English Riviera GEOPARK

Appendix:
Significance of the territory's geological heritage from the European/wider international perspective

Official application for nomination of the region

Area entered:
The English Riviera Geopark, Torbay, Devon, The United Kingdom

Application submitted by:
Torbay Council Unitary Authority

Contents

1. Introduction

The county of Devon lies within the southwest peninsula of England and enjoys some of the mildest and most pleasant climates to be found within the British Isles. With a dramatic and beautiful coastline, luxuriant countryside, picturesque villages and rugged upland moors, it has inevitably become one the most important tourist destinations in Britain. This landscape is the expression of a rich and varied geological history and every year large numbers of geological groups use this resource for teaching, recreation and research. The boundary of English Riviera Geopark is concurrent with the administrative boundary of Torbay Council, a Unitary Authority; hence Torbay Council is the lead partner in the Geopark's development. Torbay is comprised of three towns, Torquay, Paignton and Brixham and the area acquired the name of "The English Riviera" during the Victorian era when it became a sea-side resort of great style and refinement. Today the term English Riviera is used as a recognised marketing brand name for the area of Torbay.

Unique in Western Europe the Torbay district, in particular, is geologically renowned for its Marine Devonian limestones, which are of great historical importance. The rich faunas yielded by these rocks were used, in part, to characterise the original Devonian System of the pioneering geologists Sedgwick and Murchison (see section 3). In addition, excellent exposures of classic desert sandstone in the Permian "Red Bed" sequences are present (see section 4). The Marine Devonian limestones themselves also include important Quaternary karstic features such as bone caves, which provide one of the longest records of Pleistocene events not only in Southwest England but also in Western Europe. The excavations of the caves were central to the pioneering work carried out in nineteenth century and subsequent controversies about the antiquity of human beings (see section 5). Whilst very few raised beach localities elsewhere in Britain have revealed so much palaeoenvironmental information as those in the English Riviera Geopark (see section 5). The limestone, in addition, has created a range of habitats supporting plant communities and mammal species of national and international importance. In essence the English Riviera Geopark is a superb geological resource, covering 400 million years of geological time all within a compact area of land.

A considerable scientific literature exists describing all aspects of the geology of the English Riviera Geopark, much of which is historical dating from the early 19th Century (appendix 4). Crucially, however, the area has been recently re-surveyed by the British Geological Survey and the publication of a new geological map has been accompanied by a booklet describing the area (*Geology of the Torquay district*, BGS, 2003).

Fig 1: Looking north across Torbay with the town of Brixham in the foreground

2. Designations

The geology of the English Riviera Geopark is fully recognised as of international importance through the Global Geosites programme. This is the only internationally recognised and objective system for listing sites of global geological importance as detailed within Geosites – an IUGS Initiative: Science supported by Conservation, Wimbledon et al.

In the early 1990s the Global Indicative List of Geological Sites, or GILGES, was established as a collaboration between the International Union of Geological Sciences (IUGS), UNESCO, the International Union for the Conservation of Nature (IUCN) and the International Geological Correlation Programme (IGCP) to compile a list of geological sites of global importance, largely to inform World Heritage listing. In 1996 this scheme evolved into the more comprehensive '**Global Geosites'** project as more rigorous criteria and procedures were developed.

In Britain, the British Institution has coordinated the compilation of this list for Geological Conservation (BIGC) in collaboration with ProGEO – the European Association for the Conservation of the Geological Heritage. As an inventory of key geological sites had already been carried out by the **Geological Conservation Review** (GCR), BIGC produced a list of selection frameworks representing aspects of the UK's geology considered to be of international importance. Many geological sites in the English Riviera Geopark are relevant to these frameworks, which therefore provide an independent assessment of the international significance of the geology of the Torbay district. The principles of site selection are detailed in appendix 1.

Within the English Riviera Geopark a total of **15 GCR sites** are recognised within **4 Global Geosite Framework categories** (see table 1)

- Devon (marine) carbonates and clastics
- Permian-Triassic red-bed sequence (Devon coast)
- Late Pleistocene interglacial/glacial, cave/beach sediments (Saalian-Weichselian)
- Late Pleistocene Interglacial (OIS7, 5e) raised beaches (southern England, Cornwall, South Wales)

Although not recognised within the current Global Geosite Framework a further two categories are noteworthy in an international context

- Caves Fauna – Kents Cavern and Brixham Caves have revealed internationally significant palaeontological, stratigraphical and archaeological information elucidating the environmental and faunal changes during the Quaternary. Both the findings and excavations are relevant to the history of science.
- Mineralogy – mineral deposits found at Hopes Nose are so unique they are virtually unknown elsewhere hence the English Riviera Geopark's **16th GCR** designation (No.1752: Hopes Nose)

However, it must be noted that due to the nature of the process of the GCR site selection in the 1970's, a review in the early 1990's revealed that some sites of international importance had been omitted from the original GCR list. Subsequently these sites have been recognised and designated as County Geological Sites (known as Regionally Important Geological sites in other parts of the country) even though they are of international importance. The English Riviera Geopark's GCR sites are listed within Table 1 however more information is held online www.jncc.gov.uk/page-2949 and within the Geological Conservation Review Series.

Table 1: Global Geosite framework categories and Geological Conservation Review sites (for site grid references refer to The English Riviera Geopark Management Plan p 20 –21)

Global geosite framework	Types of Site	GCR	Comment
Devon (marine) carbonates and clastics (Devon [-Cornwall]) (= '*Marine Devonian Rocks*, part, / *Lyme Bay Coast (Lyme Regis to Start Point)*', part, of 1998 Key features)	**Exposure sites**: Disused quarries, pits and cuttings, Active quarries and pits, Coastal and river cliffs, Foreshore exposures, Inland outcrops and stream sections. **Integrity sites:** Unique mineral, fossil or other geological sites. **Moveable geological heritage**: Fossils.	No. 421: Babbacombe Cliffs No. 425: Daddyhole No. 468: Dyers Quarry No. 426: Hopes Nose No. 420: Long Quarry No. 471: Lummaton Quarry No. 422: Meadfoot Sea Rd No. 429 New Cut No. 424 Saltern Cove	Devon is the type area for the Devonian System, an interval of Earth history between around 416 and 359 million years ago. Marine rocks with rich invertebrate faunas of this age are only found in Devon, Cornwall and West Somerset in the UK.
Permian-Triassic red-bed sequence (Devon coast) (= '*Lyme Bay Coast (Lyme Regis to Start Point)*', part, of 1998 Key Features)	**Exposure sites**: Disused quarries, pits and cuttings, Active quarries and pits, Coastal and river cliffs, Foreshore exposures. **Integrity sites:** Unique mineral, fossil or other geological sites. **Moveable geological heritage**: Fossils.	No. 1496: Oddicombe No. 1504: Roundham Head No. 1503: Saltern Cove No. 1494: Shoalstone	The Permian-Triassic succession between Torbay and Axmouth is the most completely exposed in the UK. It records the initial stages of the development of the Wessex depositional basin and includes an important reptile fauna. Part of this succession is now included within the Dorset and East Devon World Jurassic Coast World Heritage Site.
Late Pleistocene interglacial/glacial, cave/beach sediments (Saalian-Weichselian) [provisionally includes Pleistocene giant mammal/ hominid assemblages] (= '*Quaternary Features'*, part / *Lyme Bay Coast (Lyme Regis to Start Point)*', part, of 1998 Key features)	**Integrity sites:** Static (fossil) geomorphological sites, Caves and Karst, Unique mineral, fossil or other geological sites. Moveable geological heritage**: Fossils.**	No. 1312: Kents Cavern	Cave sediments in south Devon, including in Torbay and near Buckfastleigh provide an important record of large mammal faunas and climate changes going back at least 350,000 years.
Late Pleistocene Interglacial (OIS7, 5e) raised beaches (southern England, Cornwall, South Wales) (= '*Quaternary Features'*, part / *Lyme Bay Coast (Lyme Regis to Start Point)*', part, of 1998 Key features)	**Integrity sites:** Static (fossil) geomorphological sites. **Moveable geological heritage**: Fossils.	No. 1868: Hopes Nose and Thatcher Rock	Well-developed raised beaches in both south and northwest Devon provide important information on climate and associated sea-level changes. .

Integrity sites = Small, Finite and Irreplaceable **Exposure sites** = Accessible exposures of deposits otherwise extensive but hidden

3. Marine Devonian 418 – 362 million years ago

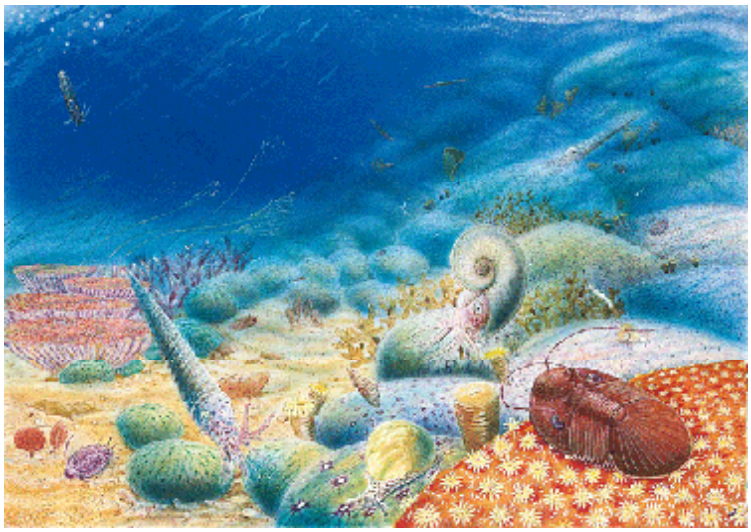


Fig. 2 The English Riviera in the Devonian Period based on fossil evidence - artwork by Brin Edwards

Devon's geological fame is in part linked to its inspiration for the establishment of the original Devonian System in 1836 by Sir Roderick Murchison and Professor Adam Sedgwick, two of Europe's great geological pioneers (Sedgwick and Murchison 1836, 1839). It is the only county in Britain to lend its name to a geological period and many of the original localities on which the faunal characteristics of the system were established still exist today. The founder of the Geological Survey, Sir Henry T. De la Beche carried out an early part of his pioneering work by mapping and describing the geology of the Torbay district: he published an extended account 'On the geology of Tor and Babbacombe bays' in 1829 and this formed a model for the subsequent geological work that resulted in the establishment of the national survey.

"The highly important deduction of Mr. Lonsdale, that the fossils of the South Devon limestones, as collected by Mr.Austen and others, really constituted a natural-history zoological group intermediate between those of the Silurian rocks and of the Carboniferous limestone, was the reason which had most weight with Professor Sedgwick and myself (after identify North and South Devon) in inducing us to propose the term Devonian"

"Still there are adequate means of bringing the disjointed and occasionally inverted masses of South Devon into comparison with the clear order of North Devon. This in great measure to the numerous and well preserved fossils of its extensive lower limestone. The lowest limestones, for example, which are a parallel of those of Combe Martin and Ilfracombe, and rise in great masses near Plymouth and Ogwell, ranging at intervals to Newton Bushell and Torquay, are laden with corals and shells, many species of which occur in rocks of the same age in various parts of the continent of Europe, and notably in the limestone of Eifel, the Rhenish provinces, and Belgium. Now, many of these fossils are quite peculiar; for, whilst they exhibit an intermediate character, approaching in the lower beds of this series to those of the Silurian system, though almost all distinct, and in the upper strata to those of the Carboniferous era, there can be no doubt that, on the whole, they constitute and independent group"

Extracted from:
Siluria. The History of the Oldest Fossiliferous Rocks and their foundations,
Sir Roderick Impey Murchison, 1859, p292 and p296.

Unlike much of western Devon the Geopark district itself is uniquely dominated by Marine Devonian limestones, including a number of classical palaeontological localities, crucial to the original definitions of the system by Murchison.

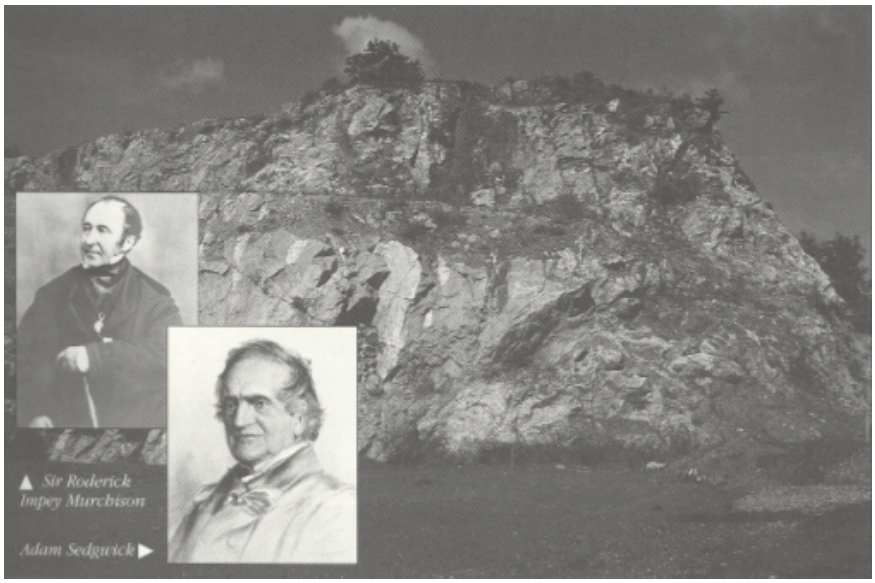


Fig. 3 The rocks exposed at Lummaton Quarry Site of Special Scientific Interest are massive limestones that were deposited in the latter part of the Middle Devonian Period (the Givetian). The limestone contains shell rich pockets seen here in the upper part of the face. This locality is of great historical importance because the rich faunas it has yielded were used, in part, to characterise the original Devonian System of the pioneering geologists Sedgwick and Murchison. Portraits reproduced with permission of the Director, British Geological Survey. NERC copyright reserved. Photo: K.N. Page. Geological Conservation Review Series, An Introduction to the Geological Conservation Review. Reproduced here with the kind permission of Neil Ellis GCR Publications Manager, Joint Nature Conservation Committee

Subsystem	Stage	Age (millions of years ago)
UPPER	Famennian	377-362
	Frasnian	383-377
MIDDLE	Givetian	388-383
	Eifelian	394-388
LOWER	Emsian	410-394
	Pragian	414-410
	Lochkovian	418-414

Table 2: Subdivisions of the Devonian System (after Tucker et al. 1998).

The Devonian limestones of the English Riviera Geopark include parts of a Middle Devonian reef system (Scrutton 1977), with both reefal and lagoonal phase facies, locally containing rich coral–stromatoporoid (coralline sponge) faunas or brachiopod-trilobite assemblages. The barrier structure lay across the Torbay district and is best seen in the massive stromatoporoid-rich exposures of Long Quarry Point. Elsewhere, bedded limestones with masses of branching, colonial rugose corals, such as at Dyer's Quarry would represent quieter back-reef conditions. Shelly faunas are well developed locally, occasionally associated with bioclastic debris derived from relatively high energy conditions associated with coral-stromatoporoid reefal developments, or in quieter micritic and muddy limestone facies. The former development includes the famous "Lummaton Shell Bed", historically one of the most important sources of Devonian fossils in Europe and especially rich in brachiopods,

but with common trilobites, also ammonoids, bivalves, gastropods, rostroconch molluscs, ostrocods, algae, tabulate and rugose corals, bryozoans, crinoids and conodonts. Lagoonal deposits are also present in the district and include fine-grained limestones with gastropods near Brixham.

The fossils were included within “Figures and descriptions of Paleaozoic Fossils of Cornwall, Devon and West Somerset” by the nephew of William Smith, John Phillips in 1841, concurrent with the work of Sedgwick and Murchison. The importance of Lummaton was also recognised within the remarkable work “A Monograph of the Devonian Fauna of the South of England by Rev. G.F. Whidbourne, M.A., FGS 1889-1892”

Fig. 4 Photographs of A Monograph of the Devonian Fauna of the South of England by Rev. G.F. Whidbourne, M.A., FGS 1889- 1892, Torquay Museum Library

Smaller exposures of clastic rocks of Lower and Upper Devonian age are also present. The former include the sandstone-dominated Staddon Group and the overlying Meadfoot Group, which has its type locality in Torquay. Both have yielded characteristic brachiopod faunas and the former is also notable for an unusually fauna of burrowing, homolonotid trilobites. Overlying the Meadfoot Group and immediately below the massive development of limestones and shales with some limestones bands which yield a varied fauna including brachiopods, corals, and rare trilobites and ammonoids – the latter confirming an early Middle Devonian age and best exposed in St Mary’s Bay south of Brixham.

Fig. 5 Thamnopora coral fragments broken and deposited during a phase of high energy

The Upper Devonian of the English Riviera Geopark shows the classical transition from shallow water limestones to deep-water shales, whilst well known throughout Europe it reveals the extinction of much of the reef fauna. Two distinct early Upper Devonian rock types are present across the Geopark, the first is a grey shale well exposed in Babbacombe Cliffs, the second is a reddish nodular limestone, locally seen in faulted wedges at Petit Tor and near Saltern Cove. Both rock types yield occasional ammonoid cephalopods, indicating deepening marine conditions.

Continental-shelf instability

Later Upper Devonian shales and slates yield typical ostrocods and conodonts and include the remarkable submarine slide deposits of the Saltern Cove Goniatite Bed, notable for the occurrence of early Upper Devonian ammonoids and orthocone nautiloids mixed with late Upper Devonian conodonts. These late Devonian deposits thus suggest instability on the continental shelf margin, and provide a unique opportunity to study such processes during this time period.

4. Permian Period 290 –248 million years ago

Fig. 6 Reconstruction of the Goodrington area of the English Riviera Geopark during the Permian Period – artwork by Brin Edwards

Torbay provides the starting point for one of the most complete continuous exposures of late Palaeozoic to Tertiary sequences i.e. from Torbay eastwards along the south coast. These rocks show the development of a major depositional basin in Western Europe, the Wessex Basin, which is extremely important in the understanding of Mesozoic stratigraphy. Whilst the Triassic through to Cretaceous part of the sequence is already recognised of World Heritage importance along the Jurassic Coast to the east of the Geopark; the base of this continuous sequence is uniquely seen in the English Riviera Geopark.

The fine coastal exposures of 'red beds' seen in the Torbay district represent the oldest rocks of the Permian and Triassic 'New Red Sandstone' strata at the westernmost edge of the Wessex basin. They provide a fascinating record of the long episode of continental conditions that prevailed during the aftermath of the Variscan continental collision and subsequent uplift. The red beds include much debris eroded from the Variscan mountains in the fierce and substantially arid environments of the Pangean supercontinent. These conditions existed throughout the Permian and into Triassic times, though only the lower part of the sequence is seen in and around Torbay. The contrast between the red beds and the underlying grey Devonian slates and limestones is a key feature of the Torbay landscape. Many questions posed by the red beds still remain unanswered, such as the precise age of the strata and the source of the igneous debris in some of the breccia units. These matters will be addressed by the geologists of the future, working in this important district.

Richard Scrivener BSc, PhD, CGeol, FGS
District Geologist, British Geological Survey

Four Permian sites have been highlighted within the Geological Conservation Review, Oddicombe, Roundham, Saltern Cove and Shoalstone as detailed in Table 1, all of which provide crucial evidence for Permian palaeoenvironments and topography.

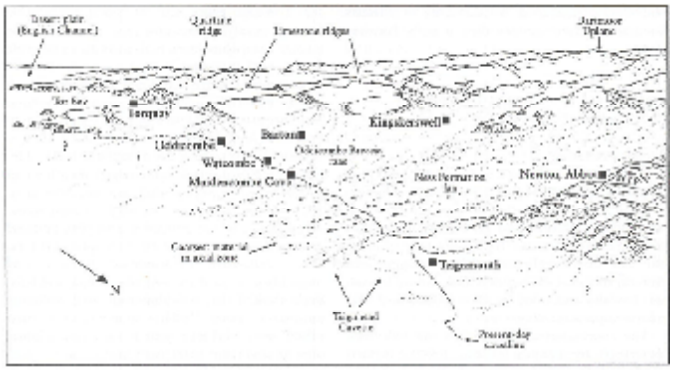


Fig. 7 Palaeogeography of South Devon during the Early-Mid Permian epochs, showing the mountainous hinterland of uplifted Devonian and Carboniferous sediments, the main depositional basins, and the present-day coastline. Geological Conservation Review Series, Permian and Triassic Red Beds and the Penarth Group of Great Britain, M.J. Benton, E. Cook and P.Turner. Reproduced here with the kind permission of Neil Ellis GCR Publications Manager, Joint Nature Conservation Committee.

Oddicombe

The excellent exposures of the Oddicombe Breccia at Oddicombe Beach provide valuable information on the early Permian palaeogeography and geological history of Devon. These sediments have been interpreted as part of a regional scale alluvial fan complex, with sediment accumulation occurring by a combination of fluvial, and, to a lesser extent, aeolian processes. The site is the type location for the Oddicombe Breccia. Notable also are the cracks and fissure infills in the underlying Devonian limestones produced by solution or synsedimentary tectonic activity during Early Permian times. The breccias are faulted against the Devonian limestones of Petit Tor.

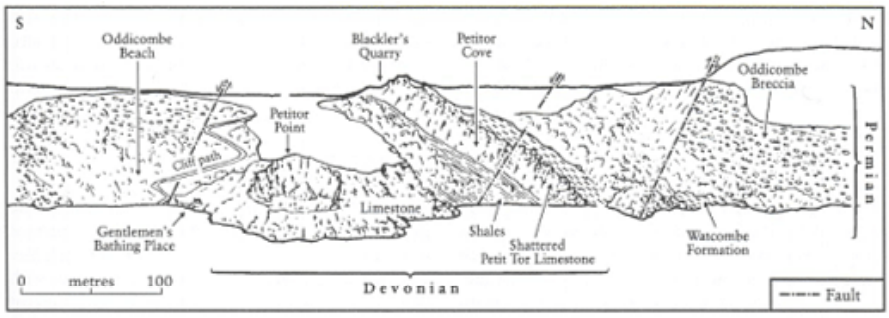


Fig. 8 The cliff section at Petitor and Oddicombe, showing the three faults that bring the Devonian and the Permian sediments into direct contact (From Laming, 1982) Geological Conservation Review Series, Permian and Triassic Red Beds and the Penarth Group of Great Britain, M.J. Benton, E. Cook and P.Turner. Reproduced here with the kind permission of Neil Ellis GCR Publications Manager, Joint Nature Conservation Committee.

Roundham Head

Roundham Head provides the best section through the Torbay Breccia on the Devon Coast. These sediments consist of interbedded sandstones and breccias and represent deposition on a large alluvial fan complex. The overlying Livermead Beds are finer grained sandstones and mudstones, and were deposited on the downstream margins of the alluvial fans.

Fig. 9 Roundham Head

Saltern Cove

Key features at Saltern Cove are the basal unconformity, the breccia composition, and the unusual burrows made by giant millipede. These fossilised burrows are the youngest fossils of the type known and are evidence of a creature wiped out in the end Permian extinctions. The site provides important information for the reconstruction of palaeogeography of Devon around the beginning of the Permian Period

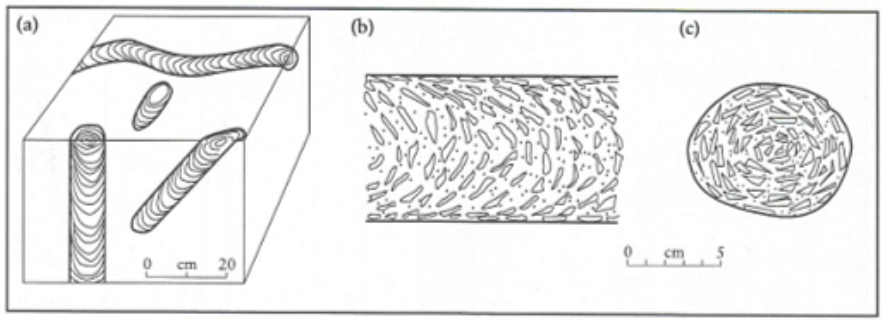


Fig. 10 Burrows from the Torbay Breccia of Waterside Cove, shown as a reconstruction (a), in vertical section, with meniscate packing structures (b), and in horizontal section, with oriented clasts (c). (After Ridgeway, 1974) Geological Conservation Review Series, Permian and Triassic Red Beds and the Penarth Group of Great Britain, M.J. Benton, E. Cook and P.Turner. Reproduced here with the kind permission of Neil Ellis GCR Publications Manager, Joint Nature Conservation Committee.

Shoalstone

Described as a key site to examine an unusual and spectacular tectonic and sedimentary phenomena, and for an insight into Permian palaeogeography and topography, Shoalstone, provides an excellent example of 'Neptunian dykes', fractures infilled partly by carbonates of hydrothermal origin, and partly by red bed sediments that reveal a graphic and extended history of uplift, tectonic extension, and continental sedimentary deposition.

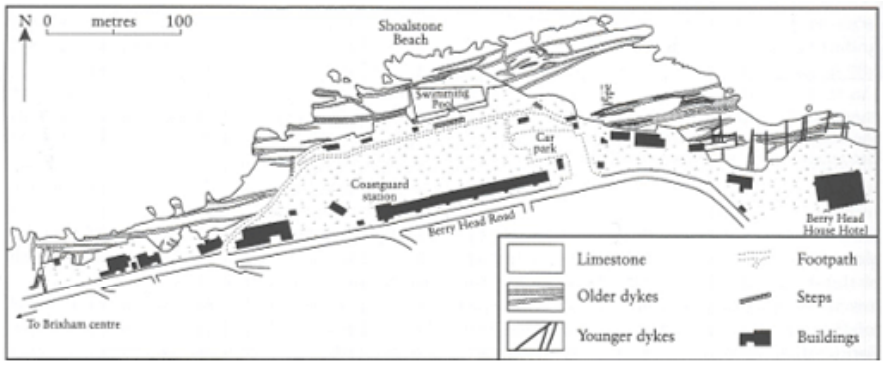


Fig. 11 Large-scale map of the sets of Permo-Triassic sandstone fissure fills (Neptunian dykes) on Shoalstone Beach, showing older and younger generations of dykes. (After Richter, 1996). Geological Conservation Review Series, Permian and Triassic Red Beds and the Penarth Group of Great Britain, M.J. Benton, E. Cook and P.Turner. Reproduced here with the kind permission of Neil Ellis GCR Publications Manager, Joint Nature Conservation Committee

Fig. 12 Neptunian Dyke

5. Quaternary From 1.8 million years ago to present

Fig. 13 The view our early ancestors would have had from Kents Cavern – artwork by Brin Edwards

The area of the English Riviera Geopark provides one of the longest records of non-glacial Pleistocene events not only in Southwest England but also in Western Europe.

Situated beyond the southern limits of Pleistocene glaciation in the UK, the region lay centrally in a zone across which a whole range of Pleistocene mammal species would have migrated in response to repeated climatic and environmental changes. On the fringes of Europe, the area would have been at the ultimate limit of hominid migration, thus developments here have had a resounding resonance.

Significant karst development within the Marine Devonian limestones provided a profusion of suitable caves, fissures and shafts where sediments, faunal remains and artefacts have accumulated by a variety of agencies. Bone preservation, even micro faunal remains, has been aided by the alkaline conditions. Bones and artefacts from these deposits were central to the pioneering work carried out in nineteenth century and subsequent controversies about the antiquity of human beings.

"Kents Cavern is beyond doubt one of the most important sites in Britain for Palaeolithic archaeology. The extensive date range of the human activity found within the cave complex and the good dating evidence create a resource which is of international significance. Human beings were using the caves from over 350,000 years ago and there is evidence of periods of occupation throughout the Palaeolithic period, up to 10,000 years ago. The value of the caves is further enhanced by the rich diversity of animal remains, which allow us to reconstruct climatic conditions through an enormous length if time, covering several glacial and inter-glacial cycles.

The access to the caves for the general public allows a very rare and valuable opportunity for a wide range of people to explore and understand a remote part of the human story. The site is designated as a scheduled monument in recognition of its value to society"

English Heritage

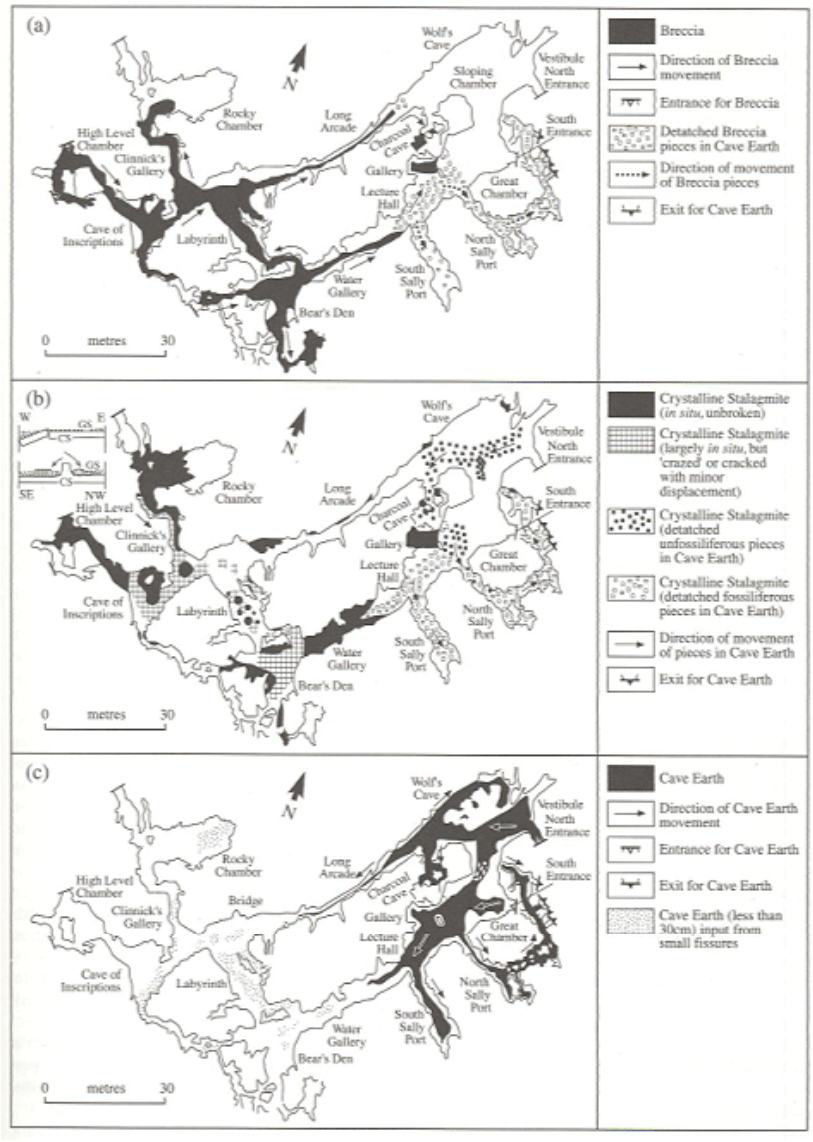


Fig. 14 Kents Cavern, after Straw (1996). Distribution of: (a) Breccia; (b) Chrystalline Stalagmite; (c) Cave Earth. (a) – (c) are shown as indicated in Reports to the British Association by William Pengelly, 1865 – 1880. Cave outline is based on the survey by Proctor and Smart (1989) Geological Conservation Review Series, Quaternary of South-West England, S. Cambell, C.O. Hunt, J.D.Scourse and D.H.Keen. Reproduced here with the kind permission of Neil Ellis GCR Publications Manager, Joint Nature Conservation Committee.

Fig. 15 Kents Cavern today

Kents Cavern contains one of the most important Pleistocene sequences in Britain. Its evidence of Middle Pleistocene conditions is unique in the South West and the site has one of the most protracted histories of research of any British Quaternary locality. Excavations in the cave date from as early as 1842 (Northmore, 1868; Kennard, 1945; Campbell and Sampson, 1971; Straw, 1995, 1996). The earliest excavations by Northmore and Dean Buckland (1824 – 1825) were shallow and did not penetrate the stalagmite floor below which the majority of bone- and artefact-bearing sediments occur. Work later in 1825 and in 1826, by Reverend J. McEnery, penetrated further into the cave and managed to break through the stalagmite to expose softer deposits beneath. In these sediments were found the bones of hyena and woolly rhinoceros, together with human artefacts, thus demonstrating the contemporaneity of human beings and extinct animals. Because of the views prevailing in the 1820s about the age and origin of humans and of geological phenomena, MacEnery did not reveal his findings, and his notes were only published after his death by Vivian (1856) and Pengelly (1869)

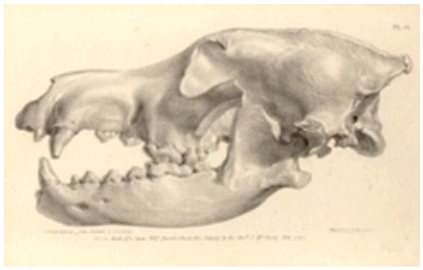
The most major excavations in the cave were conducted by William Pengelly between1865 and 1880. In contrast to previous excavators, he dug the cave painstakingly layer by layer, using a grid system to establish the three dimensional context of finds and sediments. The reports were published in both monthly and annual reports (Pengelly, 1868b, 1869, 1871, 1878). (S. Campbell, C.O. Hunt, J.D. Scourse and D.H. Keen, Quaternary of South-West England, Geological Conservation Review Series, JNCC, p. 136)

Importantly, Pengelly's excavations in the Brixham Cave in 1859 provided the first published account to demonstrate that humans had occupied the region before the extinction of the cave mammals, a fact later to be reinforced by his work in Kents Cavern (Sutcliff, 1969)

Fig. 16 Pre the work of Pengelly, MacEnery recovered and recorded a large collection of objects from Kents Cavern (photo courtesy of Torquay Museum)

"Acceptance of the fact that people had existed alongside animals that are now extinct such as mammoth and woolly rhinoceros or those extinct from Europe such as lion, hyena and reindeer suggested a long human antiquity. Filling in the details of how people lived during these prehistoric times now inspired great interest. William Pengelly's remarkable excavations at Kents Cavern between 1865 and 1880 were a major contribution to this and Franks (appointed in 1851 by Royal Commission to establish a collection of British antiquities) did not hesitate to collect a small share of some of the oldest handaxes found at the site. Such was their importance to science that bones and artefacts were also sent to the new Natural History Museum formed out of The British Museum and opened in 1881. All of this material is still frequently examined by researchers investigating the time when people first appeared in Britain."

Jill Cook
Department of Prehistory and Europe
The British Museum



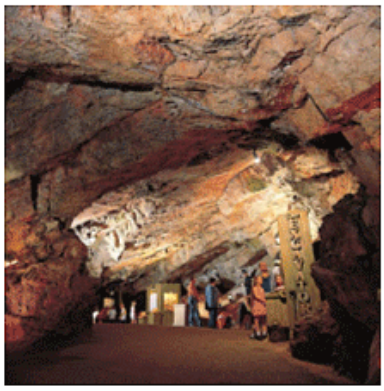


Fig. 17 Part of theTorquay Museum Kents Cavern Collection; Wolf skull with McEnery's drawing and Handaxe A3957 (photos courtesy of Torquay Museum) and Kents Cavern

Current Research

Current research involves the analysis of a piece of jawbone first unearthed 80 years ago during an excavation by the Torquay Natural History Society. Originally the piece was thought to be 31,000 years old, however the current research was initiated when Dr Roger Jacobi and Professor Chris Stringer of the Natural History Museum of London obtained new radio-carbon dates for animal bones that were found in cave sediments directly above and below where the jaw fragment was found. These indicated that the layer in which the maxilla was found dates to between 37,000 and 40,000 years ago, and if the jawbone fragment is of a similar age it would be even more significant than first thought. If the jawbone proves to be Neanderthal, then Kents Cavern will be the only place in Britain were there is direct evidence that Neanderthals once lived, but also it would confirm that Neanderthals spread across Europe and reached Britain far earlier than is currently thought.

Fig.18 Fragment of maxilla (upper jaw) excavated from Kents Cavern in 1927

However, a systematic exploration of the caves of Berry Head did not commence until 1983, when Peter Glanvill started an investigation that was subsequently continued by the Devon Speleological Society. As a result, today over 50 caves are now on record. This complex of coastal caves is unique in Great Britain and recent Uranium-series work on speleothem in the Berry Head caves confirms their potential for calibrating marine Pleistocene events (Proctor and Smart, 1991; Baker, 1993; Proctor, 1994; Baker and Proctor 1996). The caves provide an extreme marine environment the biodiversity of which is still being investigated.

Raised Beaches

The coastal Pleistocene deposits exposed in the English Riviera Geopark record an impressive variety of marine and terrestrial events dating back to at least 200 ka BP. Amino-acid geochronological techniques have shown that raised beach deposits of two distinct ages are present. These have been correlated with Oxygen Isotope stages 7 and 5 of the deep-sea record. Palaeontological analyses at this site provide vital evidence to show that sea temperatures during both of these marine phases were similar to today's. Lithified dunesand overlying the raised beach deposits at Hopes Nose can be ascribed to warm conditions in Oxygen Isotope Stage 5 (Ipswichian Stage), while terrestrial deposits which underlie it must be at least as old as Oxygen Isotope Stage 7 (c. 200 Ka BP). Head deposits which 'cap' the raised beach and dune deposits throughout the coastal sections within the Geopark are likely to have accumulated under periglacial conditions in the Devensian Stage (26 – 14 Ka BP). Very few raised beach localities in Britain have revealed so much palaeoenvironmental information. Together with the Pleistocene sequence at Portland Bill, the deposits provide an important stratigraphic and chronological model with which other coastal Pleistocene sequences can be compared. (Geological Conservation Review Series, Quaternary of Southwest England, S. Cambell, C.O. Hunt, J.D.Scourse and D.H.Keen)

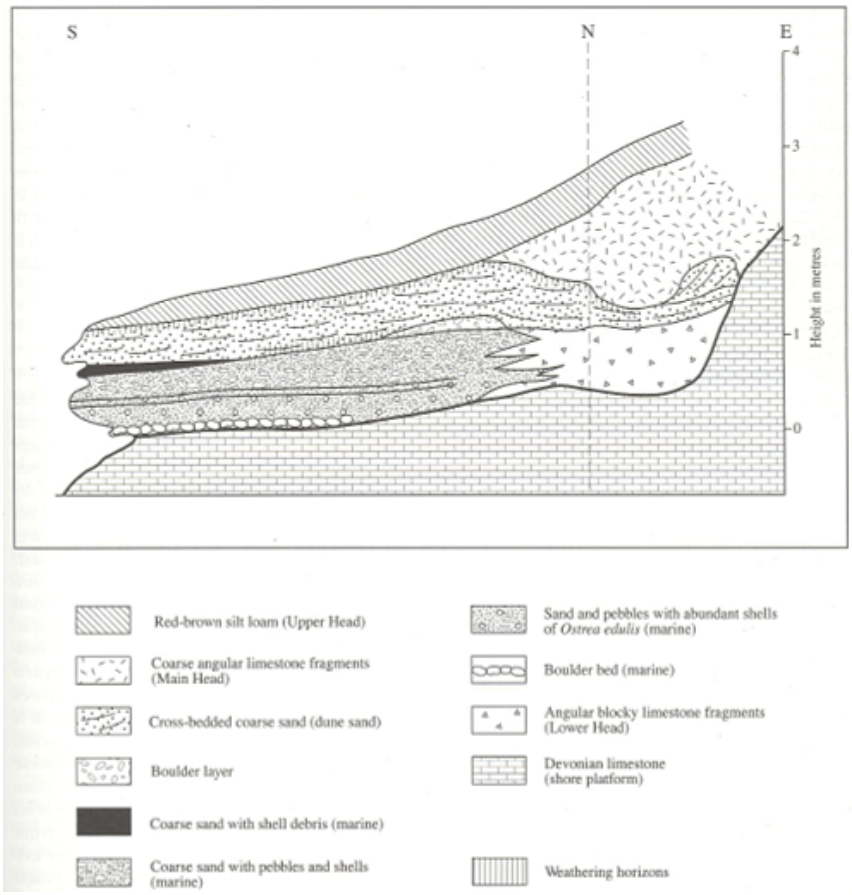


Fig. 19 The Quaternary sequence at Hopes Nose (Adapted from Mottershead et al., 1987. Geological Conservation Review Series, Quaternary of Southwest England, S. Cambell, C.O. Hunt, J.D.Scourse and D.H.Keen. Reproduced here with the kind permission of Neil Ellis GCR Publications Manager, Joint Nature Conservation Committee.

Fig. 20 Raised beach deposits at Hopes Nose

6. Mineralogy

"Hope's Nose gold and selenide minerals

The massive limestone at Hope's Nose is cut by a number of calcite veins in the vicinity of what used to be the sewage outfall and for some 50 metres to the northeast and southwest of it. Gold was first discovered in these calcite veins by Professor Gordon in 1922, although it had been reported previously from Daddy Hole Plain (1.5 km east of Hope's Nose) in 1903. Interest in the locality was renewed in the 1980s when more specimens of gold with a significant palladium content were found. Gold from this locality, when dissolved out of the calcite occurs as the most beautiful delicate fern-like crystalline aggregates, unique as far as one can tell.

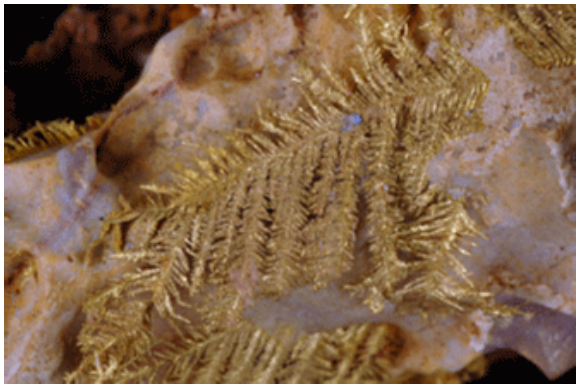


Fig. 21 Hopes Nose Gold (photo courtesy of The Natural History Museum)

Additional work by myself (Chris Stanley) and others published in 1990 detailed an assemblage of selenide minerals from one of the veins. The minerals tiemannite (HgSe), klockmannite (CuSe), umangite (Cu_3Se_2), tyrrellite $(Cu,Co,Ni)_3Se_4$, trustedtite (Ni_3Se_4), penroseite ($NiSe_2$), naumannite (Ag_2Se), eucairite (AgCuSe) and fischesserite (Ag_3AuSe_2) were reported from Britain for the first time.

Subsequently, more work by Professor Werner Paar (University of Salzburg) led to the discovery of a mineral entirely new to science which was named chrisstanleyite ($Ag_2Pd_3Se_4$). Hope's Nose is the type locality for this mineral and appears in all the relevant mineral reference works on account of this.

In 2005 Professor Tom Shepherd of the British Geological Survey and co-workers proposed a genetic model for Hope's Nose minerals linking Permo–Triassic red beds, the mixing of oxidising and reducing brines, and the development of unconformity-related precious metal mineralisation. Comparison with other European Permo–Triassic basins revealed striking similarities in geological setting, mineralogy and geochemistry with Au, Au-Pd and selenide occurrences in Germany (Tilkerode, Korbach-Goldhausen), Poland (Lubin) and the Czech Republic (Svoboda nad Úpou and Stupná). "

Chris J Stanley BSc PhD
Deputy Head of Mineralogy
Natural History Museum

7. Geo Culture

From a cultural perspective the English Riviera Geopark area provides an amazing example of how geology is the overriding influence on the history and development of an area; from the Bay's earliest residents at Kents Cavern detailed in section 5 through to the Tourism industry of today. The wealth of key heritage assets within the Geopark appears in Table 3.

Early post glacial settlers of the Bay included Neolithic and Bronze-Age farmers who left signs of their passing at Wall's Hill and Broadsands Tomb.

There is evidence of an Iron Age promontory fort on the headland, but this was probably destroyed when the Napoleonic forts were constructed. A scatter of Bronze Age and Romano - British material has been found across the headland, and there are remnants of a strip field system to the west of the site, suggesting the area was farmed communally in the medieval period.

Fig. 22 Neolithic Tomb at Broadsands

Fig. 23 Torre Abbey

Torre Abbey, established in 1196, is the English Riviera Geopark's single most important building in heritage terms, was the monastic centre for the monks that controlled much of the Bay. It is constructed from both the limestone and sandstone.

The shape of the Bay creates a safe anchorage. Firstly, this led to the development of the harbour at Brixham, which came at one time to be the largest fishing port in England. It was here that deep-sea trawling was pioneered in the UK and the maritime heritage of Brixham is therefore highly significant to the social and economic story of the Geopark.

Secondly, it led to the use of the Bay by the naval fleet during times of crisis, prompting the construction of the Berry Head Forts during the Napoleonic Wars and stimulating the birth of Torquay as a Tourist resort – the families of naval officers came to settle in the town and word spread of its attractive setting and climate.

At its greatest extent the Forts covered the majority of the headland, much of which was scheduled as an Ancient Monument as early as 1950, the schedule was further extended in 2000 (Berry Head Conservation Management (2007 - 2017) plan).

Berry Head is described by Pye and Slater as 'one of the most complete surviving examples of purpose built Napoleonic Fortifications in South West England." Exeter Museum Archaeological Field Unit's Survey of Berry Head (Pye and Slater 1990)

Building stone
The utilisation of local materials for generations is particularly evident at Berry Head National Nature Reserve where the limestone from the headland itself was used as a building stone for the two Napoleonic forts.

Theme	Key Heritage Assets within the Geopark territory
1. The making of the Bay and its original inhabitants	■ Geological Sites of Special Scientific Interest ■ Marine life ■ Limestone grassland plant communities ■ Coastal landscapes ■ Cirl buntings ■ Greater horseshoe bats ■ Natural Sciences Collection, Torquay Museum
2. The first humans	■ Kents Cavern ■ Wall's Hill ■ Kents Cavern Archive and collection, Torquay Museum ■ Broadsands Tomb ■ Brixham Cavern
3. Early settlement / rural life	■ Torre Abbey ■ Churston Ferrers ■ St. Michael's Chapel ■ Galmpton ■ Paignton Bishop's Palace ■ Orchards, rural landscapes ■ Ancient lanes and local archaeology ■ Occombe Farm ■ Cockington Court and Village ■ Devon dialects and customs ■ Historic town centres ■ Laycock Collection and Photo Archive, Torquay Museum ■ Higher Brixham
4. Maritime and industrial life	■ Brixham Harbour ■ Cider-making ■ Brixham Heritage Fleet ■ Potteries ■ Brixham Museum collections ■ Marble works ■ Paignton Harbour ■ Brixham Paint industry ■ Shipwrecks ■ Cockington Forge ■ Building and craft skills
5. A nation at war	■ Berry Head Ancient Monument ■ WWII slipways, Torquay Harbour ■ Brixham Museum Collections ■ Local Studies Section, Torquay Museum ■ Battery Gardens Ancient Monument
6. The Tourist resort / Urban life	■ Torquay Harbour ■ Paignton Pier ■ Victorian Villas ■ Torbay Cinema ■ Markets ■ The Palace Theatre ■ Churches (Babbacombe, All Saints. Montpelier Road, St John the Evangelist) ■ Princess Gardens / Rock Walk ■ Coastal walks ■ Railway heritage ■ Oldway Mansion and Gardens ■ Torquay Museum and its collections ■ The Pavilion ■ Brunel Woods
7. Famous inhabitants and connections	■ Agatha Christie / Greenway ■ William of Orange ■ Isambard Kingdom Brunel / Brunel Woods ■ William Pengelly ■ William Froude ■ I. & P. Singer ■ Rudyard Kipling ■ The Cary Family ■ Rev. Lyte ■ The Palk Family

Table 3 Key heritage assets within the Geopark

Fig. 24 Berry Head National Nature Reserve

Fig. 25 Berry Head National Nature Reserve

Fig. 26 Berry Head quarry whilst still in operation

In addition, many limestone quarries were worked both around Torquay and Brixham to provide stone for Regency and Victorian development, especially the exclusive coastal resort of Torquay. The Victorian villas that give much of Torbay its distinct character are the result of a planned development programme to accommodate visiting gentry. Many fine public buildings were constructed which reflected the prosperity of the Bay, including several churches of architectural significance, Torquay Town Hall and The Pavilion. Less magnificent but still with local stone, housing was also provided for the poor.

Fig. 27 Regency, Hesketh Crescent, where Darwin resided

The area still abounds with these sites of cultural heritage together with a number of closely associated limekilns. In addition to the residential buildings, fascinating structures in stone such as windmills and viaducts still survive as points of interest. Where naturally weathered, these buildings and structures offer a marvellous opportunity to view rich coralline faunas of the Devonian age.

Fig. 28 Limekiln in The Grove Photo J Burman

Marble and Terracotta Industry

During the Victorian era, varied limestone 'marbles' from Torquay were exploited and the Torquay marble industry came into being, to provide for the demands of the upper classes in furnishing their villa residences. One former quarry in particular, at Petit Tor, specialised in cutting and polishing this stone. Word spread of the fine quality of the stone and a significant market developed, with exports around the country and even as far away as New Zealand.

Extracted from: A Geological Manual, 1833, Henry T. De la Beche

"I know of no better or more easily accessible example than of that of the cliff named Petit Tor, in Babbacombe Bay, Devon, where so large a portion of Devonshire Marble is obtained. Of this the following section:

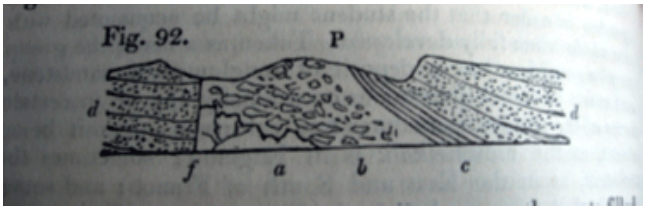


Fig. 29 A Geological Manual, 1833, Henry T. De la Beche, Torquay Museum, Library

Its most famous products were beautiful circular tabletops, inlaid with a colourful variety of local limestones, one of which was once displayed in the former Geological Museum in London, and many other items can today be seen in Torquay Museum. Exhibits at the museum also include the parallel development of the Torquay terracotta industry, which exploited deep-red clays found within the lower part of the Permian red-bed sequence.

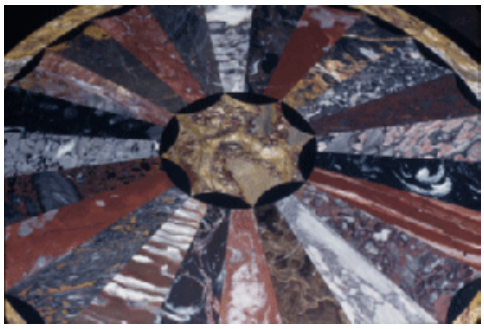


Fig. 30 Marble Table top produced from Torquay marble and terracotta bust, part of the Torquay Museum Collection.

From Torbay to Zambezi

In 1842 low-grade iron ore was discovered in the limestone plateaus at Brixham and Sharkham Point. The ore was commercially mined for smelting and for the use in the manufacture of anti-corrosion paint began. By the time the paintworks took the name of the Tor Bay Paint Co in 1895 the company was exporting all over the world. Amongst the contracts held by the company the paint was used in the maintenance of Victoria Falls Bridge on the Zambezi River. Having been designed in England, the bridge was transported from Europe in pieces and was assembled on site, bridging the Zambezi River and linking Zimbabwe and Zambia in 1906.

Victorian Shocker

The discoveries at Kent's Cavern shook Victorian popular and moral opinion. All discoveries before then had been disregarded or condemned as hoaxes, and many claimed that Pengelly's findings were inaccurate, however his scrupulous recording of every detail made most of the critics' arguments ineffectual. Little did Pengelly know that the excavation of the Cavern would last 15 years and that he would unearth some of the most crucial pieces of evidence that would make Darwin's Theory of Evolution the accepted norm. Much correspondence passed between Pengelly and Darwin, who for some time resided just down the road from the caves at Hesketh Crescent in Torquay.

Fig. 31 William Pengelly (Photo courtesy of Torquay Museum)

Whilst in residence at Hesketh Crescent, Darwin wrote in a letter to Charles Lyell (dated 20 July, 1861) “Lady Lyell & you will be glad to hear that Etty improves a little. This is a quite charming place & I have actually walked I believe good two miles out & back, which is a grand feat. — I saw M^{r} Pengelly the other day & was pleased at his enthusiasm.”

The Darwins' visited the seaside resort of Torquay in the hope that it would improve the health of their daughter, Henrietta Emma Darwin. Emma Darwin's diary is filled with references to Henrietta's recuperation while at Torquay in July and August 1861(www.darwinproject.ac.uk)

Murder in the Geopark!

On a lighter note over the years the beauty and interest of the Bay has attracted many important people, from Charles Kinglsey the late nineteenth century author to the Victorian philanthropist Baroness Burdett-Coutts. The English Riviera has even had a great influence on the work of Dame Agatha Christie, the world's most famous mystery and crime writer who was born in Torquay and lived much of her life in the area. www.englishriviera.co.uk/site/attractions/historic-and-cultural/agatha-christie/agatha-christies-riviera. Agatha Christie famously refers to Kents Cavern in her thriller "The Man in the Brown Suit".

In Torquay, the Agatha Christie Mile walk, leads around the seafront, featuring just some of the locations linked with her life, each marked with a plaque and including the only bust in the world of the most published author of all time. It is possible to find out more about the author in the gallery at Torquay Museum dedicated to the writer and each year a week long, Agatha Christie Festival is held, co-ordinated by the Torbay Cultural partnership.

Fig. 32 Agatha Christie (photo English Riviera Tourist Board)

In addition another famous British author to refer to Kents Cavern was Beatrix Potter. Did she get the inspiration for Mrs Tiggywinkle's underground home from her visit to Kents Cavern? She visited the caves in 1893, the year she wrote the Peter Rabbit letters.

Fig. 33 Beatrix Potter outside Kents Cavern, 1893 (photo courtesy of Torquay Museum)

8. Geoeducation

The English Riviera Geopark is so unique it provides the only opportunity to study the Middle Devonian reef environment. It provides possibly the best site in Europe for demonstrating to University students continuous coastal exposure showing the evolution of a major sedimentary basin with no significant time gap; in addition to the spectacular unconformity as described in Illustrations of the Huttonian Theory, Playfair 1802, P.212

Fig. 34 Students at Saltern Cove Photo K Page

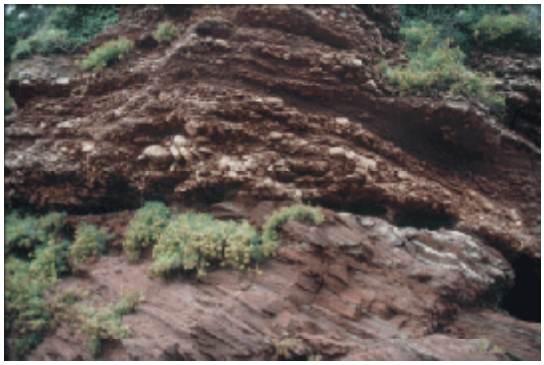


Fig. 35 Unconformity at Saltern Cove

In total the exceptional exposures of the Geopark provide superb educational value summarised within appendix 3.

The territory has a total of 32 primary, 8 secondary schools and one college of further education, the majority of which already have a close relationship with Torbay Coast and Countryside Trust (TCCT) who are experienced providers of environmental education. The TCCT education team are highly accomplished at enthusing groups of all ages both in the classroom setting and out in the environment, in addition to leading a wide range of regular public events. Other organisations such as Torquay Museum, Kent's Cavern and Living Coasts (detailed within section C.2 of the territories Official application for nomination of the region) also provide high quality environmental education within the region.

Two Universities fall within a 30-mile radius and the Geopark is frequently used by Universities from across the UK and for excursions of foreign meetings.

Interpretation
In addition to a variety of existing interpretation boards and leaflets, thanks to National Lottery funding, the new English Riviera Geopark Trail leaflet and boards are now in place. The boards are positioned at the following sites:

- Berry Head National Nature Reserve
- Babbacombe Downs
- Goodrington
- Kents Cavern

The leaflet is available at the three tourist information centres, TCCT visitor centres, Kents Cavern and the local libraries.

Fig. 36 Learning about the Geopark is fun! Over three days approximately 1000 children plus their families joined in Splosh! A marine arts festival of past and present, Aug 2007.

Fig. 37 New English Riviera Geopark Interpretation Boards

We regularly use the geology of the Torbay area because it contains many excellent exposures of key geological features which are either not exposed elsewhere in the SW of England, are nowhere near as well exposed, or are deformed by tectonic activity and not so clear. The key locations we use regularly are Roundham Head, Paignton (excellent location for introducing facies analysis and logging as well as desert facies associations deposited in alluvial fan, aeolian sand dune and inter-dune ephemeral ponds), Goodrington (fantastic angular unconformity between Devonian slates and sandstone deformed during the Variscan Orogeny and Permian alluvial gravels: this site contains one of the best locations for demonstrating the timing of Variscan deformation in SW England) and Hope's Nose and surrounding exposures (e.g. Meadfoot, Triangle Point). Hope's Nose is perhaps the best place in southern England, south of the Mendips, to introduce benthic palaeoecology, carbonate sediments and carbonate facies analysis. We've also used Berry Head, Babbacombe and Saltern Cove for trips and undergraduate projects in the past.

The Torbay area is the only place on the South British coast where the relationship between rocks deposited prior to, and deformed during the Variscan Orogeny can be seen in contact with the rocks of the proto-Wessex Basin (extensional tectonics after the Variscan Orogeny). The only other places where this can be seen are now poorly exposed around the Mendips/Bristol area and in South Wales. Also, the 'Jurassic Coast' WHS only contains Mesozoic and Cenozoic rocks, so it is a bit like studying the history of Britain back to the Tudors, but no further. The Torbay geology extends this back into the Devonian – which are the oldest rocks exposed in southern England, and the crucial contact between the pre- and post-Permian.

Dr Matthew Watkinson
Senior Lecturer in Petroleum Geology &
Geosciences Programme Leader
School of Earth, Ocean and Enviornmental Sciences
University of Plymouth

Concluding remarks

Undeniably, the geological tale behind the English Riviera Geopark is quite spectacular and one of extremes. From a seascape bathed in the warm and beautiful tropical seas of the Marine Devonian to a landscape of arid, barren Permian desert and from our earliest relatives, living in caves, to modern civilization. The Geopark's outstanding historical contribution, both in terms of the development of geological and archaeological sciences is astounding, from the Huttonian Theory, to the naming of the Devonian Period by Sedgwick and Murchison and even Pengelly's discoveries influencing world wide public opinion as to the antiquity of man.

The shape of the Bay provided the naval fleet safety during times of crisis and thus was a catalyst for the building of the Napoleonic Forts while its sheltered natural harbours led to the growth of what, at one point, became the UK's largest fishing port.

The beauty of the area influenced the early development of a tourism industry thus instigating the requirement for the exploitation of its geological resources in the form of extensive limestone quarrying, in addition to the marble and terracotta industries.

Today, designation as a Geopark is a goal that has inspired our community and has generated enthusiastic support from all sectors. The reason being that the concept of a Geopark fits so well with our area's development and regeneration plans One of Torbay Council Unitary Authority's key strategic aims is to support and enhance its tourism industry by making better use of the natural heritage with which we have been blessed and the Geopark concept will assist us in delivering that aim

New approaches to the management and promotion of geological heritage are currently being developed in Torbay - the concept of a Geopark, as promoting the sustainable use of a geological resource, being extremely relevant in the context of existing nature conservation strategies and philosophies within the Bay. Crucially, Geopark designation has the potential to become a framework within which other heritage tourism initiatives in the area can develop and an identity through which Torbay can be identified globally for the excellence of its facilities.

The unique combination of a superb geological resource, well-developed tourism facilities, a dedicated and innovative conservation trust and well-developed partnerships between the public, private and voluntary sectors makes this area well placed to develop a dynamic and successful Geopark, promoting geological heritage and sustainable development for the 21st Century.

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Appendix1
Principles of site selection
Aims of the Geological Conservation Review

From the outset the GCR used the highest scientific standards to identify systematically the key Earth science sites in Britain. The site series would reflect the range and diversity of Great Britain's Earth heritage, and each site would ultimately satisfy the legal requirements for notification as a Site of Special Scientific Interest (SSSI) by reason of its geology or physiography. The notification of SSSI's under the National Parks and Access to the Countryside Act 1949 and subsequently under the Wildlife and Countryside Act 1981, is the main mechanism of legal protection in Great Britain.

To achieve these aims, criteria and guidelines were developed. These can be encapsulated in three distinct, but complementary, components:

1. **Sites of importance to the international community of Earth scientists**
2. Sites that are scientifically important because they contain exceptional features
3. Sites that are nationally important because they are representative of an Earth science feature, event or process which is fundamental to Britain's Earth history.

The first component for GCR site selection ensures that geological and geomorphological sites of international importance are included so that our international responsibilities are met. Five main types of internationally important Geological Conservation Review site can be recognised:

- Time interval or boundary stratotypes
- Type localities for biozones (rock strata which are characterised by a closely defined fossil content, usually a fossil species) and chronozones (rock strata formed during the time span of the relevant stratotypes)
- Internationally significant type localities for particular rock types, mineral or fossil species and outstanding landform examples such as Chesil beach
- Historically important type localities where rock or time units were first described or characterised, or where great advances in geological theory were first made
- Important localities where geological or geomorphological phenomena were first recognised and described, or where a principal or concept was first conceived or demonstrated (An Introduction to the Geological Conservation Review, Geological Conservation Review Series, JNCC)

Appendix 2 Letter of Support from Norman E Butcher

As a geologist who has got to know the Torbay area extremely well since 1950, I strongly support the Application to designate the English Riviera Geopark. The Application itself and the Management Plan make clear the national and international importance of the geology of Torbay, especially with regard to the establishment of the Devonian System in the 1830's and its later refinement. Indeed, August 2007 will see the publication of a special Volume, No278, of the Geological Society entitled Devonian Events and Correlations, edited by Dr Thomas Becker of Munster, Germany and Dr Bill Kirchgasser of Potsdam, New York State, in honour of the late Professor Michael House (1930 – 2002), the worlds leading authority on the marine Devonian rocks.

House's own work in South-West England was partly based on some of the spectacular sites around Torbay. It is worth noting that House's other big contribution, to Dorset geology, has led to the dedication of the Official Guide to the Jurassic Coast, a World Heritage Site, with a Foreword by H.R.H. The Prince of Wales, to the memory of Michael House. Right up to the time of his death in August 2002 he liked nothing better to go out with interested people on a Friday. It would be most appropriate if designation of the English Riviera Geopark around Torbay would stimulate further interest in the public generally in respect of the Devonian and other fascinating rock exposures.

In addition to the detail presented in the Application and Management Plan, it is worth noting that James Hutton (1726 – 1797), Founder of Modern Geology, never visited Devon and Cornwall in establishing his Theory of the Earth. However, following his death in Edinburgh in 1797, his biographer John Playfair, Professor Mathematics in the University of Edinburgh, did so in the company of Lord Webb Seymour. In his Illustrations of the Huttonian Theory, Playfair describes the spectacular unconformity to be seen on the coast of Torbay "a little to the fouth of Paynton" (1802, P.212)

Norman E Butcher

Appendix 3 Table to summarize educational value of the territory

Site Name	Suitable for:	Key Features
Barcombe Mews Quarry	Secondary, College / Sixth Form, University.	o Excellent clean exposure of the Permian breccias of the Torbay area. o Demonstrates the variation in proportion and composition of the rock fragments found in the breccias of Torbay. o Breccias contain clasts of sandstone, limestone, quartz and shale
Berry Head to Sharkham Point	Primary, Secondary, College / Sixth Form, University	o Large headland of Devonian age limestone. Reaching a height of 195m, it is generally flat topped, with a series of cliffs, steep slopes and ledges reaching down to the sea. o Marine caves under Berry Head display a variety of calcite and mud formations. o At Shoalstone Beach wave cut platforms expose two sets of red sandstone filled fissures 'dykes' some of which are lined with large sparry calcite crystals. o The fissures are cut into the Devonian Torquay Limestones. Mark initial stages of continental deposition in the Permo-Triassic basin of south west England on a basement of much older Palaeozoic rocks.
Breakwater Quarry	Secondary, College / Sixth Form, University	o Excellent demonstration of pre-Permian solution fissures in the Devonian limestone (palaeokarst) o Infilling by Permian sandstone and limestone fragments. o Structural features o Solution fissures with flowstone in the limestone o Engineering application of rock bolts to stabilize faces and use of mesh to prevent falls of smaller material.
Brokenbury Quarry	Primary, Secondary, College / Sixth Form, University	o Middle Devonian Limestone o Strongly foliated layers represent bedding o Crinoid stem fragments and traces of burrows o Folds partially excavated on Eastern side of quarry and exposed in 3 dimensions.
Chapel Hill	Secondary, College / Sixth Form, University	o Palaeotopographical relationship between the Permian breccia and the underlying Devonian limestone. o Excellent breccia exposure on Newton Road very accessible for study. o Breccias contain angular to sub-rounded clasts of Devonian limestone, together with some sandstones, volcanic rock and possibly some granite. o Presence of older Devonian limestones above and to the east indicate breccias were infilling a Permian landscape.

		○ Remains of an old limekiln show the former use of the quarried limestone ○ St Michael's Chapel at the top of Chapel Hill is built from a variety of local stones
Daddyhole	Secondary, College / Sixth Form, University	○ Includes the type section of the Devonian Daddyhole Limestone. ○ Noteworthy in containing desiccation cracks - indicating subaerial exposure ○ Rich fossil content, especially corals
Goodrington Quarry and Road Cutting	Primary, Secondary, College / Sixth Form, University	○ Shows a valuable range of geological features. ○ Partly dolomitised limestone with slickensided fault-plane surfaces, calcite crystals and stromatoporoids. ○ Thick-bedded limestone, dolotomised and interbedded with micritic limestone. ○ Stromatoporoids, corals and other fossils occur. ○ Permian sandstone-filled fissures occur.
Hope's Nose to Wall's Hill	Secondary, College / Sixth Form, University	○ Hope's Nose exhibits excellent exposures Devonian Daddyhole Limestone (of Eifelian age) ○ Displays abundant fossil fauna including well preserved corals. ○ Mineralised veins on the eastern side of Hope's Nose consist of calcite, haematite and dolomite as well as small quantities of native gold and rare palladium and selenium minerals. The only know location within Britain for this type of assemblage of minerals. ○ Shore platforms overlain by raised beaches provide evidence for sea level-change. ○ Hope's Nose displays a flat-lying thrust fault on the southern point of the headland with the west facing cliff showing excellent exposure of a large recumbent fold. ○ Long Quarry area includes the type section of the Devonian Walls Hill Limestone, where the best exposure of the coral-rich unit can be seen in the quarry floor. ○ Dip of the beds allows an easy bed-by-bed examination to be made.
Kents Cavern	Primary, Secondary, College / Sixth Form, University	○ Important Quaternary Site for studies in palaeontology and stratigraphy. ○ Cave deposits have yielded numerous vertebrate remains of the Late Pleistocene age including Hyena Cave Bear, Cave Lion, Mammoth, Woolly Rhinoceros and Bison. ○ Sediment remains have been assigned to the Hoxnian Interglacial Period.

Quarry Woods Quarry	Primary, Secondary, College / Sixth Form, University	○ Provides a good exposure of the thickly bedded sandstone of the Staddon Grit and the thin slaty beds in between. ○ Demonstrates the sandstone lithology, together with the dip and strike of bedding. ○ Demonstrates the soil profile and the transition from weathered to solid rock.
Roundham Head	Secondary, College / Sixth Form, University	○ Represents the type section of the Permian Torbay Breccias. They include a variety of fluvial (water-laid) breccias and interbedded aeolian (wind-blown) sands. ○ The style of the bedding visible in the sandstones and the fabric and features (including desiccation polygons and suncracks) of the breccias allows for the interpretation of the prevailing environmental conditions in which they were formed.
Saltern Cove	Primary, Secondary, College / Sixth Form, University	○ Displays an extensive section through the Upper Devonian, including structures and the fossiliferous Saltern Cove Goniatite Bed. ○ Waterside Cove displays contact between the Lower Devonian and the overlying Permian beds. ○ One of the most important Upper Devonian stratigraphic localities in Britain.

Appendix 4
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