

SITE

Name: Axmouth to Lyme Regis Undercliffs National Nature Reserve

Parish: Axmouth, Combpyne-Rousdon

Local Authority: East Devon

National Grid Ref: SY 256 896 - 323 913

OS Sheets: 1:50k 193 1:10k SY28NE & SY39SW

Locality Description: Coastal site between Axmouth and the Devon-Dorset county boundary west of Lyme-Regis, at Devonshire Head.

Nature and Status of Site: Coastal cliff, undercliff and beach demonstrating a Triassic-Jurassic transition unconformably overlain by Cretaceous deposits. The area is characterised by large and periodically active landslip systems. It is a [National Nature Reserve](#) (NNR), a [Site of Special Scientific Interest](#) (SSSI) and lies within the [Jurassic Coast World Heritage Site](#).

Summary of Geological / Geomorphological Interest: The lower part of the cliffs at the western end of the reserve show excellent sections in the late Triassic Mercia Mudstone Group (c.220 - 210 million years old). These include the reddened deposits of a hot desert plain. In the upper part of the sequence, however, the colour gives way to grey and greenish-grey indicating climatic and environmental changes. These deposits, belonging to the Blue Anchor Formation, were laid down in temporary lagoons and pools on a coastal plain as the sea encroached on and periodically flooded the region. The sea eventually drowned the lagoons and beds full of shells and fish teeth are found in the marine muds of the lower part of the succeeding Penarth Group (also known as *Rhaetic*). A temporary shadowing is indicated by the tidal mudflat deposits of the upper part of the Penarth Group. These are pale coloured limestones, known historically as '*White Lias*', formed on a hot arid coastline not unlike the modern Persian Gulf. Cliff exposures in Pinhay Bay, at the eastern end of the reserve, show features in these deposits such as tidal channels and mud cracks (which formed as pools dried up).

The sea flooded back and grey shales with thin limestone bands were deposited in the deeper warm waters of the early Lower Lias Group, historically known as '*Blue Lias*'. Around 2.5m above the base of the Lower Lias the first *ammonites* have been found, proving a very early Jurassic System age, although the actual base of the system (at around 200 million years ago) is now placed lower, probably near the base of the Blue Lias Formation. The spiral shells of ammonites are the remains of an extinct group of squid-like *cephalopod* molluscs and are of crucial importance for the global dating Jurassic rocks. In particular, they are used for recognising and correlating the sequence of eleven *stages* in which the Jurassic system is sub-divided. The reserve includes deposits belonging to the first two of these stages, namely the Hettangian and Sinemurian, and includes important international references for sub-divisions of these units. Large ammonites of the genus *Metaphioceras*, are most spectacularly seen where they crowd Bed 29 on the shore platform on either side of Seven Rock Point, a veritable "ammonite slab".

The Lower Lias is also famous for the skeletons of large marine reptiles, such as ichthyosaurs and plesiosaurs, some of which will have come from the area now included within the National Nature Reserve. The characteristic regular alternation of hard limestone and soft shale, so typical of the '*Blue Lias*', is now believed to record climate fluctuations due to periodic changes in the earth's orbit, known as Milankovitch cycles. The limestone represents warm periods with high production by plankton and the shales

represent phases of slightly cooler conditions. These same planetary cycles created the alternating ice-age/ warm interglacial fluctuations of the last 2 million years.

Overlying and cutting across the Jurassic deposits are the sands and sandstones of the Upper Greensand of Lower Cretaceous age (around 107- 95 million years old). These are deposits of a shallow tropical sea. The term 'greensand' is a reference to a green iron-containing mineral in the deposits known as *glauconite*. On long exposure to air and ground water, however, this mineral oxidises to a rusty yellow-brown - hence the more typical colour of the Upper Greensand. At the base of the 'Greensand' there is thin grey muddy sand, the lateral equivalent of the Gault Clay of south eastern England.

The Upper Greensand is succeeded by Upper Cretaceous limestones around 95 - 85 million years old. These include a hard basal unit typically referred to as '*Cenomanian Limestone*'. Although normally only seen in blocks brought down to beach level by landslips, this deposit is famous and internationally important for the fauna it has yielded, including ammonites with North American and African affinities. Above the Cenomanian Limestone, softer white chalk is present with further important marine faunas, again typically seen in land-slipped blocks.

After the end of the Cretaceous, deep tropical weathering during the Palaeogene and Neogene periods (also known as Tertiary'), around 60- 5 million years ago, formed flinty clays and fissures as some of the chalk dissolved at the surface. During this interval, the collision of Africa into Europe, which created the Alps, produced some of the folds and faults which dislocate the Jurassic and Cretaceous rocks. With the arrival of coastal erosion in the Quaternary Period (over the last 2 million years) the varied geology resulted in the development of the classic landslip systems seen today. One of the most famous of these landslips occurred on Christmas Day 1839 when a vast area of land slid seaward leaving a chasm "*more than 300' broad, 150' deep and three quarters of a mile long*" to form Goat Island. The exceptional variety of different types of cliff collapse and land-slipping in the area of the National Nature Reserve has made it one of the most famous regions in Europe for studies of the processes of mass movement.

Information about this site is also contained on the [Jurassic Coast](#) website.

Safety Considerations: With high crumbling cliffs, and tides rising to the cliff base, visitors should carry out an appropriate safety assessment before entering the reserve. The responsibility for health and safety issues lies with the group and its leader and Natural England can accept no liability for any loss or injury. Under no circumstances should the coastal footpath or beach be left without permission from Natural England. Visitors to the beach should ensure that they have a low tide (preferably falling) and safety helmets if any approach is made to the cliff base. [Note that at certain times of year, especially after rain, the cliffs will be continuously crumbling and large boulders may pitch some distance across the beach.] It is recommended, therefore, that educational groups restrict visits to the period from late spring through to early autumn and ensure that they have a low tide, during which the shore platform can be examined at a relatively safe distance from the cliffs.

Educational Age Groups: Secondary, College/6th Form, University.

Parking and Access: The area is designated as a National Nature Reserve, and public access is restricted to the [South West Coast Path](#), that runs through the undercliff, and along the beach. Parking is available at Lyme Regis, west of and also above the Cobb, for access to eastern areas of the reserve (coastal footpath and shore to Pinhay Bay). At the western limit of the reserve, limited parking for cars is available just north of the access road to Axmouth Harbour and also within Seaton. There is **no** public access to any other area of the reserve. There are regular bus services to Seaton and Lyme Regis, including the 'Jurassic Bus' (X53), and bus links to the train station at Axminster. For

timetable details, visit www.traveline.org.uk. Additionally there are boat trips from Beer and Lyme Regis. Due to the site's status as a National Nature Reserve, a number of restrictions are in place to safeguard features of nature conservation importance for future generations to enjoy. Please follow these guidelines, as outlined below, at all times when visiting the reserve.

THE CONSERVATION OF AXMOUTH TO LYME REGIS UNDERCLIFFS NATIONAL NATURE RESERVE - REGULATIONS FOR VISITORS

Axmouth to Lyme Regis Undercliffs was originally declared as a [National Nature Reserve](#) in 1955 and notified as a [Site of Special Scientific Interest](#) under the 1981 Wildlife and Countryside Act in 1986. The conservation management of National Nature Reserves is core work for [Natural England](#). This management covers all aspects of the nature conservation interests of a site, including geological heritage.

As there is open access to the beach and foreshore area, and the reserve has great potential for promoting geoconservation and education, Natural England is currently developing a management plan for the area which aims to safeguard the geological heritage present, without unduly restricting sensitive and responsible use. The following conditions, therefore, apply to visitors to the reserve:

1. All visitors and visiting groups to the reserve should adopt a responsible approach to the collection of geological specimens.
 - Only a few representative specimens should be collected from fallen or loose material, and for demonstration purposes. Collecting from *in-situ* outcrops and the removal of large blocks is not permitted without a formal consent from Natural England.
 - Use of geological hammers should be minimised and used to demonstrate features of geological interest. There should be no hammering of *in-situ* outcrops or large blocks.
 - All specimens of significant scientific importance should be placed in a recognised institution (normally a museum) and thereby be safeguarded for future study. Where necessary seek specialist advice on specimen identification and care. Please contact Natural England for more information.
2. Permission from Natural England is required to collect from *in situ* outcrops (including large blocks), and the cliff and land slipped areas of the reserve. Please contact Natural England for more information.
3. The reserve is internationally important (as part of the Sidmouth to West Bay candidate Special Area of Conservation) for its habitats and species, in particular the characteristic vegetated cliffs and areas of landslip. Please minimise disturbance to wildlife by:
 - Keeping to the beach / foreshore or coastal footpath and only using established access points from either Axmouth or Lyme Regis. Please note that there is no public access away from the beach and coastal footpath and there are *no* public links between these two routes.
 - Activities which are likely to disturb plant and animal life require prior consent from Natural England.

4. Natural England reserves the right, as landowner or occupier, at any time, to amend or otherwise modify or delete the conditions and permissions pertaining to the use of the National Nature Reserve.

If you have enjoyed your visit to the reserve, please contact our Natural England Devon Office. Your views are important to guide the future management of the reserve.

Contact: Tom Sunderland, Site Manager, Natural England, Tel: +44 (0)1392 889798
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For further information, visit [Natural England](#) online.

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Detailed Geology: Triassic System; Rhaetian Stage: The Triassic succession in south west England reflects the changing environmental conditions associated with a major marine transgression at the end of the Triassic. The blocky mudstones and silty mudstones that made up the greater part of the Mercia Mudstone Group (including the Blue Anchor Formation) accumulated during the progressive development of a flat arid plain which was subjected to local flooding. The featureless mudstones are interpreted as being partly aeolian in origin as they typically show a lack of primary sedimentary structures. The laminated beds, characterised by sedimentary structures typical of a low-energy aqueous environment, are interpreted as deposits of shallow playa lakes. The overlying Penarth Group includes marine deposits and resulted from an inundation of the low-lying coastal plain that led to the establishment of widespread shelf seas over Britain during the Jurassic. The poor sorting and presence of fish debris etc. in the bone bed at the base of the Westbury Formation, in the lower part of the Penarth Group, coupled with its stratigraphical position (i.e. the above sabkha plain deposits) supports the view that these beds were deposited in a transgressive littoral zone. The black shales of this formation and the fact that fossils tend to be concentrated in bands would suggest that there were periods when stagnant or anaerobic water (but not necessarily deep) predominated. The overlying calcareous shales and limestones of the Cotham Member mark a sharp change in depositional conditions from a relatively low-energy (e.g. presence of ripple marks). A shallow depth of deposition and emergence is suggested by the presence of desiccation cracks in some beds.

The cliff section in Pinhay Bay provides one of the best exposures in Britain of the "White Lias" (Langport Member, Lilstock Formation), at the top of the Penarth Group. The section here was briefly described by Richardson (1906) but dealt with in much greater detail by Hallam (1960). The individual beds are highly variable over short distances due both to change of lithology and wedging out. The succession is dominated by fine-grained cream-coloured limestones (calcilutites). Hallam (1960), documents the presence of intraformational conglomerates, corrosion surfaces, mud-cracks, algal laminae and slump beds within the section at Pinhay. The limestones also have a very high strontium content, probably indicating that the original sediment was a fine-grained aragonitic mud. Fossils are uncommon, although *Liostrea hisingeri* can usually be found throughout the succession. Hallam (1960), recognises two distinct faunal communities, firstly, a community of bivalves and gastropods with a few solitary corals which occurs locally at certain levels as tightly packed clusters of small shells. The marls between the limestones often contain abundant *Modiolus* and oysters. The second community comprises burrowing and boring organisms, best exemplified by the upper most bed of the White Lias (the 'Sun Bed'). This unit is only 5cm thick on the coast but still displays beautifully preserved U-shaped burrows (*Diplocraterion*) and occasional desiccation cracks. These are best seen adjacent to the fault in the centre of Pinhay Bay.

The restricted fauna and the sedimentology of the 'White Lias' indicate that it was deposited under warm conditions in very shallow lagoons, comparable with the modern-day shallow water lagoons west of Andros Island in the Bahamas. Contemporaneous tectonic movements resulted in the development of intraformational conglomerates and possibly led to bed slumping. Irregular bed junctions and the presence of porcellaneous limestone suggest the possibility of emergence and recrystallisation of calcium carbonate to produce the porcellaneous texture. Periodic deepening of the water may account for the presence of interbedded grey mudstones and the bored, sun-cracked upper surface of the Sun Bed signifies emergence and desiccation.

The sections in the reserve represent the most southerly exposures of Rhaetian rocks in Britain and the White Lias (Langport Member) in Pinhay Bay is of paramount importance in studies relating to the environmental conditions associated with the Late Triassic - Early Jurassic marine transgression in Britain.

Jurassic System: Hettangian - Sinemurian Stages: The coastal cliffs from Pinhay Bay, Devon, to Seatown (Dorset) represent the only continuous section in Britain providing exposures of a complete Lower Lias sequence from Triassic below to Middle Lias above. The coastal section in Pinhay Bay shows the base and lowest parts of this classic and internationally renowned stratigraphic sequence.

In Pinhay Bay the top of the 'White Lias' (uppermost Triassic, Lilstock Formation, Penarth Group) is overlain by the 'Blue Lias' (Lower Lias) in a well exposed and spectacular cliff section. The Blue Lias Formation, described in detail by Lang (1924), comprises alternating units of shale and limestone. The lowest 2.5m (Lang's H1-24) has been conventionally included in the uppermost Triassic as it is below the first occurrence of ammonites, including *Psiloceras* in Bed 25. These forms correlate the base of conventional Jurassic System the Hettangian Stage and hence the Jurassic (Page, 1994). Bed H25 is visible low in the cliff about 500m east of the Pinhay Bay Fault (SY 318908). New information from Austria and Nevada, however, indicates that *Psiloceras* occurs earlier elsewhere and the base of the Jurassic can now be drawn at a level close to the base of the Blue Lias Formation.

The main accessible section of the Blue Lias is in the cliffs between Pinhay Bay and Lyme Regis Cobb (SY 334925), but the formation also in outcrops at Broad Ledge (SY 345920) to the east of Lyme. Lang (1924), used the numbers H1-H91 for beds only seen to the west of Seven Rock Point and Beds 1-53 for the overlying sequence which is seen on the beach around Seven Rock Point. The main impure limestones were given distinctive names by quarrymen when the beds were worked along the foreshore for cement and building stone. The shales intervening between the limestones, typically comprise three recognisable facies. A basal thin, kerogen-rich unfossiliferous black shale (possibly varved) is followed by shales with some fossils and evidence of loss of primary lamination which then passes up but generally with a sharp burrowed contact into the base of an overlying impure grey limestone. Limestone cementation is thought to be early diagenetic and it has indicated that the alternation of limestones and shales reflects sea-level or climate changes induced by cyclical changes in the Earth's orbit (Milankovitch cyclicity; House 1985, Weedon 1986).

Ammonite faunas have been used to subdivide and correlate the 'Blue Lias' succession: The lowest part of the Hettangian sequence includes smooth and simply ribbed *Psiloceras* and *Caloceras* (Planorbis Chronozone). Schlotheimid ammonites (strongly-ribbed derivatives of *Psiloceras*, including *Schlotheimia* and *Waehneroceras*) characterise higher levels up to Bed 20 (Liassicus and Angulata chronozones), thereafter, the entry of arietitid ammonites (with keels on the venter, ribbed flanks and often large size), including *Metophioceras* and *Vermiceras*, mark the base of the Sinemurian Stage (Bucklandi Chronozone, Conybeari Subchronozone). At higher levels, *Coroniceras*, *Arietites*, *Paracoriceras* and *Arnioceras* also occur (Bucklandi - Semicostaum chronozones; Lang 1924; Page 1992, 1995, 2002). Large ammonites of the genus *Metophioceras*, are most spectacularly seen where they crowd Bed 29 on the shore platform on either side of Seven Rock Point, a veritable "ammonite slab". Unfortunately this surface has been vandalised in places by fossil collectors with rock saws, emphasising the vulnerability of this heritage to irresponsible individuals and groups, and the need to protect the area for future generations to enjoy and study.

The large bivalve *Plagiostoma gigantea* is frequent at several levels and specimens get progressively larger through the Hettangian succession. The top of the Blue Lias is taken

at Table Ledge (Bed 53), the 3m of the 'Blue Lias' being known as the Saurian Shales, and have apparently provided many of the known reptile remains from the 'Blue Lias'. The overlying Shales-with-Beef (Charmouth Mudstone Formation; Beds 54-76) include only very thin limestones or concretions and differ markedly from the Blue Lias below and a deeper-water environment of deposition is inferred.

These sections on the Devon coast, west of Lyme Regis, form one of the most important and famous British geological sites and have been important to the development of Jurassic studies not only in Britain but also internationally. A significant amount of literature and scientific work relates to the Lias succession here and the exposures still offer great potential for further research. The abundance of fossils, coupled with the sedimentological changes through the succession has led to the production of a detailed zonal and lithological sub-division of the Lias sequence. The recognition of Biohorizons (*sensu* Page 1995), in particular, has provided a high resolution stratigraphic framework which has enabled correlation and dating to a high degree of accuracy with many other European Lower Jurassic sequences. The site includes stratotypes (type sections) for the *similis*, cf. *complanata*, *Schlotheimia* sp 1 and *pseudomoreana* biohorizons of Complanata and Depressa subchronozones of the Angulata Chronozone of the latest Hettangian, and also the *rotator* and *conybeari* biohorizons of the Conybeari Subchronozone and the *deffneri* Biohorizon of the Rotiforme Subchronozone (both subzones of the Bucklandi Chronozone, Lower Sinemurian; Page 1992, 1995, 2002).

The Lower Lias exposures on the coast in the Lyme Regis area are also world famous for the fossil reptiles that they yield, specimens having been collected since at least 1790. Since then many hundreds of partial and complete skeletons have been collected and finds are still being made. Many of the reptiles have been recovered from the Saurian Shales at the top of the 'Blue Lias' (Lang's Bed 52, Semicostatum Chronozone, Lower Sinemurian) and from the overlying Shales-with-Beef beds (Turneri Chronozone).

The reptile remains generally occur in the darker shale interbeds of the Saurian Shales where they may be associated with ammonites and bivalves. The skeletons are usually well articulated and stand out in the soft, dark shale after the overlying limestone has been removed by coastal erosion. Delair (1958-60) and Benton and Spencer (1995) review the fossil reptiles of Dorset and the former produced an extended list of 21 species and three forms ascribed only to genera from the Lower Lias. Subsequent taxonomic and descriptive work has reduced the number of species to 17. Of these the Lower Lias at Lyme Regis has yielded type specimens of 14 species, nine of which only occur at Lyme (*Plesiosaurus conybeari*, *P. rostratus*, *Ichthyosaurus breviceps*, *Temnodontosaurus eurycephalus*, *T. platydon*, *T. risor*, *Excalibosaurus constini*, *Scelidosaurus harrisoni* and *Dimorphodon macronyx*).

The plesiosaurs from the Lower Lias of England are some of the earliest known well preserved Jurassic specimens in Europe. In all, about ten species of Lower Lias plesiosaurs are known, the Lyme Regis material being the most abundant and varied from the Lower Jurassic of the world. Plesiosaur species are identified on skeletal morphology of the pelvis and limbs along with the relative length of the neck and size of the head. The species recorded at Lyme Regis range in size from 2-6m in total length and exhibit a span of neck lengths from short in *P. rostratus* to relatively long in *P. conybeari*, which foreshadows the later pliosaurs and elasmosaurs respectively.

The ichthyosaurs are likewise some of the earliest well preserved specimens from the Jurassic. Material from Lyme Regis has formed the basis of recent revisions of ichthyosaur taxonomy and evolution (McGowan 1989). On the basis of skull and forefin morphology at least eight of the recorded Lyme Regis taxa are presently regarded as valid. *Ichthyosaurus communis* is easily the most abundant species found at Lyme Regis

(45 recorded determinate skeletons). It was a moderate sized form reaching a maximum length of about 2.5m. *I. breviceps* is characterised by a short snout, while *Leptopterygius tenuirostris* and *I. conybeari* have longer and more slender snouts. Although *L. tenuirostris* is much less common in terms of complete skeletons, it is abundantly represented by isolated remains of humeri, partial fins and rostral segments. The larger species of *Temnodontosaurus* are rare. *T. eurycephalus* has a short snout and massive skull and may have fed on other ichthyosaurs. *T. platydon* (which has only been recorded from Lyme Regis) at 9m in length, is the second largest known ichthyosaur. The recently described ichthyosaur, *Excalibosaurus costaini*, is remarkable for the shortness of its mandible, which is only three-quarters the length of the skull, giving an extensive overbite.

Skull and skeletal material of the pterosaur *Dimorphodon* has also been recovered at Lyme Regis. The skull is relatively large and highly vaulted (although lightly constructed), rather than long and pointed as in later pterosaurs. It was about the size of a raven and had a wingspan of about 1.4m. The skeletal features exhibited by *Dimorphodon* are primitive and therefore this species provides unique information on early pterosaur evolution. The Lower Lias of the Lyme Regis district has yielded a diverse and abundant Lower Jurassic reptile fauna, including type material of several species of plesiosaurs and ichthyosaurs. The dinosaur *Scelidosaurus* (from Charmouth) and the pterosaur *Dimorphodon* are unique animals of great interest in studies on the early evolution of their respective groups. Historically, Lyme Regis is exceptional, there being no comparable site of the same age outside Britain that has yielded such well preserved and common material. A highly important site in the study of fossil reptiles and one that still has great potential for future study.

Fish remains were once commonly found at Lyme Regis, most of the specimens being derived from the Saurian Shales (Lang's Beds 50-52) at the top of the Blue Lias and in the overlying Shales with Beef. Many specimens have been recovered from the Pinhay Bay area along with reptile remains. Over forty species are now recognised as coming from the Lias in the Lyme Regis area, and because of the long history of study at this location Lyme Regis is the type locality for many of these. The following fauna has been recorded from the district (but not all from the reserve): Chondrichthyes: Selachii (sharks and rays: *Acrodus*, 2 spp.; *Hybodus*, 4 spp; *Palaeospinax* 1 sp);. Holocephali (chimaeroids: *Squaloraja*, 2 spp.; *Myriacanthus*, 2 spp); Osteichthyes: Crossopterygii (*Holophagus gulo* - a Coelacanth); *Actinopterygii* (bony fishes): Chondrostei (*Chondrosteus*, 2 spp.; *Cosmolepis*, 1 sp; *Centrolepis*, 1 sp.; *Coccolepis*, 1 sp.; *Platysiagum*, 1 sp.; *Ptycholepis*, 3 spp; *Saurorhynchus*, 2 spp.), Holostei (*Dapedium*, 5 spp.; *Furo* 5 spp; *Caturus*, 1 sp.; *Pholidophorus*, 5 spp; *Osteorhachis*, 2 spp; *Heterolepidotus*, 1 sp.; *Leptolepis*, 1 sp.).

Of the selachians, the large sharks *Hybodus* and *Acrodus*, are represented by some nearly complete skeletons along with common spirally marked coprolites. This site is the type locality for the Coelacanth *Holophagus gulo*. This species reached a large size (for this genus), attaining a length of some 70cm. The material from the Lyme Regis district includes a nearly complete skeleton, which is missing the head, although cranial material has also been recovered from the site. The most well represented group at Lyme are Holosteans (with rhombic enamel scales, of the type known as ganoid), which are reviewed and redescribed by Gardiner (1960). Many specimens are beautifully preserved, particularly of the genus *Pholidophorus*. This genus is closely related to *Leptolepis* and together they are thought to have given rise to the modern-day bony fishes or teleosts. The Lyme Regis district is a classic area for Lower Lias fish has the potential to yield more specimens of scientific importance. The fauna is reviewed by Dineley and Metcalf (1999).

Cretaceous System: Albian, Cenomanian, Turonian And Coniacian Stages: There is a major unconformity between the Lower Jurassic and Cretaceous sediments. The lowest unit of the Cretaceous succession is the "Gault", a dark, silty and slightly glauconitic clay, only around 7m thick, which grades upwards and imperceptibly into the Upper Greensand. The lower beds of the Upper Greensand comprise grey-green, soft glauconitic sands (the "Foxmould") with calcareous concretions ("Cowstones"). The latter often yield abundant fossil worms (*Rotularia concava*); other fossils from the Upper Greensand include numerous echinoids and bivalves (especially *Exogyra* and pectinids). These beds are particularly well seen at Culverhole Gully and Pinhay. Above the Greensand "Foxmould" are the "Chert Beds" which consist of yellow-brown sandstones with modular or lenticular chert bands composed of chalcedonic silica. There are occasional fossils, mainly bivalves. The uppermost part of the "Chert Beds" are coarse, calcareous and generally chert free sandstones. The "Chert Beds" beds exhibit a fairly consistent thickness of approximately 20m throughout the Reserve. Rare ammonites, including mortoniceratids indicate an Upper Albian (latest Lower Cretaceous) age for most of the the Upper Greensand sequence.

Upper Cretaceous strata ("Cenomanian Limestone" and chalk) can be seen at Haven and Bindon Cliffs, and at Rousdon, Whitlands and Pinhay where, together with the Greensand, they provide the most spectacular and beautiful scenery of the Reserve. The maximum thickness of the Upper Cretaceous is approximately 65m. The Lower Chalk of eastern England is represented by a condensed sequence of calcareous sands and conglomeratic limestones, the "Cenomanian Limestone", which attains a maximum thickness of approximately 1m. This unit locally yields well-preserved Cenomanian ammonites which have been extensively monographed by Wright and Kennedy (1984 -). The overlying Middle Chalk comprises white nodular chalk with an important Turonian ammonite fauna as monographed by Wright and Kennedy (1981); this is succeeded by Upper Chalk with scattered flints of Turonian to Coniacian age. The biozones of *Inoceramus labiatus*, *Terebratulina lata*, *Sternotaxis planus* and *Micraster cortestudinarium* are present although not all occur at each site.

Quaternary: Mass Movement: Landslipping has been taking place along the Axmouth to Lyme Regis section from at least the Pleistocene, and still continues as evidenced by movements in the Whitlands and Bindon sector of the site during 1961 and 1962 and again near Pinhay Bay in the 1990s. If, as is the tradition, the slipped Chapel Rock (SY 312 906) at Pinhay was used as a place of worship during the religious persecutions in the reign of Mary Tudor (1553-58), its date of movement must have been earlier. Other slips have been more definitely recorded: at Whitlands (SY 305 903) in about 1775; near Dowlands (SY 285 895) from about 1790 to 1800; from Pinhay to Ware in 1828; the great slip between Bindon and Dowlands in 1839; at Whitlands again in 1840.

Within the Axmouth-Lyme Regis Reserve the main topographic features are a rear scarp cut into a Chalk upland, which on the coast reaches about 170m O.D., and a broad undercliff varying in width between about 100m and 500m. At Bindon, the rear scarp reaches an elevation of 124m O.D. and the undercliff a width of 415m. The undercliff is generally broadly stepped in profile, with a gently seaward slope losing height mainly in a series of 'steps and rises'. At Bindon however, the undercliff is much more complex with major interruptions to the general seaward decrease in height. This configuration was established by the great slip of 1839 and much of the profile has been modified only detail.

The famous slip of 1839 occurred between Bindon and Dowlands on Christmas Day. Luckily two eminent geologists of that period, Buckland and Conybeare, were in the area and at once produced a detailed survey of the landslip, collected the evidence of eye-witnesses and published an account of the slip. The failure proper started in the early hours of Christmas morning, although signs of fissuring in the cliff top had been observed

a week earlier. This episode was the forerunner of the main failure, which occurred on Christmas night. A chasm opened at the rear of the slip, which was reported by Conybeare *et. al.* (1840) as being 'more than 300 feet abroad, 150 feet deep, and three quarters of a mile long'. Coastguards reported that the remainder of the events, mainly the upheaving of the submarine beach (reef), the alteration of the shore and protrusion of the cliff occurred three hours after subsidence in the chasm first started. Hutchinson (1840), stated that a 'pyramid of rock of great size and remarkable outline sank in the order of 150 feet'. The offshore reef thorn up at the toe of the slip was short-lived, being quickly destroyed by wave action. It is described by Conybeare *et. al.* (1840) as being composed of Greensand and Foxmould displaying landward dip of 30 degrees to 45 degrees and having a very fractured nature. The change in level attained by the strata forming the reef was estimated by Conybeare to be 15 m, from 3 m below the sea to 12 m above it.

The Bindon landslide originated from a Chalk-capped plateau dissected by approximately southerly flowing rivers, and truncated on its southern side by the sea. The succession consists of rocks of Triassic age (Penarth Group) showing variable dip in an easterly direction, unconformably overlain by Cretaceous Gault, Upper Greensand and Chalk, dipping SSE at a low angle. The late Triassic, and in adjacent slopes, Liassic strata, are repeated along the coast as a result of faulting. The basic morphology of the landslide appears to conform morphologically to a block slide with a graben (The Chasm), a major largely intact block (Goat Island) and a pressure ridge at the toe (The Reef). Goat Island is not however an intact block of rock, the slip producing a degree of break up of the mass into a series of units, most of which subsequently came together at the termination of movement. Some of the pinnacles however remained detached and their degraded remains exist most notably at the eastern end of The Chasm. Detailed geomorphological mapping (Picts 1979, 1981) has clarified the current state of the features, which are, in parts, now heavily overgrown. The backscar is composed of Chalk and indurated facies of the Upper Greensand. The irregularity of the backscar would seem to indicate that it was not showing tilt of strata tilted at a variety of angles and directions occur throughout. At the seaward side of the Chasm, several blocks show a seaward tilt of strata having originated as failures from the rear edge of Goat Island. The degraded pinnacles which remain the Chasm now displayed rounded tops and rarely exceed 6 m in height. The extent of their degradation since 1839 is reflected by the large amount of scree, which has accumulated around their bases.

The exposed rear face of Goat Island is composed almost totally of Middle Chalk and varies in height between 12 m and zero where it is now totally obscured by scree. The rocks forming the block dip gently seawards at virtually the same angle as the corresponding rocks in the backscar. Reconstruction of the slope before the slide indicates that no vertical movement of the main part of Goat Island took place, as was suggested in many historical accounts. The precipitous seaward edge of Goat Island is mainly composed of the indurated facies of the Upper Greensand (Chert Beds) with a thin Chalk capping. The face is very steep and occasionally overhanging, producing a complex array of features. The area in front of Goat Island is occupied by a non-circular rotational slip, that is one having a rotational mechanism but in which the failure surface does not describe part of the arc of a circle. Most striking of the features in this area are the very large crags, 'walls' and pinnacles upstanding from the general surface. These 'walls' of rock reach up to 15 m in height with almost sheer faces and knife-edged tops. It is thought that each wall was derived from Goat Island, being a sheet of rock bounded by stress relief joints and/or fissures created during the 1839 slide. They appear to have been subsequently rafted downwards by small movements of the rotational slip upon which they sit. Seaward of the 'walls' and to their west, the ground is open with a gentle seaward slope. The products of debris slides cover the surface along with some larger blocks of sandstone.

The activating cause for the slope (and others in the reserve) was undoubtedly abnormally heavy rainfall over a period, which leads to the face of the cliff, to a variable depth, becoming unstable. Such high rainfalls were recorded in 1774, 1839 and locally around Pinhay in 1960-61. The original explanation for the cause of slipping was that prolonged heavy rain partly washed out some of the loose Foxmould Sands, converting it to quicksand. The overlying Chalk and the Chert Beds of the Greensand, whose weight would have been greatly increased by saturation with rainwater, would have their foundations sapped and weakened. The Chalk and Greensand then foundered and would slide seawards (through a proposed non-circular rotational mechanism, Ward 1945) over the water-lubricated clays below, leaving a series of chasms and upstanding blocks. However, recent workers have doubted that such a dense material as the foxmould could have liquefied and suggest that it is not necessary to invoke such a process to account for the subsidence (Picts and Brunnsden 1987). These authors also suggest that a rotational mechanism for the subsidence of the main slip (Goat Island) is incorrect. The lack of tilting to the beds forming Goat Island effectively precludes rotational failure.

Through geomorphological mapping and stability analyses of the slip it is now apparent that slippage occurred along the plan of the black shales of the Westbury Formation (rather than the Foxmould). The following hypothesis for the slip has now been developed. Due to heavy rainfall and marine erosion (a high spring tide was experienced on December 23rd, immediately prior the commencement of major movements) an initially non-circular rotational failure occurred of the pre-existing undercliff, reducing the toe support to the block behind. This together, with water pressure developed in the landward cliff top tension crack, resulted in planar slippage on the Westbury Formation of a large block of material (Goat Island). Pinnacle-like masses of Middle Chalk and Upper Greensand then subsided into the Chasm created by the forward movement, both from the back of the block itself and from the rear cliff until a stabilised backscar was produced. The apparently rotation effects at the toe may be accounted for without proposing an overall rotation mechanism. The reef (since eroded away) may represent a pressure ridge, or perhaps more likely, locally reactivated shears which bounded previously rotationally slipped and eroded blocks. Since the slip in front of Goat Island clearly includes a rotational element and probably reflects a process long in existence, such relict shear surfaces are very likely to exist in the offshore region.

The Dowlands and Bindon slip is only one part of a continuous series running from Axmouth to Lyme Regis, named successively Haven, Culverhole, Bindon, Dowlands, Rousdon, Whitlands, Pinhay and Ware Cliffs. All have similar histories of large-scale landslipping throughout post-glacial times, and have been displayed similar features, although the Goat Island plateau feature is probably unique. Although the major component in most of the slips has probably been rotational, detailed examination by Picts (1979) has shown that a wide variety of mass movement types are present within the reserve. These include:

1. Rockfalls caused through the undermining of relatively competent rocks by erosion of relatively incompetent horizons, typified by the falls of Blue Lias limestone layers from the sea cliffs at Pinhay Bay.
2. Rockfalls and clayfalls caused by frost, water or desiccation in multi-jointed or fissured materials. The scale of the falls varies with the frequency of discontinuities, between the relatively widely spaced major fractures of the Chalk and the indurated Upper Greensand facies in the cliffs at the back of the undercliff, to the closely fissured Mercia Mudstones of Haven and Culverhole Cliffs.
3. Gully enlargement associated with cliff-top seepage points, as in the Mercia Mudstones of Culverhole Cliffs.

4. Forward toppling of columns of rock bounded by approximately vertical, continuous fractures, as on the seaward edge of Goat Island.
5. Successive rotational slips, as in the Chal-Upper Greensand-Lower Lias succession of Pinhay Bay, or the Chalk-Upper Greensand-Lias-Rhaetic succession of Charton Bay. These often take the form of renewed movements in already slipped masses. The region around Chapel Rock (western end of Pinhay Bay) illustrates the typical landslip structure. Here water held in the glauconitic sands of the Foxmould and Chert Beds (Upper Greensand) below the Chalk continually lubricates the plastic clays of the Gault and Lias and foundering results (Grainger et. Atl. 1986).
6. Retrogressive slips, as in the Chalk-Upper Greensand succession in The Chasm at Bindon.
7. Non-circular to transitional block slides, as at Bindon, leaving a relatively undisturbed slipped mass.
8. Debris slides with weathering or depositional discontinuities and a mainly disturbed slipped mass, as at the toe failures of Haven Cliffs, and the scree slope failures in front of slipped chalk and Upper Greensand blocks at Charton Bay.
9. Mudslides: these are mainly toe features, being the terminal stage of successive rotational slipping where adequate comminution of debris, clay bedrock and seepage tend to occur together, as at the cliff top at Pinhay Bay and at beach level at Dowlands.
10. Mudflows: both toe components of terminal mudslides, as at Dowlands and Pinhay; and cliff-foot flows from saturated talus beneath seepage points, as at Haven Cliffs and Ware Cliffs.
11. Sand-runs; collapse of dried-out, non-cohesive arenaceous deposits, especially Foxmould, as at Charton Bay.

The entire stretch of cliffs from Axmouth to Ware Cliffs shows an astonishing and quite exceptional variety and richness of mass movement types as given above. Although smaller-scale movements occur frequently within the site it is the infrequent large-scale movements that obviously attract the greatest attention. This is epitomised by the very large Bindon slip of 1839, which brought the area to public prominence, and has also led to continued instructed controversy over its formation. Through the documented historical mass-movements records for the site and the part it has played in elucidation of landslip processes this is undoubtedly the most renowned area of landslipping in Great Britain and probably northern Europe.

Suggested exercises:

1. Study geological maps and sections of the district and, based on your own observations, suggest how the landslip systems may have developed.
2. Measure a sequence through the "Blue Lias" on the foreshore; how do you think this sequence of regularly alternating beds could have formed?
3. Measure a selection of the ammonites on the platform at Seven Rock Point (at least 50 individuals if you can). Draw a graph of your results - does this tell you anything about the life and death of these animals?

4. Make a geological map or transect of the “Blue Lias” on the foreshore between Lyme Regis and Pinhay Bay (be sure to use a compass- clinometer). What geological structures can you detect?
5. There are a variety of rocks and pebbles on the beach. Can you identify them and determine from what geological rock unit they were derived?
6. Examine the blocks and outcrops of “Blue Lias” on the beach west of Lyme Regis. What types of animals and plants can you find and what does this tell you about the conditions under which these rocks were laid down?
7. Around Seaton and Axmouth Harbour there are coastal defence works and a harbour arm extension. Compare these areas with unprotected coastlines east of Axmouth and discuss how engineering works can modify coastal processes. Are these changes beneficial or detrimental - in the both the short term and in the long term?

Please contact Natural England’s Devon office for further suggestions or to discuss possible research projects within the reserve.

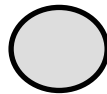
LOCATION PLAN

AXMOUTH TO LYME REGIS UNDERCLIFFS NATIONAL NATURE RESERVE, SSSI AXMOUTH/COMBPYNE-ROUSDON, EAST DEVON

National Grid Ref: SY 256 896 - 323 913



Scale 1: 60,000



Approx. SSSI Boundary

Parking and Access

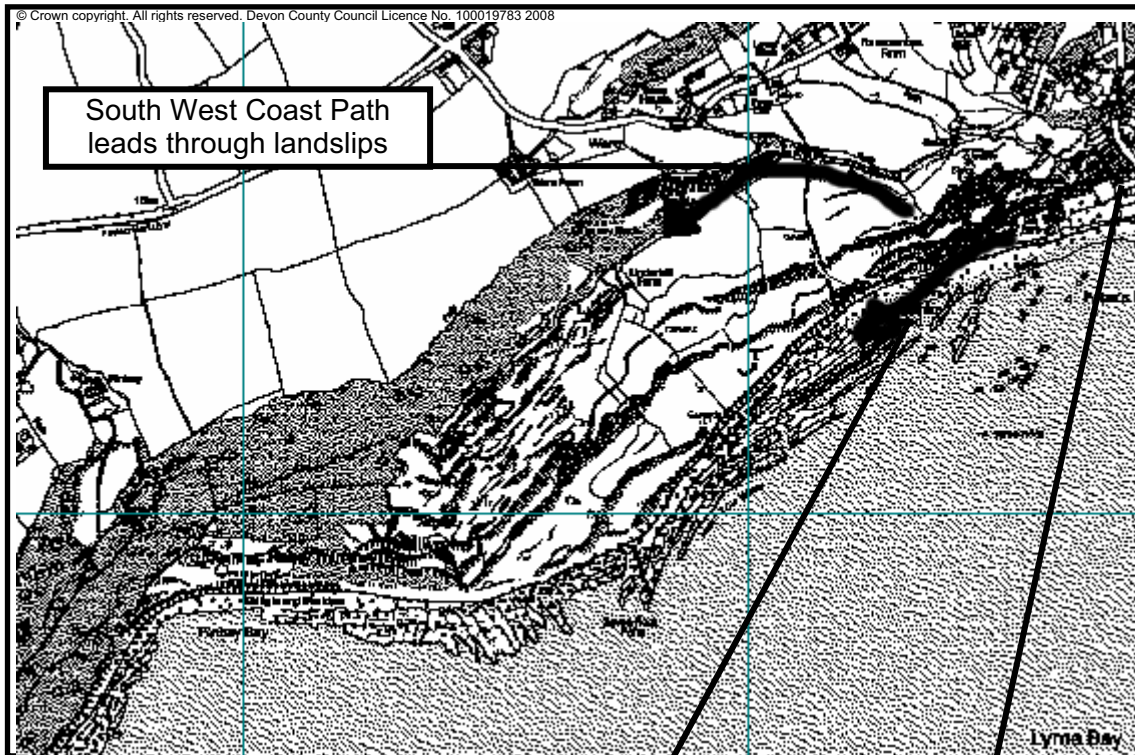
- Public access is restricted to the South West Coast Path that runs through the undercliff and along the beach. Parking is available at Lyme Regis, west of and above the Cobb. Eastern areas of the reserve are accessed by the coastal footpath or via the shore to Pinhay Bay. At the western end of the reserve, limited car parking is available just north of the access road to Axmouth Harbour and also within Seaton. There is *no* public access to any other part of the reserve.
- There are regular bus services to Seaton and Lyme Regis, including the 'Jurassic Bus' (X53), and bus links to the train station at Axminster. For timetable details, visit the [traveline](http://traveline.co.uk) website.

SITE PLAN

AXMOUTH TO LYME REGIS UNDERCLIFFS

AXMOUTH/COMBPYNE-ROUSDON, EAST DEVON

National Grid Ref: SY 256 896 - 323 913



Scale 1 : 15,000

Access along beach to cliffs at Pinhay Bay

Lyme Regis

Main Points of Interest:

Lyme Regis to Pinhay Bay:

- Cliff and foreshore exposures in limestone – marl rhythms.
- Cross sections of large ammonites seen in fallen blocks and wave cut platform around Seven Rock Point.
- White Lias – Blue Lias junction and Triassic – Jurassic boundary at the boundary at the back of Pinhay Bay.

AXMOUTH TO LYME REGIS UNDERCLIFFS NATIONAL NATURE RESERVE

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Culverhole Point, looking westwards: 'White Lias' (Lilstock Formation, Penarth Group) in middle ground with cliffs of Mercia Mudstone Group beyond (including Blue Anchor Formation).

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Charlton Bay, looking westwards, with cliffs of Blue Anchor Formation. Note landslipped Cretaceous (chalk, etc) beyond.



Charlton Bay , 'White Lias' (Lilstock Formation, Penarth Group) with Blue Lias Formation above in landslipped block.



Dowlands foreshore: periclinal structure developed in Blue Lias Formation at base of landslip system.

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The 'White Lias' (Lilstock Formation, Penarth Group- basal limestone bed only) – Blue Lias Formation in Pinhay Bay. The Triassic-Jurassic boundary probably lies close to the formational boundary. Not the problematic domed structure in the lowest thick limestone bed of the 'Blue Lias'

© Kevin Page



West Cliff ['Monmouth Beach']: general view of Lower Lias exposures (Blue Lias Formation in steep, lower part in centre and to left, with Charmouth Mudstone Formation, 'Shales-with-Beef', above in higher slopes to right).

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Two views of Pinhay Bay, the upper from the sea. Note the 'White Lias' (Lilstock Formation, Penarth Group- pale buff coloured limestones) – Blue Lias Formation (gray interbedded limestone bands and mudrock) boundary) near the base of the cliffs.

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Blue Lias Formation ammonites on the beach In the Axmouth-Lyme Regis National Nature Reserve. Above: *Metophioceras* in Bed 29 at Seven Rock Point. Below: *Arietites* (hammer is 40cm long).



Examining fallen blocks of Cretaceous 'Greensand' and 'Chalk' on the beach in Pinhay Bay (rocks of this age are only safely accessible on the beach).



A contemporary view of the famous Bindon landslip, including 'Goat Island' (from Conybeare, Buckland W and Dawson (1840).



© Clyde Bish

The active landslips on the W side of Pinhay Bay – note in-situ Cretaceous high in the cliff to the right, and slipped blocks of the same to the left.