An introduction to the geology of the area between Buckfastleigh and Ivybridge.

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Introduction

The ground between Buckfastleigh and Ivybridge to the south of Dartmoor is covered by Geological Survey Sheet 349. Sheet 339 lies to the north-east and has recently been re-mapped by workers on the Exeter University/Institute of Geological Sciences mapping contract; some elements of the structure and stratigraphy pass south-westward onto Sheet 349.

The geology of the area was first described by de la Beche (1839) who included the rocks in his Grauwacke Group. Ussher's re-mapping of Sheet 349 for the Geological Survey (Ussher 1912) indicated that an area occupied by black shales and sandy hornfelses lay surrounded by slaty lithologies referred to the Upper Devonian between Brent Hill and the Dartmoor granite. Ussher (1912) compared the sandy lithologies with his Ugbrooke type Culm (Ussher 1901) because of their immature aspect, and also clearly envisaged the Middle and Upper Devonian volcanics, limestones and slates of Brent Hill and Buckfastleigh to be thrust over the Upper Devonian and Carboniferous lithologies to the north of Brent Hill. Fitch (1933) interpreted the geology north of Brent Hill as a block of Carboniferous lithologies downfaulted into Upper Devonian slates.

Detailed mapping of the area indicates that between Buckfastleigh and Ivybridge three distinct successions occupy three structural units which are separated by major thrusts (Fig. 2a and 2b). The southernmost unit, the Denbury Unit, contains the Beacon Hill Succession and this has been thrust northward over the Bickington Unit on the Forder Green Thrust, a fracture originally described by Riddolls (1970) from Sheet 339. The Bickington Unit contains the Buckfastleigh Succession, this has been thrust northwards over the Kate Brook Unit on the south-westerly extension of the Bickington Thrust; T4 of Waters (1970). To the north of Brent Hill the Kate Brook Unit contains a much-sheared synclinal infolding of lithologies of Lower Carboniferous affinity which lie within an envelope of Upper Devonian Kate Brook Slate.

Stratigraphy

The Beacon Hill Succession

The Beacon Hill Succession (Fig 2A) was named and described by Riddolls (1970) from the area west of Newton Abbot; on Geological Survey sheet 339 it is illustrated as forming the older part of the Bickington/Beacon Hill Succession. The Beacon Hill Succession is comprised of an unknown thickness of Nordon Slate which contains interbedded clastic limestones and local volcanics. The succession ranges in age from the Eifelian in the Newton Abbot area (Riddolls 1970) to the base of the Frasnian, the youngest rocks in both the Newton Abbot and South Brent areas. In the area to the south-west of Newton Abbot the Nordon Slate forms an argillaceous base to, and lateral equivalent of, the Chercombe Bridge and East Ogwell Limestone, Riddolls (1970), Scrutton (1977). A comparable relationship between limestone reefs and basin slates has been described by Orchard (1978) from the Plymouth area.
The Nordon Slate is a brownish-grey to black calcareous slate, sometimes finely bedded, which forms the bulk of the Beacon Hill Succession. The Nordon Slate is locally fossiliferous; localities beneath the tract of tuffs and spilitic lavas which crop-out at Rattery SX(741617) have yielded stratigraphically useful faunas. An ammonoid referable to the Lower Frasnian has been recovered from slates in the railway cutting at SX(7088 6049), and at SX(7479 6257) near Bulkamore Farm stylolitoids and fragmentary ostracods occur within the Nordon Slate, the latter indicative of the torleyi-Zone, Gooday (1978). These faunas indicate a Lower Frasnian age for the Rattery Volcanics.

The Rattery Volcanics are a member of the Nordon Slate in which they form an imperstent horizon which crops-out between Ivybridge SX(636 657) and Tor Hill SX (770 656) south of Woolston Green where the volcanics are at least 30m thick. These spilites are typically developed at SX(7413 6174) in Rattery where the Nordon Slate is conformably over lain by 0. lm of slates containing rotten, scoreaceous bombs, these are succeeded by an unknown thickness of lapilli tuffs and basic vesicular lavas. Throughout its outcrop the Rattery Volcanics contains a wide variety of spilitic extrusives interbedded with dark-grey slates, including crystal and lapilli tuffs, bomb-tuffs and spilitic flows with some pillow-lavas: North of Rattery at SX(7494 6310) spilitic lavas 2m above the base of the Rattery Volcanics contain irregular pods of chert and limestone lenses. Whilst a conformable base to the Rattery Volcanics is evident at Rattery the top of the member is only seen in isolated outcrops near South Brent where thin tuffaceous horizons which continue the strike of the Rattery Volcanics lie within the Nordon Slate.

Limestones within the Nordon Slate. Ussher (1912) recognised several small outcrops of limestone between Brooking SX(790 608) and Woolston Green SX(777 658); these are limestone turbidites which lie within the Nordon Slate. Near Woolston Green the turbidite beds are thin (less than 0. lm) and sparsely developed, while at Brooking Quarry SX(765 668) the beds are prominently graded, crinoideal limestone turbidites up to lm thick with thin, black shale interbeds. Conodonts referable to the Lower Frasnian Middle to Upper varcus-Zone (sensu Ziegler, Klapper and Johnson, 1976) have been recovered from these beds and indicate a likely age for the turbidity currents. The nearby Dartington Limestone persisted into the Lower Frasnian, Middleton (1960) and could represent a source of detritus for these beds.

Calcareous developments within the Nordon Slate near Marley SX(721 608) have yielded a bentonic fauna of ribbed brachiopods, crinoid ossicles and tentaculitids. A comparable fauna occurs in slates associated with local umber patches (after limestone lenses) within the Nordon Slate south of South Brent at SX(701593). Other localities within the Nordon Slate which have yielded
Figure 2. The geology of the area between Buckfastleigh and Ivybridge.
2A: The relationships between the stratigraphic successions, major thrusts and structural units in the area.
2B: A simplified geological map of the area. Numerous small dolerite intrusions, lavas, tuffs and limestones have been omitted for clarity.
2C: A section in the Kate Brook Unit indicating the complex, sheared, synclinal core in which the higher elements of the stratigraphy of the Kate Brook Unit are preserved. Vertical faults have been omitted for simplicity.
benthonic faunal assemblages including isolate pleurodictyid and favositid corals, trilobites and bryozoans were listed by Ussher (1912, pp56-59); Champernowne (1881) compared these slates with the Wissenbach Slates from the Rhenisch Schiefergebirge. In the metamorphic aureole of south Dartmoor, calc-silicate hornfelses continue the strike of these calcareous horizons within the Nordon Slate.

The Buckfastleigh Succession
The Buckfastleigh Succession (Fig 2A) is broadly equivalent to the younger part of the Bickington/Beacon Hill Succession from Geological Survey sheet 339 where Waters (1974) considered the Gurrington Slate and tuffs to be thrust over the Bickington and Ashburton Limestones. Excellent exposures south and east of Buckfastleigh now reveal that a sequence of greyish-green to purple and green slates (Gurrington Slate) overlies and succeeds a base of laterally merging limestones, tuffs, spilitic lavas and slates which form a prominent scarp overlying the Bickington Thrust between Bickington SX(799 726) and Owley SX(677 597).

The Buckfastleigh Limestone and Volcanic Sequence
crops south-west from Buckfastleigh with the Bickington Thrust defining a tectonic base. Lenticular stromatoporoidal limestones and bedded clastic limestones are overlain by tuffs (Middleton 1960) and are laterally replaced by grey slates, lapilli tuffs and spilitic extrusives; local limestone pods on the south-eastern side of Brent Hill are now represented by skarns. The ages of the limestones and volcanics are not precisely known although they must be older than the Gurrington Slate which is not known to be older than Lower Frasnian throughout its outcrop.

The Gurrington Slate
is a lustrous, greyish-green to purple and green, colour-banded slate with local graded beds of calcareous sandstone usually less than 0.03m thick. Tuffs and spilitic flows of varied thickness are common and are scattered throughout the outcrop of the Gurrington Slate.

The Gurrington Slate contains a fauna dominated by ammonoids and pelagic ostracods with rare trilobites the only benthonic element. Ages within this area range from ammonoids and pelagic ostracods with rare trilobites the only benthonic element. Ages within this area range from Lower Famennian to the Newton Abbot area. In this belt Middle Devonian slates comparable to the Nordon Slate were deposited in basinal areas to the north of limestone reefs (e.g. the Plymouth Limestone, Orchard 1978), the sporadic development of benthonic faunas within these slates might indicate local colonisation during periods of shallowing in a basin, otherwise dominated by pelagic faunas, into which turbidites flowed from the limestone reefs to the south, Matthews (1977). Widespread deepening during the Lower Frasnian (Orchard 1978, Matthews 1977) heralded the onset of the deep water Upper Devonian Ostracod Slate Facies widely developed between Padstow and Chudleigh (Gooday 1978) and typified by purple and green slates.

The Kate Brook Succession
The Kate Brook Slate was originally described from the Bickington and Chudleigh areas by Riddolls (1970) and Waters (1974) respectively. Blocks of chert (Lower Carboniferous) and greywacke (referred to the Upper Carboniferous Crackington Formation) crop-out in the Holne Thrust zone (T3 of Waters 1970) west of Chudleigh. Waters (1974) considered these structurally isolated lithologies to succeed the Kate Brook Slate.

A more complete succession crops-out in the area south-west of Buckfastleigh (Fig. 2A & 2B) and has hitherto not been described. Beneath the Bickington Thrust south-west from Deancombe, a sequence of rocks referred lithostratigraphically to the Lower Carboniferous, crops out in a complex, sheared synclinal core within an envelope of Kate Brook Slate (Fig 2C). Outcrops to the north of Ivybridge, isolated in the Modbury Wrench Fault Zone of Dearman (1963) are also referred to this succession. Because most of the area north of Brent Hill and around Ivybridge is within the metamorphic aureole of the Dartmoor granite palaeontological control is lacking; however, lithological associations are distinctive enough to allow the establishment of a lithostratigraphy.

The Kate Brook Slate
is a well-cleaved, greenish-brown to grey, lustrous slate with some thin fissile bands, in adjacent areas it contains a restricted benthonic fauna comprised of spiriferid and crinoidal debris. Volcanic rocks are rare throughout the total outcrop of the Kate Brook Slate and equivalent formations to the west. A stratigraphic base to the Kate Brook Slate is nowhere seen but the oldest ages recorded from the formation are from SX(7360 7544) south of Buckfastleigh where a rare ostracod locality has yielded Richterina (?F.) intercostata, the index of the Middle Famennian intercostata-Zone. Stewart (1981) has recorded an Upper marginifera-Zone age (equivalent to the upper part of the Lower Famennian) for the comparable Tredorn Slate north-east of Bodmin Moor; ages older than Lower Famennian have not been recorded from the Kate Brook Slate or equivalent lithologies between Tintagel and Chudleigh. The youngest age recorded from the Kate Brook Slate is the Upper Famennian costatus-Zone (Selwood 1971) from SX(3241 6785).
The Zempson Chert crops-out between Zempson Farm SX(713 629) and Owley SX(675 597), it is extensively hornfelsed in this tract. In the Ivybridge area a restricted capping of calc-silicate hornfelses on Henlake Down SX(630 572) is referred to the Zempson Chert.

The Affinities of the Kate Brook Succession Greenish-grey slates bearing occasional bands of *Cyrtospirifer* have been identified east of Dartmoor (the Kate Brook Slate), between Dartmoor and Bodmin Moor (Whitchurch Green Slate) and westward towards the coast at Tintagel (Delabole Slate, Woolgarden Slate and Tredorn Slate). The Tredorn Slate is overlain conformably by dark grey and black slates which have yielded a *Gattendorfia Stufe* trilobite fauna at California Quarry, Selwood (1971). The nodular and calcareous slates which lie between the Kate Brook Slate and the black, silty Corringdon Slate south of Deancombe are comparable to members of the Stourscombe Formation of Stewart (1981) and the Upper Petherwin Beds of Setwood (1971), their presence indicates that, in the Deancombe area, the Kate Brook Slate passes upward into facies which are associated with the flanks of topographic highs in adjacent areas.

The Gurrington Slate and its equivalents to the west are, in part at least, coeval with the Kate Brook Slate and its western equivalents. The two facies contrast markedly. Whilst the Gurrington Slate contains an exclusively pelagic fauna and common spilitic volcanics, the Kate Brook Slate is typified by a benthonic fauna and rare volcanics.

The Corringdon Slate and the Nurston Sandstone are intruded by extensive sill-like dolerite sheets and pods which would argue strongly in favour of a Lower Carboniferous age for these rocks. The Zempson Chert is associated with an horizon of extrusive volcanics; the association of cherts and volcanics is common and widespread in Lower Carboniferous successions both east and west of Dartmoor. Where faunas occur an *anchoralis-Zone* age is indicated for the onset of chert deposition. The occurrence of immature sandstones in the succession is reminiscent of the Dinantian sandstones which are abundantly developed in the St Mellion outlier, Matthews (1966), Whiteley (1981).

The Structure of the area

Between Buckfastleigh and Ivybridge the three tectonic units are separated by thrusts (Fig. 2A). The structure of the Kate Brook Unit to the north of Brent Hill (Fig. 2C) is picked-out by the distribution of the stratigraphic elements; an envelope of Kate Brook Slate surrounds a much-sheared core of lithologies referable to the Lower
Figure 3. The structural styles and relationships between the Kate Brook Unit, the Bickington Unit and the Denbury Unit between Buckfastleigh and Ivybridge.
Carboniferous. Bedding/cleavage relationships and way-up evidence combined with the structural data (Fig. 3 E and F) indicates that a tight, reclined fold with an axial-planar slaty cleavage (SO dipping gently south-east lies to the north of Brent Hill beneath the Bickington Thrust. This simplified structure is complicated by minor thrusts (Fig. 2B and 2C), and vertical faults.

Interpretation of gross structure within the Bickington and Denbury Units is difficult because of the limited stratigraphic control and the sparsity of marker horizons. Structural data (Fig. 3) and the relationships between thin-bedded turbidites and slaty cleavage (S1) in the Gurrington Slate indicate that tight, reclined to recumbent, north-facing folds with an axial-planar slaty cleavage dipping gently south-east characterise the first deformation in the Denbury and Bickington Units in the area east of South Brent.

A locally developed crenulation cleavage which dips steeply south-east is axial-planar to small-scale open folds which deform the slaty cleavage; a comparable S1/S2 relationship has been described from the Torquay area by Richter (1969). In the River Dart section the second deformation is closely associated with fracture-zones within the Gurrington Slate; this and the variation between the orientations of slaty cleavage maxima in the three structural units east of South Brent (Fig. 3) reflects post St movement on the major thrusts which separate them. To the west of South Brent slaty cleavage in the Denbury Unit dips south-east and steepens along the southern flanks of Dartmoor. This is not thought to be the result of turning against the granite because in the Ivybridge area the steeply dipping S1 in the Denbury Unit is juxtaposed with the reclined, north-facing synclinal structure of the Kate Brook Unit (and its gently-dipping S1) across a fracture which represents the westerly equivalent of the Forder Green Thrust or the Bickington Thrust; these relationships are expressed diagrammatically in Figure 3. The Dartmoor granite intrusion was emplaced in the already deformed slate sequences and in this area turning of strata against the intrusion is less than 10°.

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References