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Geological evidence for intra-Jurassic faulting in the Wessex Basin and its margins

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Abstract: Geological observations on Jurassic outcrops close to major faults in the Wessex Basin–Mendip area reveal the local presence of ammonite- and brachiopod-bearing sediments penetrating underlying strata. Toarcian and Bajocian neptunian dykes and particularly sills are associated with the Eypemouth Fault and Bajocian sills with the Bride Fault and Mere Fault. In the Mendip area numerous neptunian dykes of Hettangian, Sinemurian, Pliensbachian and Bajocian ages, cross-cutting Carboniferous Limestone, are recorded, typically also associated with major basement faults (e.g. Cranmore and Leighton Faults). These periods of assumed sediment injection are taken as indicating times of displacement along the faults in question.

Variations in facies (Hettangian–Sinemurian, Toarcian, Bajocian, uppermost Oxfordian, Kimmeridgian) spatially linked to faults are documented from some areas, and boreholes reveal considerable fault-controlled thickness changes in Hettangian–Sinemurian, Bajocian and Kimmeridgian sediments. The timing of Jurassic faulting in the Wessex Basin–Mendip area thus polarizes into two intervals: Hettangian–Bajocian and latest Oxfordian onwards, correlating with the early rifting phases of the Central and North Atlantic respectively.

A number of authors have recently sought to clarify the evolution of the Wessex Basin in terms of current tectonic models (e.g. Stoneley 1982; Whittaker 1985; Chadwick 1986; Karner *et al.* 1987; Lake & Karner 1987; Selley & Stoneley 1987). In all these works the concept of syn-sedimentary faulting is integral to models of basin subsidence and sediment accumulation. In this paper an essentially field-based approach is adopted to spotlight the geological evidence, much of it available at outcrop, for Jurassic syn-sedimentary fault movements in the Dorset sector of the Wessex Basin and its marginal regions represented by the Mendip Swell. The latter region is important in that it may offer a window into the nature of the Hercynian basement that underlies the Mesozoic fill of the Wessex Basin.

The evidence presented includes documentation of phases of probable sediment injection along fault zones; changes in stratigraphic thickness, in some cases calibrated to the zonal level, across and around a number of faults; and changes in facies associated with certain faults. The evidence assembled below points to the Hettangian to Bajocian and the late Oxfordian–Portlandian intervals as times of particularly significant faulting and facies variation, with less pronounced differential subsidence during the intervening period. A map of the area, showing major faults, is presented in Fig. 1, and a Hettangian to Bajocian zonal scheme for Wessex Basin rocks in Fig. 2.

Some forty years ago Arkell (1942) had already realized the significance of changes in thickness and facies of Oxfordian and Kimmeridgian strata across east–west-trending faults close to Oxford, a theme apparent in the seminal work of Bailey & Weir (1931, 1932) on the Brora–Helmsdale Fault in East Sutherland, Scotland.

Evidence from neptunian sills: Wessex Basin

Eypemouth Fault, Watton Cliff, West Bay

Evidence for syn-sedimentary faulting affecting the Marlstone and Junction Bed during the Early Jurassic was presented by Jenkyns & Senior (1977), the interpretation being based on thickness changes in these units and the presence of sedimentary fissures. New (1987) rock falls laying bare large sections of Watton Cliff (SY 448909) close to so-called 'Fault Corner', allow more detailed interpretations of the section. Here Junction Bed is faulted against Fuller's Earth and Forest Marble, but the feature of major interest is the dramatic increase in thickness of the former unit as it is traced eastwards towards the fault plane (Figs 3, 4), being overlain by horizontal shales of the Downcliff Clay (*levesquei* Zone, *levesquei* Subzone). Close to the fault plane itself, an obviously coarse-grained matrix is invaded by numerous horizontally oriented sediment-filled fissures that cause the local thickening of the Junction Bed (Fig. 5); these neptunian sills were seen by Buckman (1922) and Jackson (1922, 1926) who attempted to interpret them as normal members of a Marlstone/Junction Bed succession. Buckman (1922) termed this unit the 'Watton Bed' and his and Jackson's papers reveal their struggles to understand the anomalous stratigraphy of the ammonites.

The matrix is typically developed as a grey-green to reddish-brown calcareous/ferruginous quartzarenite, locally conglomeratic and rich in shell material and brachiopods, whereas the fissures are usually filled with multiple fills of fine-grained parallel- and cross-laminated buff to pale rose calcilutites and coarser milky limestones, both of which contain sparse quartz grains. These distinctive sediments are

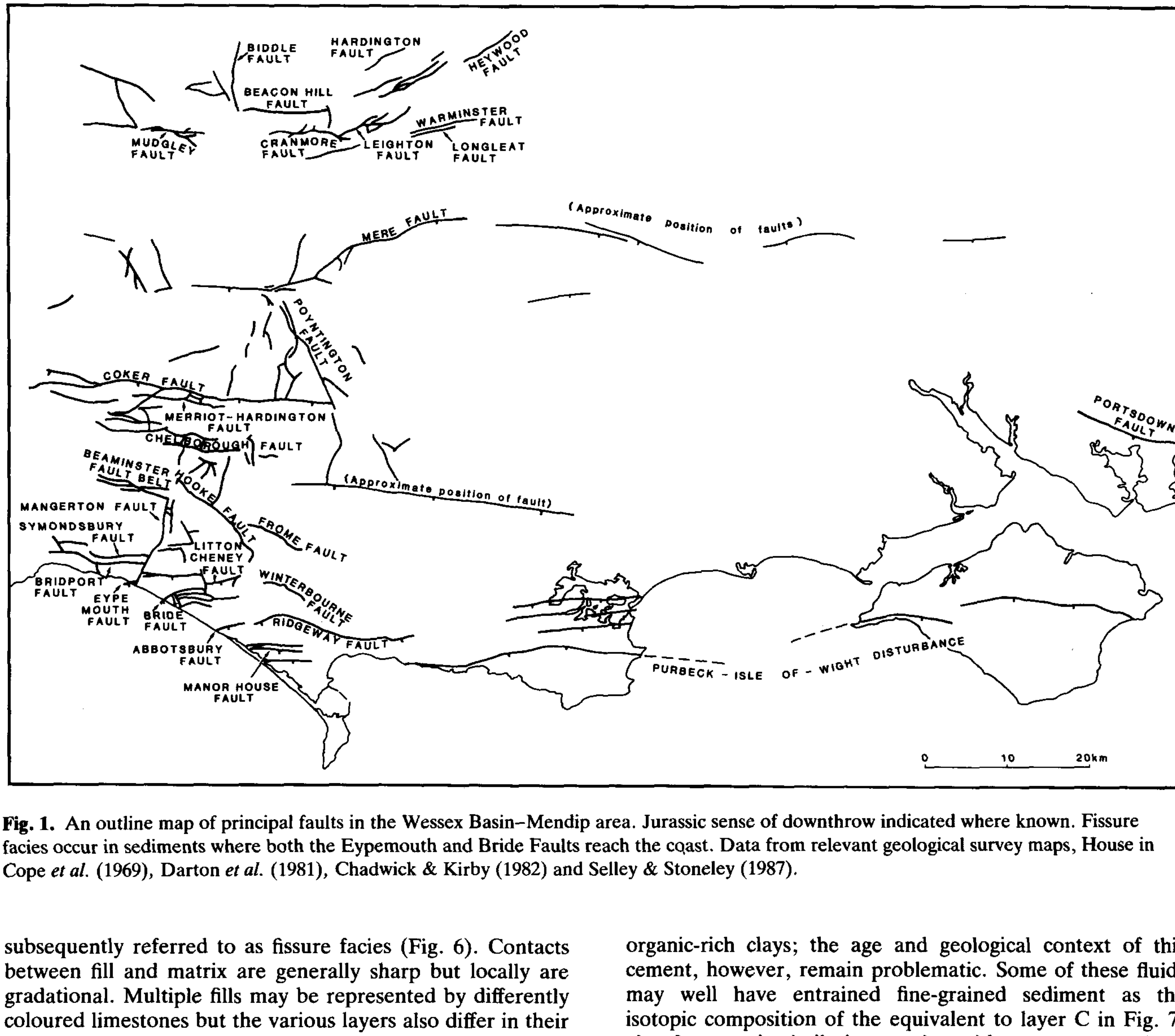

Fig. 1. An outline map of principal faults in the Wessex Basin–Mendip area. Jurassic sense of downthrow indicated where known. Fissure facies occur in sediments where both the Eypemouth and Bride Faults reach the coast. Data from relevant geological survey maps, House in Cope *et al.* (1969), Darton *et al.* (1981), Chadwick & Kirby (1982) and Selley & Stoneley (1987).

subsequently referred to as fissure facies (Fig. 6). Contacts between fill and matrix are generally sharp but locally are gradational. Multiple fills may be represented by differently coloured limestones but the various layers also differ in their density of included fossil fragments, indicating hydraulic sorting during filling of the cavities. Some degree of grading is locally apparent (Fig. 7), suggesting that filling was rapid. The micritic fabric is commonly peloidal, and is suggestive of formation as a high-magnesium calcite precipitate (Macintyre 1985); coccoliths or similar nannoflora have not been identified. The lamination exists on various scales (Fig. 8) and is constituted by peloids packed together in different densities and surrounded by differing volumes of micrite and sparite matrix.

The isotopic composition of this material is typically marine (e.g. $\delta^{18}O = -0.48‰$; $\delta^{13}C = 0.24‰$ PDB for one sample) which compares not unfavourably with a previously established value for the Junction Bed of $\delta^{18}O = -3.75‰$; $\delta^{13}C = 2.86‰$ (Campos & Hallam 1979) and other unpublished analyses. Fibrous and equant spar, typically ferroan, fill the upper levels of some fissures. One particularly well-developed sample of fibrous calcite from a sample adjacent to that illustrated in Fig. 7, when analysed isotopically, gave $\delta^{18}O = -5.5‰$; $\delta^{13}C = -8.8‰$, suggesting precipitation from waters of modified meteoric origin or fluids perhaps derived from the underlying Lower Jurassic organic-rich clays; the age and geological context of this cement, however, remain problematic. Some of these fluids may well have entrained fine-grained sediment as the isotopic composition of the equivalent to layer C in Fig. 7, also ferroan, is similarly negative with respect to carbon: $\delta^{18}O = -1.60‰$; $\delta^{13}C = -7.42‰$. It is also possible that within these cavities special micro-environments existed, where isotopic chemistry was locally modified.

These neptunian sills typically have thicknesses of tens of centimetres and may be traceable over a horizontal distance of a metre or more; they generally have smooth undulating bases, more irregular tops, and may end bluntly. Additionally tiny sediment- and calcite-filled cracks (diameter 0.05–0.5 mm) occur locally as do somewhat larger geopetal cavities. Rare subvertical neptunian dykes cut both horizontal fissures and host rock: their contained sediment is coarser than the typical calcilutite of the sills and, in the more horizontally oriented portions of the dykes, fibrous and equant sparry calcite is patchily developed.

Some fissures contain fauna; many are completely barren. The vertically oriented dykes have yielded gastropods, brachiopods, crinoid and echinoid fragments, thin-shelled bivalves (*Bositra buchi*) and foraminifera. In addition to the above some sedimentary sills contain medium-sized nautiloids, but their most abundant faunas are ammonites and their fragments which generally occur in

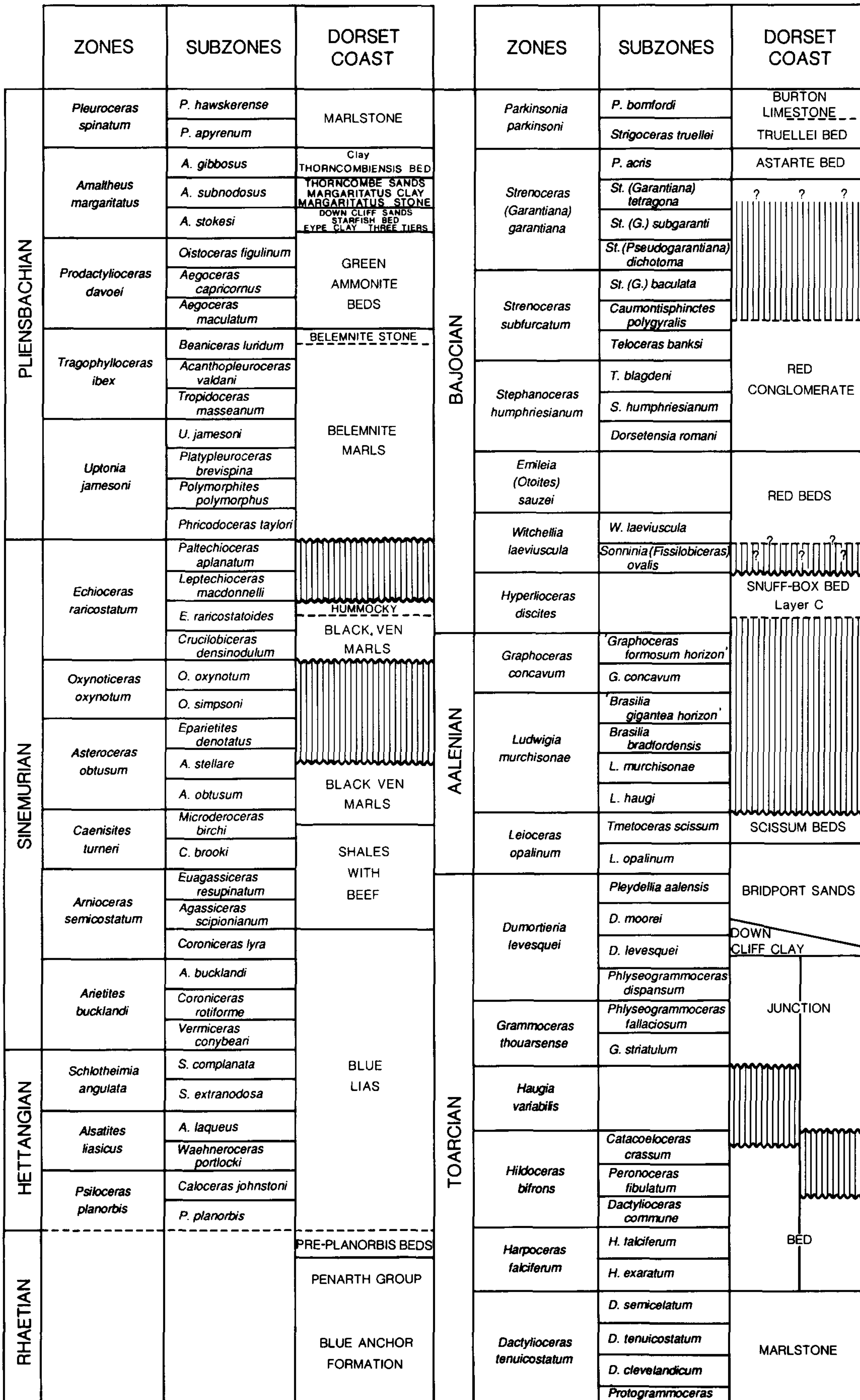

Fig. 2. Stratigraphic scheme for the Hettangian–Bajocian interval as represented by the sediments of the Dorset Coast, based on Cope *et al.* (1980*a,b*), Howarth (1980) and Ivimey-Cook & Donovan (1983). Boundary between the Blue Lias and Shales with Beef after Hallam (1960). The stratigraphic context of zones not given in this figure can be found in Cope *et al.* (1980*b*).

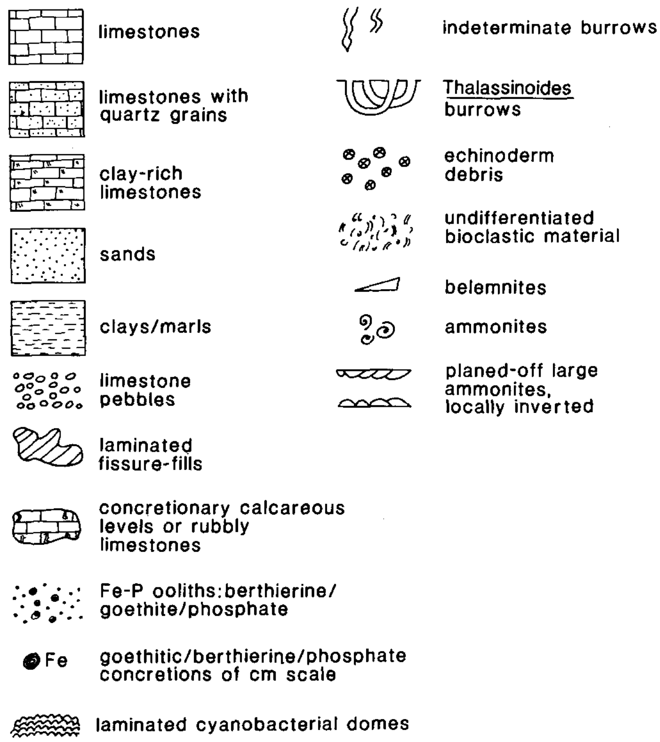

Fig. 3. Codes used in stratigraphical sections, illustrated in Figs 4, 15 and 16.

oriented clusters and, if partially filled with sparite, constitute geopetal structures. The following forms have been identified in this study: *Grammoceras* sp. (most common), *Hammatoceras insigne* (tolerably common), *Pseudogrammoceras subquadratum*? and *Haugia* sp. indicative of the Toarcian, *variabilis* and *thouarsense* Zones. Additionally, *Hildoceras Harpoceras* sp., and *Dactylioceras* sp. have been observed, indicating the *bifrons* and *falciferum* Zones. Jackson (1922, 1926) also recorded what appear from his descriptions to be fissures containing: *Alocolytoceras* cf. *germani, Elegantuliceras elegantum, Frechiella* cf. *subcarinata* and hildoceratids sp. These are similarly indicative of the Toarcian, *bifrons* and *falciferum* Zones and, in the case of the *Alocolytoceras,* probably *thouarsense* to *levesquei* Zones.

Close to the Eypemouth Fault itself the matrix of the fissures becomes more calcareous towards the top of the Marlstone/Junction Bed complex. A prominent hardground in these higher, more calcareous levels is marked by an horizon of centimetre-scale calcareous limonitic nodules (Fig. 4) similar to but smaller than the 'snuff-boxes' of the Bajocian Inferior Oolite (cf. Gatrall *et al.* 1972).

Abraded ammonites found during this study in the basal, quartzarenite-rich part of this normal stratigraphic unit are *Protogrammoceras paltum* (rare) and *Amaltheus gibbosus* (rare). The first is indicative of the Toarcian, lower *tenuicostatum* Zone, the second of the Pliensbachian, upper *margaritatus* Zone and is interpreted as derived from the Thorncombiensis Bed. The matrix is not typical Marlstone

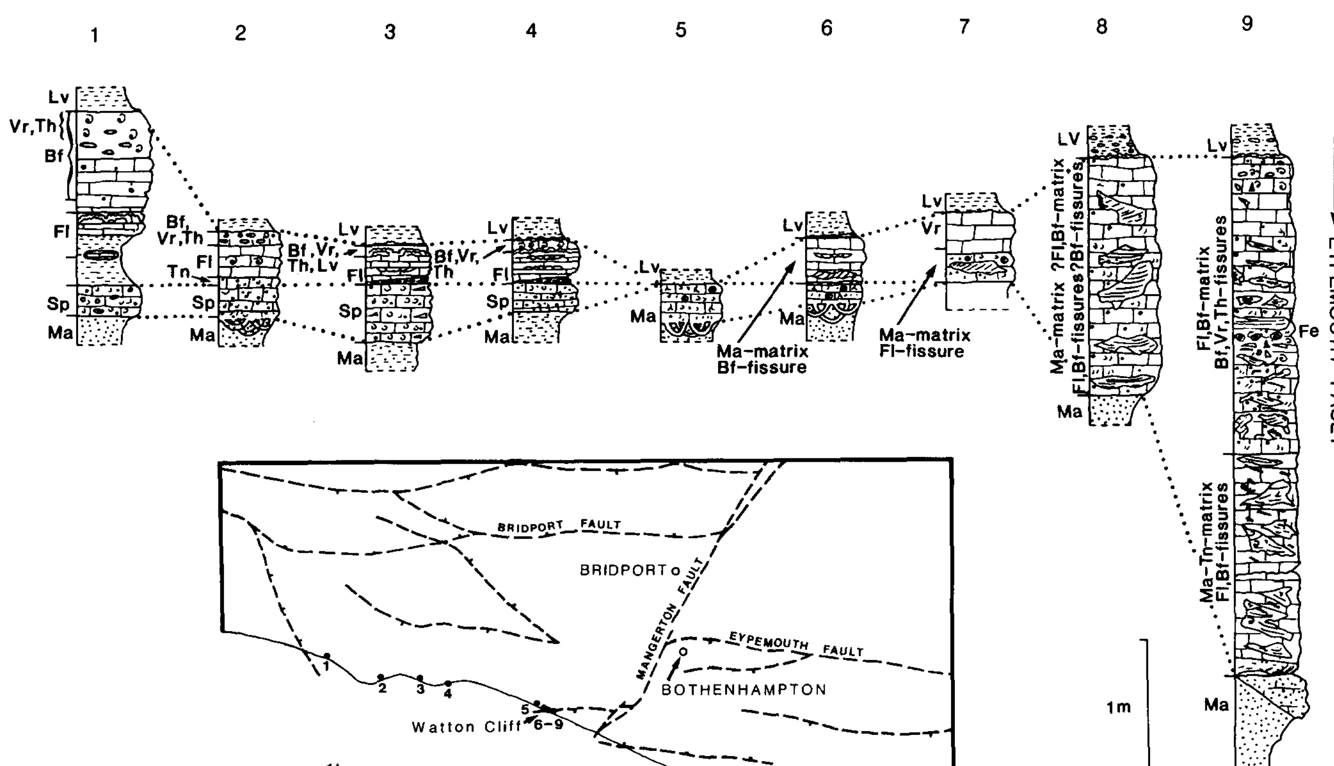

Fig. 4. Stratigraphy, calibrated to the zonal level, of the Marlstone, Junction Bed and sub- and suprajacent strata and their relationship with the Eypemouth Fault, Wessex Basin. Sections are based on personal observations with additional data from Buckman (1922) and Jackson (1922, 1926). Ma, *margaritatus* Zone; Sp, *spinatum* Zone; Tn, *tenuicostatum* Zone; Fl, *falciferum* Zone; Bf, *bifrons* Zone; Vr, *variabilis* Zone; Th, *thouarsense* Zone; Lv, *levesquei* Zone. Sections run from Ridge Cliff (1), through Doghouse Cliff (2), Thorncombe Beacon (3, in situ; 4, ex situ), east of Eypemouth (5) to Watton Cliff (6-9).

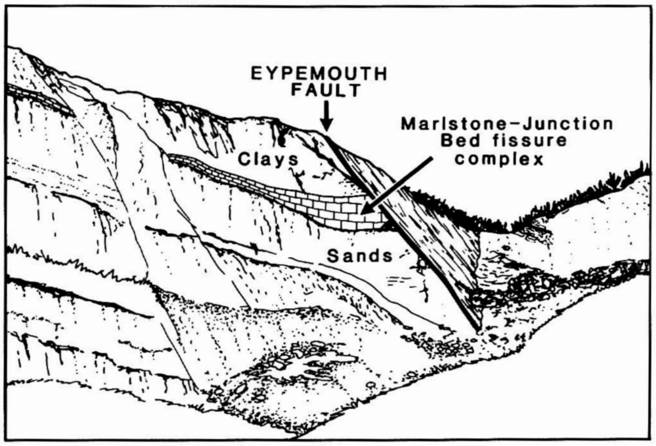

Fig. 5. Sketch, from beach level, to illustrate the geometry of the Marlstone–Junction Bed complex when traced eastward towards the Eypemouth Fault at Watton Cliff: the thickness of the limestone unit immediately adjacent to the fault is 3.65 m. Stratigraphically below and above are the Pliensbachian Thorncombe Sands and Toarcian Downcliff Clay. The Thorncombiensis Bed, which elsewhere underlies the Marlstone, is not recognizable as a distinct unit in this locality. On the downthrown side of the normal fault the Bathonian Fuller's Earth and Forest Marble outcrop.

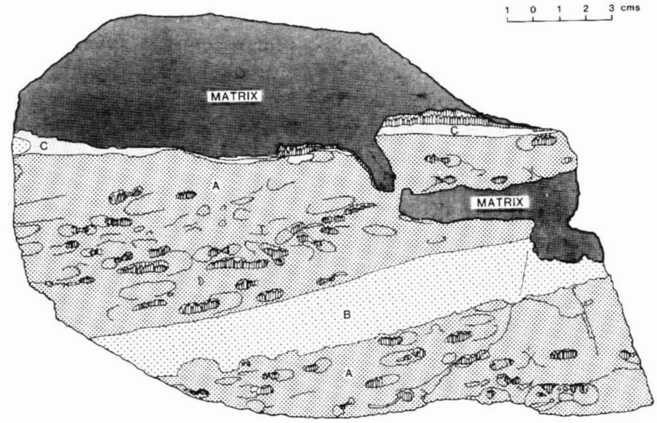

Fig. 7. Detail of Toarcian neptunian sill and matrix, showing grading of ammonites and their fragments (chiefly *Grammoceras*), multiple filling with buff (A and B) capped by white (C) micrite and subsequent filling of fibrous calcite. Note that the graded ammonite-bearing fill (A) is divided by a faunally sterile layer (B), which may represent a subsequent intrusion. Fallen block, Watton Cliff.

and seems to derive from mixing of that level (*spinatum* Zone, Upper Pliensbachian and *tenuicostatum* Zone, Lower Toarcian: Howarth 1980) and the underlying Thorncombiensis Bed (*margaritatus* Zone); there is no trace of the intervening marl as seen at Thorncombe Beacon (Fig. 4). In the upper, calcareous part of the normal stratigraphic unit the following forms have been found: *Hildoceras bifrons*, *Harpoceras* sp. and *Dactylioceras* sp. indicative of the Toarcian, *bifrons* and *falciferum* Zones.

The fact that in the most easterly section adjacent to the Eypemouth Fault, where the Marlstone/Junction Bed complex is thickest, ammonites pertaining to the *falciferum* and *bifrons* Zone occur in fissures some 3 m below their in situ stratigraphic level must account for the difficulties experienced by Buckman (1910) and Jackson (1926) in interpreting the succession (Howarth, in Cope *et al.* 1980*a*). Detailed collecting suggests that fissures with a fauna of *thouarsense*-Zone age are concentrated in the upper, more calcareous matrix of the Marlstone/Junction Bed complex of *falciferum*- and *bifrons*-Zone age, although they also occur, albeit rarely, in the more quartzarenitic portion below. The data of Jackson (1926) also suggest the presence of some fissures of *falciferum* and *bifrons* age at this lower level.

The maximum thickness of the Marlstone/Junction Bed complex of 3.65 m is developed immediately adjacent to the Eypemouth Fault; it thins westwards (Figs 4 & 5). At the feather edge of this dramatically thinning unit no fissures are apparent, although the outcrop is difficult of access and detailed study hazardous. Our initial interpretation (Jenkyns & Senior 1977) was of a series of syn-sedimentary faults that caused the abrupt changes in thickness. The new exposures rather suggest that differential intrusion of the fissure facies, with maximum density in the fault zone, was the proximate cause.

The following sequential events in the exposed fault zone are envisaged.

Fig. 6. Toarcian neptunian sill of pale-pink micrite capped by matrix of coarser-grained calcareous-ferruginous quartzarenite. Diameter of coin is 2.5 cm. Fallen block, Watton Cliff.

Fig. 8. Microfacies of Toarcian neptunian sill, showing variably packed peloids and their relationship to sedimentary lamination. Note the geopetal structure in the ammonite, which aids orientation of ex situ samples. Fallen block, Watton Cliff.

(1) Deposition of a ferruginous calcareous quartzarenite (Marlstone) during ?*spinatum* Zone to early *tenuicostatum* Zone times. Much erosional reworking and incorporation of older faunal elements (derived from the Thorncombiensis Bed of the upper *margaritatus* Zone); modest submarine lithification under conditions of minimal net sedimentation.

(2) Deposition and precipitation of lime mud locally rich in ammonites, thin-shelled bivalves, gastropods, brachiopods, belemnites, echinoids and foraminifera (Junction Bed *sensu stricto*), similarly in an environment of very slow sedimentary rate. Development of non-sequences marked by formation of concentrically laminated calcareous limonitic nodules.

(3) Various phases of submarine faulting leading to multiple intrusion of the Junction Bed, Marlstone and uppermost Thorncombiensis Bed by lime-mud variably rich in ammonites and gastropods. Injection of rapidly flowing sediment-charged liquids by vacuum suction into partially lithified sediment is suggested by grading, cross- and parallel lamination of the peloidal lime mud, the hydraulic sorting of fossils and the local gradational contacts between matrix and fill. That these fissures ever gaped partially open on the sea-floor with the cavities inhabited by ammonites (cf. Wendt 1971) seems unlikely. However, small voids filled with fibrous and equant calcite suggest that at least some cavities were incompletely filled, unless these represent a dewatering phenomenon; and the uppermost levels of some fissures contain sediment that may have entered by passive filtration (e.g. layer C in Fig. 7). Demonstrable times of intrusion, assuming that the ammonites accurately represent this, were: *falciferum*, *bifrons*, *variabilis* and *thouarsense* Zones, spanning an estimated time of 4 Ma (e.g. Harland *et al.* 1982).

(4) A further series of undated but pre-*levesquei* Zone movements resulting in intrusion of vertically oriented neptunian dykes cutting matrix and some fissures (Jenkyns & Senior 1977). Presumed deepening of water, due to regional tectonic and/or eustatic effects, leading to deposition of clay (Downcliff Clay) in *levesquei*-Subzone time (Sellwood & Jenkyns 1975).

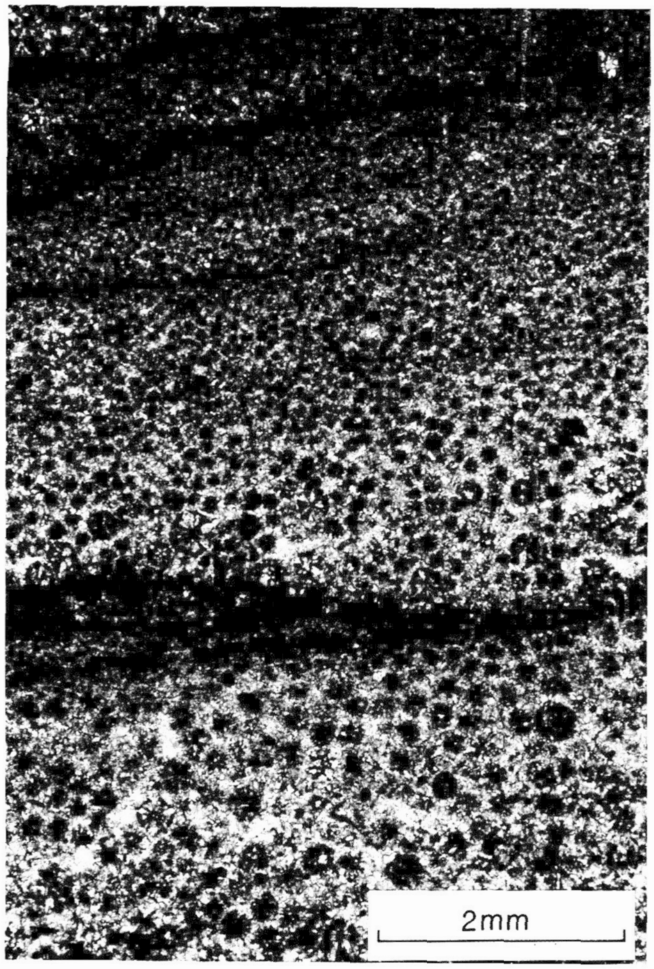

Fig. 9. Microfacies of Toarcian neptunian sill, showing graded peloids and problematic radially structured spherulites. Loose block, Bothenhampton.

Eypemouth Fault at Long Lane, Bothenhampton

Laminated pink and white fissure facies may be found in situ and abundantly in field rubble in this area, next to Long Lane (SY 478916 and 483916), where the Eypemouth Fault (Fig. 4) locally juxtaposes Junction Bed against Forest Marble, Cornbrash and Oxford Clay. Reference to the occurrence at Bothenhampton of facies similar to the 'Watton Bed' was made by Buckman (1922). The fissure-facies are typically peloidal, with peloids partly arranged in graded laminae, and locally contain problematic radial spherulites in both micrite and sparite matrices (Fig. 9); other facies include micrite with sparse echinoderm fragments, foraminifera, phosphatic fish remains, shell hash, silt-grade quartz and possible siderite-replaced berthierine ooids.

A section described by Walker (1892) from Bothenhampton mentions a 'white stone' with a lower *thouarsense*-Zone fauna which may be interpreted as a fissure facies. The abundance of such deposits in this area is here taken as evidence for Toarcian movement along this sector of the fault. Ammonites collected from ex-situ fissure facies in this locality are *Pleydellia* sp. and *Alocolytoceras coarctatum.* These ammonites indicate the *levesquei* Zone. *Alocolytoceras* was also recorded from Watton Cliff in a 'finely laminated lithographic limestone' by Jackson (1922).

Bride Fault at Burton Beach

On the coast below the houses formerly known as Burton Villas, at the east end of Burton Cliff (SY 489887), the Bride Fault (Fig. 1) reaches the coast, juxtaposing the Bridport Sands against Fuller's Earth and Forest Marble: a sliver of Inferior Oolite (dated as *subfurcatum* Zone, *baculata* Subzone) occurs in the fault zone where rare loose blocks are in anomalous facies containing bored boulders of limestone and laminated ferruginous concretions (snuff-boxes) set in a highly fossiliferous ferruginous limestone matrix. Here the Bridport Sands, with their characteristic carbonate-cemented rhythms, contain bedding-subparallel fissures full of laminated peloidal white calcilutites containing variable quantities of angular quartz grains (Fig. 10). Large blocks displaying the geometry of the fissures, both horizontal and vertical (neptunian dykes), are occasionally uncovered on the beach along the line of the fault; geopetal fills of calcite spar are a feature of the

Fig. 10. Sub-horizontal Bajocian limestone sills, penetrating Toarcian Bridport Sands. East end of Burton Cliff. Hammer is 33 cm long.

sediment-filled cavities in these blocks. The lamination of the fills is imparted by differing densities of micrite, peloids and microsparite; the peloids are graded in some laminae; glauconite grains, carbonate-replaced sponge spicules, thin-shelled bivalves, bryozoan fragments and phosphatic intraclasts are not uncommon. Echinoderm debris is locally abundant. These fissure-fills were described by Buckman (1910, 1922) and Richardson (1928) who variously considered them as parts of the normal sedimentary sequence in exotic lithology or as a secondary deposit caused by downward percolation of water. Buckman referred to them as the 'White Bed' or '*Nautilus* Bed', and recognized their similarity to the 'Watton Bed' adjacent to the Eypemouth Fault. The Geological Survey (Wilson *et al.* 1958) came close to recognizing them as neptunian sills, the interpretation favoured here. In the course of this study, the following fauna has been found in the fissures: *Garantiana quenstedti, Garantiana* sp., brachiopods and echinoids (?*Hemicidaris*). In addition Buckman (1910, 1922) and the Survey recorded nautiloids, bivalves, gastropods and a perisphinctid, as well as a *Garantiana.* This fauna is Upper Bajocian, *garantiana* Zone, probably *tetragona* Subzone. The matrix of the fissures (Upper Bridport Sands) contains *Pleydellia comata* and is thus of Toarcian age, *levesquei* Zone, *aalensis* Subzone. The penetration of Toarcian by Bajocian sediments is interpreted as related to tectonic movements along the Bride Fault during *garantiana*-Zone times. This is another example of a palaeofault active during the Jurassic which, like the Eypemouth Fault, down-throws to the south. The boulder-bed facies of the Inferior Oolite in the fault zone at Burton Beach is presumably also related to syn-sedimentary movement during the Bajocian.

Eypemouth Fault at Markets Lane, Shipton Gorge

From Bothenhampton the Eypemouth Fault runs eastwards through Shipton Gorge where it locally juxtaposes Bridport Sands against Oxford Clay. In Markets Lane, Shipton Gorge (SY 501913) a trench dug for a water meter in the early 1980s encountered a series of limestones associated with the Bridport Sands. These are now present as field rubble and are readily recognizable as fissure facies: they comprise finely laminated lithographic cream limestones, partly as single blocks, whose original dimension is unknown, and partly as centimetre-scale pod-shaped fissure-fills in a calcareous micaceous quartzarenite matrix (Fig. 11). The uppermost levels of the cavity fills commonly contain fibrous calcite cements and/or equant spar. These fissure facies are, in terms of their geometry and petrography, identical with those exposed at Burton Beach and indicate injection of Inferior Oolite sediment into Bridport Sands.

Within these fissure facies the following fauna has been found: *Parkinsonia* sp., probably *P. acris, Astarte* (*Neocrassina*) *modiolaris, Eopecten* sp. and indeterminate gastropods. The ammonite indicates the Bajocian, *garantiana* Zone, *acris* Subzone (cf. Parsons in Cope *et al.* 1980*b*). The age of these fissures is thus similar to and possibly overlaps with those at Burton Beach. The important point to note is that episodes of sediment intrusion along the Eypemouth Fault took place in both Toarcian and Bajocian time. Interestingly, the *acris* Subzone marks the time of the 'Vesulian Transgression' (Arkell 1933, p. 91, 230–1, 333–6) in the Wessex and Cotswold areas where it post-dates a substantial unconformity.

Mere Fault at Cadbury Castle

The Mere Fault is a major east–west lineament that runs close to the northern margin of the Wessex Basin (Fig. 1). In certain sectors it can be mapped with some confidence and the downthrow varies from north to south along its length (e.g. Mottram 1961; Chadwick & Kirby 1982). Towards its western extremity, where the downthrow is southerly, it becomes less well defined and a number of splays are developed, one of which crosses Cadbury Castle and throws Toarcian Yeovil Sands against Inferior Oolite. In this area (ST 626252), fissure facies occur locally at outcrop intruding the upper levels of the Toarcian sands close to their contact with the overlying Inferior Oolite and abundantly in field rubble on the top of the hill fort and around the wooded slope to the west. The fissure facies are developed as buff to pale orange laminated lithographic limestones and are found as single blocks and as finger-shaped pods of material in a sandstone matrix; spar-filled geopetal cavities are common. Petrographically the laminated calcilutites are identical with those exposed at Burton Beach.

Within these fissure-facies the following fauna has been found: *Cymatorhynchia,* nautiloids and bivalves. *Cymatorhynchia* typically occurs in mid-Jurassic rocks; and

Fig. 11. Finger-shaped fissure-facies of Bajocian age (light) in Toarcian Bridport Sands (dark). Photocopy of polished loose block, Shipton Gorge. Identical structures may be found in boulders occasionally visible, after major storms, on the foreshore at the east end of Burton Cliff.

the relative abundance of nautiloids recalls once more the fissure facies at Burton Beach which were named the '*Nautilus* Bed' by Buckman (1910, 1922). There seems little doubt therefore that the Cadbury examples are equally of Bajocian age. Penetration of Bajocian lime mud into Toarcian sands is again indicated and points to movement along the Mere Fault during deposition of the Inferior Oolite, something for which there is independent evidence in terms of thickness changes of the formation in question (see below).

Evidence from neptunian dykes: Mendip fissures

The Carboniferous Limestone of the Mendips is cut by numerous Mesozoic sediment-filled fissures of varying trend, whose ages range from Triassic to Middle Jurassic (Moore 1867; Kühne 1946; Robinson 1957; Copp in Duff *et al.* 1985). Observations made in a cutting formerly exposed on the main road immediately to the west of Leighton (ST 703438) have revealed the presence, within the Carboniferous Limestone, of numerous neptunian dykes and sills of pink crinoidal limestones, locally discoloured to grey, running close to and roughly parallel with the Cranmore/Leighton Faults (Fig. 1). In this area pink and grey crinoidal limestones are locally present in stratigraphic sequence between the Carboniferous Limestone and the Inferior Oolite, and are themselves cut by neptunian dykes and bed-parallel fissures containing fine-grained laminated carbonates. Oyster-encrusted planar hardground surfaces occur on both the crinoidal limestones and on the Carboniferous Limestone where the succession is locally more complete (Fig. 12). The following fauna has been extracted from pink crinoidal limestones in dykes that penetrate the Carboniferous Limestone: *Quadratirhynchia* sp., *Prionorhynchia* sp. and *Cirpa* sp. (juveniles). This fauna is indicative of the Pliensbachian, possibly *spinatum* Zone (Ager 1956–67). We assume this equally represents the age of the pink crinoidal limestones, which also contain *Cirpa*, locally present in the normal stratigraphic sequence between the Carboniferous Limestone and the Inferior Oolite: they would thus equate with the crinoid-rich Marlstone of the Wessex Basin area. These local intercalations of pink crinoidal limestone were recorded by Moore (1867) from nearby localities and attributed to a level 'about that of the passage of the Lower into the Middle Lias', which suggests he thought they were somewhat older than *spinatum* Zone. Moore furthermore compared these pink crinoidal limestones with the Hierlatzkalk of Austria and suggested similar ages for both deposits. Although typically of early Liassic age the Hierlatzkalk is occasionally dated as mid-Liassic and rarely even late Liassic (Tollmann 1976); a similar age range is by no means excluded for the Mendip examples, particularly as Copp in Duff *et al.* (1985) suggests that some crinoidal neptunian dykes may contain faunas as old as the *jamesoni* and *raricostatum* Zones. Differences in facies are recognizable to the extent that some of these limestones are rich in belemnites whereas others, apparently, are not. The palaeogeographic significance of Alpine–Mediterranean crinoidal limestones is such that they typically developed as submarine calcareous dunes in turbulent-water environments floored by slowly foundering platform carbonates (Jenkyns 1971), and a similar model would seem to be applicable to the Mendips.

Many of Moore's (1867) pioneer observations were made in the quarry at Holwell and observations have been concentrated in this region. Numerous neptunian dykes containing crinoidal limestone are exposed here and in Coleman's Quarry (ST 727453) where a dyke of pink crinoidal limestone has yielded one juvenile specimen of *Cirpa* sp. This form is typical of the Pliensbachian. The matrix is rich in echinoderm fragments, locally with syntaxial overgrowths, accompanied by comminuted brachiopod material, quartz grains and siltstone fragments. An adjacent dyke has yielded, in situ, numerous specimens of the brachiopod *Acanthothyris spinosa.* This form is characteristic of the Upper Bajocian, *garantiana* Zone, *acris* Subzone in the Cotswolds (Arkell 1933, p. 243). The matrix is chiefly sparite with some microspar and micrite rich in macerated brachiopod material and echinoderm fragments largely obliterated by diagenetic overgrowths.

These age assignments match those recorded by earlier workers but are somewhat more limited. Fauna collected by Kühne (1946) from fissure-fills at Holwell included material of Hettangian, Sinemurian, Pliensbachian and Bajocian ages, although some of the material may have been derived and not represent a true intrusion date. The microfaunal

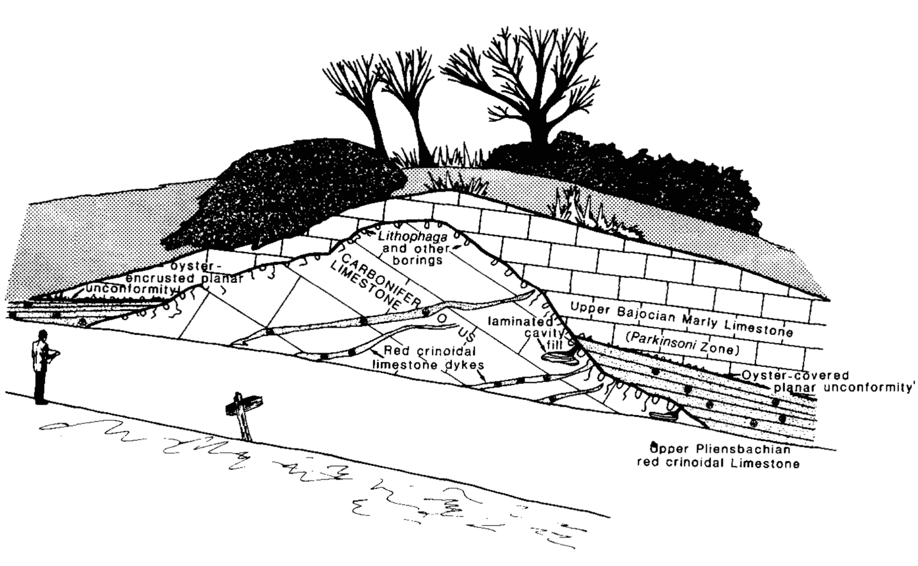

Fig. 12. Sketch of the outcrop formerly (1977) visible on the main road to the west of Leighton. Note the hardgrounds between the irregular upper surface of the Carboniferous Limestone and the overlying Pliensbachian and Bajocian sediments. Note also the numerous neptunian dykes of Pliensbachian pink crinoidal limestone that penetrate the older rocks. Crinoidal limestone in the stratigraphic succession is 0–75 cm thick; Inferior Oolite seen to 1 m.

data of Copestake (1982) confirm an early Sinemurian age (*bucklandi–semicostatum* Zones) for siltstone in fissures at Holwell and Cloford (ST 717445). Copp in Duff *et al.* (1985) records material of early Bathonian age from fissures in Holwell, but this material may represent passive fill of a pre-existing cavity rather than an intrusion formed during syn-sedimentary fracturing. Nonetheless sedimentary dykes, typically full of large amounts of calcite and pods of subhorizontally laminated sediment, do locally cut the Inferior Oolite, and these are associated with offsets of the unconformity surface on the Carboniferous Limestone, into which the fissures typically penetrate: small-scale Bathonian movement is thus possible.

A systematic study of the directionality of the various dykes has not been undertaken but the dominant trend for those dated as Jurassic is essentially east–west. It seems likely that injection of these sedimentary dykes was related to movement along the Cranmore–Leighton Faults during Early to mid-Jurassic time. These faults are mapped as down-throwing to the south. The observation of Moore (1867) that at Holwell one fourth 'of this supposed Carboniferous-limestone quarry' is of Liassic age, although probably an overestimate judging by present-day exposures, nevertheless indicates substantial Jurassic extension in this region.

Other examples show that these extensional phenomena are by no means limited to the Holwell area but are, as argued by Moore, of regional extent. At Gurney Slade (ST 623500), for example, a large sedimentary dyke, oriented east–west, is exposed in positive relief as the surrounding Carboniferous Limestone has been quarried away: it contains both Triassic and Liassic material with brecciated clasts derived from the Carboniferous, including both limestone and chert (Moore 1867; Robinson 1957). The Lower Jurassic sediment is a grey to cream crinoidal–brachiopod biomicrite with numerous quartz grains that has yielded a fauna including *Calcirhynchia calcaria,* bivalves and gastropods which suggest a late Hettangian age. Interestingly, this dyke is not obviously spatially linked to a major fault. Green & Welch (1965) record a number of fissures, from the Central Mendip area, generally dated as early Pliensbachian (Donovan & Kellaway 1984).

Abrupt lateral facies changes in Jurassic strata

To the west and WSW of Yeovil there is a local facies equivalent to part of the Yeovil Sands known as the Ham Hill Stone: this is a grey trough cross-bedded bivalve-rich limestone indicating transport from the southwest and west (Cope *et al.* 1969). It is dated as latest Toarcian, *levesquei* Zone, probably *moorei* Subzone (Wilson *et al.* 1958; Howarth in Cope *et al.* 1980*a*). The major outcrops, some 30 m thick or less, occur to the north of the Coker fault (Fig. 1), an east–west structure, downthrowing to the south, in which direction the Ham Hill Stone thins to about 6 m before disappearing. The development of this facies implies deposition in areas shielded from clastics, presumably an area of relative topographic high, where carbonate sand-bodies could accumulate. It is tempting to relate this to fault-induced submarine topography, an interpretation very different to that of Davies (1969) who viewed it as a tidally influenced channel incised through barrier deposits. However, Davies' facies map for the *moorei* Subzone clearly shows an east–west orientation of clastic sedimentary environments in this region, consistent with fault control on submarine topography. That the Toarcian sands would have provided a tolerably competent substratum is suggested by the local presence of Bajocian fissure-fills and geopetal cavities therein; early lithification of the carbonate-cemented layers in the sands is indicated by their containing uncrushed mica flakes and inter-particle carbonate cement fringes (Davies 1967; Kantorowicz *et al.* 1987).

The Ham Hill Stone passes east and west into coarse well-sorted quartzose sands, but northwards and southwards into finer grained, more bioturbated clastics. Similar intercalations of bioclastic carbonates in the Bridport/Yeovil sands are known from the Winterborne Kingston and Marchwood boreholes (Knox *et al.* 1982; Bryant *et al.* 1988), but their relationship, if any, with syn-sedimentary faults is obscure.

The Inferior Oolite, of Aalenian–Bajocian age, is locally characterized by the presence of large (tens of centimetres) laminated limonitic–calcareous concretions known as 'snuff-boxes' (Gatrall *et al.* 1972; Palmer & Wilson, 1990). The best developed of these are of *discites*-Zone age and their distribution, relative to coeval facies, is such that they were developed in a north–south belt, limited to the west by the Mangerton Fault and to the north by the Hooke Fault (Fig. 1). Without knowing the original sense of movement of the Mangerton Fault it is difficult to assign the snuff-boxes to a particular part of any notional tilted block. However, some sort of initial fault control seems likely with the snuff-boxes developing in highly turbulent water on a particularly shallow sector of the sea floor with water depths perhaps deepening gently towards the east and more abruptly towards the west. This would imply post-Bajocian inversion, as the present downthrow of the Mangerton Fault is to the east.

The Abbotsbury Fault (Fig. 1) is dated as pre-Albian as it runs beneath the Upper Greensand (Arkell 1947; Wilson *et al.* 1958). In Abbotsbury Village, to the south of the fault, the Abbotsbury Ironstone of Kimmeridgian age (*cymodoce* Zone) crops out. This ferruginous oolitic facies passes into clays (Kimmeridge Clay) about 1 km east of the village (Brookfield 1973). A similar facies, of similar age, is exposed in Litton Cheney (Cope 1971) south of a fault (Litton Cheney Fault) that could be a continuation of the Bride Fault (Fig. 1). The local presence of these ironstones is interpreted as linked to short-lived fault-induced submarine topography and/or realms of reduced differential subsidence (Hallam 1966, 1975; Sellwood & Jenkyns 1975), with the berthierine ooids generated on the upthrown side of the fault-block and then dispersed southward to accumulate in a perched basin (Fig. 13). The Abbotsbury Fault down-throws to the south, whereas the nearby Ridgeway Fault, to which it may be genetically related, down-throws to the north. The Ridgeway Fault is thought to have had a southerly down-throw during its Jurassic history, but suffered tectonic inversion during Late Cretaceous–Early Tertiary time (Stoneley 1982; Lake & Karner 1987). If the model in Fig. 13 is correct, the local presence of base-Kimmeridgian oolitic ironstones would be predicted immediately to the south of the Ridgeway Fault.

The Westbury Ironstone, part of the Corallian Group of late Oxfordian age (*pseudocordata* Zone), is also of very localized occurrence (Talbot 1974). In the type locality, in northwest Wiltshire, it crops out just south of a southerly downthrowing fault, the Heywood Fault (Fig. 1). Facies and

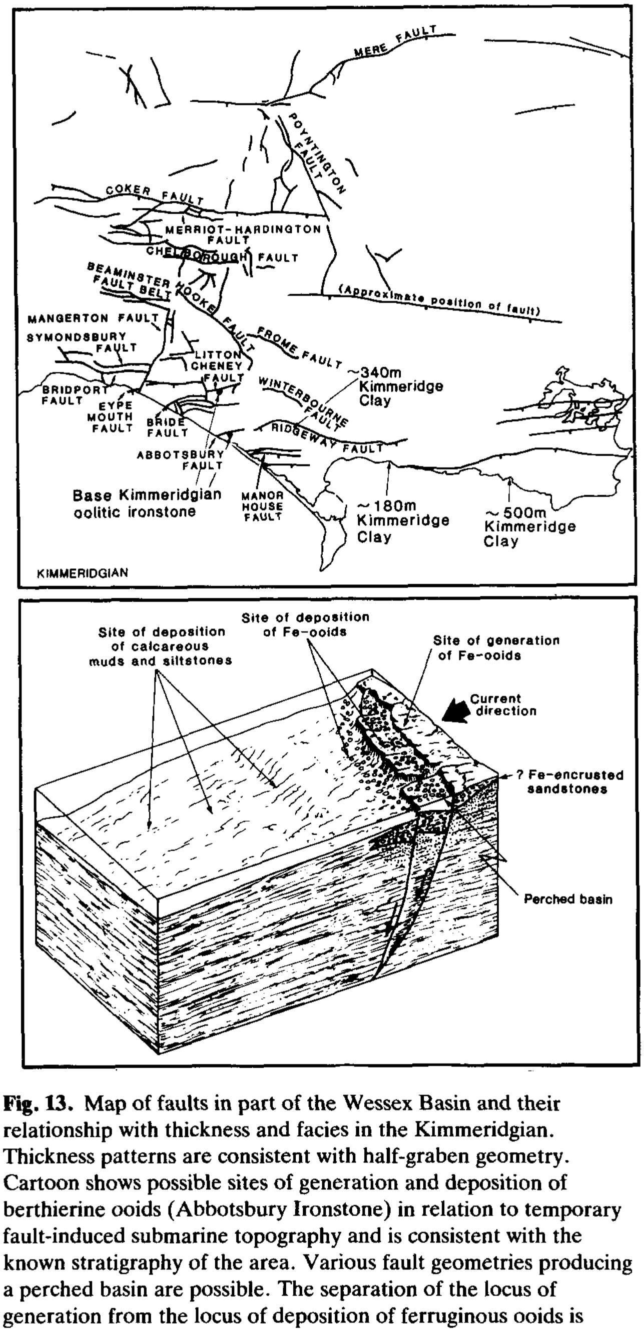

Fig. 13. Map of faults in part of the Wessex Basin and their relationship with thickness and facies in the Kimmeridgian. Thickness patterns are consistent with half-graben geometry. Cartoon shows possible sites of generation and deposition of berthierine ooids (Abbotsbury Ironstone) in relation to temporary fault-induced submarine topography and is consistent with the known stratigraphy of the area. Various fault geometries producing a perched basin are possible. The separation of the locus of generation from the locus of deposition of ferruginous ooids is implicit in the models of Cayeux (1922) and Knox (1970). Dispersal of small quantities of ferruginous ooids away from the immediate vicinity of the faults may help explain minor occurrences of these sediments elsewhere in the Upper Jurassic of the Wessex Basin. Thickness data for the Kimmeridge Clay from Arkell (1947), Wilson *et al.* (1958) and Cox & Gallois (1981).

thickness changes affecting Corallian strata (Oxfordian) in the Wessex Basin have also been related to fault-induced topography by de Wet (1987).

In the Mendip area, Liassic sediments are locally developed as the Downside Stone, a cream-coloured bioclastic limestone, chiefly Hettangian–Sinemurian in age and stratigraphically equivalent to the Blue Lias of the Wessex Basin. Cornford (1986) has linked the nature and distribution of this so-called 'littoral' facies to the northern faulted boundary of a half-graben, possibly now represented by the Beacon Hill Fault (Fig. 1), for which there is evidence of Early Jurassic mobility. In the Beacon Hill area, Downside Stone facies was deposited as late as early Pliensbachian, *jamesoni*-Zone time (Green & Welch 1965).

Lateral facies changes of the typical Bathonian Great Oolite to the Frome Clay of the Mendip region (Penn & Wyatt 1979) may possibly also be related to fault-controlled palaeobathymetry.

Thickness changes in Jurassic strata

Much information on general thickness variations of Jurassic strata in the Wessex Basin is now available from the isopachytes of Whittaker (1985) and Sellwood *et al.* (1986). Here the focus is on a selection of stratigraphic units where thicknesses of coeval strata either side of faults can be determined, namely the Hettangian–Sinemurian, Pliensbachian–Toarcian, Bajocian and Kimmeridgian stages and relevant data, derived from seismic and borehole sources, are displayed in Fig. 14.

A section from Bruton to Kimmeridge is instructive; north of the Mere fault the Blue Lias, Shales with Beef and Black Ven Marls attain a humble 45.8 m; at Winterborne Kingston, on the downthrown side of a major fault bounding the Winterborne Kingston Trough, they achieve some 240 m. They thin southward and are represented by a mere 61 m at Wytch Farm on the upthrown side of a northerly tilted block (Colter & Havard 1981); to the southwest, on the downthrown side, these strata are locally estimated as (in the Kimmeridge 5 borehole) some 641 m thick. This represents a cumulative thickness increase across more than one plane of displacement including a probable continuation of the Abbotsbury-Ridgeway Fault, and may also involve some tectonic replication of strata. Nonetheless these thickness data clearly bring out the general half-graben geometry of the various sub-basins in this area (e.g. Chadwick 1986; Karner *et al.* 1987).

In the Pliensbachian–Toarcian the picture is a trifle more enigmatic (Fig. 14). The Junction Bed and Marlstone (Pliensbachian, *spinatum* Zone and the bulk of the Toarcian) are typically only a few metres thick, except at the northern boundary of the Winterborne Kingston Trough. From Winterborne Kingston itself these units thin southward, although the relatively expanded section at Wytch Farm, particularly when compared with the succession in Kimmeridge 5, is curious, as it is the exact opposite of the thickness patterns for the Hettangian–Sinemurian: this may be more apparent than real and related to lateral facies changes into less calcareous sediments. Abrupt southward thickening across a small fault (the Manor House Fault) is, however, well displayed by two boreholes close to Langton Herring (Fig. 14). Here the Junction Bed and Marlstone change in thickness from 2.7 to 9.7 m; the overlying Downcliff Clay (*levesquei* Zone) shows a similar but less dramatic relative change: from 50 to 71 m. The Bridport Sands (Toarcian–Aalenian boundary) are essentially of constant thickness (66–67 m) in both boreholes.

Thickness changes return to a more predictable half-graben pattern with the Inferior Oolite (Fig. 14). From Winterborne Kingston through Bere Regis, Wareham, Stoborough to Wytch Farm there is a systematic thinning, followed by a jump in thickness at Kimmeridge as the

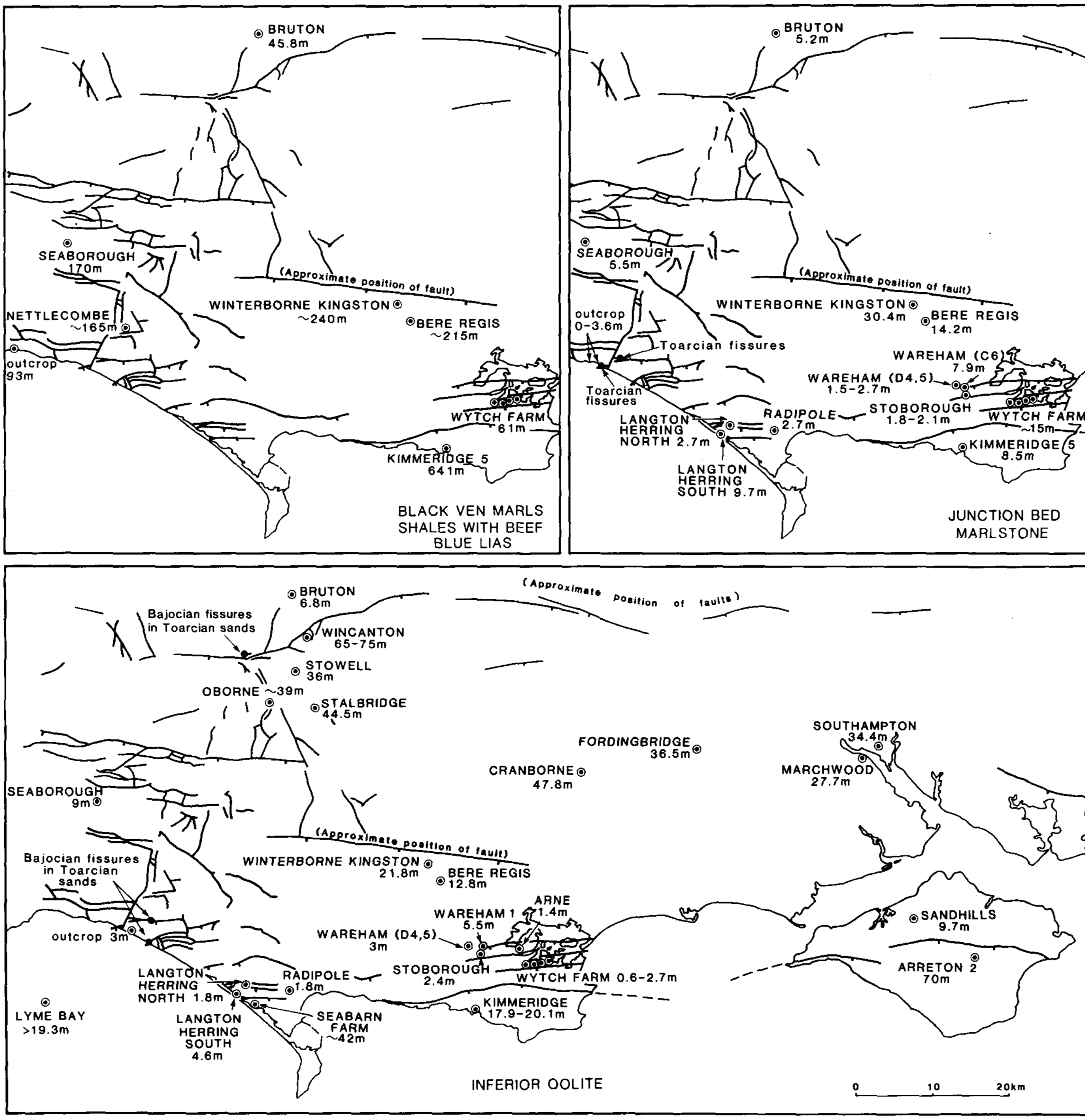

Fig. 14. Thickness data for the Blue Lias, Shales with Beef and Black Ven Marls and their equivalents (Hettangian–Sinemurian); Marlstone–Junction Bed (top Pliensbachian–Toarcian); and Inferior Oolite (Aalenian–Bajocian) and location of fissure facies plotted on a fault-block mosaic. Data from Edwards & Pringle (1926), Richardson (1928), Arkell (1933), Gatrall *et al.* (1972), Penn *et al.* (1980), Colter & Havard (1981), Ivimey-Cook (1982), Holloway & Chadwick (1984), Whittaker *et al.* (1985), Sellwood *et al.* (1986) and borehole records. Attribution of specific formations to a characteristic log signature may present difficulties where changes in facies occur, particularly in areas north of the Dorset coast; thicknesses may thus be approximate in some areas. Thus the demonstrable difference in facies of the Junction Bed (limestone) in the Dorset Coast as compared with the stratigraphically equivalent interval in the Winterborne Kingston borehole (silty mudstones), may account for the apparent anomalously thin representation of this unit in some boreholes. The considerable thickness of Hettangian–Sinemurian in Kimmeridge 5 may in part be related to fault repetition in the Blue Lias, as interpreted from log records. It should be noted that in the isopachytes of Gatrall *et al.* (1972), reproduced in Penn *et al.* (1980) and Penn (1982), the thickness of Inferior Oolite in the Wincanton Borehole would appear to be incorrect. The dips approach the vertical at depths close to the plane of the Mere Fault making estimates difficult, but 65–75 m would seem to be a realistic figure.

Purbeck–Isle-of-Wight Disturbance is crossed. Sections from Langton Herring (North and South) and Radipole to Seabarn Farm show the same trend, as does the transect from Sandhills to Arreton on the Isle of Wight. A section from Bruton to Wincanton across the Mere Fault shows an approximate ten-fold thickening (Edwards & Pringle 1926; Holloway & Chadwick 1984). The overlying Bathonian Fuller's Earth Clay does not exhibit such marked differences: 30.6 m at Bruton versus 36.6 m or less at Wincanton. It should also be noted that fault-controlled thickness changes in Bathonian Fuller's Earth at Herbury (SY 612811: Lake 1986) could not be confirmed in this study. In the Frome region Penn & Wyatt (1979) record a reduction in thickness of the Upper Fuller's Earth when traced southwards towards the Mendips, whereas the Lower Fuller's Earth and Fuller's Earth Rock show little variation. These thickness patterns are related by the authors to tilted-block geometry and interpreted as indicating limited Bathonian tectonic activity.

Impressive thickness differences are apparent in the Kimmeridge Clay (Fig. 13). For example in the Ringstead Bay area of Dorset the formation (*c.* 180 m) is considerably reduced in thickness relative to the section at the type locality (*c.* 500 m: Arkell 1947; Cope *et al.* 1980*b*; Cox &

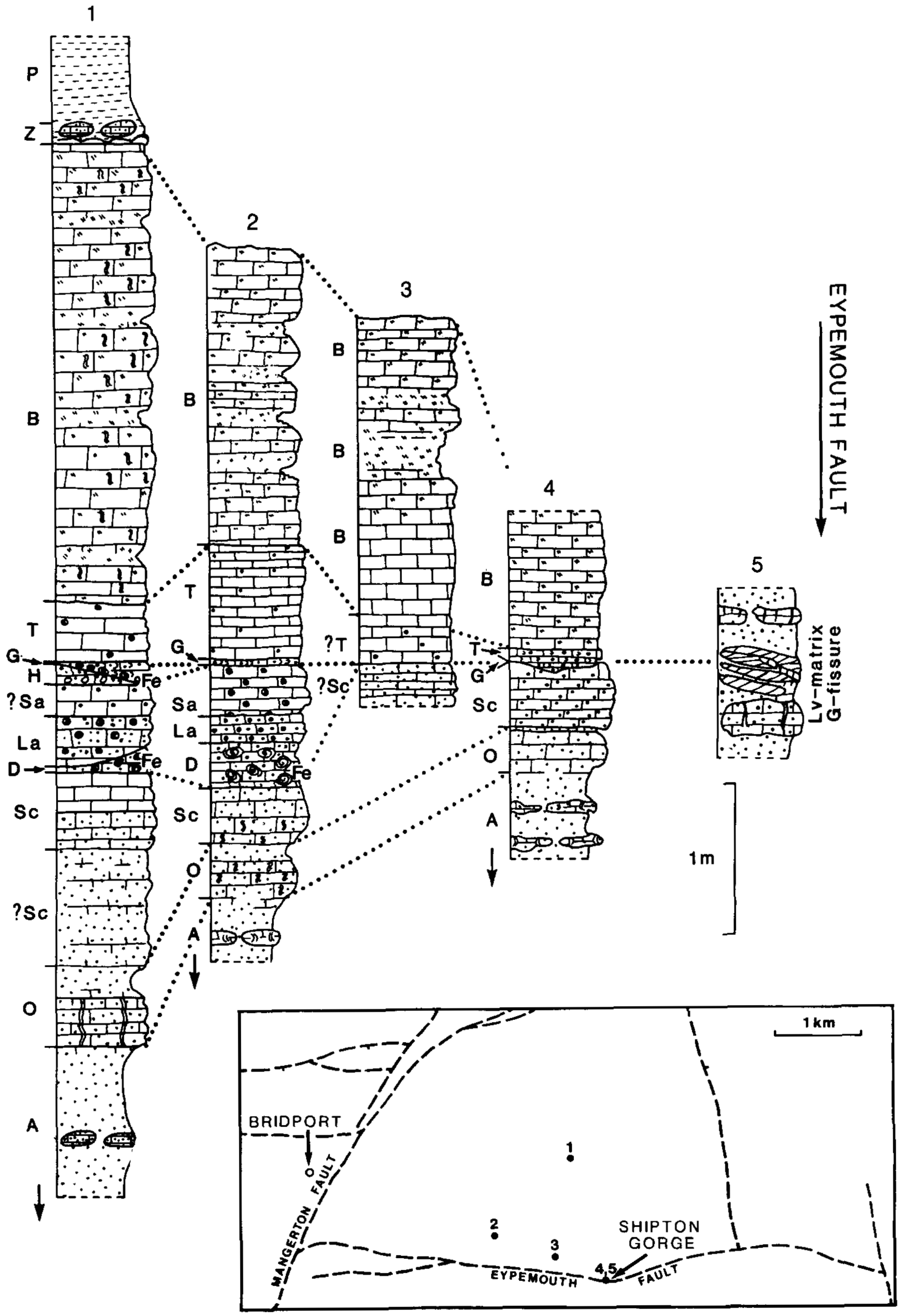

Fig. 15. Section, calibrated to the zonal level, through Aalenian and Bajocian sediments (Inferior Oolite) to the north of the Eypemouth Fault, Wessex Basin. Sediments of the various zones show no systematic thickness change, although there is an overall thinning towards the fault. Bajocian intruding Toarcian (Lv) sediment is a feature of the fault zone itself. Stratigraphic data from Senior *et al.* (1970), Parsons (1975) and personal observations. A, *aalensis* Subzone (Toarcian); O, *opalinum* Subzone; Sc, *scissum* Subzone; D, *discites* Zone; La, *laeviuscula* Zone; Sa, *sauzei* Zone; H, *humphriesianum* Zone; G, *garantiana* Zone; T, *truellei* Subzone; B, *bomfordi* (Subzone (Bajocian); Z, *zigzag* Zone; P, *progracilis* Zone (Bathonian). Note the thickness changes of strata between beds of the *scissum* Subzone and the *garantiana* Zone, suggesting intra-Bajocian non-deposition and/or erosion. Sections run from Stonyhead Cutting (1) through Bonscombe Hill (2) to Peas Hill Quarry, Shipton Gorge (3) along Markets Lane to the Eypemouth Fault (4, 5).

Gallois 1981). The two sections, although some 15 km apart, are separated by the Purbeck–Isle of Wight Disturbance. Similar thickness changes are also recognizable in the Portlandian, reinforcing the evidence for the overall Jurassic mobility of this fault which formed the northern margin of the Central Channel Basin (Holloway 1985; Selley & Stoneley 1987). At Durlston Head near Swanage (SZ 036773), Lake (1986) has interpreted changes in sedimentary thickness across a fault in terms of intra-Portlandian movement, although admittedly other interpretations of the outcrop are possible, involving solution of evaporites and post-Jurassic tectonics (e.g. Arkell 1947; West 1960).

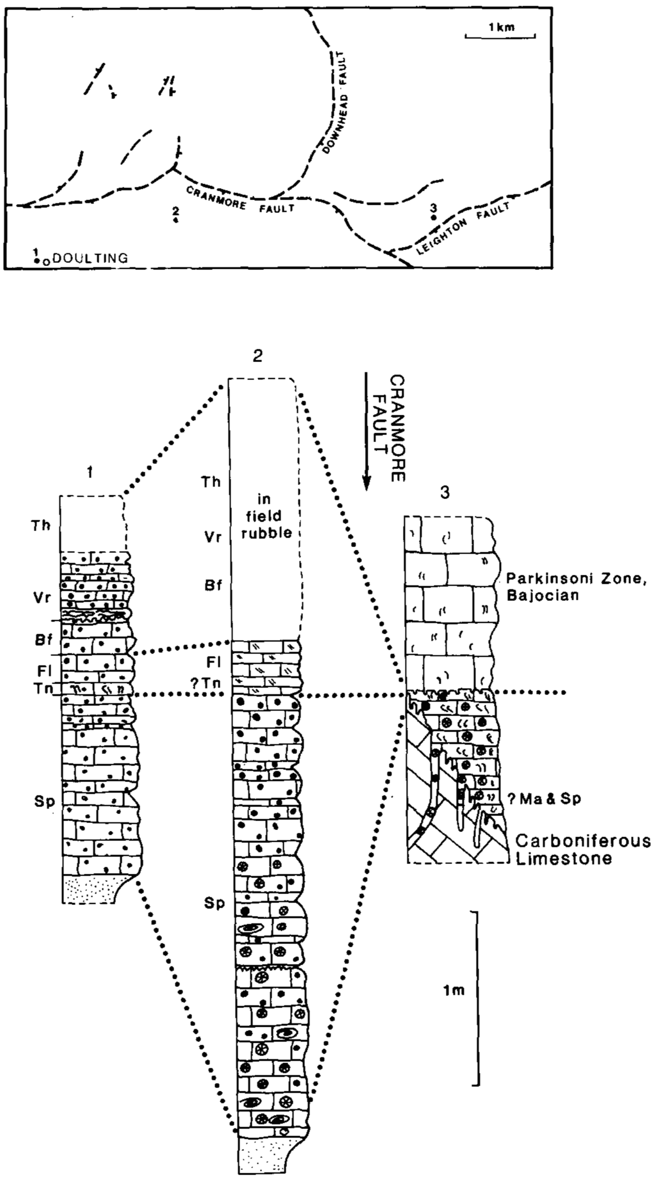

Fig. 16. Section, calibrated to the zonal level, of Pliensbachian–Toarcian sediments (Marlstone and Junction Bed) across the Cranmore–Leighton Fault System, Mendip Swell. Note the absence of Toarcian sediments on the upthrown side of the fault. Pliensbachian fracturing is indicated by the presence of neptunian dykes of that age in the Carboniferous Limestone (Fig. 12). Zonal code as in Fig. 3. Sections runs from 0.2 km northwest of Doulting Church (1) through a point 0.9 km southwest of Dean (2) to the road section at Leighton illustrated in Fig. 12 (3).

Unfortunately, there is a paucity of data on thickness changes in uppermost Jurassic strata in many other areas of the Wessex Basin as intra-Cretaceous erosion has cut deep into the succession.

In a further attempt to document the significance of Jurassic tectonism and its effects on sediment geometry on a smaller scale, a number of Lower–mid-Jurassic sections, calibrated to the zonal level, have been plotted across some of the faults in question. In Fig. 15 a series of sections from top Toarcian to basal Bathonian illustrate fine-scale variation in a north-south direction across a block bordered by the Mangerton and Eypemouth Faults, terminating with the Bajocian fissure-facies of Shipton Gorge. The general southward thinning is again notable, although there is by no means a consistent pattern. In Fig. 16 three sections close to the Cranmore Fault, Mendips are illustrated, and the control on preservation of Lower Jurassic sediment is clear: no Toarcian is preserved north of the fault, suggesting emergence or submarine erosion at this time. South of the fault the Pliensbachian–Toarcian section thins in a relatively consistent manner, in agreement with the notion of tilted-block geometry.

Discussion and conclusions

Neptunian dykes and sills

Apart from the examples documented above, syn-sedimentary fissures are apparently uncommon in the British Jurassic. Sandstones dykes and sills have been described from the Kimmeridge Clay in East Sutherland, Scotland, associated with the Brora-Helmsdale Fault and, similarly, from close to the Great Glen Fault (Bailey & Weir 1932). Intrusion of the sands was clearly related to submarine faulting in Kimmeridgian time. Recently Alexander (1987) described sandstone dykes in the Bajocian–Bathonian non-marine Scalby Formation of Yorkshire, and more specifically Martill & Hudson (1989) have documented a similar structure injected into the Lower Oxford Clay of Cambridgeshire close to and parallel to a major east–west–trending fault.

Sediment-filled fissures are widely developed in the Mesozoic of the Alpine–Mediterranean region, with the intrusive material commonly of Triassic and Jurassic ages (Castellarin 1965, 1970; Wiedenmayer 1963; Schlager 1969; Wendt 1971). Wendt's detailed analysis of Jurassic fissures in western Sicily emphasized the geometrical variety of sills and dykes, with laminated pelagic micrites constituting the most common fills and with country rock of shallow-water carbonate or stratigraphically condensed pelagic limestone. Multiple intrusions, of differing ages, are common in the fissures of western Sicily. Castellarin's (1970) work in the Southern Alps indicated how the density of fissures increases towards major tectonic lineaments which are interpreted as having formerly constituted the faulted margins between large tilted blocks of the Tethyan continental margin (Bernoulli & Jenkyns 1974). These models are relevant to understanding the significance of the neptunian sills and dykes in the Wessex Basin–Mendip area. Although it is not always possible to separate the time of fissuring from the times of filling, which is commonly polyphase, principal times of sediment injection in the Southern Alps include the Hettangian–Sinemurian, Pliensbachian, Toarcian, Bajocian and Tithonian (Wiedenmayer 1963; Castellarin 1965; Sturani 1971), and in Sicily the Toarcian and late-Oxfordian and early Kimmeridgian stages (Wendt 1971). In Hungary principal phases of extensional faulting, recognized from the dating of neptunian dykes and syn-sedimentary breccias, similarly took place during the Sinemurian, Pliensbachian, Toarcian, Bajocian and Tithonian stages (Galácz & Vörös 1972; Fülöp 1976; Haas *et al.* 1985). These ages, Late Jurassic excepted, show remarkable agreement with those of fissures from the Wessex Basin–Mendips area, and Kimmeridgian–Tithonian movement is also indicated as a regional phenomenon over much of Europe. Principal times of rifting, with delineation of major tilted faulted blocks were, on both the northern and southern margins of the Tethys, Hettangian and earliest Sinemurian and late Pliensbachian–Toarcian (Bernoulli & Jenkyns 1974; Lemoine *et al.* 1986).

Thickness changes in strata

The significance of thickness changes of coeval strata across faults needs further discussion as such changes can be generated both during and after syn-sedimentary movement, in the latter case infilling pre-existing submarine topography (Bertram & Milton 1988). If the Jurassic sea-floor of the Dorset sector of the Wessex Basin was at all times topographically very subdued, as assumed by Sellwood & Jenkyns (1975), then the absolute thickness differences of decompacted strata should closely approximate the syn-sedimentary throw on the fault. However, if relief was relatively greater during periods of regional stratigraphic condensation when units like the Junction Bed and Inferior Oolite were being laid down, then an absolute thickness difference of a few metres could indicate significant movement. Given that these condensed units were apparently lithified on the sea-floor, maintenance of modest sea-floor relief should have been possible, conceivably with the development of fault-scarps. The fact remains that there is negligible documented evidence for slope-induced redeposition (i.e. slumps and turbidites) in the exposed Jurassic of the Wessex Basin, although such phenomena are perhaps unlikely to have taken place during periods of regional condensation when little sediment was being deposited. Outcrop failure on the downthrown side of palaeofaults also hinders collection of critical data, particularly in those zones along which maximum movement was accommodated.

Although the evidence for sediment injection in the Wessex Basin indicates movement along faults during Toarcian and Bajocian, the absolute thickness changes across various zones of displacement particularly during the former interval is relatively modest. Indeed, Toarcian strata apparently thin on the downthrown side of some major faults if true thicknesses are recorded (i.e. Marlstone and Junction Bed in Kimmeridge 5 Borehole). Hence the amount of dip slip was perhaps relatively trivial during these intervals, and/or sea-floor relief greater than during times of mud and sand deposition and/or movement was predominantly lateral rather than vertical. In this context it is tempting to find some clue to the sense of movement along Wessex Basin–Mendip faults in the orientation of the fissures. Does vertical fissuring indicate normal faulting and horizontal fissuring strike-slip motion? The significance of wrench faulting in the evolution of the area has been stressed by Drummond (1970) and Lake & Karner (1987). Alternatively, the evidence of sediment injection in the Wessex Basin may cause one to place undue significance on the Toarcian and Bajocian as particularly significant episodes of Jurassic movement.

The tectonic motif

Taken together, the evidence from sediment-injection, facies and thickness changes, all closely associated with east–west trending faults in the Wessex Basin area, suggests that significant syn-sedimentary movement was taking place during the Hettangian to Bajocian interval: the late Oxfordian through Portlandian interval was also important and presumably represents a renewed extensional phase (Brown 1984; Chadwick 1986). Evidence from the Mendip fissures confirms the Pliensbachian and Bajocian as important times of extensional faulting, but also points to the Hettangian and Sinemurian as significant intervals too. No evidence of sediment injection at this earlier time has been uncovered in the Wessex Basin, although the thickness changes illustrated in Fig. 14 suggest fault-controlled deposition during this interval.

The detailed analysis of stratigraphic thickness of Jurassic Wessex Basin sediments by Hallam & Sellwood (1976) indicates deposition of a post-Callovian sedimentary blanket of more uniform thickness, implying lessening of differential movement: the Kimmeridgian would appear to be an exception to this, showing as it does both local facies changes and considerable thickness variations. In summary, available data for the Wessex Basin–Mendip area suggest contemporaneous faulting throughout Hettangian to Bajocian time, with some local Bathonian movement, followed by a period of relative quiescence until the late Oxfordian–early Kimmeridgian when renewed activity began. The Kimmeridgian faulting, also known from central eastern England and eastern Scotland (Bailey & Weir 1932; Kirby & Swallow 1987), presumably correlates with extensional activity in the North Sea region (e.g. Bertram & Milton 1988).

Viewed overall the Early Jurassic to Bajocian extensional activity in the Wessex Basin–Mendip area must reflect rifting in the central Atlantic–Tethyan domain, followed by a more passive period of thermal relaxation as Africa separated from North America and Europe. The Bathonian–Callovian regional deepening phase, named the 'Atlantic Transgression' by Lancelot & Winterer (1980) is assumed to mark the maturation of the Atlantic as a major ocean for the first time in its history (Winterer & Hinz 1984). In the Wessex Basin area and elsewhere in Britain this transgression is marked by the Cornbrash, although to what extent this deposit relates to a eustatic effect and to what degree it reflects thermal relaxation of the peri-Atlantic region is not clear (Watts 1982; Haq *et al.* 1988).

Onset of the latest Oxfordian, Kimmeridgian–Portlandian extensional phase must indicate the initiation of a different plate-kinematic regime which Ziegler (1982) interprets as dominated by the Arctic–North Atlantic rift system: indeed Kimmeridgian rifting is now established as a regional North Atlantic phenomenon (Hiscott *et al.* 1990). The major periods of fault movement and facies differentiation in the Wessex Basin–Mendip region hence correlate well with the rifting phases that predated the opening of the Central and North Atlantic Oceans.

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