

Dorset and East Devon Coast World Heritage Site

Management Plan 2014-2019

APPENDIX 1: Significance and description of the Site and Setting



United Nations
Educational, Scientific and
Cultural Organization



Dorset and East Devon Coast
• inscribed on the World
• Heritage List in 2001

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YOUR VIEWS

The most important people for the future protection, conservation and use of the Dorset and East Devon Coast are those who live or work on or near it, and visit and enjoy it. Please let us know your views on the Site and its management through the contact details below.

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A1-1 Significance

A1-1.1 Geological values

The coastal exposures within the Site provide a near-continuous, accessible sequence of rocks that documents almost 190 million years of the history of the Earth, spanning the Mesozoic Era.

The rock strata exposed within the Site provide a near-continuous geological record of earth history between 251 and 66 million years ago, in relatively undeformed sediments, representing a remarkable range of past environments. Together, the succession reveals a complete, classic and well-studied section through the Wessex Basin, one of the best known Mesozoic-Tertiary intra-plate sedimentary basins in Europe. A simplified stratigraphic column for the Site is shown in Figure 4. The structure of the coast displays its geological interest superbly. In general, the strata dip gently to the east. The oldest rocks are therefore found in the west of the Site with progressively younger strata outcropping to the east. As a direct result, most parts of the succession are readily accessible in sequential order within the cliffs and foreshore, while the continuous processes of coastal erosion mean that exposures are constantly refreshed and new material is brought to light.

The Triassic succession is a virtually continuous exposure of c. 1,100m of sediments representing most of the Triassic Period (c. 251-199 million years ago) in continental, terrestrial red-bed and, near the top of the sequence, shallow marine facies. These exposures record evidence of the gradual destruction and denudation of mountains formed in the Variscan orogeny of 330-280 million years ago, and the establishment of a widespread marine environment within a Jurassic basin, formed during the opening of the Atlantic Ocean (Warrington, 1999; Barton, 1999 contributions to nomination).

The Jurassic rocks within the Site have been known since the early days of geology as providing one of the finest marine sequences of this age anywhere in the World (Callomon and Cope, 1995). Every stage of the Jurassic is represented; of the seventy-four ammonite zones, which have been recognised within the Jurassic (Cope et al., 1980a, 1980b), only three are definitely absent. The succession provides excellent evidence of the history of the Earth between c. 199-146 million years ago, recording six major cycles of sea level change, represented by repeated rhythms passing from clay to sandstone and then limestone. Historically, these sections have played a key role in the establishment of modern stratigraphy and biostratigraphic studies. They are internationally renowned, 'classic' sections on which comparative studies continue to be based.

The boundary between the Jurassic and Cretaceous has still to be internationally defined, but, in Dorset, is expected to lie within the lowest beds of the Purbeck Formation. The succession within the Site includes rocks of all stages of the Cretaceous Period, with the exception of the uppermost stage. The Purbeck Formation in Dorset is one of the finest late Jurassic-early Cretaceous terrestrial sequences in the world and offers a unique insight into environments and life at that time. The overlying Wealden Group is the most complete sequence of this age available at a single site in north-west Europe. Much of the Site displays a spectacular example of a geological unconformity. This is an exceptionally well exposed and documented record of a world-wide Lower Cretaceous marine transgression. Uplift and erosion towards the end of the Wealden led to the erosion of the underlying Cretaceous, Jurassic, and Triassic along the length of the coast, prior to deposition of the transgressive Lower Greensand, Gault and Upper Greensand. In East Devon these strata rest directly on Triassic rocks. The unconformity becomes progressively smaller to the east, until, in the Swanage area, the Gault and Upper Greensand overlie the Wealden Formation with little angular discordance. Complex lateral changes in sedimentary environments are also recorded, allowing interpretation of the changes that took place during this important phase of sea level change. The extensive coastal exposures provided by the Dorset and East Devon coast are complemented by modern and detailed geological maps, exceptionally well documented stratigraphy and sedimentology and an extensive subsurface database. As this knowledge has been gained, the significance of the structural geology of the Site has become particularly important. Today this is one of the best understood sedimentary basins in the world, and concepts developed here have a global application.

Dorset localities have provided the names for internationally recognised stages for the Mesozoic. The Kimmeridge Clay unit gave its name to the international Kimmeridgian Stage as proposed by D'Orbigny (1846-1849). Owing to a miscorrelation at that time, only the Lower Kimmeridge Clay is now included in the modern Kimmeridgian Stage, the remainder lying within the lower Tithonian of current international use. Portland gives its name to the Portlandian Stage, named by Brongniart (1829), which is still in use in Northern Europe, though now included within the upper Tithonian. The Purbeckian, named after Purbeck, was, until recently, in international use for the lowermost stage of the Cretaceous.

The Site includes a remarkable range of internationally important fossil localities, which have produced superbly preserved and diverse evidence of life during Mesozoic times

The rocks within the Site are, for the most part, highly fossiliferous and contain the evidence of major changes in the pattern of life on Earth during the Mesozoic Era, between two mass extinctions which took place at the ends of the Permian and Cretaceous periods. The variety of environmental conditions represented within the succession, and particularly the overall predominance of shallow marine sediments, has resulted in an exceptionally diverse range of species being represented, including plants, insects, benthic and pelagic marine invertebrates, fish, marine and terrestrial reptiles and mammals. Furthermore, exceptional preservation of material is found within a number of the fine-grained sediments including articulated skeletal remains, and rare features such as soft-tissue preservation.

FOSSIL VERTEBRATES

The Site contains nine vertebrate fossil localities of international importance, ranging in age from Mid-Triassic to Lower Cretaceous.

Triassic: The Mid-Triassic Otter Sandstone Formation at High Peak and Otterton Point has yielded ten species of reptiles, fish and amphibians. It is the richest productive Mid-Triassic reptile site in Britain and has been assessed as representing one of the most promising terrestrial reptile sites of its age known (Benton and Spencer, 1995).

Jurassic: Seven sites are of international status for vertebrate remains within the Jurassic. The Liassic (Hettangian – Pliensbachian) vertebrates of Lyme Regis (Pinhay Bay to Seatown) are world famous. This fauna is the most diverse and abundant known from the early Jurassic anywhere. The latest faunal review (Benton and Spencer, 1995) reported that this locality has yielded type specimens of fourteen species of reptile, nine of which occur only here. Discoveries of species new to science are still being made on a regular basis as the cliffs erode. In recent years these include a new species of ichthyosaur from the Pliensbachian (McGowan & Milner 1999), and a second discovery from 1999 which is awaiting description. The quality of specimens is frequently exceptional, with well-articulated skeletons and soft-part preservation of features such as skin and stomach contents. This locality is the source of the geologically earliest well-preserved plesiosaurs and the earliest crown-group ichthyosaurs. The first complete skeletons were collected from these localities in the early nineteenth century (Taylor, 1997), and include holotype specimens of taxa that are still crucial to modern studies of marine reptiles (Storrs, 1997). Material from Lyme Regis has formed the basis of recent revisions of ichthyosaur relationships and evolution (McGowan, 1973-1989). The importance of Lyme Regis is further highlighted through the remains of terrestrial vertebrates. It is the only locality of *Scelidosaurus harrisoni* Owen, the oldest known thyreophoran (armoured) dinosaur (Norman, 1985).

The Lias has also produced unique records of one of the earliest flying reptiles, *Dimorphodon macronyx* which is of great importance to the study of pterosaurs (Unwin, 1988). The fish fauna is also very diverse with a broad representation of both cartilaginous and bony fishes (Gardiner, 1960), and its significance has recently been assessed (Dineley and Metcalf, 1999). About forty-six species are currently recognised of which thirty-five are unique to this locality. It is the source of some of the finest preserved Lower Jurassic fish known, some of which are preserved uncompressed in three dimensions (Dineley and Metcalf, 1999). The Middle Jurassic vertebrate fauna of the Forest Marble at West Cliff, West Bay is a unique and diverse mix of marine, freshwater and terrestrial elements (Evans, 1999). The fauna includes bony fish, sharks, amphibians, frogs, salamanders, small turtles, lizards, crocodiles, dinosaurs, pterosaurs and early mammals, and much material awaits description. It is important as one of few well-known vertebrate faunas of this age (Evans, 1999 contribution to nomination).

Furzy Cliff near Weymouth is Britain's best Oxfordian reptile site, and in view of the limited number of sites of this age elsewhere, is considered one of the best in the world (Benton and Spencer, 1995). It is the source of the unique specimen of the carnivorous dinosaur *Metriacanthosaurus parkeri* (Huene, 1923), together with ichthyosaur and plesiosaur remains.

The Kimmeridgian vertebrate fauna, from three significant localities within the Site, is world-renowned. Smallmouth Sands has produced one of the most diverse assemblages of Kimmeridge Clay reptiles known. Its fauna of four species of turtles and three of pterosaurs is unique; six of its vertebrate species are known only from this locality (Benton and Spencer, 1995). Within Kimmeridge Bay nearly twenty species of crocodylians, pterosaurs, dinosaurs, plesiosaurs, pliosaurs and ichthyosaurs have been found. Although many of the taxa are represented at other localities in the world, the quality of preservation of much of the material from the Site is exceptional. Kimmeridge Bay has yielded more type specimens of

reptiles than any equivalent site (Benton and Spencer, 1995), and its fossils have figured prominently in recent reviews of marine reptiles (Tarlo, 1960; McGowan, 1976; Brown, 1981). Encombe Bay has produced species of turtles, pterosaurs, dinosaurs, plesiosaurs and ichthyosaurs. The Kimmeridge Clay has yielded a fauna of at least fifteen published species of reptile, of which 20 per cent are unique to Dorset, but recent collections include considerable further unpublished material (Etches and Clarke, 1999). The fish fauna includes eighteen species; the material is very well preserved and new finds are made each year (Dineley, 2000 contribution to nomination).

The Isle of Portland has yielded the best faunas of marine Portlandian (Upper Tithonian) reptiles in the world (Benton and Spencer, 1995). Finds have been made in coastal sections and in adjacent quarries, which lie outside the Site. Eight reptile species have been identified, of which four are represented by type specimens. The fossil turtles are particularly important and include some of the earliest known well-preserved specimens (Benton and Spencer, 1995).

Cretaceous: The Purbeck Formation on the Isle of Purbeck (including those rocks that straddle the Jurassic – Cretaceous boundary) contains an exceptional assemblage of vertebrate fossils. Fish remains are common and locally are exceptionally well preserved. About thirty species have been identified, and the formation is regarded as one of the most important late Jurassic fish localities in the world (Dineley and Metcalf, 1999). It also contains one of the richest mid-Mesozoic tetrapod assemblages known (Howse and Milner 1995). The fauna includes amphibians, mammals and over forty species of reptiles; turtles, crocodiles, lizards and dinosaurs, complete with associated trackways. Durlston Bay is by far the richest known reptile site of this age, and has many claims to pre-eminence for specific aspects of reptile palaeontology (Benton and Spencer, 1995). The mammal fauna is also outstanding; it was first recognised in the 1850s by Samuel Beckles, and monographed by Sir Richard Owen (1871). Many new species have since been recovered. In total, the Purbeck of Dorset is unique in providing over 100 valid named species of vertebrate within a limited geographical and stratigraphic setting, indicating that they were living in close proximity at the same time. The associated range of trace fossils, egg-shells and coprolites, together with the level of sedimentological detail, provide a record of unparalleled richness in reconstructing a complete picture of the environment of the time. There is a high potential for further discoveries: recent work, for example, at a coastal locality and a nearby inland locality has revealed Britain's only reptile eggshell of this age and an additional important microvertebrate horizon (Ensom, 1997, in press, and contribution to nomination).

FOSSIL INVERTEBRATES

The invertebrate fauna of the Site is extremely rich, and the remains are found throughout the Jurassic and Cretaceous. Fossils belonging to most phyla have been described, although corals are largely missing. Many aspects have been studied in detail, including the bivalves and several different groups of microfossils. Insects are known from the Triassic, Jurassic and Cretaceous rocks within the Site. The particularly significant remains are the rich and diverse faunas from the Lias and the Purbeck Formation, and new discoveries indicate significant potential in the late Triassic strata near Axmouth, East Devon (Swift and Martill, 1999).

The Black Ven Marls near Charmouth are the best known source of Lower Lias insects in the World. The diverse fauna includes representatives of ten different groups. The insects have been the subject of modern scholarly works which have recognized over twenty new genera and species known only from the Site, including the oldest known moth *Archaeolepis mane* (Whalley, 1985) (Jarzembowski, 2000 contribution to nomination).

Insects from the Purbeck Beds have been found at Durlston Bay, Upwey, Osmington and on the Isle of Portland. The most important locality is Durlston, where over 3,000 specimens have been collected. This is one of a small number of rich Cretaceous insect sites world-wide, and it is distinct from the other sites known. Around 150 species, mostly unique to Dorset, have been named belonging to fifteen orders, and many more species await description (Ross, 1999 contribution to nomination).

The Dorset and East Devon Coast has long been famous as a rich source of ammonites, which are often well preserved, and are abundant at most levels within the marine strata. Some specimens display exceptional preservation of jaw structures and other features, and the remarkably complete succession of faunas at certain levels provides excellent material for evolutionary and taxonomic studies. Ammonites have been collected and described extensively from the Site: many type specimens of well-known species have been found here, including a significant number of important early discoveries of type specimens used in the standard ammonite zonation of the Jurassic.

The Lower Lias sequence has been described in great detail. The detailed descriptions of ammonite faunas from Dorset by Spath, based partly on the Site, form the basis of the modern zonal scheme (Callomon and Cope, 1995). The Weymouth area provides the type section for ammonite faunas of three Oxfordian subzones of the North West European province. The Kimmeridge Clay provides the reference section for the Boreal Upper Kimmeridge (Bolonian/Upper Tithonian) zones (Cope 1967, 1975). The cliffs and quarries of Portland have been fundamentally important in defining ammonite zonation

through the Upper Tithonian (Portlandian) Stage (Wimbledon and Cope, 1978; Callomon and Cope, 1995). Several important species of Cenomanian and Turonian ammonites have their type localities within the Site, including *Watinoceras devonense* (Wright and Kennedy), the standard international index for the base of the Turonian Stage.

The Lower Jurassic exposures within the Site are also noted for their echinoderm fauna. Extraordinarily preserved specimens of the crinoid *Pentacrinites fossilis* from the Black Ven Marls have provided crucial evidence for the pseudoplanktonic mode of life of this and related species. Higher in the succession the well known Starfish Bed has yielded many exceptionally-preserved ophiuroid, and rare asteroid starfish (Goldring and Stephenson, 1972). Tangled groups of the crinoid *Balanocrinus gracilis* also occur in exceptional preservation at a similar level in the succession. Intact echinoids occur locally at several levels, notably low in the Blue Lias, with several species described on the basis of material from here (Wright, 1855-80).

Because of the exceptionally continuous exposure on both foreshore and cliff the Jurassic succession has provided a great deal of material used in taxonomic studies of a wide range of other invertebrate groups. Notable among these are publications dealing with some of the more neglected groups, such as Lower Jurassic belemnites (Lang, 1928) and gastropods (Cox, 1926-1944), for which few detailed studies have been published. There are a range of other important monographs such as those on Corallian lamellibranch bivalves (Arkell, 1929-1937), Sponges (Sollas, 1883; Hinde, 1887-1912) and brachiopods (Muir-Wood, 1926-1936).

FOSSIL PLANTS

There are exceptional remains of Late Jurassic fossil forests exposed on the Isle of Portland and the coast of Purbeck. These forests once grew on the margins of a large hypersaline lagoon that, 140 million years ago, covered much of southern England. It is a uniquely complete record of a forest of this age and contains large trees, sometimes in situ with associated algal burrs which formed around the bases of the trees, and fossilised soils and pollen. The wood is exceptionally well preserved in silica, displaying microscopic details of the structure, including preserved growth rings which allow a detailed assessment of the climate of the time (Francis, 1983, 1984, 1986).

A1-1.3 Geomorphological values

The Site represents an exceptional range of text-book exemplars of coastal geomorphological features, landforms and processes

The East Devon and Dorset coast is a spectacular natural geomorphological laboratory. It is famous for its demonstration of a wide range of different mass-movement systems, the development of a unique barrier beach and lagoon, and classic examples of coastal cliff evolution in both time and space and in relation to the underlying rock structure. The Site provides a superb varied assemblage of related landforms and processes, which demonstrates numerous classic and universal features of coastal geomorphology. The importance of these features is heightened by their extensive study and long history of use as examples in text-books.

Five distinct and important aspects can be identified: landslides, beaches, the Fleet lagoon, cliffs and raised beaches. Due to the lithological variation in the Jurassic strata and the presence of the Lower Cretaceous unconformity, the coast contains a near-comprehensive range of slope failures from rotational landslides to mudslides, topple and slab failures. Some are prehistoric while others have eyewitness accounts or provide the subject of ongoing research. Possibly the most significant is the Bindon Landslip between Axmouth and Lyme Regis. The massive landslide, which took place here in 1839, created the 6.5 ha 'Goat Island' isolated by a 30 m deep 'Chasm'. Black Ven is another classic and complex site demonstrating rotational landslides, and the largest recorded coastal mudslide in Europe.

Portland shows fine examples of topple and slab failure, and rockfalls. The slides include East Weares, the second largest historical slide in the UK, and King's Pier, the first known landslide to have been caused by human activity (Brunsden, 1999 contribution to nomination). Studies on this coast provide one of the best documented analyses of beach formation and evolution on a retreating coastline (May, 1999 contribution to nomination). There are numerous small beaches, and two larger classic sites: Budleigh Salterton and Chesil Beach.

At Budleigh Salterton, the beach is formed from pebbles eroded from the Triassic pebble beds. These pebbles are found in beaches stretching all along the south coast of England and are a diagnostic marker which provide important evidence of beach evolution in the English Channel during the Holocene. The largest and best-researched beach is Chesil Beach, which faces the full fetch of the Atlantic Ocean. It is 28 km long and ranges in height from 5 m to 15 m between West Bay and

Portland. Chesil Beach is a world renowned feature, famous for the volume, type and size-grading of its pebbles. The origin of the beach and the nature of the ongoing processes have been extensively studied and are the subject of continuing research (Brunsden, 1999; May, 1999 contributions to nomination).

Chesil Beach encloses the Fleet, one of the most important lagoon areas in Europe. The sediments preserved in its sheltered waters provide information on the late Holocene evolution of the beach, and evidence for changes to sea levels, climate and vegetation. Chesil and the Fleet represent an exceptional example of a barrier beach and lagoon system, and they are recognised by a range of national and European protective designations. Over eighty per cent of the Site is cliff coastline, developed in many different combinations of mudstones, sandstones and limestones. There is a particularly superb development of beautiful coastal landforms on the Isle of Purbeck. This part of the coast is the best known example of adjacent concordant and discordant coasts, displaying the differing coastal landforms which result from the action of the sea both with and across the geological 'grain' of the coast. It is a classic location for demonstrating the evolution of caves into bays (the cave-bay sequence) and shows the full range of responses to variations in the resistance of strata, and differential coastal erosion at a range of scales. It includes text-book examples of bays, stacks and a rock arch at internationally well-known localities such as Lulworth Cove, Durdle Door and Old Harry Rocks (Brunsden, 1999; May, 1999 contributions to nomination).

Two Pleistocene raised beach deposits, of different ages, are present at Portland Bill. They provide an important association of terrestrial and marine sediments up to perhaps 200,000 years BP in age. The fossil fauna of the East Beach is the most diverse found in any British raised beach, and this is the best example of a raised beach sequence along the English Channel coast (Keen, 1999 contribution to nomination).

A1-1.4 History of Science values

The Site has been a crucible of earth science investigations for over three hundred years. It has helped foster major contributions to many aspects of geology and geomorphology

The importance of the Dorset and East Devon Coast to the earth sciences is demonstrated by its critical contributions to many of the major, formative debates in the early days of geology and geomorphology. The fossil wealth of Lyme Regis was first pointed out in 1673 by John Ray. In 1770 the fame of the area drew a visit to Weymouth from James Hutton (1726-1797) of Edinburgh, often cited as 'the father of modern geology'. The Site has since inspired a large number of other significant geologists, who were either born, worked or lived here. They include William Smith (1769-1839), who made the first geological maps of England, Dr. William Buckland (1784-1856) of Oxford University, later Dean of Westminster, Adam Sedgwick (1785-1873), Professor of Geology at Cambridge, William Conybeare (1787-1857), incumbent at Axmouth and later Dean of Llandaff, Gideon Mantell (1790-1852) the discoverer of the Iguanodon, Sir Roderick Impey Murchison (1792-1871), President of both the Geological and Royal Geographical Societies, Sir Henry De la Beche (1796-1855), founder of the British Geological Survey, Professor John Stevens Henslow (1796-1861), Darwin's Tutor at Cambridge, Sir Charles Lyell (1797-1875), the pioneer of uniformitarianism, Professor Richard Owen (1804-1892), superintendent of the Natural History Museum, London and Louis Agassiz (1807-1873), the Swiss founder of modern glacial geomorphology.

The Site rose to pre-eminence during the early part of the nineteenth century, at a time when, as observed by Sir Crispin Tickell (1995), geology was the 'queen of sciences': '*occupying the kind of place in people's minds as evolution and natural selection did in the second half of the century, physics in the first half of the twentieth, and information technology with molecular genetics in our own times*'. '*What that world had been, and how it should be understood, was the central conundrum of this time*'. At this critical period, the discoveries made by the Anning family, who ran a fossil hunting and selling business at Lyme Regis, advanced science in a way without parallel in Europe (Tickell, 1995; Torrens, 1995). They found the first ichthyosaur to come to scientific attention in around 1811-12, the World's first complete plesiosaur followed in 1823, the first British pterodactyl in 1828, to say nothing of other equally important finds in invertebrate palaeontology, coprology and taphonomy. Their activities stimulated the activities of many, now famous collectors, including the three Philpot sisters, William Willoughby Cole, third Earl of Enskillen (1807-1886), Sir Philip Egerton (1806-1881), Lt. Col. Thomas James Birch (1768-1829), and Thomas Hawkins (1810-1889), a maniacal collector of giant fossil reptiles. Their collections of fossils from the Site, and those of later collectors such as Sir A.S. Woodward (1864-1944) and James Frederick Jackson (1894-1966) now form the basis of major museum collections including those at the Natural History Museum, London, the Sedgwick Museum in Cambridge, the Bristol City Museum and the National Museum of Wales, Cardiff. A second specimen of plesiosaur discovered by Mary Anning (1799-1847) is now displayed in the Musée Nationale d'Histoire Naturelle in Paris. This and other material from Dorset was used by the great French vertebrate palaeontologist Georges Cuvier (1769-1832) in his epoch-making *Récherches sur les Ossements Fossiles* (1821-1824).

Mary Anning's life story is extraordinary, and has been retold (often inaccurately) in several biographies and children's books. Not only was she collecting at a time when discussion of transmutation or the evolution of species was regarded as subversive, she was also a poor woman, a dissenter, uneducated and working class, in a field dominated by wealthy male amateur collectors. Yet she became the friend and associate of some of the most eminent scientists of the day, such as Agassiz, De la Beche, Buckland and Murchison, and was visited by the King of Saxony. The list of her original discoveries places her in the highest rank of the pioneers of geological science. Mary Anning was also the inspiration for the World's first published palaeoecological reconstruction, *Duria antiquior* (A more ancient Dorset), produced in c. 1830 by De la Beche in her honour and for the financial benefit of her and her family. This imaginative scene was the first successful attempt to recreate a picture of the environment and animals of a geological period and became very famous throughout geological and natural history circles. It provides the clearest illustration of the leaps in scientific imagination which resulted from the finds on the coast, and the interaction of the leading scientists of the day (Rudwick, 1992).

Although the fossil-bearing strata of Lyme Regis were the early hub of scientific inquiry within the Site, other features were prominent in these early debates. One of the main controversies of the time was between the catastrophists, who believed in the reality of occasional violent events in the geological past, and uniformitarians, who claimed that geological processes had never been more intense than those observed at the present day. The topography of the Dorset and East Devon coast was used by Buckland and De la Beche to argue that the valleys must have been excavated by a violent flood in the geologically recent past, while others thought that only the slow action of rivers had been involved. Their contemporary, William Conybeare (1787-1857), was one of the first to see the results of the most dramatic historical landslide ever to occur in Great Britain, the famous event of Christmas Eve 1839 at Bindon, near Axmouth in East Devon. His illustrated account, assisted by William and Mary Buckland, is one of the two earliest scientific monographs on the mechanism of a landslide. The important vertebrate faunas of Purbeck were another early discovery. Samuel Beckles, encouraged by Sir Richard Owen, searched for mammal remains from the cliffs of Durlston Bay with such success that he collected many unique species later described by Owen (1866).

The fame of the coast as a source of fine fossil material was also helped by the activities of the then world's largest natural history agency, built up by the Weymouth hosier and glover Robert Damon (1814-1889) and his son Robert Ferris Damon (1845-1929). Between the 1840s and 1914 they supplied museums throughout North and South America, Australia and Europe with much Dorset geological material. Other specialised advances in geology and geomorphology drew on the Site. Osmond Fisher (1817-1914), born at Osmington, was inspired by his observations on the Purbeck coast to write the first ever textbook on theoretical geophysics *The Physics of the Earth's Crust* (1881 and 1889). He was the first to conclude that the crust beneath the oceans must be younger than that beneath the continents, anticipating ideas which became the basis of modern plate tectonics (Wilding, 1988).

The German palaeontologist Albert Opeel (1831-1865) used the ammonite succession of the Dorset coast within his pioneering studies of biostratigraphic zonation (Hallam, 1989), and a number of significant contributions to ammonite zonation have been made through studies of the Jurassic and Cretaceous faunas from the Site. Stratigraphic investigations at Burton Bradstock and West Bay by Sydney Savory Buckman (1860-1929), helped lead him to the first proper demonstration of diachroneity in rocks of the same lithology. E. St. J. Burton's studies of the Purbeck Coast led him to the idea of substituting space for time in explanations of landscape evolution – a forerunner of the so-called 'ergodic hypothesis' of geomorphology. Since the earliest days of study, the Site has provided inspiration for new generations of earth scientists, representing many hundreds of scientists including those who have contributed to this nomination.

The work of Joscelyn Arkell (1904-1958) is particularly notable. His *magnum opus*, *Jurassic Geology of the World* (1956) was the first example of a world-wide study of a system of rocks by a single person. Arkell began his work with a description of the Jurassic rocks of Dorset and East Devon, which he then took as the standard of reference. His statement at the beginning of this nomination (page 4), based on his understanding of the geology of the globe, is a passionate recognition of the international geological importance, and the beauty, of this coastline.

The Site is exceptionally well studied and documented, with a continuing importance for many aspects of earth science research, and is a teaching and training resource for the earth sciences of the highest quality

The Dorset and East Devon Coast is one of the best documented geological sites in the World. From the earliest days of geology to the present day the coast has generated an enormous volume of high quality scientific study. A provisional bibliography for the Site (Appendix G), based on *Bibliography and Index of Dorset Geology* (Thomas and Ensom, 1989) contains over 5,000 references, although some areas of the literature are certainly under-represented within it. The earliest geological mapping of the coast dates from the 1820s. The area has been thoroughly re-mapped since 1995 by the British Geological Survey. A full series of modern maps at 1:50,000 scale will be published during 2000 and 2001, and more detailed mapping at 1:10,000 is also publicly available from the Survey.

There is also an exceptional sub-surface database as a result of onshore and offshore oil exploration since the 1930s (Underhill, 1998). This level of information, together with the quality and accessibility of the exposures and the range of established visitor facilities, provides an exceptional teaching and training resource for all levels of study. The coast is visited by hundreds of geologists and geomorphologists each year including international groups, oil company geologists, student field trips and amateur groups. The Upper Jurassic sections are probably the most frequently visited geological sections in Europe, both by geological parties and by professional geologists, mostly from Britain, Europe and North America. Most geological undergraduate courses in the UK include field visits to this coastline, and at least 200,000 residential educational visitors come to the coast every year (Dorset County Council, 1994).

There are notable geological collections in the local museums in East Devon and Dorset, which also provide various displays and advice to the public. Their locations are shown in Figure 8 on page 116. The East Devon and Dorset Coast has a particular importance as a training ground for petroleum geologists, attracting international attention. The rock succession presents a complete section through an oil basin allowing source, reservoir and cap rocks, and its structural geology, to be studied at outcrop. The Kimmeridge Clay provides one of the World's best examples of an immature hydrocarbon source rock, and is of particular importance as the main oil source rock within the North Sea. Data from the nearby Wytch Farm oilfield, Europe's largest onshore field, together with the results of other oil exploration data, add to the importance of the area for the study of petroleum geology.

The Site has provided material for numerous post-graduate (M.Sc. and doctoral) studies, in addition to post-doctoral research. There are many active researchers on the coast, with a number of areas where leading edge science is being carried out. The geology of the coast is described in Geological Survey Memoirs (Wilson et al, 1958; Arkell, 1947) and a coastal guide has been prepared for Dorset (House, 1993). An account of the modern mapping is in preparation. There are classic reviews of the Jurassic succession by Arkell (1933, 1956), Callomon and Cope (1995) and Hesselbo and Jenkyns (1995). The geological results of the immense expenditure in the region during the search for hydrocarbons has been summarised by Underhill (1998). The geomorphology of the Dorset Coast is summarised in two recent guides (Brunsden and Goudie, 1997; Goudie and Brunsden, 1997), and there is an extensive detailed literature, including a range of technical reports on coastal processes and sediment transport.

A1-2 Description of the Site

The Site comprises eight stretches, which are described below in terms of their values in relation to its natural values .

Orcombe Rocks to Chit Rocks, Sidmouth:

The oldest rocks within the World Heritage Site are seen at Orcombe Point and record the earliest part of the Triassic period, some 250 million years ago. Hard bands of sandstone, some quite possibly ancient wind blown sand dunes, form the headlands of Orcombe Point and Straight Point while softer red clays have been eroded into the bays. The famous Budleigh Salterton Pebble Beds dip through the cliffs west of the town and mark the bed of an ancient river that once flowed from mountains in the area of Brittany today, northward across England, rather like the Nile flowing through North Africa today. The Otter sandstone first appears at the mouth of the River Otter and forms vertical cliffs of cross bedded sandstone. These rocks were laid down in braided rivers that once flowed through the deserts. Vertical pipes are evidence of plant roots known as rhizocretions. The Otter Sandstone also yields the remains of ancient Mid Triassic mammal like reptiles, most notably Rhynchosaurus which are rare throughout the World. The sea stacks around Ladram Bay are the product of weathering on the joints within the rocks.

River Sid, Sidmouth to Seaton Hole:

The red cliffs between Sidmouth and Branscombe are formed from soft red marls known as the Mercia Mudstone that are about 220 to 200 million years old. They are capped by much younger rocks, the Upper Greensand (110 million years) and Chalk (100 to about 80 million years) from the Cretaceous period. The mudstones formed in vast lakes that flooded the Triassic desert. Evaporation led to the formation of minerals such as gypsum that were once worked for plaster near Branscombe. The combination of porous Cretaceous rocks overlying impermeable Triassic clays has led to spectacular landslides, notable at Hooken near Beer Head in DATE 17?? A large cliff fall took place at Weston Cliffs in January 2006 and has been followed by further smaller events.

River Axe, Axmouth to The Cobb, Lyme Regis

The coast between Axmouth and Lyme Regis is dominated by landslides and has been designated as the Undercliff National Nature Reserve for both geology and wildlife. The earliest Jurassic rocks (200 million years old) appear along the coast towards Lyme Regis as the youngest Triassic Mercia Mudstone dip below the beach. The transition between the two is striking as the Triassic desert gave way to the Jurassic sea. The cliff top is capped by the Upper Greensand (110 million years) and Chalk (100 to about 80 million years) from the Cretaceous period and this sequence of rocks has created huge landslides such as The Plateau (a pre-historic event) and Goat Island which took place on Christmas Eve 1839. The result is a landscape of broken and fractured ground with huge blocks of slipped cliff top material, now largely overgrown by a trees.

Lyme Regis to Burton Bradstock

The Lower Jurassic rocks around Charmouth and Lyme Regis are the richest source of marine reptiles, fish and insects of that age anywhere in the World. The rocks are dark, muddy clays that formed quickly in a murky sea, packed with marine life. Further east the rocks become progressively younger and were deposited in shallow seas that led to the formation of siltstones, sandstones and eventually limestone. This section of the coast is rapidly eroding and subject to massive landslides.

Chesil, the Fleet and Portland Coast

Chesil Beach is one of the finest barrier beaches in the World. It has protected the landscape behind from erosion and so the slopes dip gently into the Fleet Lagoon which is trapped behind the beach. The pebbles came from the landslides further west at the end of the last Ice Age, less than 10,000 years ago. The Isle of Portland is formed from a wedge of hard limestone that dips gently below sea level at Portland Bill. The famous Portland Limestone and Fossil Forest directly above it are of very late Jurassic age (145 million years). The Limestone formed in shallow seas while the Forest grew on low lying surrounded by swamps and lagoons. The rocks are criss-crossed by huge fractures known as gullies and these have controlled the evolution of the cliffs. The Great Southwell landslide of 17?? is the largest historical landslide event ever recorded. The Portland Bill raised beaches provide important evidence of sea level change during the last Ice age, some 125 and 240,000 years ago. Most of the World Heritage Site on the island is completely inaccessible but the story of Portland stone contained in the landslides and the old and working quarries, is the story for Portland.

Portland Harbour Shore

The foreshore and low cliffs contain rocks from the start of the Upper Jurassic period, between about 150 and 160 million years ago but a considerable proportion are now poorly exposed due to the construction of the Portland Harbour breakwaters that have slowed erosion rates. Kimmeridge Clay forms low, slumped cliffs below Wyke Regis and these change to sandy grits and limestones through to the Nothe Fort at the mouth of Weymouth Harbour.

Jordan Cliff to Peveril Point

Upper Jurassic and Cretaceous rocks form this complicated section of the Site. Oxford Clay, Corallian Limestone and Kimmeridge Clay (165 to 150 million years) form the coast from Jordan Cliff through to Ringstead. The mass of White Nothe is formed from the Chalk (100 to 80 million years) that lies on the eroded surface of the older Jurassic rocks. Along the Lulworth coast the rocks have been heaved into a near vertical orientation and this is a classic place to study the evolution of bays and headlands as the soft and hard rock layers are eroded at different rates. East of Lulworth, the Fossil Forest sits on a bench within the cliffs. Through the Army Ranges the Portland Limestone, Purbeck Beds, Wealden Beds, Upper Greensand and Chalk form a spectacular series of cliffs and bays. From Gad Cliff through to Kimmeridge and Chapman's Pool, the Kimmeridge Clay gives rise to dark clay cliffs famous for fossils, notably reptiles and fish. From St Aldhelm's Head to Durlston Head the rocks lie at a near horizontal orientation with the Portland Limestone forming towering cliffs punctuated by dry valleys and cliff top quarries. Durlston Bay contains the thickest development of the Purbeck Beds and this is the richest source of Lower Cretaceous (135 million years) fossil reptiles, fish, insects and mammals anywhere in the world. These rocks are quarried inland and yield dinosaur footprints.

New Swanage to Studland Bay

Peveril Point juts out into the sea as a hard band of Purbeck Beds, the Broken Shell Limestone and Purbeck Marble form a resistant barrier to the sea. The large expanse of Swanage Bay has been carved from soft Wealden Beds. Punfield Cove provides the only exposure of the Lower Greensand but this is largely obscured by vegetation. Ballard Down is part of the great Chalk ridge that runs through Purbeck from Lulworth Cove through Corfe Castle and to the coast here. At one time it extended across to The Needles on the Isle of Wight. From the sea the vertical chalk layers and Ballard Fault are spectacularly exposed in the vertical cliffs. Old Harry Rocks at Foreland Point demonstrate each step in the formation of sea stacks from caves to arches and eventually stacks of rock. The end of the World Heritage Site is marked at the southern point of Studland Bay by a deep erosion surface in the Chalk. The great Cretaceous/Tertiary extinction event of 65 million years ago that killed off the dinosaurs has been removed at this point.

Therefore, from the oldest rocks at Orcombe Point at 250 million years in age, to the erosion surface on top of the Chalk at Studland Bay at 65 million years, the coast records 185 million years of the earth's history in just 155 kilometres of spectacular cliffs and foreshore.

A1-3 Description of the Setting

The landscape behind the Site is varied beautiful and rich in wildlife, reflecting the geodiversity underlying it.

East Devon: The geology of East Devon is composed of two basic elements; gently, easterly dipping Triassic sands and clays overlain by much younger Cretaceous aged Upper Greensand and Chalk that lie across the eroded surface of the Triassic rocks. The countryside can be divided into several distinct characters:

- The *Pebble Bed Heaths* are formed from a thick layer of the Budleigh Salterton Pebble Beds, a conglomerate composed from quartzite pebbles originally derived from Brittany. The pebbles mark the course of an ancient river that once flowed through the Triassic desert about 240 million years ago.
- The *Axe and Otter Vales* are the product of river erosion taking advantage of soft layers within the Triassic rocks.
- The *Greensand Ridges* are striking hills formed from the relatively hard Upper Greensand which has also been quarried as Salcombe Stone, most famously for Exeter Cathedral. The Greensand also contains a blocky form of flint known as chert which is an important building stone in villages such as Uplyme, and Beer. The flat topped nature of these hills is the remnant of an ancient land surface. After all the rock layers were deposited the sea planed away the layers to form a flat surface. Uplift elevated the rock pile and the rivers have dissected it, leaving the last remnants on the highest hills, that are similar heights and flat topped.
- The *Coastal Chalk Plateau* is formed from the youngest rocks. Chalk is a soft but massive rock layers and weathers into rolling downland and flat plateaus for the same reason as the Greensand Ridges.

Dorset: Dorset's coastal landscape is composed from rocks of Jurassic, Cretaceous and tertiary age. The Dorset Landscape Character Assessment draft Countryside Types includes some of the following;

- *Marshwood Vale and Greensand Hills.* The vale has been formed by the erosion of a thick layer of soft Lower Jurassic Clays, surrounded by hills capped with Upper Greensand. As with East Devon, the hills are flat topped and are the remnants of a vast, flat erosion surface that has been dissected by rivers to form the landscape that we see and enjoy today.
- *Tabular Hills and V-Shaped Valleys.* Running inland from Bridport and Symondsburly, through Beaminster, Mapperton and Mosterton, the relatively soft Bridport Sands, capped by a thin but hard limestone, the Inferior Oolite, gives rise to tabular hills and steep, V shaped valleys. The Inferior Oolite is an important local building stone that dominates the character of the build environment.
- *Ridge and Vale –* The Weymouth area is dominated by a landscape composed from hard limestone ridges and soft clay vales. The structure of the rocks in this area is a huge dome shaped fold or anticline and the rocks are arranged in concentric patterns, a little like the layers of an onion when sliced through. The hard rocks, the Portland Stone and older Corallian Limestones, have been used as building stones around Portesham and Abbotsbury respectively.
- *Limestone Peninsula – Portland.* The Isle of Portland lies on the south side of the Weymouth Anticline, the huge fold described above. The hard Portland Limestone dips gently into the sea at Portland Bill and represents the last remnant of this vast structure. The Island lies on the axis of the fold or the lowest point. To the east and west the rocks rise up, exposing softer Kimmeridge Clay which has been eroded away by the sea. The Portland Limestone is one of the most important building stones in the World.
- *Limestone Plateau – Purbeck.* The Portland Limestone and Purbeck Beds form a plateau that extends from Swanage through to St Aldhelm's Head. The thin soils support a diversity of limestone loving plants and associated wildlife.
- *Chalk Valley and Downland and Open Chalk Downland.* As with East Devon, the Chalk is a relatively soft but massive deposit that gives rise to high, open landscapes. The dry valleys date back to the last Ice Age when the ground was frozen. Spring thaws generated run off that could erode into the porous chalk. The valley of the Boulders near Portesham is a spectacular example where younger but strongly cemented Tertiary sands and gravels have been 'heaved' down the slopes by freezing and thawing action.
- *Chalk Ridge/Escarpment.* The ridge that runs through Purbeck from Bats Head near Lulworth, to Ballard Down north of Swanage (and on The Needles on the isle of Wight) is formed from a spectacular fold or 'kink' in the rocks caused about 15 million years ago when the Alps formed in Southern Europe. This is in fact the most northerly crumple from that event and the near vertically folded Chalk forms a great ridge across the countryside.

A1-4 The 'Jurassic Coast', Coastal Corridor and role of Coastal Towns

Jurassic Coast

The Jurassic Coast is a term often used to refer to the Dorset and East Devon Coast World Heritage Site. In fact, the Jurassic Coast World Heritage Site, refers to the Site itself, whereas the 'Jurassic Coast' on its own, refers to the Site and its broader hinterland. As with the setting of a WHS there is no line on the map that delineates the Jurassic Coast.

The name was first used in the "Jurassic Coast Project" a forerunner initiative to the World Heritage Site nomination, and of course Jurassic refers to the geological era most represented by the exposed geology of the Site.

Coastal Corridor

Of high importance for Visitor Management for the Site is an area that is being called the Dorset and East Devon Coastal Corridor. This area is defined by the main access roads to the Site and is the area likely to have the most pressure resulting from visits to coast. The bounding roads are the A351, A352 and A353 in Purbeck and Weymouth, the B3157 between Weymouth and Bridport, the A35 between Bridport and Charmouth / Lyme Regis, and the A3052 (and minor roads) to Exmouth in East Devon.

Gateway and anchor towns, and macro socio-economic picture

As described above, the Site is split into eight undeveloped stretches of coastline. The towns or communities that have built-up sea frontages, or provide the infrastructure and services to support the economy of the area, are referred to as **Gateway Towns**¹. These are: Exmouth; Budleigh Salterton; Sidmouth; Beer; Seaton; Lyme Regis; Charmouth; West Bay and Bridport; Portland; Weymouth (including Preston and Bowleaze Cove); Swanage; and Wareham. The inland towns that have a gateway role for the World Heritage Site are Dorchester, Axminster and Honiton, with Exeter, and Poole and Bournemouth being referred to as **Anchor Towns**².

The Gateway Towns are of particular importance in visitor management terms as they provide the basic services and accommodation for residents and visitors alike³. Because of the undeveloped nature of the Site and its Setting, and the imperative for it to remain in a very high quality condition, the concentration of large numbers of people in towns that have the infrastructure to cope is preferable to a more even spread along the coast putting significant pressures on smaller communities that do not have the infrastructure to cope. Gateway Towns are also likely to be the areas that could derive most economic benefit from new tourism related to the Site, or new businesses that have developed as a result of the designation.

The Gateway Towns are all very different in terms of character, socio economic profile, size and demographics. Weymouth is the largest, with c. 50,000 people, whereas Lyme Regis, a town with a very big name, only has c. 3,000 people. All these communities suffer from some common issues, including: a high dependency on a short, intense tourist season, a comparative lack well-paid employment, an aging population, relative isolation and the lack of affordable housing. If the World Heritage Site is to have an impact beyond conservation, protection and presentation for its own sake, then it must be able to influence some of these issues.

There are a range of other, smaller communities and parishes along the coast who depend on the Towns for services, but themselves are access points for the World Heritage Site. They face a different set of issues, mostly relating to impacts from tourism and traffic, which are explored more in the issues sections of this plan. Referred to as Coastal Communities, these are: Ladram Bay and Otterton; Salcombe Regis and Weston; Branscombe; Axmouth; Seatown and Chideock; Eype; Burton Bradstock; West Bexington; Abbotsbury; Langton Herring; Chickerell; Ringstead; Osmington; West Lulworth and Durdle Door; Kimmeridge; Worth Matravers and Studland.

The role of *all* of these communities, whether Anchor Towns, Gateway Towns or Coastal Communities is vital for the ongoing protection, conservation and presentation of the Site. The area receives over 15m tourist visits a year so the potential for a great deal of pressure is enormous. Moreover, these communities and their people can be the advocates for the Site, its values and importance, and can inform and raise awareness about it to visitors, encouraging sense of pride and ownership.

¹ Locum Study 2002

² The Terms Gateway Towns, Market Towns and Anchor Towns are from Locum report 2002

³ With the notable exception of Holiday Parks in the tourism sector.

A1-5 IUCN Technical Evaluation

(The following four pages are direct text from IUCN's technical evaluation of the Dorset and East Devon Coast WHS Bid)

WORLD HERITAGE NOMINATION – IUCN TECHNICAL EVALUATION DORSET AND EAST DEVON COAST (UNITED KINGDOM)

1. DOCUMENTATION

i) **WCMC Data sheet:** (19 references)

ii) **Additional literature consulted:** Goudie, A. and Brunnsden, D. 1997. **Classic Landforms of the East Dorset Coast.** The Geographical Association, Sheffield; and Ellis, N.V et al. (Eds.). 1996. **An Introduction to the Geological Conservation Review.** Joint Nature Conservation Committee, Peterborough.

iii) **Consultations:** 2 external reviewers contacted; relevant officials from government, protected area agencies, and public institutions; private estate owners; geological associations; tourist operators; and other interest groups.

iv) **Field visit:** February-March, 2001. Paul Dingwall,

2. SUMMARY OF NATURAL VALUES

Located on the south coast of Britain, the nominated property comprises eight sections along 155km of largely undeveloped coast and countryside between Orcombe Rocks, near Exmouth in east Devon in the west, and Studland Bay, Dorset, in the east. The total area of the site is 2,550ha, 80% of which is cliffed coastline. The property has a combination of internationally renowned geological features considered by both palaeontologists and geomorphologists to be one of the most significant research sites for their respective fields of study in the world. The nominated site includes a near-continuous sequence of Triassic, Jurassic and Cretaceous rock exposures, representing almost the entire Mesozoic Era (between 251 and 66 million years ago), or approximately 185 million years of Earth history. The Triassic succession of mudstones and sandstones is over 1,100m thick, representing 50 million years of deposition. The sequence of Jurassic strata exposed between Lyme Regis and Swanage is among the best sections of marine Jurassic-age rocks to be found anywhere in the world. All stages of the Cretaceous are represented with the exception of the very youngest.

The nominated site contains a range of internationally important Mesozoic fossil localities, including Lyme Regis, Kimmeridge Bay, the Isles of Portland and Purbeck, Durlston Bay, High Peak, Otter Point, Furzy Cliff (Weymouth), Charmouth and Axmouth. Great numbers of vertebrate, invertebrate and plant fossils have been discovered, along with fossil dinosaur footprints in quarries near Swanage. Examples of significant palaeontological discoveries not known from elsewhere include *Dimorphodon macronyx*, one of the earliest flying reptiles, and *Scelidosaurus harrisoni*, the "Charmouth dinosaur". Important among the marine reptiles are *Temnodontosaurus*, ichthyosaurs, and *Metriacanthosaurus parkeri*. The area has yielded a rich source of ammonites such as *Asteroceras obtusum*, *Parkinsonia parkinsoni* and *Titanites anguiformis*, which have been used to zone the Jurassic. Well preserved remains of a late Jurassic fossil forest, estimated to be more than 140 million years old, are exposed on the Isle of Portland and the Purbeck coast: many trees are preserved *in situ* with their associated soils and pollen, a boon for palaeoecologists.

In terms of the site's geomorphological significance, a great variety of landslides have formed, some of which, such as those at Bindon, Black Ven, Hooken, East Weares and Kings Pier, are scientifically important throughout Europe. The long history of scientific study of these mass-movement systems is such that these formations have become, literally and figuratively, 'textbook' examples. The site is also renowned for the study of beach formation and evolution on a retreating coastline. Chesil Beach, stretching from West Bay to Portland, is one of the best-studied beaches in the world. The beach is famous for the volume, type and grading of pebbles. The 480ha Fleet Lagoon, enclosed by Chesil Beach, is one of the most important saline lagoons in Europe, its sediments providing evidence of late Holocene beach evolution, and changes in sea level, climate and vegetation. Chesil Beach and the Fleet is an outstanding example of a barrier beach and lagoon system, protected by several national and European designations. The Isle of Purbeck is notable for its well developed coastal landforms, including cave-bay sequences and textbook examples of bays, stacks, and rock arches at Lulworth Cove, Durdle Door and Old Harry Rocks.

In addition to the site's palaeontological and geomorphological significance, important coastal vegetation habitats occur in the nominated area, such as the landslipped cliffs and cliff-top grasslands of W. Dorset, that support several rare plant species of national and European importance and parts of the nominated coast are protected under international designation. The Exe Estuary Special Protection Area (SPA), a Ramsar wetland, supports over 20,000 migratory wildfowl, including internationally important populations of avocet, dark-bellied brent goose and slavonian grebe. The Sidmouth to Beer Coast SSSI (Site of Special Scientific Interest) protects the westernmost example of species-rich grassland in England, with a very diverse invertebrate fauna. The Lyme Bay reefs provide one of the most easterly locations for several Mediterranean-Atlantic plants species, such as the pink seafan *Eunicella verrucos*, and has rich epifauna, especially sponges.

3. COMPARISON WITH OTHER GEOLOGICAL SITES

The site is significant in terms of geological history, palaeontology, geomorphology and the history of geological and related sciences.

In terms of geology, the Dorset and East Devon Coast is one of Britain's most significant areas, and one of two mainland sites nominated for its geology on the U.K. World Heritage tentative list. The area includes 67 nationally and internationally recognised localities in the statutory Geological Conservation Review. While sites representing the same geological time period are found throughout the world, there is no better example anywhere of a complete succession through the Mesozoic Era, a period of 185 million years. Among prominent geological World Heritage sites, Istchigualasto-Talampaya in Argentina and Canada's Dinosaur Provincial Park represent the Triassic and late Cretaceous respectively, but no site currently on the World Heritage list contains the complete Mesozoic succession. The nominated site also represents an exceptionally well-documented sedimentary basin, now one of the best-known and oft-studied of its type in the world. Only Australia's Sydney and Gippsland Basins, and the western flank of the Basin and Range Province in North America, are similar, but none is extensively protected.

In terms of palaeontology, the nomination document includes a comprehensive comparative analysis in which 12 selected fossil sites or interests are rated against the IUCN criteria for establishing the outstanding universal value of fossil sites (pp. 36-37). The results clearly demonstrate the global significance of the Dorset and East Devon sites in all rated categories, particularly in terms of the long geological time period represented; the diversity of fossil assemblages; the international significance of sites (all 12 are assessed as internationally important); and the quality of preservation of specimens, with some complete and well-articulated skeletons, three-dimensional and soft-part preservation and the presence of finely detailed plants and wood structures. The Lyme Regis (Lower Jurassic) and Purbeck Group formations (Lower Cretaceous) are the most significant fossil sites; specimens from them are found throughout the world's museums.

In terms of geomorphology, the landslides here are internationally recognized, comparable with those of the Black Sea Coast and New Zealand, which are also internationally renowned. The Bindon landslide complex, protected in the Lyme Regis to Axmouth Undercliffs National Nature Reserve, was the first to be fully described in a scientific memoir. Black Ven is the largest mudslide complex in Europe. No beach in the world is known to have been as intensively studied as Chesil Beach, and there are few that exhibit the exceptional degree of grading of the size of its sediments along the shore. The juxtaposition of concordant and discordant coastlines (i.e. those aligned with and against the grain of the geological structure) within the same geological strata, as found on this coast, is rare on a global scale. The nominated area also has an internationally unique status in the history of geological science. Regarded for more than 200 years as among the best available research sites anywhere for geological inquiry, the resulting prodigious output of research, published in thousands of scientific papers, has fundamentally shaped the development of geological thinking. Its role in this respect continues today.

4. INTEGRITY

4.1. Site integrity

The nominated site contains all the key, interdependent elements of geological succession exposed on the coastline. It has an almost complete representation of Triassic, Jurassic and Cretaceous rocks, all within a single sedimentary basin. Regional tilting of the structures to the east means that a walk from west to east along the coast is an almost unbroken "journey" through 185 million years of geological time. The stratigraphy represents a wide range of both marine and terrestrial depositional environments and a full range of sedimentary rock types. The array of fossil faunas and floras show interrelated elements of the prehistoric record of life and environments. The site includes a series of

coastal landforms whose processes and evolutionary conditions are little impacted by human activity. The boundary of the site is defined by natural phenomena: on the seaward side the site extends to the mean low water mark and on the landward side to the cliff top or back of the beach. This is also in general consistent with the boundaries of the nationally designated areas that protect the site. The high rate of erosion and mass movement in the area creates a very dynamic coastline; the boundaries of the site, therefore, may need periodic monitoring to ensure that significant changes to the shoreline are reflected in revised boundaries.

4.2. Management integrity

The nominated site lies almost entirely within two areas designated under national conservation legislation as Areas of Outstanding Natural Beauty (IUCN Category V Protected Landscape/Seascape). Also protected under national law are thirteen SSSIs, and a large National Nature Reserve (IUCN Category IV). The site also contains areas designated as being of international importance for wildlife, either as a Special Conservation Area or SPA under European Community Directories. Chesil Beach/the Fleet and Exe Estuary are designated as a Ramsar Wetland of International Importance.

An estimated 95km of the 155km of coastline in the nominated site are owned by public bodies, conservation agencies or large private estates. While most of the site is in private ownership, mainly within four large estates, the National Trust, a major U.K. conservation charity, owns about 35km of coastline. Smaller areas are owned by County and District Councils and by the Ministry of Defence, which uses 5km of coast as the Lulworth Gunnery Ranges: the Ministry's management of this area is subject to conservation policies set out in a Management Plan. Privately owned SSSIs have management oversight from the English Nature agency. The bed of the Fleet lagoon and part of Chesil Beach are owned by the Ilchester Estates and managed as a local nature reserve. There are two commercially owned landholdings on the Isle of Portland.

The nominated property is currently extensively protected by a variety of designations and a range of land use and protected area Management Plans. A single Management Plan has been prepared for the nominated site, coordinated by the Dorset and Devon County Councils. The plan, which has undergone public consultation, has six prime objectives relating to the protection of the geology and landforms, conservation and enhancement of landscapes and seascapes, and visitor management and education. Significantly, emphasis is given to integrating World Heritage management with wider sustainable development objectives in the counties. Management plans for existing areas inside the nominated property: they include county development plans, local district plans, mineral and waste Management Plans, Shoreline Management Plans and Environment Agency river catchment plans. The National Trust maintains plans for management of wildlife, landscape, and visitor use of its properties; all its sites are inalienably conserved for the benefit of the public. Wildlife Trust reserves, National Nature Reserve, and military lands all have management plans.

Many people are employed by landowners and agencies to undertake management operations in sites within the nominated area. More than 40 wardens and rangers are employed by the two county councils, the E. Devon and Purbeck District Councils, English Nature, the National Trust, Ilchester and Lulworth Estates and the Dorset Wildlife Trust. Two new positions - geological coordinator and tourism officer - are envisaged if World Heritage status is achieved. Management of the area is well funded on a partnership basis with more than £500,000 provided annually for staff budgets of current employees, excluding professional staff such as local government planners and tourism officers. There are many well developed and professionally managed information centres, museums, accommodation and transport facilities, and other services available to visitors. Public access to the beaches and cliff tops is available via public rights of way and permissive paths. The South- West Coastal path, one of 13 nationally designated trails, extends through part of the site. Excellent marine search and rescue facilities are located at several sites in the area. The research capacity underpinning protected area management, provided from regional and national scientific institutions, is substantial.

Only about ten people live permanently in the nominated site, though there are some seasonally occupied beach huts and holiday chalets. The population in gateway towns is estimated at less than 200,000. The area has been a popular tourist destination since the 18th Century, and about 14 million people, mostly day-trippers, visit the nominated site and adjacent coastal areas annually. There are currently few significant threats to the site. A vigilant regime of active management will address important issues such as path erosion, and vegetation and wildlife disturbance. A voluntary code of conduct has been developed to help manage the collection of fossils by amateur and professional collectors. Two sites lie within areas where there are permissions for mineral extraction, but the local authorities believe neither will be reactivated. Coastal defence works are required in places but they are not overly intrusive on site values.

In summary, IUCN believes this nominated site has strong legal protection and is managed effectively for long term preservation of its natural geological values. It thus meets the conditions of management integrity.

5. ADDITIONAL COMMENTS None.

6. APPLICATION OF CRITERIA/STATEMENT OF SIGNIFICANCE

Dorset and East Devon Coast is nominated in accordance with World Heritage natural criteria (i) and (iii).

Criterion (i): Earth's history and geological features

In relation to this criterion, the site's claim to outstanding universal value is based on the following significant values:

- The coastal exposures within the site provide an almost continuous sequence of Triassic, Jurassic and Cretaceous rock formations spanning the Mesozoic Era and document approximately 185 million years of Earth history;
- The site includes a range of internationally important fossil localities – both vertebrate and invertebrate, marine and terrestrial - which have produced well preserved and diverse evidence of life during Mesozoic times;
- The site contains a range of textbook exemplars of coastal geomorphological features, landforms and processes;
- The site is renowned for its contribution to earth science investigations for over 300 years, and has helped foster major contributions to many aspects of geology, palaeontology and geomorphology; and
- The site has continuing significance for many aspects of earth science research and is a high quality teaching and training resource for the earth sciences.

Critical examination of these elements, complemented by field inspection, discussions with protected area managers and scientists, and consideration of the views of independent reviewers and prominent scientists who have written in support of the nomination, lead to the conclusion that these claims can be fully substantiated. The site is also unlike any other geological site currently accorded World Heritage status, and it has both a scientific and conservation significance ranking it among these existing sites. IUCN considers that the nominated site meets this criterion.

Criterion (iii): Superlative natural phenomena or natural beauty and aesthetic importance

The nominated property is a substantially natural coastline in a setting of attractive rural landscapes and associated seascapes. Most of the site is designated as nationally significant in terms of its scenic qualities (e.g., as Areas of Outstanding Natural Beauty and Heritage Coasts). The attractiveness of the site derives in particular from the classically developed landforms, whose scenic qualities are enhanced by the close association of a great diversity of landforms in a relatively confined area. Component materials of the landforms also have aesthetic appeal: stone quarried from Purbeck, Portland and Beer has been used in the construction of many great buildings in Britain, some of which (e.g., the Tower of London) are themselves World Heritage cultural sites. Moreover, the landscapes have inspired a number of authors, poets and artists of international renown, adding to the rich legacy of cultural associations with the site. However, when compared to existing World Heritage sites fulfilling the criterion, IUCN considers that Dorset and East Devon Coast is of national importance rather than of outstanding universal value. IUCN considers that the nominated site does not meet this criterion.