A review of the geological heritage of Torbay with guidance for its management and a strategy for sustainable use.

TORBAY HERITAGE FORUM

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CONTENTS

EXECUTIVE SUMMARY

The county of Devon lies within the south-west 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 Torbay district in particular is geologically famous for its limestone cliffs and quarries, historically a rich source of characteristic fossils of Devonian age. In addition, excellent exposures of Permian "Red Bed" sequences are present and the limestones themselves also include important Quaternary karstic features such as bone caves. This limestone has created a range of habitats supporting living species of national and international importance.

A considerable scientific literature exists describing aspects of the geology of Torbay, much of which is historical, although a relatively recent review is included in the *Geology of Devon* (University of Exeter Press, 1975) and relevant information is also included in *Educational Register of Geological Sites in Devon* (www.devon-cc.gov.uk/geology). 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). In addition, as part of a national project by the governmental body the governmental Joint Nature Conservation Committee, scientific descriptions of all nationally protected sites of geological importance are being described in a series of '*Geological Conservation Review*' volumes.

A review of the geological heritage of Torbay is provided in Section 2. This rich natural heritage has led to the selection of 16 Earth Heritage sites of national or international importance, now protected through the designation of 11 *Sites of Special Scientific Interest* under the UK law. An additional 6 other sites have been selected for their regional importance for geological Heritage, and listed as *County Geological Sites*, and a further 8 sites are here proposed for the same status (Section 3).

To realise the full potential of the unique geological heritage of Torbay, however, a strategy is required which combines both site management objectives and recommendations for educational and tourism development. Crucially, as the latter must not prejudice the former, the conservation requirements of each identified site of geoconservation importance must be fully understood before any development or promotion takes place. Fortunately, however, the majority of geological sites are inherently robust, when compared to other natural heritage sites, and they therefore offer the potential for year-round use in a way that would be impossible for most ecological conservation sites. Section 4 includes a site-by-site summary of management requirements, to provide this basis for maintaining the features of scientific importance in a favourable condition, which can therefore guide future educational and tourism development.

Section 5 includes a framework, or broad strategy, to guide this sustainable development of site use. In particular, the national and international significance of this heritage and its educational and cultural potential has led to a proposal for European Geopark status (Section 5). This designation, supported by UNESCO and linked to European Community programmes, is analogous to a 'Biosphere Reserve' and celebrates the links between geological heritage and society and the potential to develop sustainable tourism linked to the former, for the benefit of local communities and visitors alike.

1. INTRODUCTION

The county of Devon lies within the south-west 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 (Page, 1999a, b).

Torbay has a resident population of 130,000 people within an area of nearly 80 km^2. It attracts an estimated 1.5 million staying visitors each year and tourism is therefore its most significant industry. Approximately 45% of the terrestrial area is undeveloped and 50% of the total area is sea. As a result the natural heritage of Torbay is an important part of the area's identity. However there has been a long-term decline in numbers of the traditional beach holiday market and the area is now focusing its efforts on developing new markets based on the area's heritage and other interests.
The Torbay district in particular is geologically famous for its limestone cliffs and quarries, historically a rich source of characteristic fossils of Devonian age. In addition, excellent exposures of Permian "Red Bed" sequences are present and the limestones themselves also include important Quaternary karstic features such as bone caves. This limestone has created a range of habitats supporting living species of national and international importance.

The Torbay district was first geologically mapped as part of a general survey of Devon, Cornwall and West Somerset in the 1830s by the newly formed state Geological Survey, culminated in the publication of De la Beche's classic memoir of 1839. It was not until the beginning of the next century, however, that a more detailed survey was commenced, at a remarkable 1:10,560, or "ten inches to a mile" by the W.A.E. Ussher, one of the most important geological pioneers in south-west England. This work is summarised in the accompanying memoir (Ussher 1903; second edition re-written by Lloyd 1933) and will remain one of the most important sources of site information for the area as the current 'British Geological Survey' (BGS) no longer publishes memoirs. The recent BGS re-survey of the district, completed in 2003, has, however, led to a complete revision of the earlier stratigraphical terminology, as summarised by Leveridge, Scrivener, Goode and Merriman (2003) (see Section 2).

A considerable literature exists describing different aspects of the geology of Torbay (see Scientific bibliography, Section), dating back as far as 1820s (De la Beche 1829). Relatively recent reviews referring to the district are included Edmonds *et al*. (1975) and Durrance and Laming (1982 – second edition in preparation). Crucially, however, the area has been recently resurveyed by the British Geological Survey and the publication of a new geological map has been accompanied by a booklet describing the area (Leveridge *et al.,* 2003). In addition, as part of a national project by the governmental body the governmental Joint Nature Conservation Committee, scientific descriptions of all nationally protected sites of geological importance are being described in a series of 'Geological Conservation Review' volumes. Those published to date include Campbell *et al.* (1998) on the Quaternary and Benton *et al*. (2002) on the Permian and Triassic "Reds Beds". Volumes on Marine Devonian and Mineralogical sites are currently under production. A review of the geology of Torbay is provided in Section 2. This rich natural heritage has led to the selection of 16 Earth Heritage sites of national or international importance, now protected through the designation of 11 *Sites of Special Scientific Importance* under the UK law (see Appendix). An additional 6 other sites have been selected for their regional importance for geological Heritage, and listed as County Geological Sites, and a further x sites are here proposed for the same status (Section 3).

To realise the full potential of the unique geological heritage of Torbay, however, a strategy is required which combines both site management objectives and recommendations for educational and tourism development. Crucially, as the latter must not prejudice the former, the conservation requirements of each identified site of geoconservation importance must be fully understood before any development or promotion takes place. Fortunately, however, the majority of geological sites are inherently robust, when compared to other natural heritage sites, and they therefore offer the potential for year-round use in a way that would be impossible for most ecological conservation sites. Section 4 includes a site-by-site summary of management requirements, to provide this basis for maintaining the features of scientific importance in a favourable condition, which can therefore guide future educational and tourism development.

Section 5 includes a framework, or broad strategy, to guide this sustainable development of site use. In particular, the national and international significance of this heritage and its educational and cultural potential has led to a proposal for European Geopark status (Section 5). This designation, supported by UNESCO and linked to European Community programmes, is analogous to a 'Biosphere Reserve' and celebrates the links between geological heritage and society and the potential to develop sustainable tourism linked to the former, for the benefit of local communities and visitors alike.

2. THE GEOLOGICAL HERITAGE OF TORBAY

2.2. Devonian System

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 Torbay district itself is dominated by limestones of Devonian age, including a number of classical palaeontological localities, crucial to the original definitions of the system by Murchison. This historical importance is recognised through the inclusion of a category for 'Devonian (Marine) carbonates and clastics, Devon' within the International Union of Geological Sciences global Geosites survey, a project supported by UNESCO (Wimbledon *et al.* 2000).

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

The Devonian limestones of Torbay 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 Torbay 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.

Smaller exposures of clastic rocks of the 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.

The Upper Devonian of Torbay shows the classical transition from shallow water limestones to deep water shales, well known throughout Europe and leading to the extinction of much of the reef fauna. Two distinct early Upper Devonian rock types are present in Torbay, 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. 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.

Lithostratigraphic framework: Recent research in Devon and Cornwall has revealed considerable new insights into the nature of the Devonian successions of the region, in particular that deposition took place a number of east-west basins, each with a distinct stratigraphical sequence (Holder and Leveridge 1986, Franke 1989,Leveridge *et al*. 2003). Subsequent tectonic activity, during the Variscan orogeny (around My), especially as a result of sub-horizontal thrust faulting, led to these distinct and previously separated sequences being forced adjacent to each other and even at times being virtually mixed together. As a result, previous simplistic views of the region (for instance the 'cross-sections' of xx and House) are no longer tenable. In the Torbay district, five such distinct sequences were recognised by Leveridge *et al*. (2003), two of which, however, were described as subbasins of the same basin.

The succession of stratigraphical formations recognised in each basin is described below and their distribution shown on Fig. x. Notable, the Torbay district includes type localities for 12 stratigraphical units of Devonian age, including the Meadfoot Group, also 3 formations (Torquay Limestone Formation, Brixham Limestone Formation and the Saltern Cove Formation) and 8 members (Daddyhole Member , Wall's Hill Member, Barton Member, Sharkham Point Member, St Mary's Bay Member, Berry Head Member, Goodrington Member and the Churston Member).

South Devon Basin (Northern sub-basin): Small area of outcrop of Upper Devonian mudrocks around Anstey's Cove (SX936647 and at Babbacombe (SX928656) and Petit Tor (SX927663) area assigned to this subbasin by Leveridge *et al.* (2003):

Tamar Group:

Saltern Cove Formation (Late Givetian-Famennian): Mudstones and fine-grained siltstones, typically red and reddish purple in colour. Ostrocods locally recorded, for instance at Anstey's Cove.

Nordon Formation (including the 'Babbacombe Slates') (Eifelian-Famennian): Mudstone, grey to bluish- grey in colour. Has yielded rare ammonoids at Babbacombe.

Torquay High: Classic Devonian submarine-rise sequences, dominated by limestones, are well developed around Torquay and form the Torquay High succession of Leveridge et al. (2003) and are well esposed from north-west of the harbour (SX914637) around the headland, past Hope's Nose (SX949637) and northwards to Petit Tor (SX927663).

Tamar Group:

Torquay Limestone Formation

Barton Member (Mid Givetian-Lower Frasnian): Thickly bedded, grey crinoidal and bioclastic limestone, locally with small stromatoporoids and tabulate corals. Includes the

famous 'Lummaton Shell Bed' with a rich shelly fauna dominated by brachiopods (Type locality: Barton Quarry/?Lummaton Quarry).

Wall's Hill Member (Givetian): Medium to thickly bedded, typically pale grey limestone, including fine-grained (micritic) and coarse-grained (bioclastic) lithologies, with in-situ massive stromatoporoids, including reef-style developments (Type locality: Wall's Hill, including Long Quarry Point).

Daddyhole Member (Early Eifelian): Thin to thickly bedded dark-grey to grey limestone, including levels rich in in-situ tabulate and colonial rugose corals (Hope's Nose, Dyer's Quarry, etc.), thinly bedded units with a rich brachiopod fauna (Hope's Nose) and bioclastic units (Type locality: Daddyhole, including Dyer's Quarry).

Nordon Formation (Late Emsian): Mudstone, grey to bluish- grey in colour.

Meadfoot Group (undivided) (?Pragian-Emsian): Grey silty mudstones with sandstone units; sedimentary structures typical and locally some levels yield brachiopod-dominated shelly faunas (Type locality: Meadfoot Beach).

South Devon Basin (southern sub-basin): The only significant outcrops of deposits of this sub-basin in the Torbay district are the Upper Devonian mudrocks of the Saltern Cove-Elbury Cove area (SX896587-903570)

Tamar Group:

Saltern Cove Formation (Frasnian-Famennian):): Mudstones and fine-grained siltstones, typically red and reddish purple in colour. Includes the remarkable slump deposits at Saltern Cove with Frasnian ammonoids closely associated with Famennian conodonts (Type locality: Saltern Cove).

Nordon Formation (including laterally impersistant limestone units) (Eifelian-Famennian): Mudstone, grey to bluish- grey in colour.

Brixham High: The limestone dominated sequences of Brixham, so well exposed around Berry Head (SX947565), and assigned to the Brixham Limestone Formation, pass laterally westwards into the volcanic lavas and ashes of the Ashprington Volcanic Group (Leveridge *et al.* 2003). Both formations are therefore assigned to the Brixham High succession, which also includes pre-existing Lower Devonian rocks assigned to the Meadfoot Group. The Brixham High sequence outcrops on the coast between Sharkham Point (SX936546) and Livermead (SX905631) and is also seen in various inland quarries and cuttings

Tamar Group:

Saltern Cove Formation (Frasnain): Mudstones and fine-grained siltstones, typically red and reddish purple in colour.

Brixham Limestone Formation (pt.):

Churston Member (Frasnian): Thinly bedded slaty mudstone, crinoidal limestone and volcanic ash (tuff) passing to thin to medium bedded limestone with stromatoporoids (Type locality: Churston Cove, Brixham).

Goodrington Member (Givetian): Medium to thickly bedded limestone, with some thinner units in its higher part and a stromatoporoid and shelly fauna (Type locality: Goodrington road cutting)..

Berry Head Member (late Eifelian-lateGivetian): Bedded grey imestones showing a range of lithologies from more thinly bedded crinoidal, bioclastic limestones, to massive stromatoporoid-rich lithologies (Type locality: Berry Head).

Nordon Formation:

St Mary's Bay Member (Mid-late Eifelian): Grey to dark grey slaty mudstone with thin bands and lenticles of limestone with common brachiopods and somesolitary rugose corals (Type locality: St. Mary's Bay)

Brixham Limestone Formation (pt.):

Sharkham Point Member (Early-mid Eifelian) : Grey slaty mudstone with thin beds of bioclastic limestone passing to levels with beds of volcanic ash and eventually thinly bedded limestones with stromatoporoids (Type locality: Sharkham Point).

[*Ashprington Volcanic Formation* (Eifelian-Frasnian): Includes basaltic lavas and ash and is interbedded with the Goodrington Member of the Brixham Limestone Formation]

Meadfoot Group (undivided) (?Pragian-Emsian)

Looe Basin: Looe basin successions are only present in the extreme southern tip of the district south-west of Sharkham Point, with small areas of outcrop of the Meadfoot Group, including the Staddon Formation and possibly the Bovisand Formation, of late Lower Devonian age (Emsian). Rock types will include sandstones and silty mudrocks, but as the main exposures are in an inaccessible cliff section at SX930544, no further observations are possible.

Geoconservation sites (or *geotopes*) for rocks and faunas of Devonian age are summarised in Table x and correspond to the Marine Devonian GCR (Geological Conservation Review) Network (see Section 3). The GCR site name is listed, together with the legal SSSI title of the sites, or the County Geological Site name, if RIGS designation is applicable. Some of the latter sites fall within the boundaries of SSSIs designated for other features and the associated SSSI title is therefore also stated.

GCR Site /SSSI/CGS name	**Grid reference**	**Description (GCR statement of Interest or CGS description) and lithostratigraphy**
Babbacombe GCR site (Babbacombe Cliffs SSSI)	SX929655	*"This locality includes the type section of the Babbacombe Shales, which have yielded a rich goniatite fauna of early Frasnian age. The cliff section is inverted and displays interesting structural features, and the best accessible section through the richly fossiliferous Barton Limestone. This section is of great interest in demonstrating the marked facies change from a high-energy, reef environment of the Barton Limestone to deeper water conditions represented by the Babbacombe Shales."* [*Torbay High*: Torquay Limestone Formation, Barton Member. *South Devon Basin (northern sub-basin)*: Tamar Group, Nordon Formation (including 'Babbacombe Slates']
Barton Quarry CGS (proposed)	SX913671	[*Provisional*] The old quarry, now occupied by development, still shows important exposures of the bioclastic Barton Member of the Torquay Limestone Formation, and effectively forms the type locality of the unit. In the past the site has yielded a rich fauna, not dissimilar to that from the better known Lummaton Quarry, including varied brachiopods, bivalves, gastropods, trilobites and rare ammonoids. Current exposures show rich coral-stromatoporoid assemblages, with the tabulate *Thamnopora* being particularly abundant. The exposures have also yielded conodont faunas confirming an uppermost *varcus* to lower *assymetricus* biozone age (Upper Givetian). ***Reasons for registration as a RIGS sites:*** The site is of key historical importance as a source of rich late Middle Devonian faunas and has the potential to yield additional material of palaeontological importance. Crucially, it is also effectively the type locality of the Barton Member of the Torquay Limestone Formation, and therefore has regional lithostratigraphical significance. Limited access makes the site primarily a research

		rather than educational locality. [*Torbay High*: Torquay Limestone Formation, Barton Member]
Churston Cove-Churston Point CGS (proposed)	SX920569-SX898574	[*Provisional*] Cliff and foreshore exposures between Churston Cove and Broad Sands show a thrust-bounded section through the Churston Member (Frasnian), the highest division of the Berry Head Limestone Formation, and constitute the stratotype for the unit. Slaty mudstones interbedded with thinly bedded crinoidal limestones and tuffs pass upwards into medium to massive bedded stromatoporoid-rich limestones, in part dolomitised. ***Reasons for registration as a RIGS sites:*** The area is of regional stratigraphical importance as the type locality of the Churston Member of the Brixham Limestone Formation, and makes the final stages of carbonate sedimentation on the Brixham High. Accessibility gives the site educational value, especially when studied in association with the lower part of the sequence of the Brixham High, within the Sharkham Point to Berry Head CGS (proposed). [*Brixham High*: Brixham Limestone Formation (including Churston Member)]
Goodrington Quarry and Road Cutting GCS	SX892582-891579	*"Middle Devonian (Givetian) limestone. Quarry area: Partly dolomitised, light-grey limestone with slickensided fault-plane surfaces, calcite crystals and stromatoporoids. Road cutting east side: Limestone beds, mainly thickly bedded and dolomitised, interbedded with micritic limestone. Stromatoporoids, corals and other fossils occur. The general dip is about 20° N, with very open, upright folds, at the southern end. Possible low-angle fault/thrust along bedding plane. Permian sandstone-filled fissures occur. Road cutting west side: Detailed examination difficult because of inaccessibility. Possible faults and Permian sandstone-filled fissures visible. The succession as a whole is considered to be a recumbent anticline.* ***Reasons for registration as a RIGS sites:*** *The site, which is generally readily accessible to all interest groups, shows a valuable range of geological features which have been previously documented. There is considerable potential for future development as a valuable educational resource*." [*Brixham High*: Brixham Limestone Formation (including Goodrington Member)]
Daddy Hole GCR site (Daddy Hole SSSI)	SX 928628	*"This site includes the type section of the Devonian Daddyhole Limestone and displays well the characters of this carbonate unit. There is a rich fauna which is well-exposed, and the limestones are noteworthy in containing desiccation cracks, a very uncommon feature in the Torquay Limestone. In Daddyhole Cove an alternating sequence of shales and limestones indicate local facies variations in the late Eifelian, important in interpreting the palaeoecology of the Middle Devonian limestones of the Torbay area. These units are well-displayed in a large recumbent fold."* [*Torbay High*: Torquay Limestone Formation (including Daddyhole Member and ?Wall's Hill Member)]
Dyers Quarry GCR site (Dyers Quarry SSSI)	SX921628	*"Dyer's Quarry exposes the best sections available of the upper horizons of the Daddyhole Limestone (late Eifelian); horizons which are not exposed at the type section, Daddyhole. There is a rich fauna dominated by corals which can be observed in the quarry face and also on bedding planes on the quarry floor. This locality is of particular interest in showing the presence of corals in their position of growth, the best example in south Devon, and lateral changes in coral growth and species distribution related to the substrate."* [*Torbay High*: Torquay Limestone Formation (including Daddyhole Member)]
Hope's Nose GCR site (Hope's Nose - Walls Hill SSSI)	SX948635	"*This site contains excellent exposures of the Devonian Daddyhole Limestone (Eitelian) and displays the typical characteristics of this unit as well as unusual features, such as evidence of penecontemporaneous erosion, within the limestones of the old Hope & Nose quarry. Distinct subfacies can be recognised in the limestones exposed here. A well-known Devonian locality with unrivalled exposures in the Torquay Limestone*." [*Torbay High*: Torquay Limestone Formation (including Daddyhole Member)]
Long Quarry GCR site (Hope's Nose - Walls Hill	SX937651	"*The Long Quarry area includes the type section of the Devonian Walls Hill Limestone. The best exposure of this stromatoporoid-rich unit can be seen here in the quarry floor. The steep dip of the beds allows an easy bed by bed examination to be made. Within the formation it is possible to recognise four distinct subfacies not*

SSSI)		*seen elsewhere in the Torquay Limestone. The site is unique in so well-displaying the development, growth and form of a stromatoporoid reef*." [*Torbay High*: Torquay Limestone Formation (including Wall's Hill Member)]
Lummaton Quarry GCR site (Lummaton Quarry SSSI)	SX911665	"*This quarry in the Devonian Walls Hill Limestone shows a good example of a stromatoporoid reef. This locality is, however, more important for its exposure of the lower horizons of the overlying Barton Limestone, the Lummaton Shell Beds Member. This unit comprises discontinuous pockets and lenses containing an extremely rich shelly fauna of Givetian age. Although the exact position and extent of the outcrop varies with quarrying operations, this locality is now unique as other exposures of the Lummaton Shell Beds are no longer available. A key palaeontological site in the Torquay Limestone*." [*Torbay High*: Torquay Limestone Formation (including Wall's Hill Member and Barton Member)]
Meadfoot Sea Road GCR site (Meadfoot Sea Road SSSI)	SX931631	"*This locality forms the type section of the Devonian Meadfoot Beds, of the old terminology, and displays lithological and palaeontological characters typical of the Meadfoot facies of the Meadfoot Group shallow water, outer shelf sediments. In addition to being the best locality displaying the Meadfoot facies, the east end of the site has yielded interesting sedimentary structures which have not been recorded elsewhere in the Meadfoot Group*." [*Torbay High*: Meadfoot Group]
New Cut GCR site (New Cut, Lincombe Drive SSSI)	SX935638	"*The New Cut provides the best exposure displaying the lithological and palaeontological characters of the Staddon facies of the Devonian Meadfoot Group. The composition of the brachiopod fauna and the presence of large numbers of homalonotid trilobites, unique to this locality in Britain, indicate a near-shore, inner shelf environment, which contrasts with the deeper water facies typical of most of the Meadfoot Group in the Torbay area. A unique palaeontological locality*." [*Torbay High*: Meadfoot Group, ?Staddon Formation].
Petit Tor – Maidencombe CGS (proposed)	SX927663	[*Provisional*] *Marine Devonian*: The site includes the disused Petit Tor Quarry and adjacent coastal exposures dominated by pale stromatoporoid-rich limestones of the Walls Hill Member of the Torquay Limestone Formation (Givetian), overlain to the north by reddish shales of the Saltern Cove Formation (Frasnian). The limestones also yield a scattered fauna of rugose and tabulate corals and a middle *varcus* Biozone conodont fauna, have a solution cavities in their upper surface which occasionally contain pale-pink flinty or slaty limestones or slates. The latter have been interpreted as an Upper Devonian infill and have been reported to have formerly yielded orthocone cephalopods. The overlying mudstones of the Saltern Cove Formation show deformation but apparently include a basal red nodular limestone level with Frasnian conodonts and very rare ammonoids; they are in turn overlain, unconformably, by a limestone breccia at the base of the Watcombe Formation, the Petit Tor Member. ***Reasons for registration as a RIGS sites:*** The Petit Tor area shows the final stages of evolution of the Middle Devonian '*Torquay High*', with the apparent development of palaeo-karstic surfaces at the top of the Torquay Limestone Formation, infilled with Frasnian sediments. Stratigraphical evidence also supports an intra-Devonian non-sequence, with the Barton Member being absent and the Saltern Cove Formation apparently resting directly on the Wall's Hill Member of the Torquay Limestone Formation. The area is of potential educational value.
Saltern Cove GCR site (Saltern Cove SSSI)	SX895580	"*The Saltern Cove area, including the north end of Shell Cove and the south end of Waterside Cove, displays an extensive section through the Upper Devonian, and includes interesting structures, and the richly fossiliferous Saltern Cove Goniatite Bed. The Lower Devonian beds exposed in Waterside Cove are a good example of the Staddon facies of the Meadfoot Group and are richly fossiliferous. Waterside Cove also displays well the unconformable contact between the Lower Devonian and the overlying Permian beds. One of the most important Upper Devonian stratigraphic localities in Britain*." [*Brixham High*: Meadfoot Group, ?Staddon Formation; ?Ashprington Volcanic Formation; Brixham Limestone Formation, ?Churston Member. *South Devon Basin (southern sub-basin)*: Tamar Group, Saltern Cove Formation

Sharkham Point to Berry Head CGS (proposed)	SX930544-SX573566-SX934566	[*Provisional*] *Marine Devonian*: The coastline and adjacent disused quarries between Sharkham Point and Shoalstone Point on the north-west side of Berry Head, show a key section through the changing facies of the Middle Devonian '*Brixham High*', including stratotypes for the Sharkham Point and Berry Head members of the Brixham Limestone Formation and the St. Mary's Bay Member of the Nordon Formation. The Sharkham Point Member (early-mid Eifelian) at its type locality includes slaty mudstones with thin beds of shelly crinoidal limestone below, passing upwards through levels with interbedded tuff to thin bedded limestones with abundant stromatoporoids. The Berry Head limestone sequence is then interrupted by a wedge of dark slaty mudrocks of the St. Mary's Bay Member of the Nordon Formation (late Eifelian-late Givetian), which at its type locality - St. Mary's Bay itself – includes thin seams and lenticles of limestone with a shelly fauna including brachiopods, small solitary corals and rare trilobites and cephalopods. Carbonate sedimentation resumes with the Berry Head Member of the Brixham Limestone Formation, well exposed around the Berry Head itself, its type locality, which, although locally showing signs of tectonic distortion, includes a range of facies including bioclastic and stromatoporoid rich levels indicating a reef-like biogenic bank complex. ***Reasons for registration as a RIGS sites:*** The area is of prime importance for Middle Devonian stratigraphy and sedimentology, showing the development of carbonate facies associated with the 'Brixham High'. It includes stratotypes for the Brixham Limestone Formation and three lithostratigraphical members: The Sharkham Point Member and Berry Head Member of the former formation and the St. Mary's Bay Member of the Nordon Formation. Accessible exposures, in particular in St Mary's Bay and around Shoalstone Point give the site a high educational value in addition to its scientific importance. [*Brixham High*: Brixham Limestone Formation, including Sharkham Point Member and Berry Head Member; Nordon Formation, St. Mary's Bay Member]
Quarry Woods Quarry CGS	SX89956315	"*Lower Devonian Staddon Grit. The main worked face shows a bed of tough, red-brown, fine grained, micaceous sandstone 1.5m thick, associated above and below with thin beds of reddened slate. The sandstone is jointed and shows slickensides associated with a minor fault. The bedding dips at 55° south.*" **Reasons for registration as a RIGS site:** "*The quarry provides a good exposure of the thickly bedded sandstone of the Staddon Grit and the thin slaty beds between. It demonstrates the sandstone lithology, together with the dip and strike of bedding. If the site was suitable cleared it should be possible to demonstrate the soil profile of the ground on which the woodland is situated and the transition from weathered to solid rock.*" ." [*Brixham High*: Meadfoot Group, ?Staddon Formation]

Table 2: Summary of Devonian conservation sites in Torbay

2.3. Permian

"Red Beds" unconformably overly the Devonian rocks and include a range of conglomeritic and sandy deposits, often characteristic of flash-flood deposits, desertic wadi fills and scree. Of particular note are traces of strange burrows at Saltern Cove, presumably once occupied by small reptiles sheltering from intensely hot surface climactic conditions. Occasionally the surface of the Devonian limestones shows evidence of karstic weathering prior to deposition of Permian deposits, including deep fissures near Brixham.

The first major review of the 'New Red Sandstone' of Torbay is the now classic study of Laming (196?), which remains the most detailed published synthesis of the area. Key updated reviews are included in GCR volume, with additional observations in Leveridge *et al.* (2003).

Lithostratigraphic framework: Leveridge *et al*. (2003) revised the lithostratigraphy of the Permian of the Torbay district, which now includes type localities for 3 formations (Torbay Breccia Formation, Watcombe Formation and Oddicombe Formation) and 2 members (Corbyn's Head Member and Petit Tor Member):

Exeter Group:

Oddicombe Formation (?Upper Permian): Red conglomerate with rounded clasts dominated by Devonian limestone with some Carboniferous sandstone and other rocks in a silty-sand matrix.
Watcombe Formation (?Upper Permian): Includes red breccias with limestone, sandstone, slate, etc. clasts in a poorly sorted, locally muddy, sand matrix. Includes locally 'Shale-paste breccias' with weathered red mudstone clasts in a clay matrix (= 'Watcombe Clay' of authors?).

Petit Tor Member: Forms a basal breccia to the formation, full of locally derived limestone clasts, also fragments of Devonian mudstones.

Torbay Breccia Formation (?Lower Permian): Red breccias and conglomerates, clasts dominated by Devonian limestone, also sandstones, with some mudstone, quartz and other rocks.

Corbyn's Head Member: Medium to coarse-grained sandstone, typically reddish in colour but locally with buff or greyish levels.

GCR Site /SSSI/CGS name	Grid reference	Description (GCR statement of Interest or CGS description) and lithostratigraphy
Barcombe Mews Quarry CGS	SX887620	"*Permian breccia with large angular to sub-rounded clasts of sandstone, limestone. Quartz and slate, set in a bedded, well-cemented, coarse gravel matrix. Traces of cross-bedding indicate an approximately E-W depositional flow. Minor faulting can be seen*." **Reasons for registration as a RIGS site**: "*The site provides an excellent clean exposure of the Permian breccias of the Torbay area in a safe and accessible situation particularly suitable for educational use by younger children. The site also demonstrates the variation in proportion and composition of the rock fragments found in the breccias of the Torbay district.*" [*Exeter Group*: Torbay Breccia Formation]
Breakwater Quarry CGS	SX93285660	"*Middle Devonian limestone, mainly massive and micritic but bioclastic in part. Bedding is obscure, the dip is steep to the SE. Cleavage seen in places dips about 20° NW. The limestone has an irregular palaeokarst surface and is penetrated by deep narrow fissures filled with brown Permian sandstone which contains angular limestone fragments in places, some of large size. Pleistocene/Holocene solution fissures in the limestone are associated with coatings of flowstone. Engineering geological applications include the use of rock bolts for the large scale stabilisation of rock faces in association with steelmesh to prevent falls of smaller rock fragments*." **Reasons for registration as a RIGS sites:** "*The quarry provides an excellent demonstration of pre-Permian solution fissures in the Devonian limestone (palaeokarst) with later, Permian, sandstone and limestone fragment infilling. The vertical extent of the fissure is particularly notable. Other useful aspects included structural features and solution fissures with flowstone in the limestone; also engineering application of rock bolts to stabilise faces and the use of mesh to prevent falls of smaller material*." [*Exeter Group*: Torbay Breccia Formation]
Chapel Hill CGS	SX90206531 -90316490	"*Roadside exposure of Permian breccia containing angular to sub-rounded clasts of Devonian limestone, together with some sandstone, volcanic and quartz fragments, in a matrix of red sandy gravel. Rare chert, and possible granitic fragments, also occur. Some limestone clasts contain fossil corals. Bedding traces have a 5° N dip, and imbrication indicates depositional flow from the north. Minor faults occur. Outcrops of Middle Devonian limestone above and to the east of the breccia demonstrate the infilling of Permian palaeotopography, possibly controlled by faulting, by the younger breccia. The limestone is generally massively bedded and*

		bioclastic,with a dip of 60°-70° WSW. Cleaner exposure lies beside paths at the top of the hill show corals and stromatoporoids." **Reasons for registration as a RIGS site:** "*The site demonstrates the palaeotopographical relationship between the Permian breccia and the underlying Devonian limestone. The excellent breccia exposure on Newton Road is very accessible for study. There is considerable potential for development as a valuable educational resource*." [*Exeter Group*: Torbay Breccia Formation].
Hollicombe Head-Corbyn's Head CGS (proposed)	SX898619-SX908633	[*Provisional*] *Permian*: Foreshore and cliff exposures between Hollicombe Head and Corbyn's Head provide key, readily accessible exposures of conglomerates and sandstones of the Permian 'red bed' sequence of the Torbay Breccia Formation. These exposures include the stratotype of the Corbyn's Head Member at Corbyn's Head. The member is characterised by mediuim to coarse grained sandstones, commonly cross-bedded and varying in colour from reddish brown to buff and pale greyish, which pass upwards into conglomerates. The latter include clasts of sandstone, quartz and limestone. Thin beds of reddish or greenish mudstone are also present and some show mudcracks. The sandstones indicate deposition in seasonal rivers and the conglomerates suggest more proximal alluvial fan conditions. ***Reasons for registration as a RIGS site:*** The site shows a sandstone dominated sequence within the breccias and conglomerates of the Torbay Breccia Formation, including the stratotype of the Corbyn's Head Member, of regional lithostratigrafical importance. The area has a high educational potential due to easy access in the heart of the Torbay seafront [*Exeter Group*: Torbay Breccia Formation (including Corbyn's Head Member)]
Oddicombe GCR site (Babbacombe Cliffs SSSI)	SX 927660).	"*Here the Oddicombe Breccias of Permian age are faulted against the Devonian limestones of Petit Tor. The breccias are poorly sorted sediments and are arranged in crude sheet-like spreads of sediments, (in fining-upwards units) which were deposited by ephemeral floods. Imbrication of particles in some finer units indicates fluvial transport towards the east. The site also includes a cavity and fissure system cut into the limestone and filled by Permian sandstones and siltstones*." [*Exeter Group*: Oddicombe Breccia Formation]
Petit Tor – Maidencombe CGS (proposed)	SX926664-SX932696	[*Provisional*] *Permian*: The area shows a virtually unbroken sequence through the upper sequence of Permian deposits in the area, belonging to the Watcombe, Oddicombe and Teignmouth Breccia Formations. The sequence rests unconformably on Upper Devonian Saltern Cove Formation, the contact being marked by the coarse limestone breccias of the Petit Tor Member, at its type locality. This unit includes limestone blocks up to several metres across in a pebbly and sandy matrix; it is interpreted as a local talus deposit. Higher levels in the formation include muddy siltstone with sand and fine breccia below with mudstone and siltsone above – these relatively soft lithologies give rise to large landslip systems immediately north of Petit Tor. The succeeding Oddicombe Breccia Formation includes rounded clasts dominated by Devonian limestone with some Carboniferous sandstone and other rocks in a silty-sand matrix and passes laterally, northwards into the Teignmouth Breccia Formation. ***Reasons for registration as a RIGS site:*** The site shows the lowest part of the upper Permian sequence of Torbay, separated by a non-sequence from the distinct Torbay Breccia Formation sequence below. It includes the stratotype of the Watcombe Formation, with the Petit Tor Member at its base, and key exposures of the conformable passage into the Oddicombe Breccia Formation above. Exposures are in places readily accessible and therefore have educational potential. [*Exeter Group*: Watcombe Formation (including Petit Tor Member), Oddicombe Breccia Formation, Teignmouth Breccia Formation]
Roundham Head GCR site (Roundham Head SSSI)	SX 896603-894598	"*This is the type section of the Permian Tor Bay Breccias. These here include a variety of fluvial breccias, in which types formed during ephemeral sheet floods are the most abundant. On the south side of the headland are interbedded aeolian sands showing palaeowind directions towards the north-west. This contrasts with the directions of fluvial transport, deduced from sedimentary structures such as imbrication and cross-bedding in the breccias, which was towards the south-east. A*

		key site for demonstrating Permian sedimentary environments." [*Exeter Group*: Torbay Breccia Formation].
Saltern Cove GCR site (Saltern Cove SSSI)	SX894591	"*At this locality coarse Permian fluvial breccias rest uncomformably on Devonian slates. The unconformity surface is very clearly seen as a cast on the base of the breccias. These contain much locally-derived material and are arranged in poorly organised, fining-upwards and sedimentary sequences. The coarsest Permian beds occur immediately above the unconformity. A key site showing a regionally significant unconformity*." [*Exeter Group*: Torbay Breccia Formation].
Shoalstone GCR site (Berry Head to Sharkham Point SSSI)	SX 934568-939568	"*The wave cut platform here exposes two sets of red sandstone-filled fissures (dykes). Some of the fissures are lined by large sparry calcite crystals. The fissure cut into the Devonian Torquay Limestone and they mark the initial stages of continental deposition in the Permo-Triassic basin of south-west England, on a basement of much older Palaeozoic rocks*." [*Exeter Group*: Torbay Breccia Formation].

Table 3: Summary of Permian conservation sites in Torbay

2.4. Intrusive Igneous Rocks

Although locally beds of volcanic ash ('tuff') are characteristic of p[arts of the Devonian succession in Torbay, intrusive igneous rocks are much less common. The only significant outcrops are around Black Head, south-east of Anstey's Cove, where microgabbros ('dolerite') are intruded into the Upper Devonian Saltern Cove Formation, where they are associated with basic tuffs. Small outcrops of altered basic intrusive rocks are also present at Babbacombe (SX928654) and in Saltern Cove (SX897582).

GCR Site /SSSI/CGS name	Grid reference	Description (GCR statement of Interest or CGS description)
Black Head-Anstey's Cove	SX940645	[*Provisional*] The only significant outcrops of intrusive igneous rocks in the Torbay district are between Black Head and Anstey's Cove, where microgabbros ('dolerite') are intruded into the Upper Devonian Saltern Cove Formation. The intrusions are associated with basic tuffs and believed to be typical of alkaline or sub-alkaline basalts of a within-plate Ocean Island type, as elsewhere in Devon and Cornwall. ***Reasons for registration as a RIGS site*:** The only significant outcrops of intrusive igneous rocks in the Torbay district, which are readily accessible and therefore suitable for educational use in Anstey's Cove.

Table 4: Conservation sites for intrusive igneous rocks in Torbay

2.5. Structural geology

The district was folded and faulted during the Variscan Orogeny from the latest Carboniferous to the earliest Permian. Several phases of deformation are locally recognisable, as at Brockenbury Quarry and on Berry Head, and most Devonian localities show some evidence of faulting and locally deformation may be associated with recrystallisation of the limestone or the development of slaty cleavage. Locally, faulting in the Devonian limestones may be associated with a massive development of calcite replacement, as at Crystal Cove near Broadsands (SX896580).

The most significant aspect of this phase of deformation was major thrusting (sub-horizontal faulting as a consequence of compression from the south) which dismembered the Torquay high and placed segments of different Devonian depositional basins adjacent to each other or even on top of each other. For a recent review of aspects of the structural geology of the Torbay district, including a map showing degrees of associated low-grade metamorphism, see Leveridge *et al.* (2003, pp. 20-25). Aspects of these tectonic

processes can be seen in most of the Devonian sites listed under Section 2.2, however, a small number of sites are worth listing separate as they include well developed and notable tectonic features:

GCR Site /SSSI/CGS name	Grid reference	Description (GCR statement of Interest or CGS description)
Sharkham Point to Berry Head CGS (proposed)	SX943562	[*Provisional*] *Structural geology*: The cliffs on the south side of Berry Head show spectacular structures in the Middle Devonian, Berry Head Member of the Brixham Limestone Formation, revealing several phases of deformation. These include gently inclined, northward verging, tight D1folds refolded by steeply inclined D2 folds. ***Reasons for registration as a RIGS site*:** Although not easily accessible, these spectacular folds can be viewed form the south side of the Berry Head Fort, although binoculars are recommended. In this way the site can be incorporated into educational visits to the headland. The features exposed, however, are some of the most dramatic and important structural features in the district.
Brockenbury Quarry CGS	SX897563	**"Geological / geomorphological features: "***Middle Devonian limestone. Foliated, micritic, light pinkish grey, partly dolomitised limestone. Most strongly foliated layers are probably more argillaceous and represent bedding. Crinoid stem fragments and traces of burrows in foliated layers. On the east side of the quarry the foliation/bedding dip is about 10° SW. On the west side of the quarry upright folds about 1m in amplitude with a NS trend, deform the earlier foliation. These folds have been partly excavated, possibly for research purposes and are exposed in three dimensions*." ***Reasons for registration as a RIGS site*:** "*The main interest of the quarry lies in the later folds, which deform the early foliation, and are particularly well exposed at the present time. Later fold structures are seldom seen in inland exposures. The main quarry face provides evidence of the nature of the earlier structure and lithology to which the later folds are related and can assist the overall structural interpretation of the district*."
Crystal Cove CGS (proposed)	SX896580	[*Provisional*] *Structural geology*: Crystal Cove includes a well known exposure of a relatively late (i.e. post-Variscan) north-south fault zone, associated with a remarkable 25 m wide zone crystalline calcite – indicating the presence of a major fluid pathway. The fault zone separates the Goodrington Limestone Member of the Brixham Limestone Formation from sandstones of the Torbay Breccia Formation. ***Reasons for registration as a RIGS site*:** The remarkable 25 m zone of crystalline calcite may be unique in the region and is a well-known geological feature in the district. Although damaged by mineral collectors, the feature is of educational value, especially due its proximity to Broadsands and Saltern Cove.
Hope's Nose (south) CGS (proposed)	SX947633	[*Provisional*] *Structural geology*: Exposed in the cliff face close to the raised beach on Hope's Nose is one of Torbay's best known structural geological features - an overturned F1 fold, verging north-west , in thinly bedded limestones and shales of the Daddyhole Member of the Torquay Limestone Formation, associated with a low-angle thrust A well known structure in the Torbay area. ***Reasons for registration as a RIGS site*:** A well known structural feature, useful for inclusion in educational visits to Hope's Nose by older groups (due to proximity to a high cliff).

Table 5: Conservation sites for structural geological features in Torbay

2.6. Mineralisation

Low-temperature hydrothermal fluids, apparently of Permian-Triassic age produced a significant deposit of low-grade iron ore at Sharkham Point near Brixham, by replacing limestone, and which was once commercially mined. The main commercial mineral appears to have been haematite, although other iron oxides and small amounts of Barite (barium sulphate) are also present.

Another suite of fluids led to the formation of thin gold and palladium-bearing veins in the Devonian limestones of Hope's Nose, the former characteristically forming small, delicate feather-like crystals (Clark and Criddle 1982, Scrivener *et al.* 1982; Leake et al. 1991). Very rare selenium minerals are also present, together making these deposits unique in Britain and possibly in Europe (Stanley *et al.* 1990).

GCR Site /SSSI/CGS name	Grid reference	Description (GCR statement of Interest or CGS description)
Hope's Nose GCR site (Hope's Nose to Walls Hill SSSI)	SX 949636	"*A series of mineralised veins cutting through Devonian limestone are exposed in the rock platform on the eastern side of Hope's Nose. The vein fillings consist mostly of calcite, haematite and dolomite but small quantities of native gold also occur, as fine branching filaments. Recent detailed research has also revealed the presence of very rare palladium minerals (isomertieite and mertieite II). This is the only known occurrence of this assemblage of minerals in Britain, making this a nationally important site for mineralogical structures*."
Sharkham Point to Berry Head CGS (proposed)	SX933548	[*Provisional*] *Mineralisation*: Sharkham Iron Mine is a remarkable but little known geological site. The deposit is characterised by hematite replacement of Devonian limestones, associated with limestone breccias and localised developments of botryoidal goethite, limonite and hematite. Some surfaces show patches and radiating crystals of white and pink barite. The source of the iron was almost certainly from Permian 'red beds' in the area, probably via circulating hot fluids migrating along fractures. The process of replacement is likely to be similar to that known in South Wales, where iron minerals replace zones in Lower Carboniferous limestones close to an unconformity with *Triassic* red-beds. Although the former opencast workings are largely filled in, good exposures remain in the coastal slope. ***Reasons for registration as a RIGS site*:** The former mine workings reveal a form of mineralisation that is virtually unique in the region, and which postdates the better known Variscan phase of metallogenesis in south-west England. An important site with an associated cultural significance, although requiring improvements to access to realise its full educational potential.

Table 6: Conservation sites for mineralisation in Torbay

2.7. Quaternary

The Neogene left little trace across south west England, but relatively high sea levels at this time cut the high level marine platform, or plateau, conspicuous on the limestone massif of Berry Head. The development of karstic features and caves in the limestones is characteristic of the Pleistocene, however, and several caves in the district are famous for their rich deposits of ice age and interglacial mammal bones. Kent's Cavern in particular, long ago established as a show cave, has yielded interglacial and glacial mammal faunas including mammoth, straight tusked elephant, narrow nosed rhinoceros, woolly rhinoceros, hyaena, cave lion, European sabre toothed tiger, cave bear, bison, hippopotamus, horse, reindeer and some human remains. A second and much smaller cave at Brixham has also yielded elements of these faunas. Other caves, as recorded by Lloyd (Ussher) (1933), had even then been largely destroyed by quarrying.

On the coast raised beaches are locally well developed, formed during periods of high sea level during interglacial periods, including at Hope's Nose and Thatcher's Rock, Torquay. Elswhere, cold stage deposits include periglacial loess and Head (soil and stones transported downslope due to solifluxion). Rising sea levels after the end of the last ice-age drowned parts of coastal woodlands, the remains of which have historically been seen at low tide on certain beaches (Leveridge *et al.* 2003, pp 18-19). The latter are reviewed in more details by Lloyd/Ussher (1933) and are potentially of great scientific and archaeological importance, although their current extent is unknown.

GCR Site /SSSI/CGS name	Grid reference	Description (GCR statement of Interest or CGS description)
Brixham Cavern CGS (proposed)	c. SX925557	[*Provisional*] *Quaternary*: Brixham Cavern is a historically important source of Pleistocene vertebrate remains, indicating an assemblage similar to that known from Kent's Cavern. The site is a Scheduled Ancient Monument and was formerly operated as a show cave. The cave was discovered in 1858 and subsequently excavated, yielding mammoth, horse, woolly rhinoceras, deer, cave lion, hyaena, bear, amongst other remains. ***Reasons for registration as a RIGS site*:** Brixham Cavern is a key historical site in Torbay, a former source of rich Pleistocene vertebrate faunas. Access is currently restricted and the cave is privately owned – use is therefore likely to be primarily for research purposes.
Hope's Nose and Thatcher Rock, Devon GCR site (Hope's Nose – Walls Hill SSSI)	SX 948633 and SX 944628	"*Hope's Nose and Thatcher Rock are key sites for studies of Quaternary stratigraphy and sea-level change. At Hope's Nose a shore platform at 8 m is overlain by cemented raised beach, comprised of cobbles and boulders at its base, fining upwards into bedded sands. Blown sand an hillwash lie above. A similar raised beach occurs on the offshore stack of Thatcher Rock. The beach deposits are particularly important for their assemblages of fossil marine molluscs and foraminifera. Seventeen species of mollusc have been recorded from Hope's Nose and forty-three from Thatcher Rock. The assemblages from both sites are temperate in nature, although that from Thatcher Rock indicates slightly cooler conditions than those of the present day. Amino-acid dating suggests that the Hope's Nose beach relates to oxygen isotope stage 7 (ca. 210,000 years BP). The well-preserved molluscan faunas and the sedimentary detail of the raised beaches are of crucial importance for dating and interpreting Quaternary sea-level changes and related environmental conditions in south-west England*."
Kent's Cavern, Devon GCR site (Kent's Cavern SSSI)	SX 935641	"*Kent's Cavern is a famous and important Quaternary site. It is significant for studies in palaeontology, dating and stratigraphy and for elucidating environmental and faunal changes during the Quaternary. It has yielded vertebrate remains of Middle and Late Devensian age and is also notable for the presence of deposits that are probably of Middle Pleistocene age*."
Sharkham Point to Berry Head CGS (proposed)	SX935567-SX943566	[*Provisional*] *Quaternary*: The Devonian limestones of Berry Head include a remarkably sequence of caves with associated deposits, some of which lie below present sea-level, ranging form –15 OD to +29 OD. The caves provide a unique record of marine transgression with 3 levels of horizontal passage development, at –2 to +2 m, +5 to 9 m and 22 to 29 m OD, clearly related to former sea level stands. The morphology of the caves is also typical of passage development at the boundary between fresh and saline waters. Cave sediments are extensive and speleothems have been dated using Uranium series methods, indicating ages between around 107,000 and 332,000 years for the caves. Shoalstone Beach, to the west of Berry Head Quarry, where most of the caves have been recorded, includes a raised beach platform at +8.5 m O.D., clearly related to the intermediate level of cave development on Berry Head. The beach is marked by a cobble deposit suggesting an ancient storm deposit. ***Reasons for registration as a RIGS site*:** The site is unique in the region, and similar features related to cave development under the influence of changes in sea-level in the Plymouth limestone are either inaccessible or have now been largely destroyed by development. The scientific value of the site is potentially national, although educational use is limited by health and safety considerations too viewing openings form a safe distance.

Table 7: Quaternary conservation sites in Torbay

2.8. Geological heritage in a cultural context

Cultural links to the geological heritage of Torbay are extensive. The limestones in particular have long been a source of building stone and many of Torbays older and more substantial buildings are constructed of this stone. Where naturally weathered, these buildings and structures such as older sea-walls, offer a marvellous opportunity to view the rich coralline faunas of Devonian age. One former quarry in particular, at Petit Tor, also specialised in cutting and polishing local limestone as an ornamental stone. Its most famous products were beautiful circular table-tops, inlaid with a colourful variety of local limestones, one of which was once displayed in the former Geological Museum in London and others are still in daily use in the Sedgwick Museum in Cambridge.

Torbay also has a historically important natural history museum in Torquay, with famous old collections of local Devonian and Quaternary faunas and was closely associated with one of the most important pioneers of the scientific study of cave deposits in Britain, William Pengelly. Arguably, Pengelly's most famous excavations took place at Kents's Cavern in Torquay, a site with a remarkable record of Pleistocene vertebrate faunas. In particular, Pengelly and others have found evidence of some of the oldest known inhabitants of Britian, namely stone hand-axes indicating the presence of humans akin to *Homo heidelbergensis,* some 500,000 years ago.

Key sites include: Goodrington beach car park sea-wall (SX894594 – limestones rich in relatively well-preserved stromatoporoids and colonial rugose corals), Meadfoot Beach sea-wall (SX936631-SX935633 – limestones with common stramatoporoids and corals), Torbay Museum (SX924636 – distinctive building largely constructed of fossiliferous Devonian limestones, housing historically important fossil collections from around Torbay), Berry Head Fort (SX944565 – Napoleonic fort constructed of Devonian limestone, includes geological interpretation in former artillery store), Paignton Zoo (including SX878595 – limestone exposures, disused quarries with associated lime kilns, plus cave entrances beside paths linking exhibits) and Kents Cavern (SX935642 – show cave with a range of stalactite formations and cave deposits with visible Pleistocene vertebrate remains, includes interpretation and displays of specimens).

Many other buildings and structures throughout Torbay also reveal local rocks with a range of geological features, especially fossiliferous Devonian limestones. Further survey will therefore reveal additional features within the built environment suitable for educational use or inclusion in guided trails.

3. GEOLOGICAL SITE PROTECTION IN TORBAY

3.1. Introduction

The introduction of the Wildlife and Countryside Act in 1981 first established the present mechanisms for legally designating and protecting '*Sites of Special Scientific Interest*' under UK law. This process was strengthened by the Countryside and Rights of way Act 2001, as presently administered in England by English Nature (a descendant of the former national Nature Conservancy Council). The same laws also cover the legal framework for designating 'National Nature Reserves' and 'Local Nature Reserves'.

Various Town and Country planning laws have also developed environmental themes, and most notably the Planning and Compensation Act (1991) required all local structure and development plans to contain nature conservation policies. These policies are required to specifically mention the need to identify and protect sites of biological, geological and geomorphological importance at both national and local level. Crucially, sites of local importance for nature conservation can be protected through this system by invoking relevant development planning laws. Torbay's statutory Local Plan for 1995 – 2011, developed in accordance with this legislation, therefore includes policies and strategies to protect natural heritage sites. These sites include areas of local importance for geoconservation, known collectively as '*Regionally Important Geological Sites*' or RIGS, although in Devon, the term '*County Geological Sites*' (CGSs), is preferred.

Five basic categories of protected natural site or area relevant to geological conservation have consequently been established in the Torbay district through this legislative framework:

3.2. Sites of Special Scientific Interest (SSSIs)

These sites are considered to be of at least national importance, although many can also be of international importance. Although designated and monitored by English Nature, the governmental agency for nature conservation in England, SSSIs remain owned and managed by the original owner or occupier in accordance with a consultation system comprising a list of designated operations which cannot be carried out unless formally approved by the agency.

The selection of geological sites for conservation in the UK has been taken place since the 1940s, but it was not until the late 1970's that such selection was put into a systematic framework by the initiation of the Geological Conservation Review (or GCR; Wimbledon *et al*. 1995; Ellis *et al*. 1996). The GCR selected around 3000 sites in England, Scotland and Wales within 97 subject blocks, the latter related to specific geological and geomorphological topics (e.g. within stratigraphical, palaeontological, petrological, mineralogical, structural or geomorphological disciplines). Site selection within each subject area – now termed 'Networks' – essentially recognised three classes of site:

- Sites of *international importance (e.g.* stratotypes, type localities, 'classic' sites, etc.)
- Exceptional sites (e.g. with unique, rare or unusual features, also 'Highlights' of UK geology)
- Representative sites *(e.g. showing* characteristic features of the GCR network)

Remarkably, this process and framework was never applied to sites in Northern Ireland, although an analogous selection structure is now used to classify sites.

As a consequence of the GCR survey, a remarkable 16 separate GCR sites were selected within the Torbay district, now notified within 11 SSSIs, as listed below with the GCR selection networks that they represent (see Section 2 for further details):

Babbacombe Cliffs SSSI (Marine Devonian, Permian-Triassic)
Berry Head to Sharkham SSSI (Permian-Triassic)
Daddyhole SSSI (Marine Devonian)
Dyer's Quarry SSSI (Marine Devonian)
Hope's Nose to Walls Hill SSSI (Marine Devonian (x2 sites); Mineralogy; Pleistocene/Quaternary of south-west England)
Kent's Cavern SSSI (Pleistocene/Quaternary of south-west England or Pleistocene Vertebrata)
Lummaton Quarry SSSI (Marine Devonian)
Meadfoot sea-road SSSI (Marine Devonian)
New Cut, Lincombe Drive SSSI (Marine Devonian)
Roundham Head SSSI (Permian-Triassic)
Saltern Cove SSSI (Marine Devonian, Permian-Triassic)

3.3. National Nature Reserves (NNRs)

Declared by English Nature and owned or leased and managed by that agency or another approved body (for instance a county Wildlife Trust), these sites represent some of the best and most fragile examples of Britain's natural heritage. Torbay includes the recently declared Berry Head NNR, managed by Torbay Coast and Countryside Trust, with a unique complex of Pleistocene cave systems and stratigraphically important exposures of Devonian limestone. None of these geological features, however, form part of the SSSI or NNR designation, although are proposed here for County Geological Site (CGS) status.

3.4. Local Nature Reserves (LNRs)

English Nature approval is required for the declaration of LNRs, which must be owned or leased by a local authority or other approved body. Sugarloaf and Saltern Cove LNR, Torbay, which includes the important Devonian and Permian exposures of the Saltern Cove SSSI, is one of two Local Nature Reserves in Torbay, (the other being Occombe Woods LNR), and is also managed by Torbay Coast and Countryside Trust.

3.4. County Geological Sites (CGSs)

These sites are selected and proposed through the Devon RIGS Group, an NGO whose voluntary membership includes members of the local universities of Plymouth and Exeter, together with a range of representatives from other locally based organisations, including the British Geological Survey, English Nature, the Environment Agency and Devon County Council. Sites considered to be of at least county importance for geological heritage are notified to the relevant local planning authority and protected through both local development plans and policies and voluntary agreements. Initially, six CGS were recognised in the Torbay district (Taylor and Grainger 1995) and a further 8 have been identified through the current survey. Sites selected are listed below, together with their equivalent GCR category – fuller descriptions can be found in Section 2:

Barcombe Mews (Permian-Triassic)
Barton Quarry (Marine Devonian)
Black Head-Anstey's Cove (Igneous rocks of SW England)
Breakwater Quarry (Permian-Triassic)
Brockenbury Quarry (Variscan structures of south-west England)
Brixham Cavern (Pleistocene/Quaternary of south-west England; Pleistocene Vertebrata)
Chapel Hill (Permian-Triassic)
Churston Cove-Churston Point (Marine Devonian)
Crystal Cave ('Structural geology', i.e. post-Variscan)
Goodrington Quarry and Road Cutting (Marine Devonian)

Hollicombe Head-Corbyn's Head (Permian-Triassic)
Hope's Nose (south) (Variscan structures of south-west England)
Petit Tor-Maidencombe (Marine Devonian, Permian-Triassic)
Sharkham Point to Berry Head (Marine Devonian; Mineralogy; Variscan structures of south-west England; Pleistocene/Quaternary of south-west England; Caves and Karst)
Quarry Woods Quarry CGS (Marine Devonian)

Although a number of these CGS sites overlap with existing SSSIs, separate listing is necessary to ensure that the identified features are taken into account in future management. This issue is particularly relevant where the designation is primarily biological, as in the case of the Berry Head NNR – it can also be relevant, however, within geological SSSIs, as management practice on the latter sites focuses on the conservation requirements of the nationally selected GCR site, which could, under certain circumstances, lead to inadvertent damage to non-GCR geological features.

3.5. South Devon Area of Outstanding Natural Beauty (AONB)

Although primarily a landscape designation, the southern-most part of Torbay forms part of this larger site. Enhanced planning controls as enforced within AONBs, serve to maintain a natural character and prevent damaging and inappropriate development.

3.6. IUGS Global Geosites programme

Although not a legal designation, the International Union of Geological Sciences (IUGS) with support from UNESCO and IUCN, has commenced compilation of a global indicative list of Earth Heritage sites of significant international importance. The aims of the IUGS Global Geosites Working Group, are:

(1) To compile the Global Geosites list
(2) To construct the Geosites database of key sites and terrains
(3) To use the Geosites inventory to further the cause of geoconservation and thus support geological science in all its forms
(4) To support regional and or national initiatives aiming to compile comparative inventories
(5) To participate in and support meetings and workshops that examine site selection criteria, selection methods or conservation of key sites
(6) To assess the scientific merits of sites in collaboration with specialists, research groups, associations, commissions, subcommissions, etc.
(7) To advise IUGS and UNESCO on the priorities for conservation in the global context, including World Heritage.

Crucially, several sites in Torbay are likely to be listed within several selection categories established within this global process, although individual site selection has not yet been carried out. Categories are as follows (after Wimbledon etc) with possible included sites:

Stratigraphic categories – Phanerozoic:
Devonian (marine) carbonates and clastics, Devon (i.e. historical type area for the definition of the Devonian system) (potentially including Daddyhole, Dyer's Quarry, Hope's Nose, Long Quarry Point, Lummaton Quarry and Saltern Cove GCR sites).
Permian-Triassic red bed sequence of Devon coast (potentially including Shoalstone Beach, Saltern Cove, and Oddicombe GCR sites and Petit Tor-Maidencombe CGS (proposed)).

Phanerozoic-Quaternary

Late Pleistocene Interglacial (OIS 7, 5e) raised beaches southern England, Cornwall, South Wales (potentially including Hope's Nose raised beach).

3.7. European Geoparks and UNESCO Geoparks

The European geoparks programme is derived from the concept of UNESCO Geoparks as developed by UNESCO's Earth Science Branch in Paris, as a geological equivalent to biosphere reserves (ref.). The European initiative was developed in the context of the European Community LEADER IIc Programme by the four initial European Geoparks, all within LEADER II zones (the Reserve Geologique de Haute-Provence, France; The Natural History Museum of the Lesvos Petrified Forest, Greece; Geopark Gerolstein / Vulkaneifel, Germany, and Maestrazgo Cultural Park, Aragón Spain). The network now includes x areas, including in Sicily, France and the north and south of Ireland and one in England. As defined in the project:

"A European Geopark is a territory which includes a particular geological heritage and a sustainable development strategy supported by a European programme to promote development. A European Geopark must comprise a certain number of geological sites of particular importance in terms of their scientific quality, rarity, aesthetic appeal or educational value"

"*A European Geopark has an active role in the economic development of its territory through raising the profile of geological heritage, including through the participation of its residents and promoting the development of geotourism. The Geopark should also support environmental education, training and research in aspects of the Earth Sciences and the enhancement of the local natural environment, including through sustainable development policies*."

The designation is ideally suited to the context of Torbay, where a rich geological heritage provides opportunities for developing linked educational, interpretative and public awareness programmes with a very real potential for sustainable economic benefits for the area when linked to tourism. The potential benefits of developing geological heritage management and education within this international context is discussed further in Section 5.2. As with IUGS Geosites, the designation has no legal protected area status, but it does commit network members to adopt a sustainable approach to the management of the geological heritage under their control.

Outside of Europe, equivalent designations under the title of 'UNESCO Geoparks' are gradually being established around the world, most notably in China (ref.), where a major international meeting on geoparks was held in June 2004. This designation is equally applicable in the UK and the next global geoparks meeting will be held in Belfast in 2006.

4. Managing the geological heritage of Torbay

4.1. Background

English Nature, as the governmental nature conservation administrator in England, has ultimate responsibility for ensuring that the national network of SSSIs is safeguarded and managed appropriately. It utilises the provisions of the Wildlife and Countryside Act 1981 and the Countryside and Rights of Way Act 2001 to achieve such ends, which include mechanisms to enforce management where the site owner or occupier has failed to take appropriate actions.

Every geological SSSI, such as those in Torbay, has a '*Site Management Brief*' document in place, which both scientifically describes the locality and provides guidelines for management. In addition, and in accordance with national guidelines developed by the Joint Nature Conservation Committee, each site has a defined set of conservation objectives and monitoring targets. Site condition is assessed using these guidelines, to be reported nationally to central government.

Nevertheless, sensitive site ownership remains crucial to the success of SSSI protection in the UK and Torbay is remarkable in that 7 of the 11 SSSIs in the district of geological importance are now leased by the Torbay Coast and Countryside Trust. 3 SSSIs are in the ownership of Torbay Council, the local government body for Torbay and 1 is in private ownership, although this owner is an active member of the Torbay Heritage Forum. Torbay Coast and Countryside Trust is therefore in a unique position to implement the management regimes developed by English Nature and its own specialists and ensure that the geological heritage of Torbay is protected and enhanced. This influence extends to all other nature conservation sites in the district, through collaboration with Torbay Council, including County Geological sites. In addition, recent developments by the Trust specifically aimed at safeguarding the geological heritage of the area include the implementation of a policy on the collection of fossils based on the national guidelines established by English Nature (1996).

4.2. Conserving Earth heritage sites – the 'Integrity' and 'Exposure' sites concept

The key document in what is essentially a transition from a selection phase to a management phase for Earth science sites in the UK is the Nature Conservancy Council's '*Earth Science Conservation – A Strategy*' and its companion handbook on conservation techniques (1990a, b). This document includes the first description of an Earth Science Conservation Classification (ESCC) and demonstrates its value in determining appropriate management criteria for different types of sites. Crucially the concept of 'integrity' and 'exposure' sites was introduced as fundamental to this process:

Exposure sites: The scientific and educational value of 'exposure sites' is as accessible exposures of deposits which are otherwise extensive, but not visible due to being buried by soil, vegetation and constructions. Exposure sites include:

- Disused quarries, pits and cuttings (ED)
- Active quarries and pits (EA); Coastal and river cliffs (EC)
- Foreshore exposures (EF)
- Inland outcrops and stream sections (EO)
- Mines and tunnels (EM)

The primary aim of conservation at such sites is to maintain a representative exposure of the deposit, in a context in which it can continue to be used for research and education.

Integrity sites: At such sites the deposit or geological/geomorphological feature is relatively small in extent and is therefore considered to be finite and irreplaceable; such sites include:

- Static (fossil) geomorphological sites (IS)
- Active process geomorphological sites (IA)
- Caves and Karst (IC)
- Unique mineral, fossil or other geological sites (IM)
- Mine dumps (ID)
- Mineral and thermal springs (IW)

The primary aim of conservation at such sites is therefore to maintain the integrity of the deposit or feature by minimising any changes and controlling any operations that might lead to any net loss or damage.

Moveable geological heritage: A third category of geological heritage is becoming increasingly relevant, however, the concept of *Moveable geological heritage (or "Movable Natural Values")*. This category includes all e*x situ* geological heritage, such as specimens in museum and other collections and becomes highly relevant to site conservation where the locality includes collectable minerals and fossils. Under such circumstances, the needs of geological heritage conservation can be achieved by ensuring that any significant specimens removed from the site as part of genuine research or educational activity are deposited in an appropriate museum or other nationally recognised collection. Ironically, for some integrity sites at high risk of damage by irresponsible and illegal collectors, such as the Hope's Nose gold-bearing veins, conservation in an institution may be the only secure option.

4.3. Threats to Earth heritage sites and management solutions

Threats to the integrity of Earth heritage site were also reviewed in the 1990 Nature Conservancy Council Strategy, together with a review of the main management solutions to address such problems. The classification presented in the original document remains a very useful framework and was subsequently adopted by Wilson (199?) and Gray (2003) and is presented below, with minor modifications after Page (2004):

1. Natural degradation and vegetation growth: Affects most lowland and inland sites in a temperate, wet climate regime. Sites can become concealed or even inaccessible as a consequence of the vegetation growth, including the development of scrub and the growth of lichens. In addition, certain exposures, in particular of mudrocks and soft Quaternary deposits can become chemically and physically weathered, thereby losing some of their original physical and chemical characteristics. In many cases the latter can be associated with either the development of scree and talus or even collapse, in the case of poorly on non-cemented sediments. The surface weathering of some limestones, such as those of Devonian age in Torbay can, however, can also lead to surface etching and an enhancement of the visibility of internal features such as fossil corals.

Solutions: Controlling vegetation growth through the use of hand tools or, in some cases, mechanical excavators, are standard management tools in the UK. Under certain circumstances, rock-face stability issues, especially in some disused quarries, may make vegetation clearance problematic and additional geotechnical advice may therefore be necessary. Vegetation can also be controlled with non-persistent

herbicides, such as glyphosate. Clearance of limestone exposures should be undertaken with great care so as to minimise surface damage to rock faces - the surface weathering of some limestones, such as those of Devonian age in Torbay, has typically lead to surface etching and an enhancement of the visibility of internal features such as fossil corals – such features can be easily damaged by abrasion or impact.

Accumulated scree and talus can also be removed by mechanical means to re-expose concealed parts of exposures. Where this material includes fragments of the rock-face being cleared, it is advisable to leave excavated materials as a rock-pile within the site, to enable educational visitors to study the deposit without the necessity to remove in-situ samples, which may lead to further deterioration of the exposure.

In sites requiring periodic clearance of scree and fallen rock, it is advisable to leave a minimum 5 metre zone of level ground between the base of the exposure and any structure such as a fence. This 'clearway' should be sufficient to allow vehicle access to aid any future site clearance works. In addition, it is recommended that at least a similar distance is kept clear of trees at the top of a rock face, as root growth can loosen rocks and create a hazard. Similarly, fences and walls should not be placed close to the top of a rock face as even minor falls of loose materials can then threaten or undermine the structure and consequently make it difficult for clearance operations to improve a quarry face by scaling of loose materials. Such operations should only be carried out be qualified contractors, several of which now specialise in safety works on rock faces.

2. Coastal protection and flood defence: Soft coastlines are most at risk from loss of exposures or damage to landforms and natural processes by the construction of coastal defence works. In Torbay, the majority of areas at risk from erosion due to the presence of relatively soft deposits have already been defended, due to the presence of intensive development. There are, however, a number of areas where recent coastal erosion has threatened to lead to potentially damaging works, most notably at the eastern end of Meadfoot beach, where the coastal road is at risk, and at Oddicombe. At Redgate Beach, although not strictly a consequence of coastal erosion, collapse of the coastal slope, has led to the area being closed to the public and consequently not currently being available for educational use.

Solutions: 'Soft engineering' provides many alternatives to 'traditional' 'hard' coastal defences, such as beach nourishment, and the use of groynes and off-shore berms. Areas at risk and appropriate solutions will generally be identified within Shoreline Management Plans and impact assessment procedures come into play when schemes are proposed. The greatest risk to Torbay's coastal geological heritage, however, comes from small local and typically private schemes which 'side-step' the normal legal procedures. Examples include the tipping of limestone waste onto Meadfoot Beach in a perceived attempt to protect the sea-wall – although fortunately, however, once the error was discovered, the material was quickly removed.

3. Waste disposal (landfill and effluent): The disposal of waste materials, including domestic waste and construction materials, is a major problem for many Earth Heritage sites, especially where illegal tipping is prevalent. In Torbay there are no waste disposal sites in disused quarries – a major issue for geoconservation in many areas – but the high price of commercial waste disposal and a desire to rapidly dispose of unwanted domestic items, such as appliances and garden waste, on the part of a small number of householders means that illegal fly-tipping is an increasing problem. Such tipping can bury scientifically important exposures, or inhibit access to them. It can also create significant health and safety issues, as jagged metal, broken glass and putrefying organic materials can, in the extreme, render sites unusable for educational group work.

The disposal of liquid effluent or contaminated water can similarly create major health and safety issues, in particular to cave systems, where underground karstic drainage systems can channel discharges into

accessible passages and chambers. As well as producing noxious gasses and toxic liquids, such discharges can destroy sensitive cave ecosystems and chemically alter or degrade cave formations and deposits, hence affecting their scientific value as well.

In Torbay, fly-tipping, in particular of domestic and builder's waste can be a local problem at some sites, although constructions of barriers such as a perimeter fence around Industrial units at Lummaton Quarry can reduce the incidence. Incidences of effluent discharge affecting cave systems appear to be rare and as the sewage outfall at Hope's Nose has now been bypassed, this major health issue for site users is fortunately history.

A significant issue at certain sites, however, are the health and safety consequences of inconsiderate recreational use, including again at Hope's Nose, camping and other activities which frequently lead to spreading of rubbish and other contaminating materials.

Solutions: An effective measure to control fly-tipping is the construction of barriers to prevent vehicle access into sites – some materials may still be thrown over such structures, but at least the volume is unlikely to be significantly site-threatening. The nature of the materials that have been historically dumped into sites, may mean that clearance of exposures may need to carried our professionally by appropriate contractors, with the obvious assurances that materials removed are taken to an appropriately licensed disposal site! Where the materials are mainly inert soil and rubble, removal to an unimportant area of the same site may be a simpler alternative.

Illegal tipping of commercially generated materials can also be tackled by extra-vigilance of people living near sites, especially if they can be provided with appropriate contact telephone numbers for reporting incidences. Addressing domestic disposal is always problematic, as disposal at a council-designated facility is often no more complicated then transporting the waste materials to a geological site to illegally dump it... As well as improving physical barriers to sites at risk, signage with information about the location of domestic waste-disposal facilities may be beneficial, and where the materials are being generated by local residents, leafleting is certainly recommended. Similarly signage may assist resolving problems associated with recreational activities, although site inspections and the invoking of legal powers and processes may also be necessary where issues are most significant.

Although rarely an issue in Torbay, any detection of effluent discharge should be reported immediately to the Environment Agency.

4. Mineral / aggregate extraction and restoration of working sites: In densely vegetated lowland Britain, active quarries frequently provide the only 'fresh' exposures of an otherwise concealed geological heritage – under certain circumstances, however, the working of such sites can also be a major threat, where relatively small scale deposits and features are at risk from complete or partial removal (cf. 'integrity' sites). In addition, inappropriate restoration and landscaping schemes, post cessation of working, can cover exposures or make access difficult or impossible.

As Torbay has no working minerals sites**]**, active quarrying is no longer an issue – either beneficially or negatively – however the historical consequences remain. The most significant issues are at Lummaton Quarry, where quarrying removed most of the famous 'Lummaton Shell Bed' – an 'integrity deposit' – and high, vertical faces make safe access difficult. Berry Head Quarry is also a classic example of where quarrying not only removed integrity Earth heritage features in the form of cave systems, but also damaged cultural heritage – parts of the napoleonic fort.

Solutions: Within working sites, the modification of working and restoration schemes to provide safe and accessible exposures or minimise damage to integrity features is the typical approach, requiring the use of appropriate planning systems and engineering solutions. In disused sites, however, the absence of financial resources and logistical support – e.g. availability of machinery – typically makes modifications of quarry profiles difficult. In addition, as many sites have been worked to their original planning permission boundary or are now constrained by structures such as walls and buildings, modification of quarry faces, for instance by benching to improve access is now virtually impossible.

In sites with high faces, carefully consideration will need to be given about the nature and level of access permissible. In open access areas no measures may be possible, beyond simple warning signs (worded in accordance with current accepted practice regarding the identification of natural / semi-natural risks). In more restricted sites, safe public access can be promoted should either a geotechnical risk assessment prove favourable or if a barrier or fence is erected at an appropriate distance from the base and/or top of the quarry face. Any such barrier should, however, include a gate to permit authorised access for study and also clearance of scree and vegetation (for instance mechanically – see *Natural degredation*, etc. above also).

Improved access to different levels in a high quarry face for study can be achieved by banking soil and scree against the rock face or excavating an inclined path or track. Access to such inclines is likely to be primarily for scientific use, although in certain cases, risk assessments or the design may favour/facilitate wider use. At Lummaton Quarry the access problem was solved by creating a new, gated access to the upper levels of the quarry and hence the last surviving exposures of the Lummaton Shell Bed.

5. Civil engineering, industrial and domestic developments and projects: Development is a major threat to many Earth heritage features including both geological sites and geomorphological features. Loss or damage can be a result of direct burial of exposures, effective sterilisation by removing potential access to buried deposits, partial or complete removal of features and by changing natural systems such as by canalising rivers and streams.

Historically development has been a major issue for Earth heritage sites in Torbay, especially the construction of industrial estates and housing / recreational complexes in disused quarries, for instance at Barton Quarry and at Lummaton. There are also obvious links to *Coastal protection*, etc. (see above), where development close to the coast either incorporates or leads to a need for the construction of coastal defences.

Solutions: Modern planning systems and development planning can minimise the risk of future damage by development to geological and geomorphological sites – including through appropriate impact assessment procedures. In reality there are many positive benefits for incorporating geological heritage into development schemes and a range of engineered solutions to ensure a mutual co-existence. At Lummaton Quarry, construction of a barrier fence to separate the geologically important quarry faces from the area of industrial development was an important measure – together with an alternative access route.

6. Forestry: Loss of or damage to geological exposures or landforms by forestry operations is mainly an issue in upland areas, where the use of machinery to prepare the ground and the eventual concealment by growing trees of landforms can be a major issue. Elsewhere, localised planting or even passive allowance of scrub development can create similar problems.

Solutions: Minimisation of issues associated with tree planting is best achieved by maintaining non-planting zones around geological features, ideally a minimum of 5 metres wide to allow mechanical access for clearance works (cf. *Natural degradation*, etc. above). Tree roots can also be damaging, not only in

loosening rocks on quarry faces, but also by penetrating and consequently physically and chemically damaging sensitive deposits – it is important, therefore, that tree growth is controlled above geological exposures where there may be a significant risk of either process.

7. Agricultural and other land management practices: Agricultural activity includes a number of operations which do not require a formal planning permission under current Town and Country planning legislation. This can include the deposition of some agriculturally derived waste materials in disused quarries which are not subject to statutory conservation protection (e.g. SSSI designation), with obvious potential consequences for geological heritage.. The construction of certain farm buildings, drainage systems, deep ploughing, etc, all have the potential to create problems for Earth heritage conservation. In Torbay, however, the dominantly urban environment means that there is limited risk of any of these issues becoming significant.

The complexities and requirements of different disciplines within heritage protection, can however, lead to potential conflicts of interest. Examples include the construction of coastal defence works to protect cultural heritage features such as archaeological sites leading to damage to geological features in Hampshire and the installation of heavy equipment for bat-related monitoring on top of delicate geological features, including a unique Pleistocene bone deposit elsewhere in Devon.

In reality, however, most cases of perceived 'conflict' are a consequence of poor communication, and in reality the aims of geoconservation and ecological and cultural heritage conservation are eminently compatible.

Solutions: Agri-environment schemes and an increased awareness of geoconservation issues and opportunities amongst countryside agencies and advisors is crucial to addressing agriculture related issues. Similarly, improved mutual understanding and communication between geological, ecological and cultural heritage management organisations and specialists will not only avoid potential conflicts, it can also present new opportunities.

An excellent example of the potential benefits of collaboration from Torbay was the discovery of common Kidney Vetch at Lummaton Quarry, the food-plant of caterpillars of the rare Small Blue Butterfly, during a routine inspection of the geological SSSI. Subsequent visits revealed the region's largest known colony of the butterfly and follow-up scrub-clearance has not only improved geological exposure, it has enabled the colony to expand.

8. Overuse or misuse: In the UK, large scale site protection issues such as those related to development and waste disposal have been largely addressed through a well developed legislative framework for site protection. One of the most significant remaining threats to a key group of sites where the key geological features are fossils and minerals, are third party collecting activities. This '*moveable geological heritage*' lacks direct protection under UK law and its loss is to date virtually unaddressed.

Britain has a long traditional of amateur naturalists, many of whose activities included the collecting of items of natural-heritage interest. UK geology, in particular, still benefits from the healthy interaction between amateur enthusiasts and academic specialists (Page *et al*. 2000, etc). There is, however, a small but very active group of collectors whose main interest is either the selfish accumulation of specimens or commercial exploitation, including to supply a burgeoning international, and often now web-site based specimen trade.

In the extreme, this activity can lead to the virtual removal of sections of geological sites, as has happened to the gold-bearing deposits of Hope's Nose. In the latter case, illegal collectors have used rock saws to

extract mineral-bearing calcite veins from the Devonian limestone, leaving the site in a badly damaged condition with most of the accessible sections of its internationally important deposits removed. This material has been sold *via* catalogues, mineral fairs and web-sites and such activities have regrettably also been supported by national institutions failing to ensure that when purchasing materials they have been obtained legally (ref.).

Hope's Nose is a nationally extreme case, however, but specimen collecting can also inadvertently lead to a loss of geological resource at other sites, if the rate of removal outstrips erosion. For instance St. Mary's Bay, south of Berry Head, has long been noted as source of fossil corals and shells, which weather out of early Middle Devonian slaty mudrocks. Erosion at the site is, however, limited and fossils only typically become visible after a period of beach-tumbling of scree material. As a result, the collection of fossils in the bay over the last 20 years or so has led to a marked decrease in the availability of fossil material and whereas, for instance, large solitary corals were once common, they are now relatively rare. Clearly at this site, the continued recreational collection of fossils is not *sustainable*.

Other non-geologically inspired recreational activities can also occasionally damage geological sites, such as climbing and caving, although neither of these activities are believed to be currently a significant issue in Torbay as limestone rock-faces are relatively robust and the main cave systems are all restricted access. A more significant issue, however, especially where sites are to be promoted for public access, could be the abrasion of beautifully etched-out fossils, especially corals and stromatoporoids, by visitors walking or climbing over key exposures. Attempts to collect these faunas by inexperienced persons would also be extremely destructive..

Solutions: In extreme cases of damage to sites by collecting activity, legal powers associated with SSSI or property-ownership legislation can be invoked. In the former case, the recent Countryside and Rights of Way Act 2000, provided mechanisms, for the first time, to address third party activities, where the land-owner is not a party to the operation. A key issue remains, however, the identification of those responsible, and local assistance can clearly be beneficial in informing the relevant authorities.

Nevertheless, as large scale and consequently damaging collecting activity, is frequently linked to the commercial sale of specimens, intelligence gathering at rock and mineral fairs, using specimen-dealing web sites and dealer-produced catalogues can be very successful. In the case of the Hope's Nose Gold, an example of the latter led to a police investigation, and the seizure of materials taken from the site (ref.). Unlike many other European countries, UK law does not specifically protect geological specimens, especially when they have been removed from the site, and even at that initial stage, very few sites actually have any real legal controls on specimen collecting (the latter include a restriction on specimen collecting as part of the SSSI designation; ref.). As a general approach to this issue, organisations such as English Nature promote a Code of Conduct for 'responsible' fossil collecting, which acts as a guide as to what activities are appropriate and which are not, in the context of geological conservation. In extreme cases, however, such as at Hope's Nose, scientific removal of the remaining deposit to a museum or university may ultimately be the only conservation method guaranteed to safeguard the unique deposit.

For the continued development of geological science, both in the UK and abroad, however, it is crucial that geological sites do remain available for the responsible, bone-fide collection of specimens for research and education. Any measures which are adopted to protect sites should not therefore inappropriately restrict such activities, otherwise the site will loose its scientific value and hence a key aspect of its original justification for conservation. In addition, suitably experienced amateur geologists and amateur groups still have a role to play in this process and under certain circumstances it may also be appropriate to allow such parties to collect samples at certain key sites, provided that such sampling is linked to an approved scientific project. Crucially, geological heritage conservation can be achieved by ensuring that scientifically important

specimens are deposited, without charge, in a recognised institution, typically a museum or university – the emphasis simply shifts from site-based to institution-based geoconservation.

TORBAY COAST AND COUNTRYSIDE TRUST POLICY ON FOSSIL and MINERAL COLLECTION

Fossils are a key part of our natural heritage and form a major scientific, educational and recreational resource. They are fundamental to understanding the evolution of life and past environments. Fossils also provide a basis for the division and correlation of rocks the world over. Fossil collecting is an activity pursued by many people, for whom discovering the fossilised remains of ancient life provides a stimulating experience of the natural world. However, the available fossil resource is finite and it is only through a prudent approach to collection that this resource will remain viable for future generations to experience, study and enjoy.

Responsible fossil collecting In most circumstances responsible fossil collecting can offer positive benefits for Earth heritage conservation and the furthering of geological understanding. This is particularly true where the fossil resource is extensive and subject to high levels of natural or artificial degradation, as in eroding coastal sections or active quarries. In such situations fossils can be lost unless collected. The responsible collecting of fossils can therefore be an acceptable approach to the management and safeguard of our fossil heritage.

Irresponsible fossil collecting Irresponsible collecting delivers no scientific gain and is therefore an unacceptable and irreplaceable loss from our fossil heritage. It will pose a clear threat where fossils are rare or the fossil resource is limited in extent, as in a cave or a river channel deposit. Collecting without proper recording and curation, inexpert collecting, over-collecting and inappropriate use of power tools and heavy machinery are likely to reduce or even destroy the scientific value of such sites. Unless the activity is undertaken in an appropriate manner, TCCT will oppose fossil collecting on the small number of Sites of Special Scientific Interest where this activity would cause significant damage to the special interest.

Code of good practice Adopting a responsible approach to collecting is essential for conserving our fossil heritage. The basic principles set out below should be followed by all those intending to collect fossils.

- **Access and ownership** - permission to enter TCCT land and collect fossils must always be sought and gained in writing and local byelaws/ site restrictions should be obeyed. A clear agreement should be made over the future ownership of any fossils collected.
- **Collecting** - in general, collect only a few representative specimens and obtain these from fallen or loose material. TCCT recognises that formal academic research may require collection of fossils in situ, parameters and methodology of any such activity should form part of written agreement.
- **Site management** - avoid disturbance to wildlife and do not leave the site in an untidy or dangerous condition for those who follow.
- **Recording and curation** - always record precisely the locality at which fossils are found and, if collected in situ, record relevant horizon details. Ensure that these records can be directly related to the specimens concerned. Where necessary, seek specialist advice on specimen identification and care. Fossils of prime scientific importance should be placed in a suitable repository, normally a museum with adequate curatorial and storage facilities. A copy of all records/ reports must be forwarded to TCCT.
- **Indemnification and licensing-** Persons entering TCCT land as part of formal academic research or as part of a group, club or society are also required to indemnify TCCT against liabilities arising from their visit, they may further be required to provide proof of insurance cover.
- **MINERALS-** All principles and practices stated above also apply to the mineral resource and its collection at all TCCT sites.
- **SSSIs-** Persons wishing to undertake the above activities on areas designated as Sites of Special Scientific Interest are reminded that English Nature must be consulted and may require an additional formal request for consent.

Table 8: Torbay Coast and Countryside Trust policy on fossil and mineral collecting

In Torbay, as a consequence of relatively slow coastal erosion rates, there are no sites at which the recreational collection of fossils is sustainable, although limited and licensed removal for educational purposes may by permissible in certain locations such as Hope's Nose Quarry and St. Mary's Bay. To such ends, Torbay Coast and Countryside Trust has adopted a policy for geological activities on Trust owned or managed land, which will promote this approach (Table 7).

More general aspects of geological site use are incorporated into the national Geologist's Association Code of Conduct for geological field work (19xx) and analogous codes also exist for climbers and cavers, including those produced, respectively, by the British Mountaineering Association and the National Caving Association.

To promote a responsible approach to site use and inform visitors of any restrictions (and of course why the restrictions are in place!), signing is required at access points to sensitive sites, together with appropriate messages incorporated into a range of publications and guides. Regular site monitoring is also essential, especially where key features may be at significant risk. Where sensitive features such as fossil corals can be damaged by abrasion, measures could also be adopted to minimise risk, such as physical barriers, 'deflective' interpretation strategies and way-marking of paths.

The use of agreed management plans is also a very valuable approach, especially where site management can be effectively controlled by a site owner, occupier or manager. Such an approach is fundamental to Cave Conservation, where complex conservation issues and the great sensitivity of the features present – not only to physical damage but also to environmental and chemical changes – has led to the production of national guidance by the National Caving Association (ref.).

4.4. Management planning for Earth heritage sites

A fundamental aspect of management planning for geological sites is the clear identification of the key features to be conserved. To aid this process, the concept of '*manifestation*' of the Geological Conservation Review (GCR) interest has been introduced through the JNCC Common Standards Monitoring guidance for Earth science sites (2004).

The GCR categorisation is as equally applicable to RIGS sites as SSSIs and firmly states the context within which the site should be viewed or assessed – for instance for its contribution to the study of *Marine Devonian* sedimentation and palaeontology in the UK or its significance in the context of the events and processes that characterise the *Pleistocene/Quaternary of south-west England*. The *manifestation* of this GCR Network or *theme* (for non-SSSI sites) is what is unique or special about the sites within the context of their selection network or *theme*. For instance at Hope's Nose, the manifestation of the *Pleistocene/ Quaternary of south-west England* network is the raised beach and at Lummaton Quarry, the primary manifestation of the *Marine Devonian* network is the palaeontological importance of the Lummaton Shell Bed.

This initial process is crucial to the correct assessment of the conservation requirements of the site, using the Earth Science Conservation Classification, for instance a first examination of Lummaton Quarry might suggest that an exposure site classification as '*Disused quarries and pits*' might be appropriate – however as the primary manifestation of the Marine Devonian network is a small surviving exposure of the Shell Bed, for conservation purposes, classification as an integrity site - *Unique mineral, fossil or other geological sites* (IM) – is more appropriate. This classification not only aids the identification of the keys threats to which the site might be at risk, it also guides management practice.

Once the 'manifestations' or key *expressions* of the geological or geomorphological interests of a site has been established, and its ESCC classification theme or themes derived, based on its scientific importance, conservation objectives can be developed. Crucially, as few defined sites are geological 'homogenous', it is likely that a range of key expressions or manifestations of a theme or indeed of several themes may be present, a site may therefore need to be *zoned* for management purposes, based on the scientific nature and conservation requirements of each of the different features. Each zone is effectively a separate *management unit* and may therefore require different management objectives.

When considering objectives, JNCC's (2004) guidance, based on previous work within English Nature and other country agencies, recommends that four fundamental aspects of the *quality* of the site are addressed:

- *Visibility* – Is sufficient exposure of the key manifestation/s of the interest theme/s visible or are the equivalent key manifestation/s of the geomorphological interest theme/s sufficiently visible to meet the needs of general scientific study and education? (e.g. is it concealed by vegetation, trees, structures, etc.?).

- *Quality / Physical Integrity* – Is the exposure or feature in good condition, e.g. free of damaging excavations, structures, etc. and not constrained or threatened by such structures or activities which could prejudice its future continued management in favourable condition.

- *Extent* – Are the geological / geomorphological features of the site of sufficiently size to demonstrate the full range of expressions of the selection theme and allow them to be maintained in a favourable condition.

- *Process dynamics* – for active geomorphological sites, where the naturalness of the hydrological, coastal, etc., proposes driving the continued evolution of features within the site is crucial to its scientific importance.

Assessment of each of these four qualities guides the current setting of conservation objectives for geological SSSIs by English Nature, although typically the new system has been informed by an earlier programme of production of *Site Management Briefs* (SMBs) - site-specific documentation and management guidance reports. The latter exist for all geological SSSIs in England and are a valuable resource for site management, not least in that they contain a photographic record of site condition, which can act as a base line for future condition monitoring (refs.). Copies of these documents are held in English Nature's head office in Peterborough and each Local Team has a set specific to its area of responsibility. Copies of SMBs for Torbay sites are held in the Devon Team Office in Exeter (Renslade House, Bonhay Road, Exeter, EX4..) and duplicates are also deposited with Torbay Coast and Countryside Trust.

4.5. Condition monitoring and site enhancement

Condition assessment is linked fundamentally to conservation objective setting and aims to monitor if the condition of the site and its contained features conform to the idealised aims of the objectives. However, where sites are incorporated into more general countryside management programmes and objectives, non-scientific aspects of site condition may also be important. Under such circumstances, the following features require periodic review:

- Access
- Completeness of exposure of designated/ cited features (or '*manifestations*'), i.e. *Visibilty*, *Quality/Physical Integrity*, *Extent*, *Process dynamics*.
- Levels of natural degradation

- Levels of degradation or damage due to human activity
- Levels of site use, with particular reference to cumulative pressure and misuse
- Integrity and security of resource, including potential future threats
- Naturalness of physical systems (for a process-related site)
- Condition of linked facilities (interpretation, etc.)

Templates can be established to aid such monitoring, and have the advantage of standardising responses and enabling non-specialists to monitor geological sites. It is crucial, however, that a rigorous baseline is established by appropriate specialist, otherwise there is a risk of under-recording of site damage.

Condition assessment will identify any site-management issues that may need addressing to ensure that the features for which the site is important are maintained or restored to a favourable conservation condition. Site enhancement may also include the installation of visitor facilities, such as interpretation, or the inclusion of the site within guided walks or self-guided trails – both of which have implications for the management of the site itself. In general, therefore, the following are typical site-enhancement measures that may need consideration following site inspection:

- Mechanical or hand clearance of scree, vegetation, or obstructing materials and structures - to re-expose geological features
- Reinstatement of natural processes - for process related sites
- Control or prevention of natural processes - where processes may be damaging static or inactive features
- Geotechnical engineering – to improve access or safety.
- Improving accessibility – improving or constructing paths, gates, etc.
- Visitor management schemes – including signs to inform or direct visitors, barriers, wardens, etc.
- Interpretation – to inform and educate visitor.

4.6. Interpretation for Earth heritage sites

The principles of site interpretation, as applied to Earth Heritage sites, are reviewed by Page et al. (1995?) – available free of charge from English Nature (details..) – and are briefly reviewed here. The aims of environmental interpretation can be achieved through a range of methods including publishing and broadcasting media (radio, television, newspapers and magazines), general education (information leaflets, guidance notes, seminars / conferences, adult / continuing education, museum activities, etc) and through the site-based resource, using sign boards, self guided trails, heritage centres and guided walks.

Site-signing can be a very effective method in areas where visitor numbers are high, and can have the multi-layered function of:

- Informing visitors of the conserved status of the site
- Controlling or managing visitors and therefore aiding site conservation
- Establishing to role of the organisation or organisations responsible for the management and/or protection of the site
- Interpreting features at the site for visitors.

Signs with well developed interpretative rather than management themes have additional benefits (ref):

- They enhance visitor enjoyment in the belief that an understanding of the countryside increases the pleasure derived from visiting it
- They increase the public understanding and appreciation of the countryside leading to a respect for it and an awareness of the need for its conservation

- They facilitate the management of a natural resource by influencing the pattern of visitor movement
- They satisfy a visitor demand for information.

Not all sites are suitable for sign boards, however, and in general their use is best restricted to sites where geological features are obvious or specatacular and visitor numbers are high – to offset high production costs, key teaching sites where their presence can significantly aid educational use and sites at risk from over use, bad practice or ignorance – although only then if there is an appropriate level of management to ensure that the facility is maintained in good order.

Interpretative signs are most effective if they are linked into an existing or planned natural and/or man-made heritage interpretation or management programme (e.g. with links to museums, centres, other sites, etc.) and where there must is a strong and interesting story to be told (and preferably dramatic or obvious features, so that the interpretation provides links with features people can see or experience…). Under certain circumstances, the establishment of Heritage centres, may be a natural progression from simple site signboarding, although the financial and managerial implications will restrict their use to only the most scientifically important and well-visited locations.

Geological trails or "*...booklets [or leaflets] involving the identification and explanation of a collection of linked sites which can be examined by the reader without the physical presence of an interpreter, i.e. self paced structured distance-learning packages"* (Keene 1995) provide another very effective way of guiding visitors around sites where sign-boarding may be inappropriate. They also give a visitor more freedom and independence to select, explore and experience geological features in natural settings.

The principles of self guided trail production are fully discussed by Keene (1995) and reproduced in Page *et al.* (1995?), and include the following considerations:

- Is your trail really necessary or is some other technique more appropriate?
- Target audience - who is likely to use the trail and will their expectations influence its development?
- Focus - what is the theme of the trail and what do you wish your target audience to gain from using it?
- Participation - what degree of interaction do you expect to achieve with your chosen target audience?
- Adjustment to audience - can some of the needs and expectations of other potential audiences be combined with those of your target audience without significantly prejudicing the effectiveness of the trail?
- Language and authorship - populist communicator or technical specialist?
- Logistics and finance - availability of sponsorship, maintenance services, etc., site access permissible (e.g. along rights of way, etc.) and levels of site safety, etc., are acceptable for the target audience.

What ever form of interpretation is established, however, as with conserved sites, some form of monitoring is crucial, not only to ensure that the facility remains in good order (for sign boards), widely available (for guides) and that the geological/geomorphological features interpreted remain visible and accessible on the sites themselves. In addition, it is also advisable to monitor the effectiveness of the interpretation schemes themselves, for instance using the methodology of Hose (19xx, *in* Page *et al*. 1995, etc.).

4.7. Conservation objectives for Torbay's geological heritage – recommendations for site management

The principles and practice described above have been applied to Torbay's suite of geoconservation sites, as described and listed in sections 2 and 3, and are tabulated below. Each site includes ESCC classifications (see Section 4.2) for each theme (e.g. GCR category – Sections 2, 3.2, 3.3), a list of key threats (Section 4.3), general conservation objectives (Section 4.4), management recommendations (Section 4.5) and a summary of its interpretative potential (Section 4.6). Note that the conservation objectives listed here are independently derived from those that English Nature may have established for SSSI sites based on its own corporate priorities. Cross-reference with these is therefore advisable when producing definitive site-specific management plans.

Abbreviations as follows: TCCT = Torbay Coast and Countryside Trust; TC = Torbay Council; DRG = Devon RIGS Group; EN = English Nature; SWW = South West Water;

Site name	GCR theme	Key features/ ESCC	Main threats	Conservation Objectives	Management recommend-ations/ actions	Interpretative/ educational potential
Babbacombe Cliffs SSSI	Marine Devonian (GCR)	Exposures of Barton Mb (Torquay Limestone Fm.) in coastal slope (EO)	1. Growth of trees and other vege-tation obscuring exposures; 5.Civil engineering works to stabilise slopes. 7.Maintenance as woodland without intervention.	1. Ensure that future coastal or footpath main-tenance works do not lead to any net loss of exposure of 'Babbacombe Shales'. 2. Clear and main-tain key expo-sures of Barton Limestone, etc. in wooded slopes above beach, incl-uding access routes. 3. Ensure that cliff stabilisation and other works at Oddicombe Beach do not lead to any loss of key expo-sures of the strat-otype of the Oddi-combe Breccias Fm.. 4. Ensure that the collection of geo-logical samples from in-situ is only for research or education.	Initiate survey of exposures of Barton Limestone, etc. in wooded slopes and establish clearance and maintenance programme.	(a) Incorporation of exposures of 'Babbacombe Shales' and Oddicombe Breccias in guided trails. (b) Installation of sign board at Oddicombe telling the story of the Bay (tectonic inversion of rocks in Babbacombe Cliffs and desert floods of the Oddicombe Breccias)
		Foreshore and cliff of 'Babbacombe Shales' (Nordon Fm.) (EC/EF)	2. Coastal protection; 5.Civil engineering including cliff stabilisation and footpath mainten-ance projects; 8.Collection of rare fossil faunas.		Ensure that TC is aware of geological significance and consults with EN/TCCT before initiating any works.	
	Permian-Triassic (GCR)	Cliff exposures of Oddicombe Fm. (stratotype) (EC)	1.Natural degra-dation and veget-ation growth; 2.Coastal protection; 5.Civil engineering including cliff stabilisation		Ensure that TC is aware of geological significance and consults with EN/TCCT before initiating any works.	
Barcombe Mews Quarry CGS	Permian-Triassic (CGS)	Exposure of Torbay Breccia Fm. in disused quarry (ED)	1.Natural degr-adation and veget-ation growth; 3.Fly-tipping; 5. Domestic housing and related develop-ments; 8. Misuse, e.g. inappropriate recreational activities	1. Maintain exposure in safe accessible condition for school-level use.	1. Ensure that vegetation and any tipped material is regularly cleared and face is inspected for any potential safety issues.	(a) Provide simple site-signage to inform visitors/ local residents of significance of site. (b) Provide information/ support for teachers in form of leaflet or sheet descrobing the site and proposing activities.

Barton Quarry CGS (proposed)	Marine Devonian (CGS)	Exposure of Barton Mb. (Torquay Limestone Fm.) in disused quarry (ED)	1.Vegetation growth obscuring exposures; 3.Waste disposal, including fly-tipping. 5.Civil engineering including stabil-isation of faces, and industrial and domestic development.	1. Ensure that there is no further net loss of geological exposures in the site or removal of potentially scientifically important scree material. 2. Maintain access to scientifically important areas of quarry face. 4. Ensure that the collection of geo-logical samples from in-situ is only for research or education.	1. Initiate survey of site to document surviving features and identify areas for vegetation clearance. 2.Discuss significance of site with owners and managers to ensure aims of designation and management are fully understood.	Although the significance of the site is primarily scientific, site owners may wish to provide leaflets or sheets for the benefit of their visitors.
Berry Head to Sharkham SSSI / Sharkham Point to Berry Head CGS (proposed)	Marine Devonian (CGS)	Exposures of Sharkham Point Mb. (Brixham Limestone Fm.) in cliffs and coastal slope around Sharkham Point (stratotype) (EC)	2.Coastal protection; 5.Civil engineering associated with sewage outfall.	1. Maintain current level of cliff and foreshore expo-sure and ensure that there is no net loss of key geolo-gical features, in particular those associated with stratotypes of the Sharkham Point, St. Mary's Bay and Berry Head Mbs. 2. Maintain geol-ogical and geomo-rphological feat-ures of cave systems in good condition and ensure that only suitably experi-enced persons access systems. 3. Enhance and maintain expo-sures of deposits of Sharkham Iron Mine. 4. Ensure that the	Ensure that development and maintenance of sewage outfall does not prejudice key geological exposures (e.g. through liaison with SWW).	(a) Maintain geological interpretation in Old Artillery Store or provide elsewhere on site if necessary (b) Incorporate geological interpretation into existing range of leaflets and self-guided trails
		Exposures and talus of St. Mary's Bay Mb. (Brixham Limestone Fm.) in cliff and coastal landslip (stratotype) (EC)	2.Coastal protection; 5.Civil engineering to stabilise cliffs and landslip, including linked to development in coastal zone; 8.Unsustainable recreational fossil collecting.		1. Ensure that development plans for adjacent derelict site do not permit construction close to the top of the active landslip systems which in turn may require potentially damaging stabilisation works. 2. Discourage unsustainable recreational fossil collecting to ensure specimens remain available for other visitors to see.	

		Exposures of Berry Head Mb. (Brixham Limestone Fm.) in cliffs around Berry Head (stratotype, part) (EC)	2.Coastal protection; 5.Civil engineering to stabilise cliffs, including as a result of development close to cliff edge.	collection of geo-logical samples from in-situ is only for research or education.	Ensure that any proposals for coastal works do not lead to the loss of key geological features.	
		Exposures of Berry Head Mb. (Brixham Limestone Fm.) in Berry Head Quarry (stratotype, part) (ED)	1.Natural degradation and vegetation growth; 4.Inappropriate restoration of site which has led to high and unstable faces; 5.Civil engineering to stabilise faces; 7.Conservation management restricting access inappropriately.		Ensure that safety and other works do not lead to the loss of key geological exposures.	
		Exposures of Berry Head Mb. (Brixham Limestone Fm.) in cliffs and foreshore of Shoalstone Beach (stratotype, part) (EC/EF)	2.Coastal protection; 5.Civil engineering to stabilise cliffs.		Ensure that any proposals for coastal works do not lead to the loss of key geological features.	
	Permian-Triassic (GCR)	Permian sandstone 'dykes' in Devonian limestone on Shoalstone Beach (EC/EF)	2.Coastal protection works; 5.Civil engineering and other develo-pment affecting foreshore.		Ensure that any proposals for coastal works do not lead to the loss of key geological features.	
	Mineralo-gy of SW England (CGS)	Exposures of iron ore deposit of Sharkham Mine in upper part of coastal slope (ED)	1.Natural degra-dation and vegetation growth; 3.Waste disposal/ dumping; 8.Unsustainable recreational collecting.		Ensure that collection of samples is only carried out for scientific and educational purposes.	
	Variscan structures of SW England (CGS)	Folded limestone (Brixham Limestone Fm.) in cliffs on south side of Berry Head (EC)	None likely.		None necessary.	

	Pleistocene/Quaternary of SW England	Raised Beach and platform at Shoalstone Beach (IS)	1.Natural degradation and vegetation growth; 2.Coastal protection 5.Civil engineering including cliff stabilisation, potential linked to cliff top development.		Ensure that any proposals for coastal works do not lead to the loss of key geological features.	
	Caves and Karst	Caves and passages in and under Berry Head Quarry (IC)	1.Natural degradation and vegetation growth leading to collapse of entrances; 2.Coastal protection; 4.Inappropriate restoration of quarry leading to high and unstable faces; 5.Civil engineering to stabilise faces; 7.Conservation management restricting access inappropriately; 8.Damage to systems and deposits by inexperienced or irresponsible users.		(a) Ensure that conservation of bats in caves is fully integrated with geoconservation objectives. (b) Consider gating any cave entrances currently not with physical access controls, in liaison with cave specialists. (c) Promote further research on the caves of Berry Head to ensure that scientific importance is more widely appreciated.	
Breakwater Quarry CGS	Permian-Triassic (CGS)	Palaeokarstic fissures filled with Permian sediments; Quaternary karstic fissures also present (IC)	1.Natural degradation and vegetation growth; 3.Waste disposal/ fly tipping; 5.Civil engineering and development.	1. Maintain documented exposures. 2. Improve access subject to safety considerations.	1. Ensure that vegetation growth engineered stabilisation does not lead to loss of exposure. 2. Investigated potential for improved access for educational groups.	If educational access is permissible, incorporate sites into guided trails/educational information provision, etc.
Brockenbury Quarry CGS	Variscan structures of SW England (CGS)	Foliated Devonian limestone folded by later deformation event (IM).	1.Natural degradation and vegetation growth; 3.Waste disposal / fly tipping; 5.Civil engineering and development.	1. Maintain documented exposures. 2. Improve access subject to safety considerations.	1. Ensure that vegetation growth engineered stabilisation does not lead to loss of exposure. 2. Investigated potential for improved access for educational	If educational access is permissible, incorporate sites into guided trails/educational information provision, etc.

					groups.	
Brixham Cavern CGS (proposed)	Pleistocene vertebrata (CGS)	Small cave with sediments and bone deposits (IM)	1.Natural degradation (e.g. due to unsuitable environmental conditions in cave); 5.Development in proximity of cave that may lead to stability, etc., issues; 7.Scheduled Ancient Monument status or presence of bats inappropriately inhibiting geological research; 8.Overuse or misuse leading to damage to deposits.	1. Maintain what remains of cave system is favourable condition. Including through stabilisation if necessary. 2. Ensure that environmental conditions within cave are stable and do not lead to damage to features including bone deposits. 3. Maintain restricted access to cave and gating in good order to ensure that site is only used for scientific, archaeological or managed educational purposes. 5. Produce and implement an agreed Cave Conservation Plan.	1. Initiate full engineering and environmental survey of cave to determine what measures might be required to stabilise conditions. 2. Incorporate recommendations of survey into a Cave Management Plan and implement.	No current requirements for interpretation provision as no public access. Future provision will depend on results of survey and liaison with owner.
Chapel Hill CGS	Permian-Triassic (CGS)	Roadside cutting in Torbay Breccia Fm. close to unconformity with Devonian limestones (ID)	1.Natural degradation and vegetation growth; 5.Civil engineering including roadworks and stabilisation.	1. Ensure that exposure is not damaged or concealed by road works including installation of signs and other infrastructure.	1. Mainatin exposure free of vegetation, etc. 2. Liaise with highways authorities to minimise risk of inadvertent damage.	Incorporate in self-guided trails, etc, although proximity to road will limit group use.
Churston Cove-Churston Point CGS (proposed)	Marine Devonian (CGS)	Cliff and some foreshore exposures of Churston Mb. (Brixham Limestone Fm.) (stratotype) (EC/EF)	2.Coastal protection; 5.Civil engineering associated with cliff stabilisation, e.g. linked to development;	1. Maintain current level of cliff / foreshore exposure and ensure that there is no net loss, in particular key features of the stratotype of the Churston Member. 2. Ensure that the collection of geological samples	1. Ensure that coastal defence and other works do not lead to a net loss of key exposures.	Area has potential for incorporation into self-guided trails, as public footpaths provide access and Broadsands is a popular beach.

				from in-situ is only for research or education.		
Daddyhole SSSI	Marine Devonian (GCR)	Cliff, disused quarry face and coastal rock-platform exposures of Daddyhole Mb. (Torquay Limestone Fm.) (stratotype) (ED/EC/EF)	1.Natural degradation and vegetation growth; 2.Coastal protection; 5.Civil engineering including cliff stabilisation; 8.Overuse or misuse including unsustainable recreational collecting.	1. Maintain current level of cliff and foreshore exposure and ensure that there is no net loss of key geological features, in particular key features of the stratotype of the Daddyhole Md. 2. Ensure that the collection of geological samples from in-situ is only for research or education purposes in the area of Daddyhole Quarry 3. Sampling of the fossil-rich bedding surface at Triangle Point should only be permitted under exceptional circumstances and only then of small samples from inconspicuous areas, following full agreement of EN/TCCT.	Ensure that cliff stabilisation does that prejudice key exposures, whilst improving safe access to Triangle Point.	The site shows the best accessible exposure of a stromatoporoid 'reef' in Torbay – with appropriate safety measures this feature can be incorporated into self-guided trails, potentially with sensitive placed signage.
		Stromatoporoid 'reef' exposure of Triangle Point (?Wall's Hill Mb., Torquay Limestone Fm.) (EC/EF)	2.Coastal protection; 5.Civil engineering to stabilise adjacent cliff; 8.Attempts to collect fossils from *in-situ* exposures.		1. Place signs and/or interpretation to help protect sensitive exposures from irresponsible attempts to collect specimens 2. Provide/ excavate steps to improve safe access for visitors in conjunction with safety works on slopes above.	
Dyer's Quarry SSSI	Marine Devonian (GCR)	Cliff and disused quarry face exposures of Daddyhole Mb. (Torquay Limestone Fm.) (ED/EC)	1.Natural degradation and vegetation growth; 2.Coastal protection; 5.Civil engineering including cliff stabilisation;	1. Maintain current level of exposure and ensure that there is no net loss of key geological features. 2. Ensure that the collection of samples is only for research purposes, in particular the fossil-rich quarry floor should only be sampled under exceptional circumstances and only then of small samples	1. Place signs and/or interpretation to help protect sensitive exposures from irresponsible attempts to collect specimens. 2. Provide/ construct steps to improve safe access for guided visitors only, in conjunction with safety works on slopes/ rock faces above.	The site shows the best exposures of large coral colonies in Torbay, but is extremely sensitive to collecting and abrasion. It has a high educational potential, subject to improved access (currently only via a potentially hazardous track), although it recommended that this should only be developed

		Rock platform in disused quarry rich in coral colonies, etc. (Daddyhole Mb.; Torquay Limestone Fm.) (ED/EF)	1.Natural degradation and vegetation growth; 2.Coastal protection; 5.Civil engineering including cliff stabilisation; 8.Attempts to collect in-situ corals, etc. and abrasion by visitors.	from inconspic-uous areas, following full agreement of EN/TCCT.	Ensure that the coral-rich surfaces are not damaged by: (a) Preventing fossil collecting from *in-situ*. (b) Directing access to defined areas/ routes to minimise abrasion to delicate features.	as guided access, to ensure visitors are appropriately managed.
Hollicombe Head - Corbyn's Head CGS (proposed)	Permian-Triassic (CGS)	Cliff and foreshore exposures of the Torbay Breccia Fm., including Corbyn's Head Mb. (stratotype) (EC/EF)	2.Coastal protection; 5.Civil engineering to stabilise cliffs and development of coast.	Maintain current level of cliff and foreshore expo-sure and ensure that there is no net loss, in particular of key features of the stratotype of the Corbyn's Head Mb.	Ensure that cliff stabilisation and foreshore works do not prejudice key exposures, including through liaison with TC and owners of cliff-top properties.	Easy access from major beaches and other visitor facilities gives this site great potential for interpretative provision including sign boards and incorporation in self-guided trails.
Hope's Nose to Wall's Hill SSSI / Black Head-Anstey's Cove CGS (proposed)**/ Hope's Nose (south) CGS** (proposed)	Marine Devonian (GCR 1-Hope's Nose)	Disused Hope's Nose Quarry, including rock faces and talus in both massive and thinly bedded limestone facies (Daddyhole Mb., Torquay Limestone Fm.) (ED)	1.Natural degra-dation and veget-ation growth; 3.Waste dumping by site users; 8.Unsustainable recreational collecting.	1. Maintain current level of cliff and foreshore expo-sure and ensure that there is no net loss, including to stratotype of Long Quarry Mb. 2. Protect fossil-rich platforms at Hope's Nose and Long Quarry, only exceptionally allowing sampling, following full consultation with EN/TCCT.	1. Monitor site and periodically clear hazardous rubbish. 2. Collecting fossils in quarry is permissible for educational reasons, providing that rare species are deposited in an appropriate institution. 3. Investigate provision of safe access to quarry including steps.	Hope's Nose has an established use for higher education, which is not dependant on current state of access. Long Quarry is also used, but mainly for project work as access is not suitable for groups. Suitable improvements, however could include: (a) Hope's Nose – provision of steps

		Coastal rock-platform exposure, NE and E of quarry in massive coral-stromatoporoid rich limestones (Daddyhole Mb., Torquay Limestone Fm.) (EF)	1.Natural degradation; 3.Waste disposal (by site users); 8.Attempts to collect in-situ fossilsand abrasion by site users walking across outcrops.	3. Monitor/police exposures of gold-bearing veins to prevent further loss. 4. Ensure that the collection of in-situ samples else-where is only for research or education. 5. Improve public access.	1. Educate site users and direct them to avoid walking over key areas of fossil-rich exposure to minimise abrasion including (also contamination by rubbish). 2. Ensure that only small *in-situ* samples are only taken for research purposes and from areas agreed with EN/TCCT, to minimise damage.	into quarry area, plus improve-ments/ directional signs, followed by establishment of geological trail. (b) Establisment of signboard overlooking Long Quarry, interpreting its context within Torbay.
		Low cliff in thinly-bedded limestone-marl sequence above rock-platform E of quarry (Daddyhole Mb., Torquay Limestone Fm.) (EC)	5.Civil engineering associated with maintenance of sewage/storm water outfall; 8.Non-scientific collecting of fossils.		Ensure that samples are only collected in this area for research purposes to minimise loss of unusual shelly fauna (also seen in quarry).	
	Marine Devonian (GCR 2 – Long Quarry)	Rock-platform in floor of disused Long Quarry and adjacent coastal exposures of stromatoporoid 'reef' facies of Wall's Hill Mb. (Torquay Limestone Fm.) (stratotype, part) (ED/EC/EF)	1.Natural degradation and vegetation growth; 2.Coastal protection (unlikely); 7.Maintenance of flower-rich grassland in quarry floor if machinery used; 8.Attempts to collect in-situ fossils..		1. Educate site users and direct them to avoid walking over key areas of fossil-rich exposure to minimise abrasion including (also contamination by rubbish). 2. Ensure that only small *in-situ* samples are taken for research purposes and from areas agreed with EN/TCCT, to minimise damage.	
		Cliff and coastal slope/quarry face exposures of Wall's Hill Mb. (Torquay Limestone Fm.) (stratotype, part) (ED/EC/EF)	1.Natural degra-dation and veget-ation growth; 5.Civil engineering including cliff/ quarry face stabilisation.		Ensure that any proposed cliff stabilisation works do not prejudice geological important exposures.	

		Rock-platform in floor of disused New Quarry and adjacent coastal exposures of Wall's Hill Mb. (Torquay Limestone Fm.) (stratotype, part) (ED/EC/EF)	1.Natural degradation and vegetation growth; 5.Civil engineering works to stabilise rock faces; 8.Attempts to collect in-situ corals, etc..		Ensure that no non-scientific collection from in-situ takes place.	
	Igneous rocks of SW England (CGS)	Microgabbro exposures associated with Upper Devonian sediments in cliff and foreshore exposures between Blackhead and Anstey's Cove (EC/EF).	2.Coastal protection; 5.Civil engineering including cliff stabilisation.		Ensure that coastal defence and other works do not lead to a loss of accessible exposure, especially at Anstey's Cove.	
	Variscan structures of SW England (CGS)	Fold structures in Devonian limestones in cliff and rock-platform of southern extremity of Hope's Nose (EC/EF)	None likely.		None necessary	
	Mineralogy of SW England (CGS)	Carbonate veins with Au-Pa-Se mineralisation in coastal rock platform on SE part of Hope's Nose (IM)	2.Coastal defence to maintain sewage/storm water outfall; 3.Waste disposal (contamination of deposits by effluent); 5.Civil engineering associated with maintenance of outfall; 8.Illegal collecting from unique deposits, including use of mechanical tools.		1. Monitor/police to ensure that no further illegal collecting occurs, especially after sewage outfall diverted (including through monitoring mineral dealing websites). 2. Initiate scientific survey to locate and remove any surviving remnants of deposit.	
	Pleistocene/ Quaternary of SW England (GCR)	Pleistocene raised beach exposed at top of cliff on southern tip of Hope's Nose (IS)	1.Natural degradation and vegetation growth; 8.Non-scientific attempts to collect fossil shells form raised beach.		Ensure that the collection of in-situ samples is only permitted for scientific purposes to safeguard resource.	

Kent's Cavern SSSI	Pleistocene/ Quaternary of SW England (GCR – effectively includes Pleistocene Vertebrata interest)	Show cave with public access and stalactite formations and fossiliferous Pleistocene cave deposits (IC/IM)	1.Degradation due to inappropriate environmental conditions; 3.Leakage of effluent, etc. from houses above; 5.Engineering, etc. works to maintain or improve public access; 8.Inappropriate aspects of touristic cave use.	1. Maintain cave system in favourable condition by ensuring that touristic use is compatible with conservation. 2. Ensure that environmental conditions within cave are stable and do not lead to damage to features including bone deposits. 3. Maintain restricted access to non-public areas of the cave to minimise risk of disturbance or damage. 4. Encourage scientific and archaeological studies to improve understanding of the system. 5. Implement an agreed Cave Conservation Plan.	Use Cave Management Plan to direct future patterns of use and maintenance.	Development of guided visits, guidebooks and educational resources provide the most complete suite of interpretative resources currently available for the geological heritage of Torbay. The recent opening of new facilities has provided further opportunities for linked displays.
		Accessible passages not open to the public with stalactite formations and fossiliferous Pleistocene cave deposits (IC/IM)	1.Natural degradation due to inappropriate environmental conditions; 3.Leakage of effluent, etc. from houses above; 5.Engineering, etc. works to maintain or improve public access; 8.Inappropriate aspects of touristic cave use.		Use Cave Management Plan to direct future patterns of use and maintenance.	
		Former quarry faces in Devonian limestone and external cave entrances (ED/IC)	1.Natural degradation and vegetation growth; 5.Civil engineering to stabilise faces.		Maintain exposures by minimising impacts of any external works.	
Lummaton Quarry SSSI	Marine Devonian (GCR)	Main quarry faces, disused, and access corridor defined by fencing (Wall's Hill Mb. (Torquay Limestone Fm.) (ED)	1.Natural degradation and vegetation growth; 3.Fly-tipping and dumping from industrial units; 5.Civil engineering to stabilise faces and industrial development; 8.Non-scientific or illegal fossil collecting.	1. Maintain exposures and ensure that there is no net loss, including due to both vegetataion growth and development. 2. Maintain gated, secure access to upper levels of quarry. 2. Manage surviving exposure of Lummaton Shell	1. Maintain access to exposures in quarry faces by controlling vegetation growth and maintaining fenced access at base. 2. Ensure that users of industrial units do not dump materials within the geological site boundary fence – ensure that TC enforces compliance.	The site is currently only suitable for visits by guided groups. Provision of a commemorative plaque or sign board may ultimately be possible, although the industrial estate location is not ideal. At some future date, should the estate relocate, however, incorporation of

		Exposure of basal Barton Mb. and remnants of Lummaton Shell bed facies on platform at top of quarry (IM)	1.Vegetation growth; 5.Civil engineering to stabilise faces or for safety reasons; 7.Agricultural and other land management practices; 8.Non scientific or illegal fossil collecting.	Bed by only permitting scientific collecting.	1. Maintain gated, secure access to exposures. 2. Monitor site to ensure that no unconsented collecting takes place, involve operators of industrial units as observers if possible. 3. Continue to clear vegetation to maintain exposures.	interpretation into public open space might be appropriate.
		Overgrown and scrub-covered platform and slope around top of quarry (ED/EO)	1.Natural degradation and vegetation growth; 3.Fly-tipping; 5.Engineering, works or development; 8.Non scientific fossil collecting.		Control vegetation as far as is possible to maintain access to key exposures.	
Meadfoot sea road SSSI	Marine Devonian (GCR)	Former sea-cliffs, with tree and scrub cover, behind coastal road (EO)	1.Natural degradation and vegetation growth, especially trees and scrub; 5.Civil engineering to stabilise exposures and slopes and development; 7.Maintenance of woodland without integration with geoconservation objectives; 8.Collecting of fossils from outcrops reported *in litt.*.	1. Maintain existing exposures and ensure that there is no further loss, for instance due to coastal defence or other civil engineering projects.	Initiate survey to locate fossiliferous exposures of Meadfoot Group reported *in litt*. and clear of vegetation/ improve access.	The area includes a popular beach and incorporation in self-guided trails and the installation of a signboard here or at Triangle Point (Daddyhole SSSI) would be appropriate.
		Foreshore exposures of Meadfoot Group (type locality) in western and central part of Meadfoot Beach (EF)	2.Coastal protection; 5.Civil engineering works.		Ensure that civil engineering and other works do not effect exposures.	

		Cliff and foreshore exposures of Meadfoot Group (type locality) below Kilmorie (EC/EF)	1.Natural degradation and vegetation growth; 2.Coastal protection; 5.Civil engineering to stabilise cliffs and protect coastal road; 8.Recreational attempts to collect fossils.		1. Ensure that works to protect coastal road do not lead to loss of key fossiliferous exposures.	
New Cut, Lincombe Drive SSSI	Marine Devonian (GCR)	Low bank/ cutting beside public road and below private gardens (ED/IM)	1.Natural degradation and vegetation growth; 5.Engineering or building works industrial; 7.Maintenance or landscaping of private gardens; 8.Non-sceintific or illegal fossil collecting.	1. Improve and maintain exposure. 2. Ensure that any sampling is only for scientific purposes as the exposure is very small.	Clear vegetation from exposure and liase with site owners to ensure that they understand the significance of the site.	Given the small and sensitive nature of the site (i.e. privately owned) no interpretation is appropriate.
Petit Tor-Maidencombe CGS (proposed)	Marine Devonian (CGS)	Coastal Cliff and disused quarry exposures of limestones around Petit Tor Point ((Wall's Hill Mb., Torquay Limestone Fm.) (EC/ED)	1.Natural degradation and vegetation growth; 2.Coastal protection; 5.Civil engineering to stabilise cliff or rock faces; 8.Non-scientific collection of in-situ fossils.	1. Maintain exposure and ensure that no net loss occurs, especially to stratotype of Petit Tot Mb. and Watcombe Fm. 2. Ensure that collection of samples from *in-situ* is only for scientific and educational purposes.	Ensure that the collection of samples from *in-situ* is only for scientific and educational purposes.	Incorporation into a geological trail would be appropriate.
		Exposures of Upper Devonian mudrocks and associated (rare) nodular limestones in Petit Tor Combe and in low cliff (EC/EO/IM)	1.Natural degradation and vegetation growth; 2.Coastal protection; 3.Fly-tipping; 5.Civil engineering to stabilise slopes; 7.Maintenance of combe without integration of geoconservation objectives; 8.Non-scientific collecting of fossils, especially from *in-situ*.		1. Initiate survey of Combe to locate key geological exposures and clear of vegetation and improve access. 2. Ensure that the collection of samples from *in-situ* is only for scientific and educational purposes.	

	Permian-Triassic (CGS)	Cliff and limited foreshore exposures of Permian Watcombe Fm. (including Petit Tor Mb.) (stratotype), Oddicombe Breccia Fm. and Teignmouth Breccia Fm. (EC/EF)	2.Coastal protection; 5.Civil engineering to stabilise cliffs.		Monitor proposals for coastal defence works, in particular around beach access points, and ensure that no key exposures are lost.	
Roundham Head SSSI	Permian-Triassic (GCR)	Cliff and foreshore exposures of Torbay Breccia Fm. (stratotype) (EC/EF)	1.Natural degradation and vegetation growth; 2.Coastal protection; 5.Civil engineering to stabilise cliff, potentially linked to cliff-top developments.	Maintain current level of cliff and foreshore exposure and ensure that there is no net loss, in particular of key features of the stratotype of the Torbay Breccia Fm.	Ensure that cliff stabilisation and foreshore works do not prejudice key exposures, including through liaison with TC and owners of cliff-top properties.	Easy access from major beaches and other visitor facilities gives this site great potential for interpretative provision including sign-boards and incorporation in self-guided trails.
Saltern Cove SSSI / Crystal Cove CGS (proposed)	Marine Devonian (GCR)	Cliff and foreshore exposures of sandstones and slaty mudrocks of ?Staddon Fm. on south side of Goodrington sands, including well developed anticline (EC/EF)	2.Coastal protection; 5.Civil engineering to stabilise cliffs, and/or linked to cliff top development.	1. Maintain exposures and ensure that there is no net loss of geological features, including stratotype of Saltern Cove Fm. 2. Ensure that collection of samples from in-situ is only permitted for scientific and educational reasons.	Ensure that coastal defence and other works do not threaten exposures.	(a) Promote Saltern Cove self-guided trail. (b) Incorporate within future self-guided trails (c) Incorporate geological themes within Goodrington Sea-life Centre.
		Cliff and foreshore exposure of sandstones and slaty mudrocks of ?Staddon Fm. below basal Permian unconformity on north side of Waterside Cove (EC/EF)	2.Coastal protection; 5.Civil engineering to stabilise cliff.		Ensure that coastal defence and other works do not threaten exposures.	
		Cliff and foreshore exposures of Saltern Cove Fm. in Waterside and Saltern coves (stratotype, part) (EC/EF)	2.Coastal protection; 5.Civil engineering to stabilise cliff and/or slopes; 8.Non-scientific collecting of *in-situ* fossils.		1. Ensure that coastal defence and other works do not threaten exposures. 2. Collection of specimens from in-situ should only be for scientific reasons.	

		Cliff and shore platform exposure of Saltern Cove Goniatite Bed and associated slumped units between waterside and Saltern coves (Saltern Cove Fm.) (stratotype, part) (IM)	2.Coastal protection; 5.Civil engineering to stabilise cliff, 8.Non-scientific collecting of fossils.		1. Ensure that coastal defence and other works do not threaten exposures. 2. Collection of specimens from in-situ should only be for scientific reasons.	
		Cliff and foreshore exposures on south side of Saltern Cove, including Brixham Limestone Fm., ?Ashrpington Volcanic Fm., associated with altered dolerite (EC/EF)	2.Coastal protection; 5.Civil engineering for instance to stabilise cliffs;		1. Ensure that coastal defence and other works do not threaten exposures.	
	Permian-Triassic	Cliff and foreshore exposures of Torbay Breccia Fm. north of Waterside Cove, including surfaces with unique *Beaconites* burrows (EC/EF/IM)	2.Coastal protection; 5.Civil engineering to stabilise cliffs; 8.Collection of in-situ *Beaconites* or non-scientifc removal of loose specimens.		1. Ensure that coastal defence and other works do not threaten exposures. 2. Collection of specimens from in-situ should only be for scientific reasons, although only in exceptional cases, in consultation with EN/TCCT should any *Beaconites* be removed.	
		Cliff and foreshore exposures of Torbay Breccia Fm. south of Saltern Cove (EC/EF)	2.Coastal protection; 5.Civil engineering, including to stabilise cliffs.		1. Ensure that coastal defence and other works do not threaten exposures.	
	'Structural geology' (post-Variscan) (CGS)	Cliff exposure of calcite-coated fault zone between Devonian limestone and Permian breccias (IM)	2.Coastal protection; 5.Civil engineering including to stabilise cliffs 8.Non-scientific collection of *in-situ* samples.		1. Ensure that coastal defence and other works do not threaten exposures. 2. Collection of specimens from in-situ should only be for scientific reasons.	

Quarry Woods Quarry CGS	Marine Devonian	Disused quarry showing sandstone and slate of ?Staddon Formation, with minor fault (ED)	1.Natural degradation and vegetation growth; 3.Waste disposal and fly-tipping; 5.Engineering works or development; 7.Agricultural uses including storage or dumping of materials.	1. Maintain exposure including all described features.	1. Clear vegetation and maintain exposure. 2. Investigate potential for educational use.	Proximity to Cockington gives this site educational potential improvements to access would be needed. Owner is TCCT.

Table 9: Conservation objectives and recommendations for Earth heritage sites in Torbay.

5. STRATEGY FOR THE SUSTAINABLE USE OF TORBAY'S GEOLOGICAL HERITAGE

5.1. Existing strategies and programmes in the region

Geological conservation and educational work in Torbay has been supported and informed by a number of systems and projects established in the broader Devon County context, including:

- *The Devon RIGS Group*: This voluntary NGO has responsibility for over-seeing the selection and designation of Regionally Important Geological Sites throughout the county of Devon. Sites are termed County Geological Sites in acknowledgement of their equivalent status to County Wildlife Sites. The composition of the group includes representatives from both regional universities (Plymouth and Exeter) and from a range of local and national governmental organisations, including Devon County Council, Dartmoor National Park Authority, other unitary and district authorities, English Nature, British Geological Survey and the Environment Agency. Other NGOs such as the Devon Wildlife Trust are represented, as well as members providing links to industry, schools and amateur geological groups. The Devon RIGS group is also a consultee on planning related issues affecting geological heritage sites in the county and in relation to statutory local plans.

- *The Devon County Council Educational Register of Geological Sites*: This register is designed as a web-based resource to support educational groups visiting geological sites in the county and was produced as part of a collaborative initiative between the Devon RIGS Group and Devon County Council. It provides a review of the geology of the county and scientific and access information for around nearly 80 sites, including several in Torbay. It is available via www.devon-cc.gov.uk/geology, or can be purchased on CD from Devon County Council (Environment Directorate, Luccombe House, County Hall, Topsham Road, Exeter, EX2 4QW, UK). Compilation of the register was supported by English Nature as a contribution to the European Union-funded GRECEL project (Geological heritage: Research in environmental Education and Cooperation in European Level) (Socrates Programme, Directorate General XXII (Education,Training and Youth)) (Drandaki *et al.* 1999).

- *Devon Biodiversity Action Plan (Devon Biodiversity Partnership, including Devon Wildlife Trust, English Nature and Devon County Council 1998)*: This innovative Action document fully integrates biological and geological conservation and establishes Action Plans for key habitats, species and other key features of nature conservation importance which are present in the county (Devon Biodiversity Partnership 1998). Significant geological content is present in the following sections: Caves, Karst and Mines; Sea Cliff and Slope; Pits, Quarries and Cuttings. Other sections referring to Earth Heritage features and processes include: Cities, Towns and Villages; Rivers, Streams, Floodplains and Fluvial Processes; Estuaries; Rocky Foreshore.

  Each Action Plan, has been developed through consultation with a range of organisations, and presents a review of issues, threats, and presents positive initiatives and sets objectives and targets for future work. The provision of interpretative and educational facilities is also a key part of each action plan. This document guides local and national governmental policy and action for Nature Conservation in Devon, and the principles established are relevant to the establishment of a Local Action Plan for geological sites in the Torbay district. The BAP is currently (2004) being updated to take account of recent developments in conservation procedure and practice in the region and nationally, although the fundamental, integrated approach will remain.

- Devon, Cornwall and Isles of Scilly Geological Interpretation Strategy (English Nature, Devon, Cornwall and Isles of Scilly Team 1998): South-west England with its rich and varied geological and geomorphological heritage offers excellent opportunities for interpretation and educational use. To date, however, the development of schemes has been somewhat haphazard and lacking in any strategic overview. The aim of this project was to develop a strategy to focus the work of English Nature and other organisations, increase public awareness, identify opportunities for educational use and, where appropriate, target resources for site management.

  The unpublished project report (Sargeant, 1998), included a detailed review of existing facilities, together with recommendations for future projects and suggested timetables. An accompanying three volume set provides a valuable compilation of all available interpretive publications focussing on the geological heritage of the region and forms an important resource for future work. This document is relevant to development of interpretative facilities in the Torbay district as it provides a context within which to develop key themes and subjects of regional educational relevance.

- *Devon Roads and Geological Conservation Project (Devon County Council and English Nature, Environmental Impacts Team 1998)*: This project was developed as a national pilot by English Nature to investigate and demonstrate how Earth Heritage conservation might be promoted through the development and management of the roads network at a local level. The project had three main themes: 1.Conserving geological sites on Devon's roads, 2.Interpreting Devon's geology through the road network, and 3.Promoting geological conservation in road development.

  The results of the project, compiled by Earth Resources Centre (University of Exeter) have been published as a technical document (Dean *et al.* 1998) and implementation has included site management and interpretative provision at selected geological sites associated with the roads network in Devon (Macadam *et al.* 1998).

These documents and projects provide a valuable regional context with which to develop a sustainable approach to managing the geological heritage of Torbay and can inform the development of site-based interpretative and educational programmes. A broader international context is, however, provided by the rapidly expanding European Geoparks programme which aims to develop geological heritage as an asset for local communities, by using it as a basis for the development of sustainable tourism, literally '*geotourism*'

5.2. Existing strategies and programmes in the region

A number of key local strategies and action plans provide the context and supporting framework for Torbay's geological heritage. These include:

- *Torbay Community Plan and Action Plan 2004 - 05:* This overarching plan was produced by the Torbay Strategic Partnership, a body that brings together local government, health, crime and disorder, economic regeneration, voluntary, community and faith groups in order to plan a sustainable future for the area. The Plan contains specific actions relating to sustainable tourism and developing the area's potential to use its heritage assets to greater advantage.

- *Torbay Heritage Strategy 2004*: Developed by the Torbay Heritage Forum, this documents details the heritage assets found in Torbay, from parks and gardens to buildings, museum collections and earth heritage. It specifies actions and priorities and these include realising Torbay's geological

importance in the development of sustainable tourism initiatives. There is also a strong emphasis on educational and community involvement in conserving the geology of the area.

- *Torbay Local Plan 1995 – 2011*: This is the land use planning document adopted by the local authority. It contains a wide-ranging array of policies to control development in the area, including a chapter on nature conservation, and this includes earth heritage sites. A key policy is that: **"Development should preserve or enhance the biodiversity, wildlife and geological value of the terrestrial and marine environment".** All existing protected sites including SSSI and CGR sites are mapped on the "constraints map" included in the Local Plan.

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5.3. Key objectives and recommended actions for the sustainable management of Torbay's geological heritage

The Devon (integrated) Biodiversity Action Plan provides a valuable framework for developing a Local Geodiveristy Action Plan for Torbay, thereby cascading key elements of the principles established by the county-wide plan down to a local level – as was previously carried out for the Dartmoor BAP (ref.). In the latter, geological features included within separate Habitat Action Plans (HAPs) in the original Devon BAP (1999), in particular for *Caves, Karst and Mines* and *Pits, Quarries and Cuttings* were united within a single HAP for ….. although retaining the fundamental integration of ecological and geological/geomorphological elements.

Torbay is in the process of developing an ecological BAP and a Biodiversity partnership is working on drawing up detailed Action Plans. The Local BAP will be fully integrated with this LGAP.

Key overall objectives for the sustainable management of Torbay's geological heritage are listed below and actions required to achieve or consolidate these aims listed in Table 10.

Objective 1 – Protection and Conservation

Ensure that all Earth heritage sites of regional and national/international importance are protected from development through appropriate Local Plan policies and constraint mapping. Policies should also allow for flexibility of application should 'new' sites of at least regional geological heritage importance be subsequently identified and/or facilitate the scientific recording and sampling of temporary exposures where site conservation is not reasonably practical.

Objective 2 – Management planning

Develop and implement site-specific management plans for each designated site of Earth Heritage importance, seamlessly integrating ecological, geological and cultural heritage objectives where the site is multi-interest.. Ensure that relevant specialists in each discipline maintain a constructive dialogue throughout this process.

Objective 3 - Use

Ensure that irresponsible use, including inappropriate recreational activities, does not lead to damage to sensitive sites by promoting Codes of Conduct (including concerning fossil and mineral collecting), installing physical barriers or marking access routes, improving site-signage and through targeted wardening programmes.

Objective 4 - Access

Develop or improve access to selected sites, to provide opportunities for visitors to view key geological and geomorphological features within acceptable safety limits, including by installing or improving steps, fences, carrying out geotechnical works, etc. As part of this process sites can be graded according to difficulty of access and potential risk.

Objective 5 – Communication and Education

Develop appropriately themed interpretation linked to geological sites, including through sign-boards, leaflets and trails, and through additions and enhancements to existing heritage centres and other suitable facilities. Ensure that the needs of local and regional educational institutions are fully met through the provision of guidance and teacher's packs.

Objective 6 – Coordination and Community involvement

Work with local communities and owners and managers of heritage sites and attractions to coordinate activities and to develop key themes within the geological heritage of Torbay and thereby increase and improve the range of opportunities for local communities and visitors alike to experience, enjoy and learn from their rich heritage.
This process should also involve local producers and the tourism industry, by developing geoproducts and increasing services relating to sustainable tourism thereby contributing to the economic welfare and sustainable development of Torbay.

5.4. Recommended actions for the sustainable management and development of Torbay's geological heritage:

Abbreviations as follows: THF = Torbay Heritage Forum; TCCT = Torbay Coast and Countryside Trust; TC = Torbay Council; DRG = Devon RIGS Group; EN = English Nature; KC = Kents Cavern; TDA = Torbay Development Agency

Action		Potential deliverer/s	Target FY end for completion				
			05	06	07	08	10
A. Policy and legislation	1. Confirm County Geological Site (CGS) status for new nominations	DRG	√				
	2. Include confirmed new CGS sites in next revision of Torbay Local Plan	THF, TCCT, TC					√
	3. Ensure that policies in next revision of Torbay Local Plan recognise and protect geological sites of actual and *potential* SSSI or CGS status	THF, TCCT, TC, EN					√
	4. Encourage adoption of planning principle which requires developers to grant access to construction and other sites for the purposes of scientific recording of temporary exposures	THF, TCCT, TC, DRG	√				
B. Site safe-guard and management	1. Produce, agree and implement site specific integrated geological-ecological management plans for all SSSIs and CGSs in Torbay	TCCT, DRG, EN, KC			√		
	2. Encourage adherence to TCCT policy on geological specimen collecting and consent activity on the basis of site-specific criteria derived from management plans and liaison with scientific advisors	THF, TCCT, EN and scientific advisors	√				
	3. Ensure that all designated geological sites are in "favourable condition" as assessed by English Nature, by carrying out a programme of site management works	THF, TCCT, TC, site owners					√
C. Advisory	1. Establish network of scientific advisors to guide site management decisions, including with respect to development proposals, temporary section recording and assessment/ refereeing of proposals for sampling at sensitive sites and interpretation	THF, TCCT, regional universities, etc.		√			
	2. Contact all site owners and occupiers of CGS and establish constructive dialogue to aid site management and investigate potential, where appropriate, for developing access and interpretation	THF, TCCT, DRG.			√		
	3. Produce and distribute guidance notes and codes to encourage safe and responsible use of geological heritage sites	TCCT, EN, DRG, KC.	√				
D. Research and monitoring	1. Encourage research into Torbay's geological heritage, including both site-based and document-based in particular where contemporary reviews are lacking (e.g. on regionally Devonian palaeontology) or sites have not yet been fully documented (e.g. Berry Head caves)	TCCT, KC, regional universities, etc.		√			

	2. Monitor all geological SSSIs and CGS in Torbay to appropriate timescale, for instance with sensitive sites visited at least every 3 months and robust sites visited annually	TCCT, EN, DRG.		√			
E. Management Framework	1. Establish a Coral Coast Geopark Committee of the Torbay Heritage Forum involving key public, private and voluntary sector representatives	THF	√				
	2 Establish a Coral Coast Geopark administrative body to act as steward and bailiff of the Coral Coast brand	THF	√				
	3 Develop codes of conduct and terms of reference for all participating organisations	THF	√				
	4 Monitor and steer the development of the Coral Coast concept and police activity as required	THF	√				
F. Public Access	3.1 Develop improved public access to key sites including Lummaton Quarry, Dyer's Quarry, Daddyhole, Hopes Nose and Saltern Cove	TCCT		√	√		
	3.2 Encourage the development of geological boat trips to view inaccessible sites from the sea (see also Torbay Marine Biodiversity Action Plan)	THF	√	√			
	3.3 Develop new exhibition facilities at museums and other visitor facilities to give improved access to the geological heritage	TCCT, KC, THF, TNHS		√			
	3.4 Incorporate geological heritage in touring exhibitions and other outreach facilities, eg mobile libraries, doctors surgeries	THF, TC, KC, TNHS		√			
	3.5 Develop new interpretive media that are accessible to everyone, regardless of ability.	THF, TCCT, TC, KC, TNHS		√			
G. Communication and Education	4.1. Develop an interpretation strategy to ensure that interpretative provision is suitably targeted and integrated and addresses the needs of a range of different site users, including geological/technical groups, school groups (including teaching aids) and general visitors	THF	√				
	4.2 Work with local communities to develop events and activities linking people to the district's geological heritage	THF, TCCT		√			
	4.3 Develop curricular resources for use by schools and colleges	THF, TC, KC, TNHS			√		
	4.4 Offer field study trips to Geopark sites to schools, colleges and community groups	TC, TCCT, KC	√				
	4.5 Develop themed Geopark tours for adult and family audiences	TCCT, THF, KC, TC	√				
	4.6 Develop adult and community learning packages on the Geopark theme	TC, TCCT, TNHS	√				
	4.7 Extend and improve interpretation and education facilities at key Geopark "magnet" sites: Berry Head, Goodrington and Kents Cavern	TCCT, KC, TC, TNHS	√				
	4.8 Develop the Coral Coast Geo-trail incorporating a generic leaflet, individual site leaflets and on-site interpretation boards	THF, TCCT, KC		√			

	4.9 Foster educational links with other natural heritage attractions such as Living Coasts	THF	√				
	4.10 Develop a new "Gateway" Geopark Visitor Centre / orientation point at a central location	THF				√	
	5.2 Develop the Coral Coast website	THF	√				
H. Economic development	5.1 Develop the Coral Coast Geopark logo and register as a trademark	THF	√				
	5.2 Organise an annual Geopark training and awareness event for tourism operators	THF	√				
	5.3 Liaise with the ERTB and TDA and other advertisers to ensure widespread use of the Coral Coast Geopark in all marketing literature	THF	√				
	5.4 Review all signing to and within Torbay to feature the Geopark designation where appropriate	THF, TC		√			
	5.5 Promote the development of Geopark-related tourism packages for the niche and short-break markets	THF, TDA		√			
	5.6 Organise an annual Geo-Day aimed specifically at local residents to encourage enjoyment and understanding of Torbay's geological heritage	THF	√				
	5.7 Develop links to other Earth Heritage sites in Britain, eg The Jurassic Coast, Cornwall and Dartmoor.	THF	√				
	5.8 Develop links to other earth Heritage sites in Europe and the rest of the world.	THF	√				
I. Resources	6.1 Develop a "Coral Coast Fund" made up from subscription charges and other income from participating organisations and use the Fund to generate conservation and interpretation improvements.	THF	√				
	6.2 Seek funding to achieve the above from grants and other funding sources	THF	√				

Table 10: Recommended actions for the sustainable management and development of Torbay's geological heritage.

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Useful Website addresses:

- Devon County Council: www.devon-cc.gov.uk/geology
- Earthwords: www.earthwords.co.uk
- Earth Science Teachers Association (ESTA): www.soton.ac.uk/~ukgec/ESTA/
- English Nature: www.english-nature.org.uk
- European Geoparks: www.europeangeoparks.maestrazgo.org
- GRECEL: www.pi-schools.gr/grecel
- Joint Nature Conservation Committee: www.jncc.gov.uk
- ProGEO: www.sgn.se/hotell/progeo
- UK RIGS: www.ukrigs.org.uk
- UNESCO, Earth Science Division: www.unesco.org/science/earthsciences/geological_heritage

7. GLOSSARY

Built environment: *The built environment of our towns and cities is a reflection of their Earth heritage resources. It has two basic components: (1) remnants of the primary geomorphology of the region prior to construction (in many cases, the original siting of a town or city was controlled by the nature of the geomorphology), and (2) the buildings, roads and other constructions which are composed primarily of materials derived from the geological resource, in the form of building stones and other construction materials.*

Earth Heritage: *The inheritance of rocks, soils and landforms (active and relict) and the evidence they contain that enables the history of the earth to be unravelled*.

Earth Science: *Earth Science is the application of principles, methods and approaches of mathematics and the basic sciences, and those special to the Earth sciences (geology, geochemistry, geophysics, geomorphology, oceanography, climatology, etc.) to the elucidation of the history of the Earth and the use of this knowledge to recognise and solve resource and environmental problems. It encompasses the formation, constituents, structure, history and continued evolution of the Earth. The two major disciplines of relevance to geoconservation are: geomorphology, concerned the understanding the recent and ongoing physical processes, which have shaped, and continue to shape, the Earth's surface (e.g. erosional and depositional, water and wind driven systems); and geology, concerned with the historical development, constituents, structure of the Earth and ongoing sub-surface processes and their surface expression (e.g. volcanoes, earthquakes, etc). Together they provide the framework for understanding the history and heritage of the Earth.*

Environmental geology: *Environmental geology it the application of geological concepts to problems created by man, and their effects on the physical environment*.

Fossil: *The preserved remains or traces of once-living animals and plants*.

Geoconservation (= Earth Heritage Conservation): *Earth Heritage Conservation is concerned with sustaining the part of the physical resources of the Earth that represents our natural and cultural heritage, including our geological and geomorphological understanding, and the inspirational and aesthetic response to the resource*. N.B. There are other definitions!

Geodiversity: "*The natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (land form, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems*" Grey (2004) (N.B. Can also be used to include geological materials in a cultural and economic context, such as building stones, gems and ornaments….)

Geology: "*Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature; it enquires into the courses of these changes, and the influence they have exerted in modifying the surface and external structure of our"* (Lyell, 1830).

Geological column: *A composite diagram showing, in chronological order (base of column to top), a succession of known strata or geological time units, compiled on the basis of their fossils or other evidence of relative or actual age.*

Geological heritage: *The part of the physical resources of the Earth that represents our natural and cultural heritage, including our geological and geomorphological understanding, and the inspirational and aesthetic response to the resource*.

Geological time scale: *A sequential arrangement of named geological time units, arranged with the oldest at the base, and the youngest at the top of the presented table or column.*

Geomorphology: *The scientific discipline concerned with surface features of the Earth, including landforms and forms under the oceans, and the chemical, physical, and biological factors that act on them, e.g. weathering, streams, groundwater, glaciers, waves, gravity, and wind.*

Geotope: *Geological, geomorphological and pedagogical features and processes are manifestations of the long and complex heritage of the Earth. Certain sites and regions, however, represent key aspects of this heritage, and therefore can have a scientific, educational or aesthetic value to our society. They represent significant moments in the history of the Earth, important witnesses of its long evolution, or simply demonstrate ongoing natural surface processes, relatively uncluttered by human interference. These sites, are therefore worth protecting, and are collectively known as geotopes***.**

Hydrological cycle: *The day-to-day and long-term cyclic changes in the hydrosphere (i.e. "the water cycle")*.

Hydrogeology: *Hydrogeology is concerned with the waters beneath the Earth's surface, especially water associated with earth materials and with water-flow mechanisms through rocks, i.e. emphasising the geological aspects of groundwater .*

Historical geology: *Study of the chronology of the Earth's past events, both physical and biological (also known as "Stratigraphy")*.

Igneous rocks: *Rocks formed from molten magma. These usually consist of interlocking crystals, the size of which is dependent on the rate of cooling (slow cooling gives larger crystal (e.g. granite, gabbro, etc.); rapid cooling produces small crystals (e.g. lavas such as basalt and rhyolite, and dolerite)*.

Landforms: *Landforms are the physical expressions of internal (endogenic) and external (exogenic) processes which have operated to shape the surface of the Earth. Landforms are varied in form and reflect the diversity of the processes which have formed them, but a convenient way of classifying them is by considering them as either static or active. Static landforms are those in which the activity that produced them no longer operates, although other processes may be acting upon them. Active landforms are those in which processes are still operating to form and transform the landscape*.

Landscape: *A Landscape is effectively a collection of both active and static landforms*.

Lithology: *A description of the character of (typically) a sedimentary rock, based on a systematic description of it's mineralogy and texture*.

Metamorphic rocks: *Rocks which have been changed in typically an essentially solid state by heat and/or pressure without complete melting. They may originally have been igneous or sedimentary rocks or* pre-existing metamorphic *rocks, e.g. slate, gneiss, schist, marble, etc..*

Mineral: *A naturally occurring chemical compound or element, typically a crystalline solid with a definable chemical composition and a characteristic crystal structure. Can also included rocks or soft sediment deposits (e.g. sand and clay) if they have an economic value as "Bulk Minerals".*

Mineralogy: *The branch of geology that deals with the classification and properties of minerals .*

Orogeny: *A mountain building period during which continental crust is thickened by processes associated with the closing of oceans and subsequent collision between continents*.

Palaeontology: *The study of fossils, and other traces of ancient life and biological evolution (including chemical and genetic evidence), and their morphology, ecology, evolution, sedimentology, chronology and distribution in time and space.*

Pedology: *The study of the morphology, origin, and classification of soils*.

Petrology: *The branch of geology that deals with the occurrence, origin, and history of rocks, primarily from a mineralogical perspective*.

Physical geology: *The study of the processes that operate at or close to the surface of the Earth, and the materials on which those processes operate (includes Geomorphology)* .

Plate tectonics: *A special branch of tectonics, derived from a synthesis of geological and geophysical observations that deals with the processes and consequences of the movement of the Earth's Crust as a series of large rigid plates that are moving relative to each other. These plates interact with each other along relatively narrow zones of volcanic and seismic activity*.

Tectonics: *The study of movement and deformation of the Earth's crust and the consequent effects (folding, faulting, earthquakes, etc).*

Rock cycle: *The cyclic movement of rock-forming materials, in the course of which rock is created, destroyed, and altered through the operation of internal and external Earth processes*.

Rock outcrop: *An "outcrop", by strict definition, is the presence of a rock unit at the Earth's surface or immediate below (i.e. below sub-subsoil). An "exposure", however, is where that unit is actually visible, and unmasked by soil, vegetation or other superficial deposits.*

Sedimentary rocks*: Formed from the compaction and/ or lithification (cementation) of sediment. Sedimentary rocks may be composed of mineral or rock particles (clasts) (e.g. conglomerates, sandstones and shales) or be of biological origin (e.g. limestones, coals and some cherts) or formed by chemical precipitation (e.g. evaporites such as gypsum or salt)*.

Stratigraphy: *The study and classification of rock strata and their distribution in space and time*.

APPENDIX 1: LEGAL DESIGNATION PAPERS FOR GEOLOGICAL SITES OF SPECIAL SCIENTIFIC INTEREST IN TORBAY

APPENDIX 2: DOCUMENTATION SHEETS FOR COUNTY GEOLOGICAL SITES IN TORBAY

APPENDIX 3: SITE MAPS SHOWING GEOLOGICAL MANAGEMENT UNITS

Disclaimer: The conservation guidance and recommendations provided by this strategy do not include a rigorous assessment of any related health and safety issues – it is the responsibility of the site manager, therefore, to ensure that all relevant legal and established procedures are in place before implementing any site-conservation, access or interpretative measures. In addition, the provision of recommendations for the management of any sites does not remove the legal requirement for any owner, occupier or third party to obtain, prior to commencing any proposed operations, formal written consent from English Nature for SSSI sites or, in the case of operations covered by other legislation and procedures, formal planning permissions or consents from Torbay Council, Torbay Coast and Countryside Trust, other regulatory bodies or site owners. The inclusion of a site in this document does not imply any right of access and, unless, otherwise stated, site users should make prior arrangements to obtain permission to visit inland localities, or observe procedures such as requirements to obtain consents for sampling at open-access coastal locations.