxic or dysaerobic, depositional/diagenetic regime compared with the probably better oxygenated benthic conditions that prevailed during the original deposition of this fine sandstone.

The lower pebble bed (Bed 3 of section 2) is formed from fragments of pale-grey lithified burrow fills of various types embedded in pale brownish siltstone (Figure 6). Most of the burrow fills appear to represent squat or elongate barrel-shaped vertical burrows a centimetre or two across and now broken into sections several centimetres long. Several examples of these were observed in situ in the Dyrham Formation at this site. Some are broad blunt cones that can perhaps be assigned to the ichnogenus *Kulindrichnus* (Hallam, 1960) while others appear to be worn fragments of large branching horizontal burrow systems. Most are perforated by irregular cavities up to a few millimetres across and all are encrusted with small

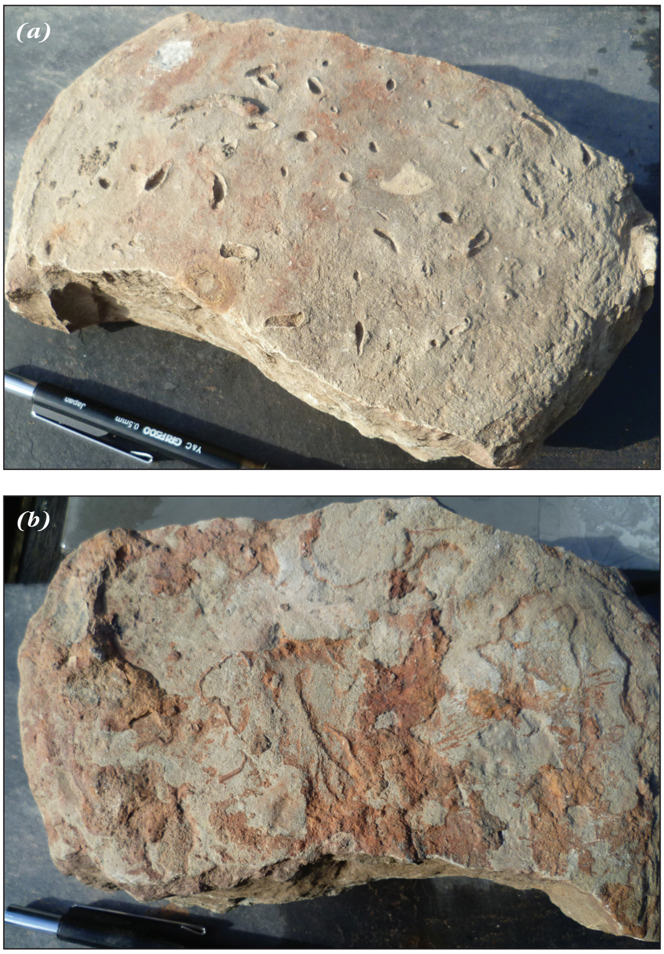

Figure 5. *Reworked sandstone clast from the upper pebble bed, Dyrham Formation, of section 2.* ***(a)*** *Upper surface penetrated by lithophagid borings.* ***(b)*** *Lower surface colonised by small serpulid worm tubes and patchily encrusted with pyrite.*

Figure 6. *Siltstone lens from the lower pebble bed, Dyrham Formation, of section 2 containing bored and encrusted burrow fills.*

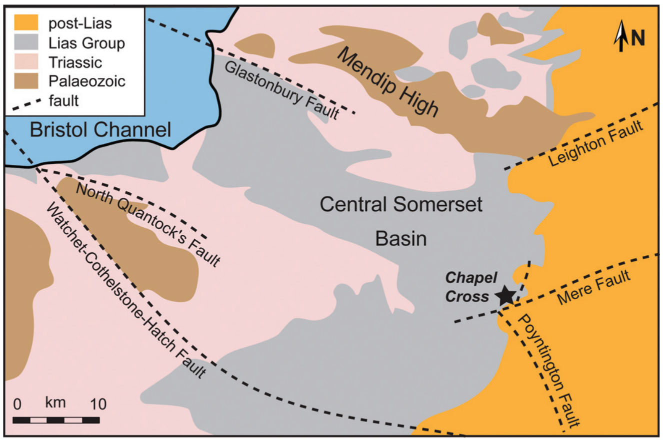

Figure 7. *Location of the Chapel Cross site in relation to the Somerset Basin and some of the main structural features. Note the site's close proximity to both the Mere and Poyntington faults.*

oysters. They lack the pyritic coating seen in the upper pebble bed but the enclosing siltstone does contain grey or ochraceous patches which appear to represent decomposed pyrite. These pebbles clearly indicate that burial of the burrow fills occurred to a sufficient depth for them to become lithified before erosion subsequently exhumed them on the sea floor, but the presence of pyrite within the enclosing siltstone, rather than as a crust on the pebbles, indicates a subtle difference in the diagenetic environment that accompanied reburial of the lower pebble bed compared with the upper one. Clearly these pebble beds testify to at least two significant episodes of erosion not previously observed in the Dyrham Formation of the Somerset Basin. Although now separated by less than a metre, they may represent a significant total stratigraphic gap both in terms of thickness and of time. The Coinstone, in the Sinemurian of the Dorset coast, is similar in some respects to these nodules (Hesselbo and Palmer, 1992) and represents a stratigraphic gap of more than an entire ammonite zone. However, in the absence of any biostratigraphic data associated with the pebble beds at Chapel Cross it is impossible to ascertain the scale of erosion here. It probably was at least several metres, or a depth sufficient for early diagenesis of the sandstone and burrow fills to occur, and may have been significantly greater, perhaps even tens of metres. As with the Coinstone in the Sinemurian of the Dorset coast, described by Hesselbo and Palmer (1992), the exhumation of the burrow fills and lithified units in the Dyrham Formation at Chapel Cross probably can be attributed largely to bioerosion by organisms similar to those that created the cavities that penetrate the pebbles.

In north Gloucestershire there were several episodes of erosion within the Dyrham and Marlstone Rock formations, the extent of which appears to have been associated with a series of parallel north-south faults within the Severn Basin. Periodic movement on one or more of these may have altered the depositional regime locally causing erosion, exhumation and subsequent reburial of earlier lithified horizons (Simms, 1990). The Eype Nodule Bed in Dorset shows still closer similarities to the Chapel Cross pebble beds, with exhumed Eype nodules experiencing encrustation and boring before being reburied in a different depositional regime that produced thin pyrite coatings on the nodules (Ensom, 1985). The extent of reworking of the Eype nodules appears to vary with proximity to the Eypemouth Fault, which is known to have been active through much of the Early Jurassic (Jenkyns and Senior, 1991), implying that it was related to synsedimentary movement on this structure (Simms *et al.*, 2004).

It seems likely, therefore, that the influence of nearby faulting is critical to understanding the Dyrham Formation pebble beds at Chapel Cross, and their apparent absence elsewhere in the Somerset Basin, as well as the thickness variations seen in the Marlstone Rock Formation and Barrington Limestone Member across the region. The Mere Fault is a major east-west trending fault that passes just 1.7 km south of Chapel Cross (Figure 7) and has a long history of synsedimentary activity (Bristow *et al.*, 1999). The principal segments of the Mere Fault dip south at about 70° and display components of both syndepositional normal displacement and later reversal of movement during basin contraction (Bristow *et al.*, 1995). In the Wincanton area further east (British Geological Survey Sheet 297) are several approximately east-west trending faults which extend west into the area under consideration here. An extension of the Mere Fault is associated with a line of low hills extending from Long Sutton in the west via Knoll, Knoll Knap, Camel Hill and to Sparkford Hill in the east. This appears to be a horst structure bounded by faults on the north and south sides. The cutting at Chapel Cross lies to the north of the line of the Mere Fault but it may well be located within a similar horst bounded by E-W faults. Synsedimentary movement along one or more of these faults may, by analogy with those examples documented in Gloucestershire and Dorset, account for the periods of erosion represented by the pebble beds at Chapel Cross.

Structure

Numerous pipeline trenches have criss-crossed the Ilchester-Sparkford Clay Vale, to the west of Chapel Cross, during the last 50 years and have provided a mass of new information on dips and faults, as well as records of zonal ammonites, that has helped to understand the structure of this topographically subdued region (Donovan and Harvey, 2012; Prudden, 2005; Burt and Prudden, 2007). For instance, between Ilchester in the east and Kingsbury in the west at least twenty N-S or NNE-SSW faults have been recorded. Many appear to be en echelon and some are closely spaced double faults. They appear to be the result of strike-slip faulting which is clearly extensive in South Somerset. Further afield a cluster of north-south faulted slivers are mapped near Sandford Orcas [ST 661 203], to the south of Chapel Cross (British Geological Survey Sheet 312, Yeovil), as well as near Bradford Abbas near Yeovil. A fine example can be seen cutting the Bridport Sands Formation in a sunken lane at Gore Lane, Nether Compton [ST 6035 1675]. The Poyntington Fault (Figure 7) still further to the south-east has been mapped as a net, dextral post-middle Jurassic offset of approximately 3 km with a NNW-SSE trend (Bristow *et al.*, 1995) and linked with the Mere Fault at its northern end (Jenkyns and Senior, 1991).

North of Sherborne the general strike of the Jurassic strata is from north to south with a gentle regional dip to the east (Figure 2). This is reflected in a 4° dip to the east-north-east on the west side of the overbridge at Chapel Cross. Thus the

Dyrham Formation crops out at the west end of the cutting and the Bridport Sands at the east end. However, a narrow horst containing Dyrham Formation trends NNW-SSE (Figure 2), cutting across the Chapel Cross exposure, and is associated with varying dips: 14° to the south east, 13° to the south, 10° to the south east. Shears with horizontal striations lie on either side of the horst and trend NNW-SSE, parallel to the horst. These features suggest a strike-slip element to the formation of this structure, with the unusual dips to the south east perhaps the result of strike-slip drag, and provide still further evidence of the importance of strike-slip faulting within the Somerset Basin. With the Mere Fault located just 1.7 km south of Chapel Cross, and probably representing just the most prominent of a series of parallel east-west strike-slip faults traversing the area, it is possible that the horst and associated shears exposed at Chapel Cross are associated with relay ramps linking the main fault structures (Barton *et al*., 1998).

CONCLUSIONS

The temporary exposure at Chapel Cross provides new information on the Upper Pliensbachian and Toarcian succession in an area of the Somerset Basin for which relatively little previous data existed. It also demonstrates once again the ubiquity of strike-slip faulting across this region.

The Toarcian succession here is broadly similar to that in the Ilminster region further south but significantly expanded compared with that seen in the intervening Yeovil region. However, the Marlstone Rock Formation shows a four-fold thinning from Ilminster to Yeovil and is then more than halved again in moving further north to Chapel Cross. The underlying Dyrham Formation also shows clear evidence, in the form of intraformational pebble beds, for significant periods of erosion. It is suggested here that repeated episodes of movement on the Mere Fault, and other subsidiary faults associated with it, may account for this complex pattern of thickness changes across the region.

ACKNOWLEDGEMENTS

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Hugh Prudden died on 8th January, his 86th birthday. He appreciated more than most the contribution that small temporary exposures, such as described in this paper, could make to understanding the region's geology. His knowledge of so many facets of Somerset's geology and landscape, and his readiness to share this with others, will be greatly missed. MJS.

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