

Review of Somerset's Local Geological Sites (LGS) 2017 – 2021

Final report for the Exmoor area, May 2021

This Review of Somerset's LGS is a partnership project between Somerset Geology Group (SGG) and Somerset Environmental Records Centre (SERC). Please note that LGS may be of regional to local value, are the equivalent of the former Regionally Important Geological Sites (RIGS) and that LGS status does not imply any right of public access. The scope of our review has been to cover existing LGSs only, not recommendations for new sites, although some gaps in coverage and potential for future designation may have been identified in the process. See DEFRA Guidance on Local Sites published in 2006 for further information on LGS designation and SERC's web page at <https://www.somerc.com/local-geological-sites/> for the key questions that we have used in this review for assessing the four criteria (scientific, educational, historic and aesthetic). The information below is completed to the best of our ability, but there may be errors or omissions and/or more recent or more detailed information available. For progress with our review across Somerset as a whole see SGG's Updates at <http://wp.somerc.co.uk/specialist-groups/somerset-geology-group/>.

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Our thanks also to the SERC-based graduate/student volunteers and members of SGG who have assisted voluntarily with knowledge of recent geological research on Exmoor, preparation of site forms, site visits and desk assessments and Panel review of these Exmoor area LGS. This report has been compiled by Wendy Lutley (SGG), based on the information gathered for the review, with those contributing to the review including: Phil Parker and Garry Dawson (SGG); Wesley Harris (SERC's LGS Project Officer and SERC-based graduate volunteer, summer 2018 to May 2019); Hugh Galloway and James Voysey (SERC-based graduate/student volunteers summer 2017); Louis Warnes (SERC-based graduate volunteer summer 2018); with assistance for some site visits from Derrick Reid (SGG) and Connor Allen (graduate volunteer) in 2017; and with assistance for form preparation and desk studies for LGS in the Devon part of the ENP from John Kirby (SGG) in 2019/20. Our thanks to them all; to all those who contributed to the LGS Panel sessions, including Peter Chamberlain for those in the Devon part of the ENP; and to Pamela Harris (ENPA) for her continued support and encouragement for the project.

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1. Introduction and sites covered

This report covers what is now 63 LGS in the ENP, including 49 LGS in the Somerset part and 14 sites in the Devon part, plus 8 sites in Somerset West & Taunton district beyond the ENP boundary that are also underlain by similar Devonian or Carboniferous rock strata. It is intended to provide an overview of the conservation interest and management needs of the LGS in the ENP and adjacent areas of Somerset and their potential for education and interpretive use. ***It does not constitute a full geo-diversity action plan for Exmoor:*** our recommendations result only from our review of the LGS and the contextual information that we have gathered for that.

- **R1** Our first recommendation is therefore that the ENP Authority liaise with key partners, such as Natural England in relation to GCR sites (see below), the National Trust (NT) and adjacent North Devon AONB to assist in developing appropriate priorities for geo-conservation as a whole.

SERC was able to identify ownership and obtain permission for site visits for a good proportion of the LGS, so that when complete it is anticipated that over 70% of the post-review forms for the ENP will have been sent to the land owner/manager (or the owner will have been offered the form). A quite high proportion of the sites are in some type of public ownership (ENP Authority, NT, Highways Authority, etc).

Most of the LGS (ie former RIGS) for Exmoor were originally adopted in 1993, following work in 1991, by the late Hugh Prudden, former secretary of Somerset Geology Group (SGG), with the support of a grant from the Curry Fund for the Somerset part of Exmoor; and in 1993 for the Devon part of the ENP as a contract for the ENP Authority. This original selection was very thorough. For example, the then 55 LGS in the Somerset part of the ENP were selected from 295 sites considered.¹

Our review has reconfirmed most of these original LGS, with a few mostly relatively minor adjustments to site boundaries. Only c 9 sites have been deregistered as not of substantive interest to meet the criteria (3 in the Somerset part of the ENP and 6 in the Devon part). Plus, in a few cases our review made recommendations to amalgamate adjacent or overlapping sites into one or a composite site, which has caused further reduction in the numbers. There is therefore relatively little substantive change to the original suite of sites, but the updated site forms include more detailed evidence-base on their conservation interest and current condition.

¹ See Prudden, H C, 1991, *Site recording in West Somerset* in *Geology Today*, vol 7, 201-202 and Prudden H C and Anderson, M, 1992: *The survey of west Somerset's geological sites* in *Nature in Somerset*, p 26-29. A few LGS in the east appear to have been identified prior to this, from 1988 onward; and/or subsequently by Hugh as part of his work in the former district of Taunton Deane.

Most of the LGS are on strata of Devonian age (c 300 to 400 m years old) with the formations striking east-west, the oldest in the north, with the succeeding younger Carboniferous 'Culm Measures' to the south; the whole then affected by the Variscan mountain building folding and faulting. Younger Permo-Triassic strata (c 200 to 280 m years old) occupy the Vale of Porlock, while superficial Quaternary deposits (dating from the last c 2m years) include periglacial 'head' covering much of the area, peat deposits on some moorland summits and fluvial gravels and alluvium in valleys.

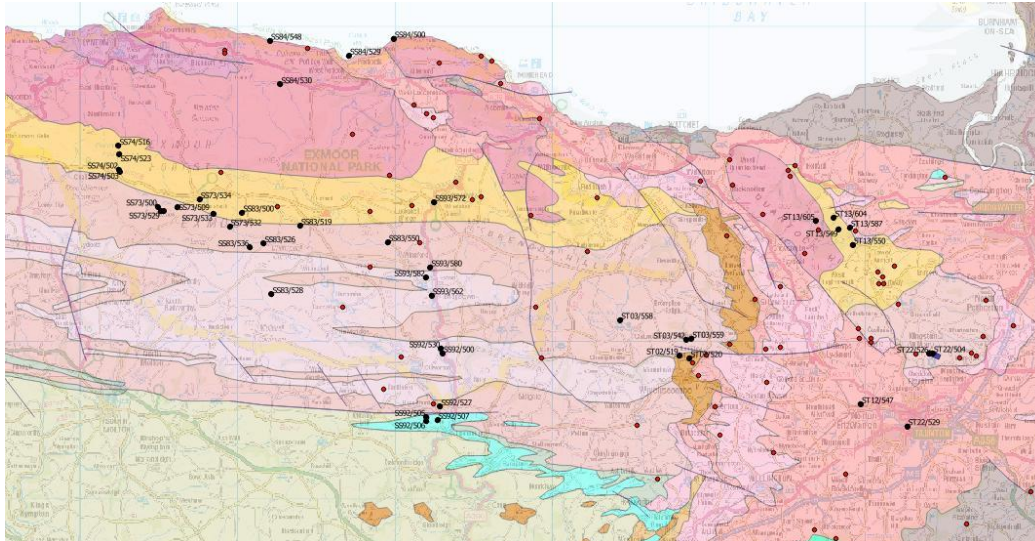


Fig 1: Over view geological map for Exmoor and the Quantocks showing the main geological formations present and distribution of LGS NB LGS in the Devon part of the National Park not shown. LGS in Somerset shown as they were pre-review, those surveyed by 2018 in red, others black and not all site ref nos shown. Devonian Formations from north to south: Lynton (purple); Hangman Sandstone (dark pink); Ilfracombe (yellow); Morte Mudstone (pale pink northern band); Pickwell Down Sandstone (pale lilac); Pilton Mudstone (pale pink southern band). Carboniferous 'Culm Measures' turquoise. Permo-Triassic of Porlock Vale orange.

2. Scientific interest

- Nationally important designations** - The LGS on Exmoor complement 11 nationally important Geological Conservation Review (GCR) sites on Exmoor (all earth science Sites of Special Scientific Interest (SSSIs) or part of wider biological interest SSSIs) and an additional complexity for our review - particularly in the coastal zone of the ENP in Devon – has been LGS that overlapped with these nationally important sites. LGS designation has been removed where the interest is the same. However, in cases of overlap where additional local interest exists that is not mentioned in the GCR description or in the SSSI citation, the LGS designation has been retained. For further detail of the GCR sites in the ENP at the current time see Appendix 1.
 - See R1 above re liaising with Natural England – including on priorities for GCR sites.
- LGS** - most of the GCR sites are on or near the coast, including cliff and foreshore rock exposures and the LGS here also tend to have the best rock exposure, providing additional localities for study to complement those sections that have been identified as nationally important. The inland LGS, although often less spectacular and with poorer exposure are no less important as they provide a valuable suite of sites to allow examination of Exmoor's geology inland, where there are virtually no nationally important sites.
- The importance of non-designated exposures and features** - there are many other rock outcrops, in for example stream sections and old quarries and mines, and wider landscape-scale

geomorphological features on Exmoor. Conservation of these is also important at a wider landscape scale. Some sites may be of similar calibre to those currently identified as LGS - our review has not considered prospective new LGS.

- **R2** We recommend that conservation of other small rock exposures, old mines and quarried landscapes and wider landscape geomorphological features be incorporated within other wider policies, such as those to protect biological SSSIs, multiple-interest green infrastructure, industrial archaeology and the new Nature Recovery Areas.
- **Variscan mountain building orogeny** - Since the LGS were originally selected in the early 1990s there has been more recent geological research in the South West of England, particularly on the structural deformation of the older Devonian and Carboniferous strata in the Variscan mountain building orogeny. Much of the research has taken place on the Carboniferous 'Culm Measures' to the west, rather than the Devonian of Exmoor and there is no detailed British Geological Survey Memoir for the 'Dulverton' area, so that there remains potential for future more detailed scientific research on Exmoor. See Appendix 2 for more detail.
- **Quaternary periglacial and fluvial erosion processes** - Similarly, in recent years there has been considerable research interest in the much younger Quaternary periglacial and fluvial erosion processes that have shaped the landforms in the South West, with gelifluction in tundra conditions and differential down cutting of river valleys over different types of rock with changes in sea level, etc². Exmoor is thought to have been close to the margins of the extent of the last glaciation and again, there is potential for more research for these interests (which are often at a landscape scale and may not be fully assessed by our LGS review). There appears, for example, to be no published scientific information on the knolls which are a characteristic feature of Exmoor's landscape locally (although they are probably largely of fluvial origin) and we have not been able to identify the source reference for reported patterned ground at Holdstone Down.
 - **R3** The ENP Authority could consider hosting a seminar on the Quaternary landscapes of Exmoor, in conjunction with, for example, the Quaternary Research Association, Ussher Society and Universities of Exeter and Plymouth and/or establishing a Quaternary landscapes advisory group from these sources to bring together experts to assess the current information available, what additional research might be desirable and appropriate conservation measures.
 - **R4** More detailed topographic and condition surveys of some of the knolls sites, and any other features identified by the initiative above, might then be considered, with the potential to develop conservation packages that might be suitable for the new Environmental Land Management payments system (ELMS) and/or contribute to Exmoor's agricultural Nature Recovery Network (NRN). See also below for the potential for such a project to include development of interpretive and educational material to deliver additional 'ecosystems services' benefits.

3. Opportunities for geo-conservation and interpretation and education

- Opportunities for geological field study use of LGS on Exmoor are generally limited by the availability of appropriate coach or minibus parking and associated facilities nearby, with the

² See for example Gunnell, Y, 2020: *Landscape evolution of Dartmoor, S W England: a review of evidence-based controversies and their wider implications for geoscience*, Proc Geol Assoc, vol 131, p187-226 which includes a comprehensive reference list, including for example listing papers by Harrison on Exmoor (re the Punch Bowl) but not the thesis mentioned under Section 4.11 below.

main use at present currently being, for example, in and around the Valley of Rocks in the Lynton and Lynmouth area, Dulverton area or field study centres such as at Pinkworthy.

- The larger opportunity identified by this review has been the considerable potential for new off-site and on-line interpretative materials both for the public, and for schools and other education groups, to provide more of an understanding of the forces and processes that have resulted in the formation of Exmoor's landscape. This might best be layered - to provide for different levels of interest and use. Particular opportunities that have been identified are given below.
 - **R5** There is potential for a project to develop online interpretive material that reflects the new understanding of the **Variscan mountain building orogeny** that affected the Devonian strata of Exmoor, including the range of folding and faulting and low-level metamorphism that produced a range of mountains that has since been eroded. This has potential for good visual material (see Appendix 2) including photos and diagrams of micro- and zig-zag folds exhibited at some LGS. There appears to be virtually no information on this to date.
 - **R6** This adds to the interest on the changes between **marine and non-marine conditions at the time that the sediments that form the Devonian aged strata were deposited** - with again scope for good illustrations, including desiccation cracks and fossil ripple marks for the terrestrial strata; and of the trace 'worm cast' type fossils found in marine horizons.
 - **R7 History of Earth Sciences** - Our review has indicated a number of papers written by well-known geologists visiting the ENP from the early 1800s onward. This suggests, for example, the potential to develop interesting stories on the history of understanding the age and origin of the Devonian rock strata, particularly for example in the Foreland Point area, as to whether the rocks here are younger than the Lynton Formation. See Section 4.2 – and other examples mentioned below.
 - **R8 An accessible urban geo-trail and building stones** - Early visiting geologists to Exmoor included Sedgwick and Horner and archival research for the Lynton and Lynmouth area might potentially reveal links between visiting geologists and local prominent landowners and the early development of tourism, including links to the Romantic movement. There is scope to develop an accessible urban geo-trail, including information on building stone used in the resort³. See information under Section 4.1 and 4.2.
 - **R9 Limestone quarrying and museum specimens** - old quarry workings in Roadwater Limestone within the Ilfracombe Formation provide potential for both conservation initiatives and a community project, particularly for parishes in the Brendon part of the ENP. It is important to conserve the old pits themselves, quarry faces and surrounding wooded and hummocky ground that reflect the line of the original limestone outcrops. Conservation requirements might be eligible for the new Environmental Land Management payments system (ELMS) and/or contribute to Exmoor's Nature Recovery Network (NRN). At some of these sites there is also potential for conservation of associated industrial archaeological remains, including lime kilns. Some further research is also desirable to locate if there are

³ See <https://swheritage.org.uk/historic-environment-service/built-heritage/traditional-building-stone-research/> for research on building stone for Somerset as a whole by Garry Dawson and Peter Wright. This covers much of the Somerset side of the ENP and its adjacent parishes and there is also a link to Mike Barr's, 2017: *Building Stone Inventories for Devon* (2 vols and including parts of Somerset and Dorset) which can be downloaded, covers both the Devon and Somerset part of the ENP and includes both distribution maps and photographs. There is also a link to a previously unpublished list of Somerset Church Building Stone compiled by Hugh Prudden which includes some coverage of the ENP.

museum specimens available, including microscope sections, photos and drawings of the fossil corals - as these could provide good visual illustrations. Local communities may also be able to gather memories and historic documentation of the quarrying, lime burning and use of the lime in agriculture and for whitewash, etc – with the potential for interpretive displays at some village locations that could benefit sustainable tourism. See additional information under Section 4.4.

- **R10 Limestone in Porlock Vale** - There is a similar opportunity in relation to small limestone quarries and the undulating farmed landscape in the Permo-Triassic strata in the south of Porlock Vale. See additional information under Section 4.10.
- **R11 Road stone quarrying** - LGS in the Exe Valley in old road stone quarries for Carboniferous radiolarian chert (just south of the ENP), provide the opportunity for similar community local history projects, where information on geology and fossils can be included within the project, with scope for good visual material and a link to interest for the history of geology, with study by early geologists. See Section 4.9. Two LGS in the Exe Valley (on different formations in the ENP) are also historic road cuttings with plaques to this effect.
- **R12 Building stone quarries** – Building stone quarries near Dulverton and old slate quarries, such as Oakhampton Quarry (beyond the ENP boundary) and Treborough Slate quarries (the latter apparently not originally identified as a LGS, probably as it was still a working quarry in the early 1990s) provide similar opportunities.
- **R13 Mineralisation and old mine sites** - LGS cover only a very few of Exmoor's old mining sites and it is not clear why these were originally selected as opposed to others. Consideration is therefore needed as to whether other old mine sites are adequately protected by other designation(s). Some additional LGS coverage may be useful to flag up the interest of their ore genesis. There is in any case considerable potential for including **information on the geology of the country rocks and the mineralogy of the ores in interpretive material on industrial archaeology sites related to mining** - again with scope for good visual material. See further information under Section 4.12.
- **R14 Links to archaeology** – A few LGS illustrate linkage with, for example, iron age hill forts, such as in the Barle Valley and Clatworthy, where there is scope to explain the underlying geology at accessible locations. Higher up the Barle Valley, archaeological investigations in recent decades suggest that some mineralized veins may have originally formed quartz ridges running across the moor, with early use for ochre - before quarrying for their metals. There is plenty of scope therefore to include more geology in archaeological information.
- **R15 Quaternary periglacial landscape and fluvial erosion features** - there is scope for more interpretive material on these features of Exmoor, including scree developed on the Hangman Sandstone Formation and the knolls, etc mentioned above - and more widely than simply the Lyn catchment to include the River Exe valley, and its tributary the Barle. See R3 and R4 above and Section 4.11.
- **R16 Taw catchment of Exmoor** - the south-west corner of Exmoor drains south (via the Bray and Mole) into the then north flowing Taw, with examples of what is thought to have been river capture (ie earlier abandoned river valley routes) in the vicinity of Barnstaple. There could thus be potential to include geology in **a river project for local schools and community groups** focusing on this lesser-known corner of Exmoor and adjacent parishes.

- **R17 Coastal geomorphology** – The geomorphology of the Exmoor coast provides opportunities for interpretive and educational materials more widely than simply the nationally important gravel barrier at Porlock. Newell Arber's classic 1911 book *The coastal scenery of north Devon* covers the Devon part of the ENP and is well-known for its description of the 'hogs back' cliffs and coastal waterfalls. See Section 4.11 below. This also provides another aspect of the history of geology on Exmoor.
- **R18 Educational materials** – There is considerable scope from the above examples to include more on geology and geomorphology within the ENP's existing and new **moorland classroom** and other on-line resources for education users at different key stages. The only printed published resources available at present would appear to be two Thematic Trails booklets and Edwards' popular book on the geology of Exmoor⁴, while a few sites in the Devon part of the ENP are included in the Devon County Council register of geological education sites.
- **R19 Practical conservation work** - Our review has identified some specific needs where regular practical conservation work is required for face cleaning, examples being: at Clatworthy Reservoir, where work has already been carried out by SW OU volunteers in tandem with assisting Wessex Water with wording for an interpretive panel; and fold structures at Oaktrow that were illustrated in early geological literature. Then there are several other sites which are overgrown and where requirements for clearance might be developed in tandem with developing new interpretive and educational material.
- **R20 National Trust (NT)** – See a R1 above re liaison with the NT. Several LGS are under NT ownership and in several cases, particularly in the Devon part of the ENP, our assessment suggests more detailed work would be helpful (beyond the scope of this review) to further define features within the LGS boundaries where there is particular scope for geological trails or multiple interest walks – this could help to clarify any practical face-cleaning that might be desirable as well as potential for interpretative material. See also comments above re History of geology and materials for schools.
- **R21** There may be scope for some type of overarching **geo-park or similar initiative** that might complement the geo-park in South Devon⁵ and help to promote geo-tourism. A coordinated approach of this type might, for example, be explored particularly **in conjunction with the North Devon coast AONB**, which extends west from the ENP boundary at Combe Martin, includes a number of nationally important GCR sites along its coastline for similar interests, has had a geo-diversity audit carried out in recent years and was also covered in Arber's classic book on the coastal scenery of North Devon (see above). NB A global geopark requires significance at the international level.
- **R22 Training for staff and volunteers** - Finally there is scope to develop a training programme for ENP staff and volunteers involved in Exmoor's conservation to ensure an

⁴ Keene and Elsom, 1990, *Lyn in Flood, Watersmeet to Lynmouth* and Keene and Pearce, 1993 *Valley of Rocks, Lynton*, both Thematic Trails, booklets; and Edwards, R A., 2000. *Exmoor Geology; Exploring the Landscapes Rocks and Mines of the National Park*. The latter includes a walk on Foreland Point for example.

⁵ **English Riviera Geopark** http://englishrivierageopark.org.uk/section_main.cfm?section=15 . The UNESCO Global Geoparks web site explains the international geological significance needed for recognition at this level <http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/> .

understanding of how geology contributes to Exmoor's landscape character types, semi-natural habitats, archaeology and built heritage. This would benefit those working more widely in landscape, biodiversity and heritage conservation and assist in ensuring geology is more fully embedded in conservation and interpretative projects. This could range from individual training days on site to studying for OU degree units.

4. Formations present

4.1 Devonian – Lynton Formation

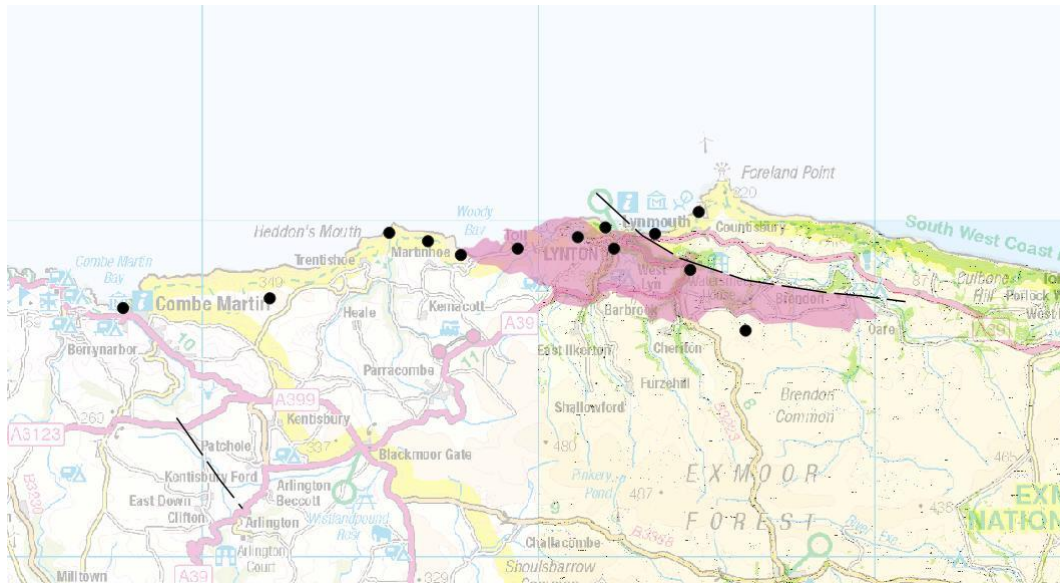


Fig 2: Lynton Formation shown pink; black dots showing the LGS on it (as revised post-review) and in the adjacent coastal area of the Devon part of the ENP. NB LGS in the Somerset part of the ENP not shown.

There are now 9 LGS with exposure of this Formation, which forms the oldest strata on Exmoor and is found in Britain only in the Lynton and Lynmouth area, almost entirely in the Devon part of the ENP (see map). Its slates and siltstones are of marine origin and the LGS complement 4 nationally important GCR sites for this interest, the latter including the well-known Valley of Rocks (see Appendix 1). The LGS illustrate different sedimentary features in the siltstones and slates, trace fossil burrows and occasional other fossils, and structural features such as folding and faulting.

Those LGS on the coast west of the Valley of Rocks complement the Hollowbrook GCR site there, which is the best site for observing the gradual transition into the overlying non-marine Hangman Sandstone Formation. Other LGS to the east cover the structural features at and near the faulted boundary with the Hangman Formation along the Lynmouth-East Lyn fault. LGS close to the town of Lynton and Lynmouth provide potential for geo-trails/interpretative information, including the opportunity to consider the fluvial erosion history of the East Lyn river gorge.

4.2 Devonian - Hangman Sandstone Formation

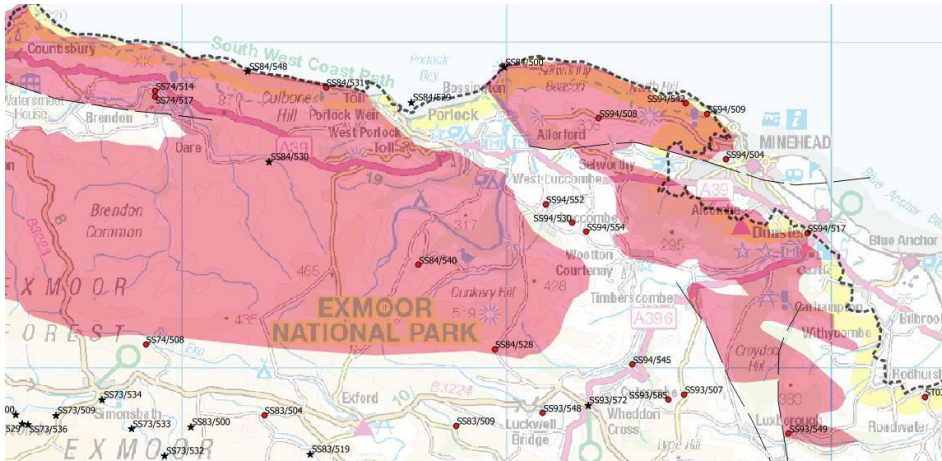


Fig 3: Hangman Sandstone Formation shown deep pink. NB LGS in Somerset shown as they were pre-review, with those surveyed by 2018 in red, others black and not all site ref nos shown. LGS in the Devon part of the ENP not shown.

The Hangman Sandstone Formation (formerly referred to as the Hangman Grits) consists of *non-marine* Devonian sediments laid down following the marine Lynton Formation. It underlies much of the northern coastal part of the ENP in both Devon and Somerset (and the northern part of the Quantocks AONB). There are now 3 LGS in the Devon part of the ENP and 12 LGS in the Somerset part underlain by this Formation (plus those included above under the Lynton Formation covering the boundary between the two) complementing 2 nationally important GCR sites representing this interest (Little Hangman and Glenthorne - see Appendix 1).

The best exposure is found on the coast, where sedimentological features are well exposed at some LGS, including ‘fossil’ desiccation cracks and ripple marks, while an understanding of the Variscan mountain building period can be derived from some of the same and other LGS with features such as folding, faulting, slickenside features from inter-bed movement and *en-echelon* tension gashes. There is also an interesting story in relation to understanding their age, source material and deformation in the Variscan orogeny - from their examination by early geologists in the 1800s to contemporary research from the 1990s onward.

The Formation has locally differentiated horizons within it (including the Trentishoe, Rawn’s and Little Hangman Members), although it is not always possible to distinguish these - and the most comprehensive recent description by Edwards, 1999 (in the Minehead BGS Memoir)⁶ describes instead a number of different sedimentary ‘facies’.

The main interest of some of these LGS is also as examples of Exmoor’s characteristic ‘hogs back’ cliffs, localised aprons of superficial ‘head’ that fronts them, scree slopes and knolls (all best developed over this Formation, with the latter three all thought to be of Quaternary periglacial origin), while a few are of interest for their fluvial erosion features.

4.3 Devonian - Ilfracombe Slate Formation

⁶ Edwards, R A, 1999: *The Minehead District – a concise account of the geology: BGS Memoir for sheet 278 and part of sheet 294*. See also Edwards R A, 2000: *Exmoor Geology*, Exmoor Books for a more popular account.

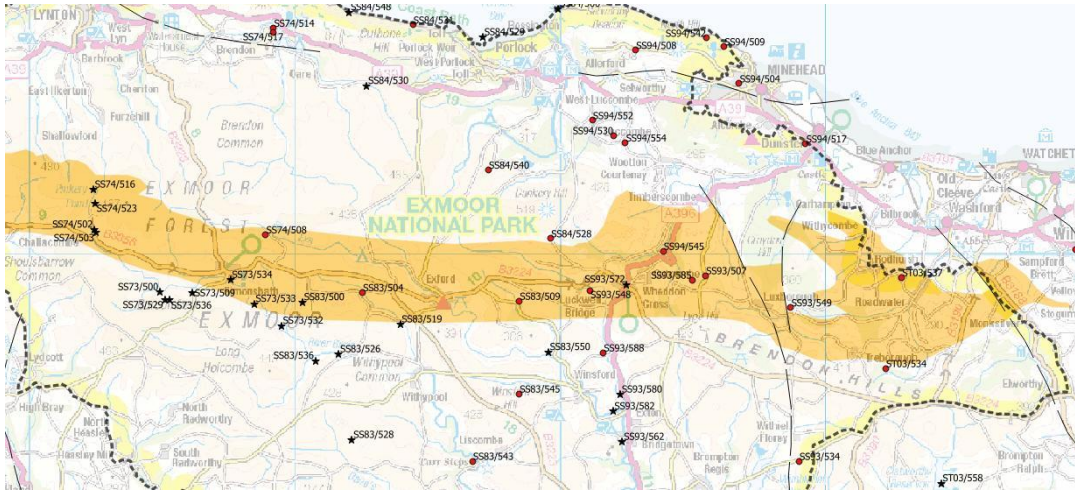


Fig 4: Ilfracombe Formation shown yellow. NB LGS in Somerset shown as they were pre-review, with those surveyed by 2018 in red, others black. Not all site ref nos shown. LGS in the Devon part of the ENP not shown.

This Formation represents a change to marine sedimentary conditions and consists largely of slates, but with variations in lithology, resulting in a number of differently named Members. The Kentisbury Slates, for example, are mapped in the western part of Exmoor (with locally named horizons including the Lester Slates and Sandstones Member that occur only in the Combe Martin area of the ENP), while the Cutcombe and Leighland Slates are mapped in the east. Discontinuous horizons and lenses of limestone also occur within the slates, particularly in the eastern part of the National Park - and are of particular interest as the limestone is fossiliferous and has been quarried for lime (see next section for more detail).

There are 16 LGS (15 Somerset and 1 in Devon) in the ENP on or over this Formation, with 6 being for the limestone horizon. There are no LGS beyond the ENP boundary (except in the Quantocks).

They illustrate the variation in sedimentary types from different Members and positions within the sequence and along the strike of the Formation, with occasional structural interest such as a recumbent synclinal fold first described in the geological literature in the 1800s. Other LGS, particularly in the Pinkworthy area also provide the opportunity, close to the ENP's field education centre, for field examination of the superficial periglacial head deposits on the valley side slopes, with their range of different soil types and associated vegetation from the deep peat deposits on the hilltop area of The Chains (a GCR site) to the valley base; and to consider the origin of Exmoor's characteristic valley knolls and their probable periglacial/fluvial origin. Some provide the opportunity for locally-based interpretive material in various settlements and a few cover mineralogy.

4.4 Devonian - Ilfracombe Slate Formation: Roadwater Limestone

The 6 LGS for the lenses of fossiliferous Roadwater Limestone (see pale blue on geological map below) within the Ilfracombe Formation are an important conservation asset although the limestone has been largely quarried out (as is the case for the same interest in the Quantocks). The limestone is known to have been richly fossiliferous, with a range of coral species present, which assisted nineteenth century geologists in understanding the stratigraphy and age of the strata covering Exmoor and the Brendon Hills as a whole. These sites are of importance for the history of interpretation of the geology of Exmoor; for their ancient quarried landscapes; and their associated industrial archaeology and local history interest. There may be fossil specimens held in museum collections and there is good potential for an associated community history and conservation project (including potential creative activity, collection of memorabilia and development of interpretative displays) covering a number of inland parishes that are lesser frequented by visitors.

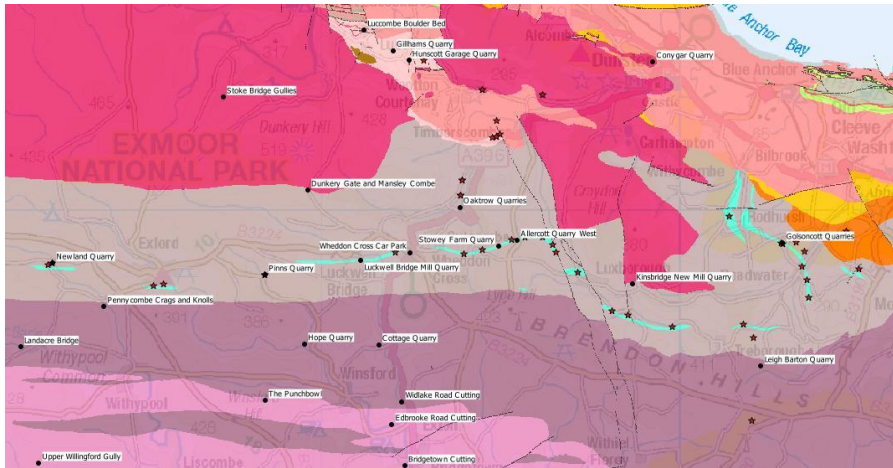


Fig 5: Roadwater Limestone shown turquoise within the Ilfracombe Formation (beige). LGS shown as black dots. Lime kiln records (red stars) courtesy of ENP Authority. Geological map derived from BGS Geology 50k data (<https://www.bgs.ac.uk/datasets/bgs-geology-50k-digmapgb/>). For key to other formations see BGS viewer at http://mapapps.bgs.ac.uk/geologyofbritain/home.html?_ga=2.138656113.371923445.1610012182-153181825.1546632697.

The type locality for the Roadwater Limestone was described by Webby in the 1960s⁷ as at *Harpers Wood* while he mentions with the most varied fossil fauna at *Sandhill Farm, Withycombe* (both in the eastern Brendon Hills). They were reported no longer accessible by the 1980s, neither are LGS and so have not been considered for this review. There are no LGS for the separate Rodhuish Limestone, while an old quarry for the Leigh Barton Limestone (again a different and more localised limestone lens in the Ilfracombe Formation) was incorrectly identified, but has been retained as a Morte Slates LGS, with the pits at the accurate location a potential new LGS.

4.5 Devonian - Morte Slate Formation

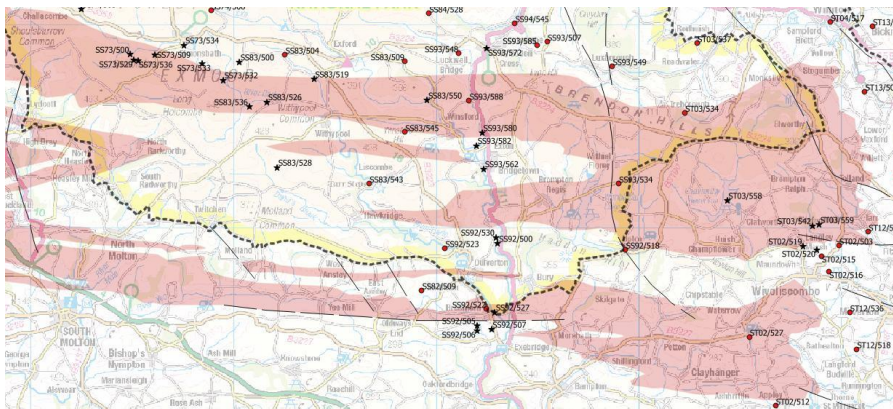


Fig 6: Morte Slate Formation Northern pink area only (the southern bands are the Pilton Formation). LGS in Somerset shown as they were pre-review, with those surveyed by 2018 in red, others black and not all site ref nos shown. No LGS in the Devon part of the ENP.

⁷ See Webby, B D 1964: *Devonian Corals and Brachiopods from the Brendon Hills, West Somerset*, in *Palaeontology*, Vol 7, 1-22, for detail on the fossil fauna; Webby, B D, 1965: *The stratigraphy and structure of the Devonian rocks in the Brendon Hills, west Somerset*. *Proc Geol Assoc*, Vol 76, pp.39-60; and Webby, B.D. and Thomas, J.M., 1965: *Whitsun field meeting: Devonian of West Somerset and Carboniferous of North-East Devon: 15–18 May 1964*. *Proc Geol Assoc* Vol 76, pp.179-193.

The marine-origin strata of the Morte Slates Formation extend from Morte Point in the North Devon AONB to the southern part of the Quantocks in the east. There are 9 LGS on the Formation within the Somerset part of the ENP and 2 LGS beyond the ENP in the Brendons in Somerset West & Taunton district. The Formation includes well foliated slates and forms a band of mostly moorland terrain across Exmoor, south of and succeeding the Ilfracombe Formation. These slates are particularly useful for looking at structural deformation of the Variscan orogeny at the microstructure level, often including features such as kink banding, as well as low grade metamorphism, while some of the LGS represent interest for mineralogy, or periglacial and fluvial erosion features developed over the Morte Slates along the River Barle valley.

Bittadon Tuff - the base of the overlying Pickwell Down Formation is marked by a volcanic ash horizon, the Bittadon Tuff, with 2 Devon LGS designated for this interest in north Devon beyond the ENP. This horizon is however only present infrequently across Exmoor, but there is one roadside-cutting LGS in the Exe Valley where it is thought to occur above Morte Slates, identified as a potential new locality by Prudden in the early 1990s. This site is of potential research interest, given the rarity of igneous rocks on Exmoor, although it is now covered with vegetation. Volcanic and other related igneous rock types are better represented within the Morte Slates of the Quantocks.

4.6 Devonian - Pickwell Down Formation

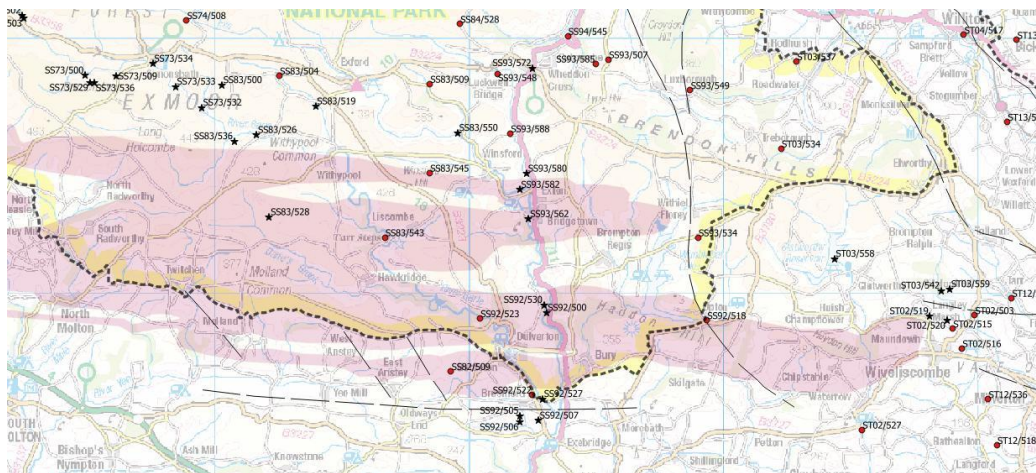


Fig 7: Pickwell Down Formation shown pale lilac. NB. Includes Baggy Sandstone Formation as a thin strip in the south. LGS in Somerset shown as they were pre-review, with those surveyed by 2018 in red, others black stars. Not all ref nos shown and 1 LGS in the Devon part of the ENP is beyond the extent of this map.

The non-marine Pickwell Down Sandstone Formation follows the Morte Slates and occupies a band of countryside in the southern part of the ENP. The Formation does not extend to the Quantocks, unlike the three previous older formations. It also represents a folded and fractured sequence as a result of deformation in the Variscan mountain building period.

There are 9 LGS for or on the Pickwell Down Sandstone Formation within the ENP. They provide a suite of sites showing its variation in lithology with, at some locations, sedimentary features such as ripple marks in the more massive beds, and structural deformation features of the Variscan. They include: old building stone quarries; river valley locations along the Rivers Barle and Exe; and exposures in an ancient trackway and along an early nineteenth century turnpike road. Some of the locations, such as Tarr Steps on the River Barle and that within walking distance from the town of Dulverton, have good potential for interpretive material, while others are less suitable, given the constraints of remote locations or adjacent busy A roads.

These LGS also include some Quaternary features of interest. They include the famous Punchbowl, developed largely over this Formation, but designated for its Quaternary periglacial interest as a possible nivation hollow of glacial margin origin, with potential moraine in its base.

There is one LGS just beyond the ENP boundary in Somerset West & Taunton District providing the most easterly LGS for the Pickwell Formation. Prudden did not apparently identify a better site further east, although the Formation underlies the terrain for several more kilometres to the east.

4.7 Devonian Baggy Sandstone Formation

The Pickwell Down Sandstone is succeeded to the south by the Baggy Sandstone Formation, but this occupies a narrower band of countryside and does not extend very far east. There are no LGS for this formation in the ENP, but there is one a few km west of Dulverton, in a relatively remote location beyond the ENP boundary and it provides the only LGS in Somerset representing this Formation. The nationally important GCR site for this formation is on the coast in north Devon.

4.8 Devonian/Carboniferous - Pilton Mudstone Formation

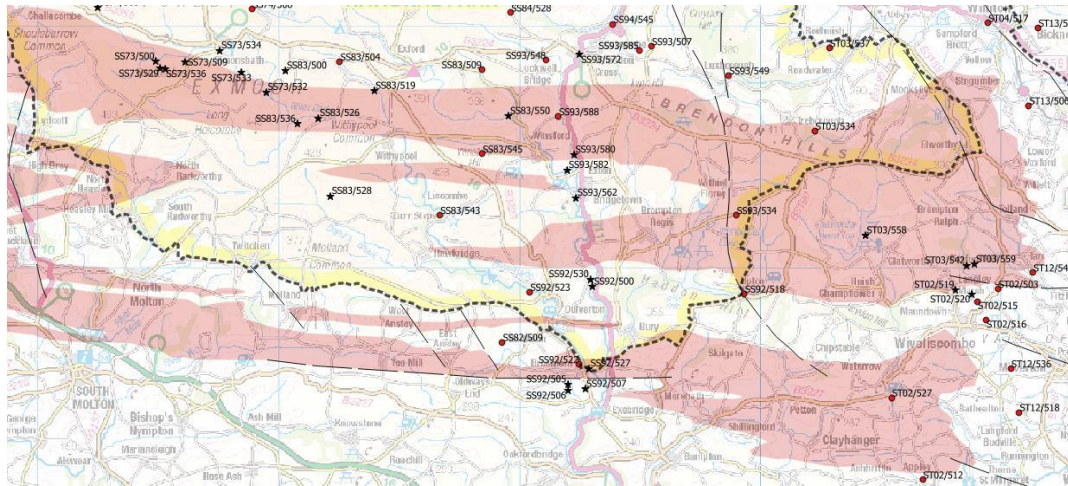


Fig 8: Pilton Mudstone Formation NB Southern pink band only. LGS in Somerset shown as they were pre-review, with those surveyed by 2018 in red, others black stars and not all ref nos shown.

This formation, previously referred to as the Pilton Shales, is found to the south of the Pickwell Down and Baggy Sandstones and extends from the North Devon coast (south of Baggy Point) in the west to the Brendon Hills in the east. The upper part is now thought to be of Lower Carboniferous Dinantian age, rather than Devonian, but this boundary within the Formation is not clearly defined. It is not present further east in England.

There is 1 LGS, just within the ENP boundary near Brushford, created when a new road was built in 1895-6 (with a plaque to this effect on the rock cutting). Another is just beyond the ENP boundary and is an old quarry on private land of potential future research interest only as a probable location where fossils were located in the 1800s. A third lies further east in Somerset West & Taunton in the River Tone Valley and is an old slate quarry, apparently the eastern-most good exposure of this Formation in Britain. There are no LGS, or GCR sites, in north Devon for this Formation.

4.9 Lower Carboniferous (Dinantian)

There are 2 LGS on strata of this age formerly known as the 'Culm Measures', both beyond the ENP in Somerset West & Taunton District, 1 in the Exe Valley and 1 further east in the River Tone Valley.

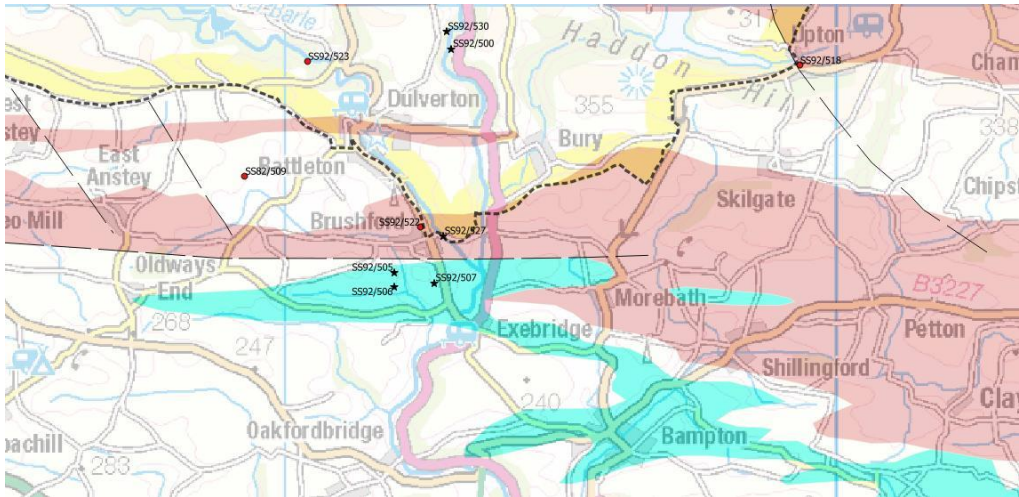


Fig 9: Lower Carboniferous Bampton Limestone Group shown turquoise. LGS shown as they were pre-review, with those surveyed by 2018 in red, others black stars.

The LGS in the Exe Valley is a composite of 3 separate locations within the **Bampton Limestone Group** which lies immediately south of the Brushford fault and the ENP boundary (quite close to the ENP centre at Dulverton). All 3 parts are reported to include radiolarian chert, radiolaria being marine plankton with siliceous spicules that can, with slow and undisturbed sedimentation, remain as microfossils. Two of the locations were researched in the late 1800s, when an understanding of radiolarian chert was being developed, and thus have interest for the history of earth sciences, with the possibility of microscope slides in the Natural History Museum. The third location is reported to also have conodont micro-fossils.

These are the only LGS in Somerset for radiolarian chert, with the only LGS for this interest in mid and north Devon being Coddon Hill Quarry, near Barnstaple, which is mentioned in the same late 1800s research – although the ‘Culm Measures’ of Devon and Cornwall are known more widely to include radiolarian cherts⁸. There is considerable scope for the interpretive material including illustrations to cover this interest - without necessarily needing to encourage site visits. Radiolaria can exhibit very beautiful structures under the microscope and there is also scope to cover structural deformation during the Variscan mountain building period and the historic interest of quarrying in this part of the Exe Valley, which also includes the Exe Valley long-distance footpath.

The other LGS is an old slate quarry in the overlying Doddiscombe Formation further east at Trace Bridge in the River Tone Valley, the eastern-most significant exposure of ‘Culm Measures’ in Britain.

4.10 Permo-Triassic strata of the Vale of Porlock

⁸ Nearby at Bampton, Devon, there is also a nationally important GCR site, **Kersdown Quarry SSSI**, which is the type locality for the ‘Kersdown Chert Member’ and its SSSI citation mentions the loss of many former exposures of this type in this area.

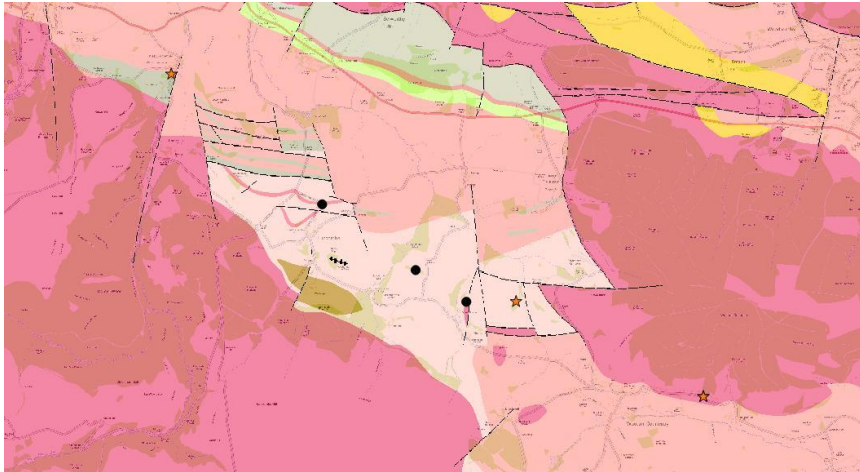


Fig 10: Geological map of southern part of Porlock Vale showing the three LGS on the Luccombe Breccia Formation LGS shown as black dots and Luccombe Breccia Formation pale orange. Lime kiln records (red stars) courtesy of ENP Authority. Geological map derived from BGS Geology 50k data (<https://www.bgs.ac.uk/datasets/bgs-geology-50k-digmapgb/>). For key to other geological formations see BGS viewer at http://mapapps.bgs.ac.uk/geologyofbritain/home.html?_ga=2.138656113.371923445.1610012182-153181825.1546632697.

The Vale of Porlock is a geologically interesting area in the ENP, being a fault-bound inlier of Permo-Triassic strata within the older Devonian rocks. There are 3 LGS representing this interest, all on the Luccombe Breccia Formation, which is unique to the Vale and forms the undulating landscape in its southern part. One LGS is a sunken lane with exposure also of the more localised Luccombe Boulder Bed and the other 2 are old quarries, one described in the geological literature as having a calcite vein previously quarried for lime, with the quarry apparently visited by the geologist Leonard Horner in 1816. There are also other old quarries and limekilns in the area, so there is potential for a community local history project on the lime quarrying and/or for interpretive material/local walks leaflets - as for the Roadwater Limestone LGS. There is also the possibility that there may be archival material on the quarrying held by the NT in the Acland family's estate papers for the Holnicote estate. Horner's visit was hosted by the previous estate owners, the Acland family.

4.11 Quaternary periglacial deposits, fluvial erosion and coastal geomorphology

Exmoor NP is of considerable interest both for its Quaternary periglacial features and geomorphological processes. This is reflected in the nationally important GCR sites for the *Valley of the rocks* (Quaternary periglacial features), *Lyn Valley* (fluvial processes) and *Porlock shingle barrier* (coastal geomorphology), but features for these various interests are also well represented within the LGSs including: scree and head deposits; possible patterned ground at Holdstone Down and the possible periglacial nivation hollow of the Punch Bowl; sections of the East Lyn, Barle and upper Exe river valleys with fluvial erosion features including the valley 'knolls' caused by fluvial incision, (probably in combination with the underlying rock structure) and flood gravels above the current river levels; and the hogs back cliff profiles and water falls described by Arber. These are developed over the various older rock formations described above.

Scree is best developed over the Hangman Sandstone Formation in the coastal zone, but periglacial head is widespread and knolls and fluvial erosion features are also found in the south-flowing Barle valley, over the Ifracombe and Morte Slates Formations. NB Dalzell, D, *Relict periglacial features on Exmoor and adjacent areas* (Exeter Ph D thesis) has not been looked at for this review and may provide some more detailed information to assist in considering periglacial features.

Newell Arber (1870 - 1918) was a palaeobotanist, who is also well-known for his classic 1911 book *The coastal scenery of north Devon*, where he first used the term hog's back cliff and describes features such as the coastal waterfalls. His archives are held in the Sedgwick Museum of Earth Sciences at Cambridge University. There are also a few locations along the coast, where the hog's back cliffs are fronted by aprons of periglacial head with the actively eroding cliff cut in the head deposits which rest on an older platform of the underlying hard-rock (2 are LGS, one a GCR site).

4.12 Mineralogical interest and economic geology

There appear to be only 2 LGSs selected originally primarily for their mineralogical interest in the Somerset part of the ENP (both in the River Barle Valley within the Ifracombe or Morte Slates Formations) and 1 on the coast at Combe Martin in the Devon part of the ENP (retained as a LGS as, although a GCR site for other interest, it is also an example of what might be regarded as syngentic mineralisation, ie distributed through a particular sedimentary rock horizon, and is close to the ancient Combe Martin silver lead mines). We are not aware of any LGS selected for the iron mineralization in the Brendons, although there are a few sites there and elsewhere, which might 'fit the bill' in the future if they do not have any other relevant protection.

Appendix 1: Geological Conservation Review (GCR) sites in the ENP

GCR sites are the nationally important sites for earth science conservation in England, designated by Natural England (see <http://jncc.defra.gov.uk/page-2947>). They are Sites of Special Scientific Interest (SSSIs): some in their own right and with the same name as the SSSI; while others are within wider SSSIs of mainly biodiversity interest – and which may be differently named.

There are currently 11 GCR sites in the ENP (8 in the Devon part of the ENP and 3 in the Somerset part) selected for their scientific interest from a number of conservation interest 'blocks'. The block names relevant to the ENP and Exmoor fringes are:

- *Devonian marine* – 5 GCR sites in the ENP
- *Devonian non-marine* - 2 GCR sites in the ENP
- *Dinantian of Devon and Cornwall* (the former Lower Carboniferous 'Culm Measures' - of separate and different character to the *Dinantian of the Mendips*) – no GCR sites within the ENP or Somerset, but there are GCR sites in Devon
- *Variscan structures of South West England* – no GCR sites but interest represented within the Devonian GCR sites above
- *Permo-Triassic* – no GCR sites within the ENP
- *Mineralogy of South West England* – no GCR sites within the ENP
- *Quaternary of South West England* - 2 GCR sites in the ENP
- *Fluvial processes* – 1 GCR site in the ENP
- *Coastal processes* – 1 GCR site in the ENP

Devon part of the ENP (west to east) - 8 GCR sites along the coast and in the West Lyn valley. Those below with an * are described in Whittaker, A and Leveridge, B, 2011: *The North Devon Basin: a Devonian passive margin shelf succession*, Proceedings of the Geologists' Association, V 122, pp 718–744 (available on line – see also Fig 1 in Appendix 2):

- **Combe Martin Beach GCR Site** - within the wider Hele, Samson's and Combe Martin Bays earth science SSSI – *Devonian marine* interest of the Ifracombe Formation - see the wider SSSI citation as well as the GCR site description*. *The overlapping Combe Martin LGS is*

retained for its mineralization interest, while the former Wild Pear Bay LGS has been deregistered as it covered the same interest.

- **Little Hangman GCR site** - covering *Devonian non-marine* interest of the type locality for Members of the Hangman Sandstone Formation above the Trentishoe Member, described in Whitaker and Leveridge 2011, but not included on the GCR web site*.
- **Hollowbrook GCR site** - covering *Devonian marine* interest of the Lynton Formation with transition into *Devonian non-marine* Hangman Sandstone Formation above in a cliff-side valley between Heddon's Mouth and Woody Bay within wider SSSI.* *The overlapping Great Burland LGS is retained – with boundary adjusted to match that of the GCR site - to flag up the geomorphological interest of the coastal geomorphology including the coastal waterfall.*
- **Crock Point GCR site** – *Devonian marine* interest for the Lynton Formation - a small area in the woodland above the road, between Lee and Woody Bays, ie not on the cliffs of Crock Point *per se**. Within a wider SSSI.
- **Two Valley of Rocks GCR sites** - one covers the main part of the Valley of Rocks for *Devonian marine* interest of the Lynton Formation*. The other covers an overlapping but wider area, including Lee Bay and Crock Point to the west, for *Quaternary of South West England* interest, with a description in the GCR volume: Campbell, *et al*, 1998: *Quaternary of South-West England*, Geological Conservation Review Series, No. 14. Both are within a wider SSSI. *Our review has retained Lee Bay LGS, although within the GCR site for Quaternary interest, as there is good exposure of the Lynton Formation.*
- **Dean Steep GCR and earth science SSSI** – no published GCR site description, boundary as for SSSI. *Marine Devonian* Lynton Formation grading conformably into the overlying Hangman Sandstone Formation, with fossils recorded indicating that the boundary corresponds approximately to that between the Lower and Middle Devonian. *The former overlapping Barb Brook Road Cutting LGS has been deregistered as it covers the same interest.*
- **River Lyn GCR site** - an earth science SSSI for fluvial processes, boundary as for the SSSI. See the GCR volume: Gregory, K.J. (Ed.), (1997): *Fluvial Geomorphology of Great Britain*, Geological Conservation Review Series, No.13 and the SSSI citation. Boundary as for SSSI. *The overlapping LGS is retained pending future site visit beyond the scope of this review to assess whether there is any interest not covered by the GCR designation.*
- The GCR sites for the Morte Mudstone Formation and Pickwell Down to Baggy Sandstone Formations are further west along the north Devon coast between Ilfracombe and Barnstaple (NB the North Devon AONB commissioned a geo-diversity report in 2016).

Somerset part of the ENP (3 GCR sites from a total of c 60 GCR sites for Somerset as a whole):

- **Glenthorne GCR site** and earth science SSSI, boundary as for SSSI – *Devonian non-marine* interest of the Hangman Sandstone Formation with its associated sedimentary features; the best coastal exposure of Trentishoe Member sediments of sheet flood /fluvial /temporary lake origin. See SSSI citation. The boundary is as for the SSSI.
- **Porlock Gravel Barrier GCR site** for contemporary *coastal processes* (Porlock Ridge and Saltmarsh SSSI) – see GCR series, *Volume 28: Coastal Geomorphology of Great Britain Chapter 6: Gravel and 'shingle' beaches*. See also the SSSI citation. The boundary is as for the

SSSI. Our review has removed most of the overlapping LGS, but retained part with an adjacent area for its additional Quaternary interest.

- **The Chains GCR site** (within North Exmoor SSSI) for its *Quaternary of South West England* Pleistocene peat sequence. See GCR volume: Campbell, S., Scourse, J.D., Hunt, C.O., Keen, D.H. & Stephens, N., 1998: *Quaternary of South-West England*, Geological Conservation Review Series, No. 14. LGS in the adjacent Pinkworthy area provide complementary interest.

Appendix 2: Context of recent geological research

Exmoor and the Quantocks are underlain by Devonian rocks, with some Carboniferous 'Culm Measures' strata on the southern edge of the Exmoor area. Much of the geological history of these rocks is now understood to be very different from the similar age Devonian and Carboniferous rocks in the east of Somerset in the Mendips and South Wales. They are now thought to have been deposited in separate sedimentary basins many miles distant.

They are now regarded (along with strata further west in Devon and Cornwall) as belonging to the *Rhenohercynian zone* and having more in common with the rocks in Germany, than the rest of Britain and to have been brought into close proximity to the Mendips and South Wales by earth movements associated with the closure of the *Rheic Ocean*. This was part of the Variscan Orogeny, a period of mountain building resulting from plate tectonic movements.

This updated geological understanding is described for South West England as a whole by Leveridge and Hartley, 2006 (<http://nora.nerc.ac.uk/1518/1/GEWChapter10.pdf> and http://nora.nerc.ac.uk/7135/1/Shail_Leveridge_revised.pdf). A second important reference is Whittaker, A and Leveridge, B, 2011: *The North Devon Basin: a Devonian passive margin shelf succession*, Proceedings of the Geologists' Association, v 122, pp 718–744 (also available on line).

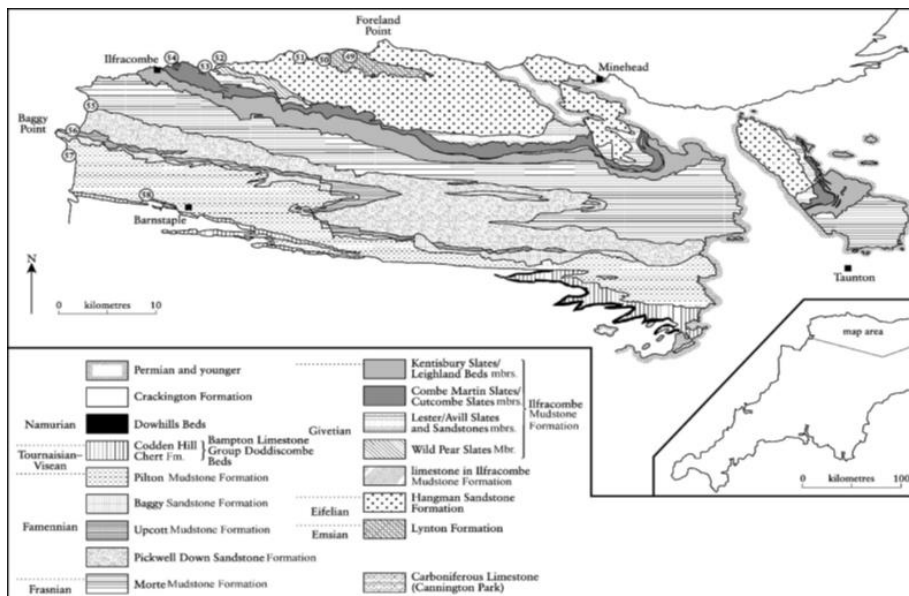


Figure 1 from Whittaker, A and Leveridge, B, 2011: a geological map showing the distribution in north Devon and west Somerset of the Devonian rocks of the North Devon Basin, and the locations of GCR sites, after Fig 10.10 in Leveridge and Hartley (2006). Based on BGS maps.

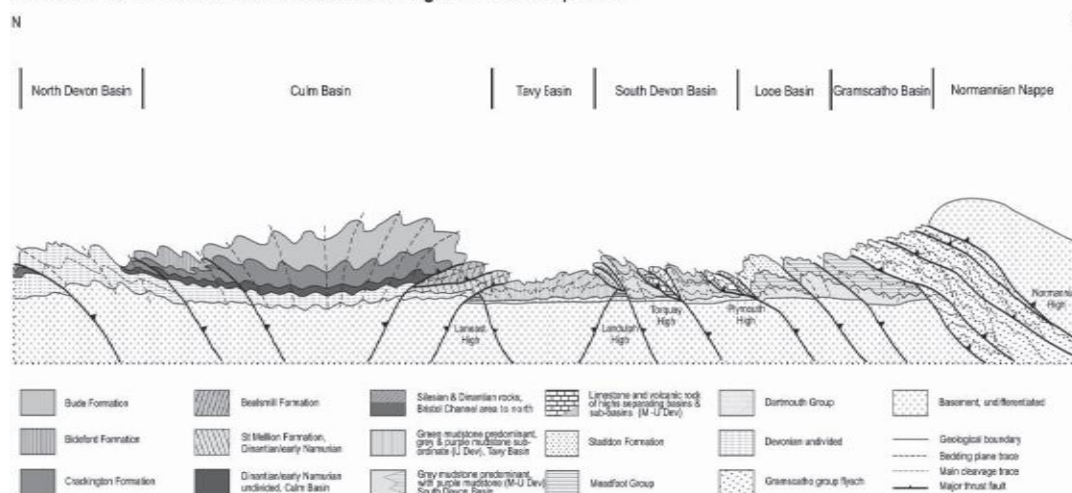
Fig 10.16 in Leveridge and Hartley, 2006 (see below) also provides a cross section across the South West, giving an indication of how the strata are thought to have been formed in a series of different

fault-bound basins and subjected to thrusting and folding, so that sometimes the strata are overturned. This dynamic geological history of the area can be interpreted from examination of the range of structures that are visible in the local rocks, including microstructures. Several of Exmoor's LGS are therefore valuable for their varied structural features resulting from the Variscan Orogeny, rather than simply for their Devonian stratigraphy and sedimentary interest.

Other figures in the same paper provide cross sections or cartoon block diagrams which help with an understanding of the earth movements involved (and may be helpful in the preparation of any future interpretive material).

This research (developed from the 1970s onwards) replaces earlier understanding of Exmoor's geology as a simpler interleaving of marine and terrestrially deposited sediments, between Devonian strata deposited in desert conditions in South Wales and the marine Devonian strata in South Devon.

N-S section of the Variscan belt of South-west England : late Westphalian



Most research on this new interpretation has been further west in the South West on the Carboniferous strata - with relatively little on Exmoor Devonian - and hence there is scope for potential research in the future. Plus as far as we are aware, there is no interpretive material for the general public that reflects this new understanding of the earth science history of the ENP.
