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The social and economic value of the UK's geodiversity

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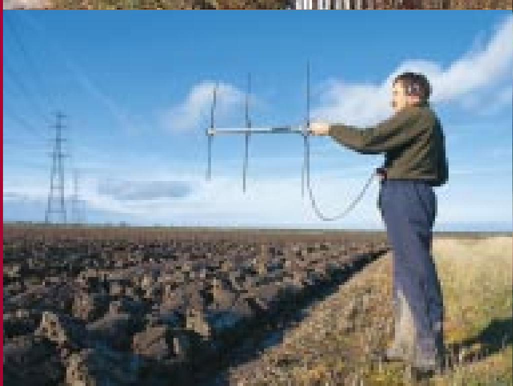


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The social and economic value of the UK's geodiversity

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Cover note

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Executive summary

Geology and geomorphology are the rocks, fossils, minerals and landforms, and the natural processes which form and change them. The variety of these can be described as geodiversity. Geodiversity provides many economic, social and cultural benefits. Recent research effort into the value of nature (see De Groot 1992; Daily 1997; English Nature 2002; Gray 2004) suggests that these benefits may be considered under four main value classes: appreciation, knowledge, products and ecosystem/natural functions. Each of these value classes may be further split into detailed categories (English Nature 2002). In this research, we utilise the research protocol developed to value nature and specifically apply these classes to investigate the social, economic and cultural benefits associated with geodiversity.

The social and economic value of geodiversity is explored using a variety of methods. First, a review of existing research was undertaken to identify existing knowledge on the value of geodiversity, and also identify where gaps in this knowledge exist. New empirical research was then undertaken to provide information on where gaps in the knowledge occurred. This research included a series of interviews and focus groups with members of the public and specific user groups to collect descriptive and anecdotal evidence of the way in which people value geodiversity. A number of geodiversity-rich case studies were explored to illustrate in greater detail the social functions provided. Empirical research was also undertaken to specifically explore the economic values of geodiversity. In particular, the choice experiments method was used to assess how much people would be willing to pay to protect and enhance two geological sites: Wren's Nest National Nature Reserve (NNR) and the Jurassic Coast World Heritage Site (WHS). Economic impact analysis was also carried out on the Isle of Wight to determine the size of the local economic impacts that geodiversity brings to the Island.

Much of this report explores the various ways in which geodiversity contributes towards enhancing people's quality of life. In particular, the benefits of geodiversity were considered under four classes: appreciation, knowledge, products and ecosystem services.

Geodiversity may be directly appreciated by many people as demonstrated by the large number of visitors attracted to geological sites, and also people collecting fossils. People may also appreciate geodiversity indirectly through artistic inspiration and through cultural heritage. For example, geodiversity features significantly in folklore.

Geodiversity also provides a significant contribution to mankind's knowledge. The knowledge gained from geology helps us to better understand the history of the planet, evolutionary biology, and how the environment around us is changing.

Geodiversity also provides a number of products useful to man including building materials and minerals for industry, and products such as fossils and minerals, collected by individuals for their own enjoyment.

Finally, geomorphological processes provide a number of essential ecosystem/natural system functions including beaches and floodplains, providing us with natural flood defence.

The value of different elements of geodiversity was examined using two choice experiments valuation studies: one at Wren's Nest NNR near Dudley and the other at the Jurassic Coast World Heritage Site in Dorset.

The value of 'knowledge' of geodiversity was explored by comparing the value of access to different geological sites both with and without the provision of interpretative material.

- At Wren's Nest NNR, access to the whole site with educational material was valued at £21.26 per household per year compared to £7.83 per household per year without the provision of educational material. Similarly, access to the geologically-rich Seven Sisters caverns within the NNR with extensive interpretation was valued at £13.95 per household per year compared to £12.22 per household per year without.
- Similar findings were also found at the Jurassic Coast WHS where access with extensive interpretative material was valued at £62.35 per household per year compared to a value of £23.69 per household per year for access without educational material.
- In all three cases, the provision of educational material on geodiversity (and hence 'knowledge') clearly enhances the value that people attain from visiting a geodiversity site.

The value that people placed on the opportunity to collect fossils was also explored at both case study sites.

- At Wren's Nest NNR a proposal to allow public collection of fossils to the loose spoil heaps at Wren's Nest (where only common fossils are found) was valued at £5.18 per household per year, while a further restriction to only allow fossil collecting by geologists was valued at £6.58. Thus, people value the opportunity to collect fossils.
- In a third fossil collecting scenario at Wren's Nest NNR, respondents were informed that 'Fossil collecting could be allowed by the public in all areas, including the Seven Sisters Caverns where more rare fossils could be found than elsewhere in the nature reserve. However, since collection would not be monitored, some of the rare fossils may be lost'. This scenario was negatively valued at -£11.76 per household per year. This negative value reflects the concerns that people have for losing important and rare fossils. Thus, the preservation of important fossils appears to be of more importance to people than the opportunity to actually collect these rare fossils.
- The results relating to fossil collecting on the Jurassic Coast would appear to back up the findings from Wren's Nest. In particular, fossil collecting by geologists only was negatively valued at -£15.46 per household per year, while public fossil collecting via a code of conduct at £57.73 per household per year. Thus, people would appear to value the opportunity to collect fossils themselves, with the important proviso that the important fossils are protected.

A multiplier analysis study was also undertaken to provide an estimate of the local economic impacts associated with geodiversity on the Isle of Wight. This research found that 39% of tourists in this survey had visited the Isle of Wight specifically for the geodiversity. Average daily spend by these visitors was £73.86. The estimated expenditure related to geodiversity can be applied to the expenditure generated by all tourists to the Isle of Wight. Tourism on the Isle of Wight was estimated to be worth £352 million for the tourism year 2004/2005 (Isle of Wight Council 2006a). Geodiversity was therefore estimated to account for approximately £11 million of this value. Applying income and employment multiplier coefficients, it is argued that geodiversity generates between £2.6 million and £4.9 million in local income and supports between 324 and 441 full time equivalent local jobs.

Qualitative data, collected during focus groups and interviews, were also collected to provide descriptive evidence of the values that the general public hold for geodiversity. The evidence collected here was indicative of the high values that the public place on geodiversity resources and when considered alongside the findings from the choice experiments, provide strong evidence in support to the continued management and conservation of these resources.

Finally, the HM Treasury, in its revised *Green Book* on policy appraisal (HM Treasury 2003), suggests that the non-market costs and benefits should be considered in policy and project appraisal. Indeed, in terms of nature conservation, these non-market costs and benefits now play an important and crucial role in policy appraisal. This study demonstrates that the use of environmental valuation techniques, such as choice experiments, can be utilised to estimate the non-market benefits that geodiversity provides. These techniques, combined with qualitative and economic impact methods allow for the wider values associated with geodiversity to be identified. These values should now be used to develop policies and provide future management and conservation strategies for geodiversity.

Contents

Figures

Tables

Research Information Note

1 Introduction

Geology and geomorphology are the rocks, fossils, minerals, landforms and the natural processes which form and change them. The variety of these can be described as geodiversity. The UK's geological and geomorphological resource, or 'geodiversity', is extremely varied and includes rocks from all periods of geological time.

While the scientific value of geodiversity has been evident and recorded for hundreds of years, its economic, social and cultural contribution to human welfare has been largely overlooked.

Geodiversity potentially contributes to people's well-being and quality of life in many ways. For example, people will travel long distances to view interesting geological features (such as the Giant's Causeway) or to collect fossils. Geodiversity also provides artistic inspiration for many painters and poets, and is a significant feature of folklore. The geological resource also provides man-kind with a wealth of knowledge on, for example, long-term environmental indicators on the health of our planet and also palaeontology (the study of fossils) provides fundamental knowledge of evolutionary biology. In terms of products, geodiversity provides a wide range of products useful to man including building materials and minerals for industry, as well as products collected by individuals such as fossils. Finally, geomorphological processes provide a number of essential ecosystem functions including natural flood defence.

It is important to place value on geodiversity for a number of reasons:

People obtain satisfaction and well being from geodiversity.

Geodiversity provides products and services.

Decision-making for the appropriate and sustainable management of geodiversity.

Geodiversity research is required for the advancement of science and industry.

To train earth scientists.

To provide teaching facilities for schools.

Sites have aesthetic, amenity, cultural, historical and wildlife value.

The measurement of these social and economic values provides evidence for the conservation and management of these resources.

This report draws on research carried out as part of an English Nature funded PhD that explores the social, economic and cultural values of geodiversity in the United Kingdom. The research reported here was undertaken in three stages. First, a conceptual framework in which to capture and illustrate the range of social, economic and cultural functions of geodiversity was produced. This framework is reported in Section 2. Sections 3 to 6 respectively provide greater detail of the key functions of geodiversity in terms of its contribution to 'appreciation', 'knowledge', 'products' and 'ecosystem function'. In each of these sections a review of the existing research that demonstrates the contribution that geodiversity provides to society is provided, as well as present case study examples to illustrate in greater detail the social functions provided. The economic literature is reviewed and where possible the findings of studies that have attempted to place economic values on these functions are reported. In the review of existing research, it was clear that there were many gaps in our knowledge of the value of geodiversity, and therefore empirical work to feed into this research was undertaken. The empirical work included a series of interviews and focus groups with members of the public and specific user groups which aimed to collect descriptive and anecdotal evidence of the way in which people value geodiversity. Empirical research was also undertaken to explore the economic value to geodiversity. First, the choice experiments method was used to assess how much people would be willing to pay to protect and enhance two geological sites: Wren's Nest National Nature Reserve (NNR) in the West Midlands and the Jurassic Coast World Heritage Site (WHS) in Dorset. Second, economic impact analysis was carried out on the Isle of Wight to determine the size of the local economic (income and employment) impacts that geodiversity brings to the Island. This report draws on the findings of this empirical work where appropriate. Further details of this empirical research can be found in the technical annex to this report.

Section 7 of the report pulls together the key findings from this research to provide a comprehensive overview of the economic and social value of geodiversity, and importantly identify where gaps in our knowledge still exist. Finally, Section 8 provides a critical discussion of the research and highlights areas requiring further research.

2 Revealing the value of geodiversity – an overview

Although the scientific value of geodiversity has been widely documented, the economic, social and cultural contribution of geodiversity to human welfare has so far been largely overlooked. Geodiversity, arguably, does make important contributions to enhancing human welfare. However, these values have yet to be comprehensively explored and documented.

Recent research into the value of nature provides a useful starting point from which to explore the benefits of geodiversity in more depth (see De Groot 1992; Daily 1997; English Nature 2002; Gray 2004). Generally, this research has identified four main classes in which nature is valued: appreciation, knowledge, products and ecosystem/natural functions. Each of these value classes is further split into detailed categories (English Nature 2002). This research aims to follow the research protocol adopted by English Nature (*ibid.*), but with a particular focus on the values associated with geodiversity. Figure 1 thus provides a summary of the many benefits offered by geodiversity. As with the English Nature (2002) research on 'Revealing the value of nature', this value framework for geodiversity is based around four main value categories: appreciation, knowledge, products and ecosystem/natural functions. These value categories are then further divided into 24 sub-categories. Further detail of the various value categories are provide in the following four sections that respectively address the four main value types. Within each section, a detailed description of the value categories and sub-categories are presented, along with specific case studies examples to illustrate these values.

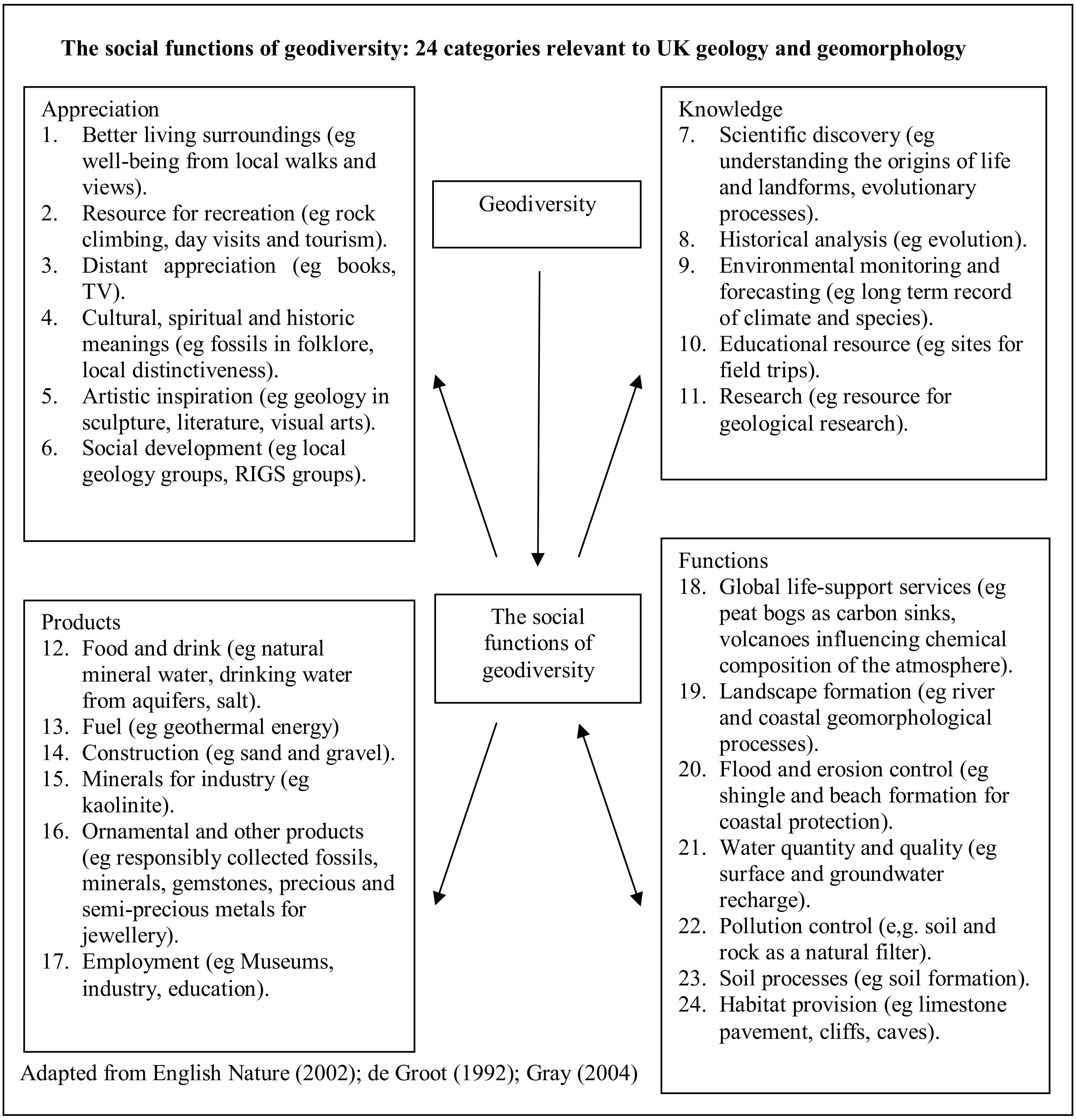

Figure 1 The social functions of geodiversity

3 Appreciation

Direct and indirect contact with the natural world provides people with many benefits (English Nature 2002). Geodiversity is the foundation of the natural world and is therefore around us at all times. For that reason, aspects of geodiversity are experienced constantly whether people are aware of it or not. Geodiversity is appreciated and experienced in a wide variety of ways, from the way in which it features in culture and folklore, to the inspiration it provides and the spiritual and historical importance that it holds.

3.1 Better living surroundings

The landscape as we know it is formed and shaped by geomorphological processes. These processes have made the landscape a pleasing and suitable place to live and work in. It has been stated that interaction with the natural world is a vital part of human well-being (Irvine and Warber 2002). Hughes and Morrison-Saunders (2003) also found that natural area visitors ranked spiritual meaning and rejuvenating well-being significantly higher than those who did not regularly visit natural areas. The case study reported in Figure 2 provides a further example of the positive impacts that geodiversity may have on the health and well-being of people. Finally, Rohde and Kendle, (1994; as cited in English Nature 2002) clearly demonstrate the positive benefits that contact with nature has on mental well-being. Certain landscapes and scenery thus appear to evoke feelings of tranquillity and serenity, and hence improve quality of life.

Better living environment – better health

Barrow Hill local nature reserve (LNR) is next to Russell's Hall Hospital, Dudley, West Midlands, and is the base for Action Heart, a cardiac rehabilitation programme. Recovering patients have access to the LNR with waymarked routes where groups of 20-30 people exercise twice a week. Dudley Metropolitan Borough Council in partnership with the Black Country Geological Society obtained an Aggregates Levy Sustainability Fund grant from English Nature for work to promote the geology and improve access to Barrow Hill LNR (English Nature 2006a). A Green Gym project and walking and running groups are being set up on the reserve.

Figure 2 Health benefits of geodiversity in Dudley, West Midlands

As part of this research, a series of focus groups were undertaken to explore the public's perceptions of geodiversity. Participants identified that certain places evoked feelings of well being and had a health value *"you feel like you're on top of the world and just looking down…"*. Others discussed how the local landscape made them feel *"marvellous views…gives you peace…"*, *"relieve a lot of people's stress"* and *"it [Golden Cap, Dorset] really cheers you up and brightens your day"*. Other participants described the tranquillity and solitude felt when out walking, looking at the geodiversity features or looking for fossils and enjoying the peace, quiet and relaxation provided.

While the anecdotal evidence presented above clearly illustrates how geodiversity may directly contribute to a better living environment, there has been little scientific research in this area. The psychological and physiological values therefore should be further explored in future research effort. Although, economic values have been quantified in studies which address house prices, agriculture, landscape, amenity and recreation values (Garrod and Willis 1992a; b; Willis and Garrod 1991; Mitchell and Carson 1989; Garrod and Willis

1999), none of these studies focus specifically on the value of geological and geomorphological features in terms of contributing to a better quality of life.

3.2 Resource for recreation and tourism

The natural world has long been recognised as a place for recreation, where people go to rest, engage in physical exercise and recreational sports, pursue hobbies or simply for relaxation (De Groot 1992). Geodiversity provides a wide variety of areas for these activities from short day visits to longer term stays. National Parks (eg Peak District, North York Moors, Exmoor, Dartmoor, Lake District, Snowdonia) demonstrate the scale and diversity of the geology resource in the UK. These unique landscapes and habitats attract millions of visitors every year.

Mountains, caves, disused quarries and coastal features provide unique geological environments for a range of recreational activities including hiking, walking, climbing, caving, mountain biking, surfing, and abseiling. People also visit areas specifically because of its geology: for example, the Dorset and Yorkshire coast, Ludlow and the Isle of Wight. People are also drawn to certain areas to collect fossils. Monmouth Beach in Dorset teems with fossil hunters scouring the beach for ammonites. Visitor and heritage centres located in areas with particular geological diversity provide further recreational opportunities, as well as providing interpretative material on the geology found at the site. Museums with geological and palaeontological collections also provide a unique visitor experience. Many museums also document and display the close links of industrial development, archaeological, and ecological links with geodiversity (eg Ironbridge Gorge Museum, Black Country Living Museum, Big Pit, Dolaucothi Gold Mines, National Stone Centre). The world's first dinosaur park was opened in 1854 in Crystal Palace Park. The park has recently been restored and reopened.

There are also many museums or attractions that exhibit geodiversity features, such as caves and gorges (eg Dan-yr-Ogof, Cheddar Gorge) and caves (Wookey Hole), natural arches, and stacks (Isle of Wight Needles, Old Harry Rocks, Durdle Door). Finally, there are also a large number of geological trails in the UK (Macadam 1997; Kent RIGS Group 1998; 2003; RIGS Wales, New RIGS 2001a; 2001b; 2001c; Mason; English Nature 2003). Table 1 illustrates the numbers of visitors that are annually attracted to a sample of these geological attractions.

Table 1 Visitor numbers to geodiversity attractions

Visitor numbers to selected geodiversity attractions	
Geological	
Dinosaur Isle	81,486 in 2002/2003
Big Pit	116,278 in 2002/2003
Dan Yr Ogof Caves	79,515 in 2002
Welsh Slate Museum	130,201 in 2002/2003
Wrens Nest National Nature Reserve	10,000 visitors per year
General Natural History and Heritage	
Natural History Museum:	1.66 million in 2000/2001
National Museum and Gallery, Cardiff:	321,968 in 2002/2003
Snowdonia National Park:	10 million visitor days per year
Dartmoor National Park:	8 million day visitors in 1994
North York Moors National Park	9.75 million visitor days in 1999
Dudley Museum and Art Gallery	17,882 in 2004
Black Country Living Museum	229,304 in 2004

Sources - Annual reports, personal communications

Geodiversity also provides a resource for tourism. In a recent BBC survey of the fifty places that everyone should see in their lifetime, the Grand Canyon was number one (BBC 2003a). The same survey produced a top five of the best natural wonders, which featured the Grand Canyon, Uluru (Ayers Rock), Niagara Falls and Victoria Falls. This again demonstrates that geodiversity has a significant bearing on our lives (BBC 2003b).

3.2.1 Economic benefits from geodiversity-based recreation and tourism

Geodiversity also provides welfare benefits to people who visit or recreate in an area of geological interest. This economic value associated with recreational use of an area may be estimated using revealed preference valuation techniques (such as the travel cost method) or stated preference techniques (such as contingent valuation or choice experiments). Such methods have been extensively applied to value landscape features such as woodlands and forests, open spaces, nature reserves, coastal and inland water (see Farber 1988; Willis and Garrod 1991; Willis and Garrod 1993; León 1996; Garrod and Willis 1999; Christie and others 1998). There are, however, only a handful of valuation studies that have specifically examined the values of recreation activities that are directly attributed to geodiversity. These studies, summarised in Table 2 have valued the recreational benefits from rock climbing, mountain biking and beach recreation.

Table 2 Summary of recreational values directly associated with geodiversity

Activity	Value
Rock climbing (Hanley and others 2001)	£31.15 consumer surplus per trip
Mountain biking trail (Fix and Loomis 1998)	\$205 - \$235 consumer surplus per trip
Beach visits (Kline and Swallow 1998)	\$3.06 (week days) and \$4.18 (weekends)
Beach recreation (Bell and Leeworthy 1990)	\$33.91 consumer surplus

In addition to existing research, a choice experiment study was undertaken at Wren's Nest National Nature Reserve to further explore the economic value of different geological features found at the reserve. Geology is an important attraction of Wren's Nest NNR, with 43% of visitors stating that they 'looked at the geology' while visiting the reserve and 35% 'collected fossils' during their visit. The actual choice experiments technique utilised survey questionnaires to present hypothetical management options for the future management of the reserve. In particular, these options related to access to the reserve, access to limestone caverns on the reserve, the provision of educational material and access to fossil collecting. Analysis of the survey results indicated that access to the reserve for recreation was valued at £7.83 per household per year without education material and £21.26 with education material (Table 3). Access to the Seven Sisters Caverns on the reserve was valued at £12.22 per household per year without education material and £13.95 with educational material. Clearly these results indicate that the provision of information on the geology found at a geological site greatly improves people's enjoyment of that site. The opportunity to collect fossils in spoil heaps was also highly valued (£5.18 per household per year). The values estimated are relative the status quo, or the current situation. The choice experiment provides the survey respondents with alternative scenarios, therefore any negative values are generally associated with a loss of a good, in this case, access to Wren's Nest NNR and the Seven Sisters Caverns. Detail of this study can be found in the technical annex to this report (Appendix 4), while a summary of the key findings is reported in Table 3.

Table 3 Implicit prices of attributes of Wren's Nest NNR and Seven Sisters caverns

Attributes of Wren's Nest NNR	Implicit price per household per year (£)
Access to all areas of Wren's Nest NNR, no explanation of geology	7.83
Access to all areas of Wren's Nest NNR, with explanation of geology	21.26
No access to Wren's Nest NNR	-29.09
Group access to Seven Sisters Caverns with guide, no explanation of geology	12.22
Group access to Seven Sisters Caverns with guide with explanation of geology	13.95
No access to Seven Sisters Caverns	-26.17
Fossil collecting in all areas (including rock faces) by public	-11.76
Unlimited fossil collecting from loose rock/spoil heaps	5.18
Fossil collecting by geologists only	6.58

A choice experiment survey was also carried out at the World Heritage Site in Dorset. Different aspects of the Jurassic Coast were valued. In this application, willingness to pay for: access to the Jurassic Coast with and without geological interpretation; fossil collecting; and coastal defence were examined. On average, people were willing to pay £23.69 per household per year to gain access to the coast with some explanation of the geology, and £62.35 per household per year to gain access with extensive interpretive material (Table 4). Thus, again the importance that interpretation of geological features has in terms of enhancing the recreation experience was demonstrated. A proposal to restrict public collection of fossils was negatively valued, while maintaining public access to fossil collecting was valued at £57.73 per household per year.

Table 4 Implicit prices of attributes of Jurassic Coast, Dorset

Attributes of the Dorset Jurassic Coast	Implicit price per household per year (£)
No access to the Jurassic Coast	-86.04
Access to most of Jurassic Coast via beaches with some explanation of geology	23.69
Access to all of the Jurassic Coast with extensive explanation of geology	62.35
Coastal defence with hard engineering (use of concrete walls, pilings)	14.19
Coastal defence in gateway towns only (none in areas outside of towns)	-11.28
Allow natural erosion to take place	-2.91
No fossil collecting	-42.27
Fossil collecting in all areas by geologists/collectors only	-15.46
Fossil collecting via code of conduct by geologists/collectors, public collect on beaches	57.73

The survey respondents were found to be representative of the local populations. The results from these studies, along with other existing research, clearly demonstrate that people gain value from recreation in areas of high geological importance. Importantly, people appear to gain greater benefits if the geological features are explained. Also, it is demonstrated that people highly value opportunities to collect fossils.

3.2.2 Economic impacts of geodiversity-based recreation and tourism

Tourism and recreation associated with geodiversity may also generate significant economic impacts in terms of local income and job creation. As outlined above, many areas in the UK attract tourists because of the geodiversity and landscapes, for example the Yorkshire Coast, Dorset and the Isle of Wight. The Isle of Wight in particular relies heavily on it's geodiversity for tourism. An economic multiplier study was undertaken for this research to estimate the economic impacts of geodiversity to the Isle of Wight economy. Multiplier studies estimate the income generated from the injection of visitor expenditure in a local economy. These are expenditures on accommodation, travel, food, activities and services. For example, £1.00 of visitor expenditure generates between £0.24 - £0.45 income within a local economy (Rayment 1995). Applied to the Isle of Wight, the results based on 150 groups interviewed. The average daily expenditures of respondents who visited the Island specifically because of the geodiversity was £73.86. An estimate of the income impacts of geodiversity between £4,626 and £8,675 and the employment impacts as 0.6 and 0.8 full time equivalent (FTE) local jobs (Table 5).

Table 5 Income and employment impacts of geodiversity

		Income impacts		Employment impacts (FTE jobs)	
	Local spend (£)	**Lower bound (£)**	**Higher bound (£)**	**Lower bound**	**Higher bound**
Aware of geology, influenced visit	19,278	4,626	8,675	0.6	0.8
Aware of geology, no influence	17,068	4,096	7,680	0.5	0.7
Unaware	5,722	1,373	2,575	0.2	0.2
Unaware, but will return	7,384	1,772	3,322	0.2	0.3
TOTAL	49,454	11,869	22,254	1.5	2.0

Estimates of income impacts are based on income multipliers of 0.24 and 0.45 (Rayment 1995).
Estimates of employment impacts are based on employment multipliers of one FTE job generated per £34,000 (Countryside Agency 2000) and £25,000 (Rayment 1995) expenditure.
Income impacts are shown with no decimal places.

Tourism on the Isle of Wight was estimated to be worth £352 million for the tourism year 2004/2005 (Isle of Wight Council 2006a). This represents the estimated tourist spend from domestic and overseas visitors. Geodiversity tourism or geotourism can be estimated as 3.13% of the total tourism spend on the Island, and thus provides between 324 and 441 FTEs and income impacts of between £2,644,224 and £4,957,920. These estimates are based on direct jobs and income associated with geodiversity.

The above discussion provides an insight into the economic value and impact of geodiversity as a resource for recreation and tourism. Research undertaken for this report clearly demonstrates that people gain substantial economic benefits from recreation activities directly associated with geodiversity. However, it is also clear that there are a wide range of other recreational activities that rely specifically on geodiversity for their existence. The links that these activities have with geodiversity and their values have not yet been fully investigated.

3.3 Distant appreciation

Sections 3.1 and 3.2 above demonstrated how geodiversity may be directly appreciated in terms of improved quality of life and through recreation and tourism. Geodiversity may also be appreciated distantly through for example television, radio, films, and print media and through associated merchandise such as gifts and toys.

The popularity of geology (and palaeontology in particular) has been escalated by Hollywood films such as ‘Jurassic Park’ (based on Michael Crichton’s books) and television series such as ‘Walking with Dinosaurs’. The box office gross income from Jurassic Park was $920 million worldwide, with the two sequels making a further $980 million (The Numbers 2003).

The 'Walking with Dinosaurs' series broke all UK viewing records for documentaries with each episode being watched by 13 million people (BBC 2003c). Fossil digs have also been the subject of a number of television series including 'Live from Dinosaur Island' and 'The Big Monster Dig'. Although many of the above programmes draw on the general publics' fascination with dinosaurs, other programmes such as the BBC's 'British Isles: a Natural History' and 'Journeys from the centre of the Earth' depict the relationship between man and the geological environment. Another BBC series 'Seven Natural Wonders' featured eight episodes describing natural wonders from different areas of England including the Cheddar Gorge, the cliffs of Dover and the Scilly Isles (BBC 2006). Geodiversity also featured in the 2002 televised Royal Institution Christmas Lectures, which was viewed by over 1.5 million people (Royal Institution Website 2003). Table 6 provides a summary of some of the more popular media in which geodiversity is appreciated from a distance.

There are also a number of specialist television channels (for example National Geographic, Discovery and UK Horizons) which broadcast programmes that feature geodiversity. Although it is unlikely that these channels have been bought solely for the geological programmes, the subscription charges for these channels does demonstrate that people are willing to pay some amount of money for distant appreciation of geodiversity.

In addition to television and film, geodiversity has also been the subject of many books targeted to all ages, and in the form of both fiction and non-fiction. Geodiversity also regularly features in the news and newspapers; for example through stories on earthquakes to new fossil finds. There are various magazines that also feature aspects of geodiversity, Geographical, National Geographic, New Scientist and other specialist magazines such as for activities like caving, mountain biking and climbing (eg Caves and Caving, Bike, Mountain Bike, Climbing, Rock). While these are not totally dedicated to geodiversity, there are many articles and features that depict geodiversity in some way.

The internet also provides another medium for distant appreciation of geodiversity. Most museums, academic institutions and geological organisations have web sites relating to their collections. The Natural History Museum website recorded 3.1 million visits to their website in 2000/2001, and 7.7 million in 2003/2004 (Natural History Museum 2006); although it should be noted that this was for the whole site and not just those pages associated with geology.

Table 6 Geodiversity featured in the media

Films	TV
Jurassic Park (1, 2 and 3)	Walking with Dinosaurs – BBC (15 million viewers per episode)
The Land That Time Forgot	The Big Monster Dig – Channel 4 (1.25 million viewers per episode)
The Land Before Time	Pompeii – BBC (10 million viewers)
Dante's Peak	Landscape Mysteries - BBC
Earthquake	Sea Monsters - BBC
Volcano	The Lost World - BBC
Ice Age I and II	Live from Dinosaur Island - BBC
	Earth Story - BBC
	British Isles – A natural history – BBC
	Journeys from the centre of the earth - BBC
	Coast – BBC
	Horizon - BBC

Sources – BBC, RDF Media

The value that people attain from distant appreciation of geodiversity is difficult to gauge. Viewing figures along with subscription / sales charges could be used to represent this some of this value. However, many of the television programmes are either free to view or included as a package, and therefore it would be extremely difficult to isolate the value directly associated with geodiversity.

One approach used by environmental economists to valuing distant appreciation is through measuring 'passive use' values. Passive use value is the term used to describe the situation where a person gains value from the knowledge that a resource exists (for future use or use by others) even although that person does not have any current plans to utilise that resource. Distant appreciation can be considered as one component of passive use value. Passive use values of the geodiversity at Wren's Nest NNR were estimated using a choice experiment. In this application, a sample was drawn from the local population who stated that they had no actual or planned use of the site. Thus, the value derived from this study may be considered to represent the distant appreciation of this geological site. The results from the choice experiment can be found in Table 7. As with the use values (reported in Table 3 in Section 3.2.1) respondents had higher passive use values for the site when interpretation on the geology was provided. Overall, the passive use values are slightly lower than the use values; although this difference is not statistically different.

Table 7 Passive use values of Wren's Nest NNR and the Seven Sisters Caverns

Attributes of Wren's Nest NNR	**Implicit price per household per year (£)**
No access to Seven Sisters Caverns	-26.76
Group access to caverns with guide, no explanation of geology	7.59
Group access to caverns with guide with explanation of geology	19.17
No access to Wren's Nest NNR	-22.51
Access to all areas of Wren's Nest NNR, no explanation of geology	11.14
Access to all areas of Wren's Nest NNR, with explanation of geology	11.37
Fossil collecting by geologists	7.90
Fossil collecting in all areas by public	-13.01
Unlimited fossil collecting from spoil heaps	5.11

3.4 Cultural, spiritual and historic meanings

Geodiversity has significant cultural, spiritual and historic meaning to societies. Landscapes and landforms, for example, are (and have been) significant determinants of the pattern of settlements. Early man used geodiversity to his benefit: from caves for shelter, to stone for tools, and later minerals and metals (Corfield 2002). The locations of towns and villages have, throughout history, been determined by the topography of the land, the availability of water and food. Coastal towns such as Poole and Lulworth Cove were developed around natural harbours, which lead to the development of thriving maritime industries. The presence of mineral resources has also shaped urban geography and economic prosperity in locations such as the Black Country (Prosser and Larwood 1994).

The influence of geodiversity has also been celebrated in many communities. For example, the people of Dartmoor recently celebrated its 370 millionth anniversary, recognising the important links between geology, farming, wildlife, archaeology, industry and water supply (Dartmoor National Park Authority 2001). The Wren's Nest National Nature Reserve celebrated its 50th anniversary of designation in 2006 with the production of a 'Wren's Nest Anniversary Beer', as well as many other activities to celebrate its history, particularly to the local community (Worton, pers. comm. 2003).

Geological landforms are also strongly associated with folklore. For example, the Giant's Causeway in Northern Ireland is famed to be stepping stones of giants. Many geological features have spiritual meaning to certain societies; for example many caves, mountains and other landforms are regarded as sacred. Fossils also feature heavily in folk history (Bassett 1982). Fossil ammonites have been referred to as rams' horns, snakestones and conger eels, due to the coiled nature of the shell. Many fossils are known by different names due to their shape or local legends (Table 8). Fossils were also incorporated into many towns' coat of arms: the trilobites of Dudley became known as the 'Dudley Bug'; ammonites of Whitby; Gryphaea of the Borough of Scunthorpe; and the Iguanodon in the Borough of Maidstone.

Table 8 Fossils in folklore

Fossil	Alternative Name	Origin
Ammonite	Rams' horn	Greek origin – associated with the God Jupiter Ammon
	Snakestone	Whitby, Yorkshire – from the legend of St Hilda who turned serpents into stone
		Keynsham, Somerset – St Keyna turning serpents into stone
	Conger eels	Dorset and Wiltshire – quarrymen of Portland Stone found particularly large ammonites which looked like sea-serpents or eels
Belemnites	Thunderbolts	From Jurassic and Cretaceous rocks – thought to be darts thrown down from heaven during thunderstorms
		Also called Devil's fingers or St. Peter's Fingers in other areas
		South-east England – Bullets
	Scaur pencils	Whitby, Yorkshire – from the Scaur platform of shales
Gryphaea	Devil's Toenail	Jurassic rocks throughout the country – so called because of it's curved toenail like appearance
Myophorella	'Osses 'eds	Headington, Oxfordshire – thought to look like a horses head
Bucardites	Bulls hearts	Headington, Oxfordshire – thought to look like a bulls heart
Gastropods	Screwstones	Jurassic rocks of southern England – named due to the spiralled nature of the fossil
Crinoids	Screwstones	Carboniferous rocks of the Midlands – crinoids with a screw-thread appearance
Cyrtospirifer	Delabole butterfly	Devonian rocks of Cornwall – shell resembled butterfly wings

Adapted from Bassett (1982)

The cultural, spiritual and historic value of geodiversity is clearly apparent in many forms. The measurement of such values is difficult due to the nature of the value and the extent to which geodiversity influences these values varies. In an attempt to capture some of these values, a series of focus groups were undertaken for this report. During these focus groups, participants were asked to discuss their sense of identity with their local area and also to discuss the local distinctiveness of various parts of the UK. Examples of how geodiversity creates local distinctiveness included the golden rock and the blue lias of Dorset, and the white cliffs of Dover. One participant stated that *"these are the features that make this country famous"*. When referring to the stones used in buildings, another participant indicated that *"you would know where you are by what's around you"*. Figure 3 provides another example of how geodiversity can contribute to the local distinctiveness of an area – in this case Dorset.

Geodiversity and local distinctiveness

The geodiversity of Dorset has influenced local culture and history extensively. The varied geology has given rise to local distinctiveness and character of settlements in the area. For example most of the Isle of Portland is built from Portland freestone (Thomas 1998). Many of the quarries on Portland still produce stone for memorials, headstones and sea defences. Portland stone has also been used in many historic buildings, including St. Paul's Cathedral. The stone used in each village in the area records not only the geology, but the history of family connections, of working practices and trade.

Figure 3 Local distinctiveness in Dorset

Research into the cultural, spiritual and historic value of geodiversity is limited. However, some research has been published on the valuation of historical buildings, monuments and artefacts, with studies based on the willingness of visitors to pay higher entry fees and restoration costs, and valuing damage to historic buildings and monuments (Navrud and Ready 1999; Eftec 2005). The cultural, spiritual and historic importance of geodiversity is an area of research that needs to be addressed further.

3.5 Artistic inspiration

Geodiversity has been an inspiration to many artists, poets, musicians, and writers both classic and modern (see Figure 4). Natural features, landscapes, landforms and fossils have been represented in all artistic media, from paintings, drawings, sculpture, photography, poems, novels and music. There are many examples that demonstrate the role and importance of geodiversity as an influence to artists. Carter and Badman (1994) state that 'the link between rocks and the feel of a place is indisputable and deeply engrained in our culture'.

Designs based on fossils were also used in the façades of houses during the 19th Century Regency Period. This style of architecture, know as the 'Ammonite Order' features in Lewes and Brighton in Sussex (Bassett 1982).

Geodiversity is celebrated and imagined in many ways, from large scale exhibitions by world renowned artists to primary school children's fossil art and poems, from sand sculptures to ancient cave paintings. Dove (1997) provides a summary of the connections between geodiversity and art. Geodiversity provides inspiration to all, regardless of age, sex and nationality, whether a professional or not, there are exhibitions that demonstrate the pleasure that we get from the natural world. For geodiversity to have such a powerful effect on people that they feel so inspired and influenced by its form and mood is a major benefit to society.

Selected writers	
Jane Austen	Wrote about Lyme Regis in *Persuasion*
Thomas Hardy	Wrote many works including a description of Portland, Chesil Beach and Lulworth Cove
Llewellyn Powys	Wrote about the local Dorset countryside
John Cooper Powys	Wrote about the local Dorset countryside
John Fowles	*French Lieutenant's Woman* – one of the main characters was a palaeontologist
Lord Byron	Work inspired by geological research of his day
Norman Nicholson	Wrote about his home county of Cumbria
W.H. Auden	Many works inspired by the karst landscape of Yorkshire Dales, including *In Praise of Limestone*
Jules Verne	Many works included descriptions of landscapes
John Keats	Visited the Isle of Wight
Tennyson	Visited the Isle of Wight, heritage coast named after him
N.T. Carrington	Wrote many works inspired by landscapes and nature, including *Dartmoor*,
Frederick Treves	Wrote about Dorset in *The Highways and Byways of Dorset*
Paul Hyland	Wrote about the Dorset landscape and the Isle of Wight
Composers/Musicians	
Mendelssohn	Fingal's Cave on the island of Staffa off west coast of Scotland provided inspiration for *Hebrides Overture*.
Elgar	Worcestershire landscapes provided inspiration
Arnold Bax	An English composer inspired by the beauty of the landscape
Vaughan Williams	Work inspired by landscape
Artists and Painters	
John Everett Millais	Landscapes
John Brett	Landscape painter, including the Isle of Wight. His work *The Glacier of Rosenlaui* became a vital source of information for geologists in the 19th Century (Bendiner 1984)
Constable	Sketches and paintings of Dorset
Turner	Sketches and paintings of Dorset and Isle of Wight
Paul Nash	Depicted Dorset coast in different media including watercolours and photography
Dave Gunning	Etchings and paintings of landscape in Dudley
Graham Jones	Giant wooden trilobites carvings
Ilona Bryan	Finds inspiration for her work from the landscape, colours and textures, ceramics and pebbles
Charles Rennie Mackintosh	Painted landscapes of Purbeck
Sculptors	
Peter Randall-Page	Wayside carvings in Lulworth, Dorset
John Maine	Created a large scale landscape sculpture in Dorset to stratigraphically represent the Portland Beds
Susheila Jamieson, Joe Smith, Jim Buchanan, Frances Pelly	Sculptors inspired by geodiversity, in particular have work at Knockan Crag, Scotland
Steven Marsden	Sculptor with work at Tout Quarry, Portland, a disused quarry now an outdoor gallery
Dominique Bivar Segurado	Rock structure and landscape of Lyme Regis inspired her to create ceramics that mimic the texture and structure of rock formations (pers. comm. 2004).

Sources: Bird and Modlock (1994), Clifford (1994)

Figure 4 Geodiversity and the arts

The artistic value of geodiversity could be quantified by the amount paid for works of art, but the value geodiversity contributes to culture is less understood, while it is clear that it is socially valuable, measuring this value is difficult. Geodiversity contributes both directly and indirectly to the value of artistic inspiration.

3.6 Social development

Geodiversity provides many opportunities for social development, through the formation of local groups, voluntary organisations, and through the stewardship of geological sites. The Aggregates Levy Sustainability Fund provides funding to conserve and enhance geological and geomorphological features, particularly Regionally Important Geological and Geomorphological Sites (Prosser 2002). Sites such as disused quarries can be transformed into education resources, provide a recreation facility and hence will help to unite communities through the appreciation and pride in their local resource. The rehabilitation of disused quarry sites could also enhance the quality of life in urban areas (Damigos and Kaliampakos 2003). Urban geological sites can be adopted by local communities, local authorities, industry and schools and used as a way to become involved in conserving and managing a part of their local heritage (Prosser and Larwood 1994). Volunteering develops volunteers' skills and some volunteers may enjoy the social atmosphere that volunteering provides (Brown 1999). Other ways in which geodiversity contributes to communities is through the network of Local Nature Reserves, interest groups and through specific projects such as the Dinosaur Coast Project in Yorkshire, and the Jurassic Coast Project in Dorset.

The way in which geodiversity contributes to social development is significant and therefore is valuable to society. The economic value of volunteering could be calculated by multiplying hours volunteered by an hourly wage or by the savings made to organisations (Brown 1999).

3.7 Summary of appreciation

Geodiversity provides us with many opportunities for appreciation. It provides improved living surroundings and health benefits and a resource for recreation and geotourism. The distant appreciation and artistic inspiration of geodiversity is important in our artistic and cultural life to provide access to geodiversity for many people. The cultural, spiritual and historic significance of geodiversity is important for local identities and distinctiveness, and forms and integral part of our heritage. The social development opportunities provided by geodiversity and the conservation of geodiversity can improve and provide focus for communities, this in turn can develop a sense of pride and confidence.

4 Knowledge

Geodiversity provides a knowledge resource for scientific and historic discovery, it is also important in environmental monitoring, and as an educational and research resource. Volcanoes, earthquakes, landslides, hydrogeology, minerals, fossils, evolution, extinctions, glacial features and processes, soils, rivers and coastal processes are all component parts of geodiversity. Then there are the people and organisations associated with geodiversity from the pioneers of geodiversity in the UK to the academics and professionals that rely on the knowledge of geology and geomorphology. The conservation of geodiversity is essential for the continued knowledge provided. The contribution that geodiversity brings to knowledge in terms of scientific discovery, historical analysis, environmental forecasting and monitoring, educational resource and research will now be further explored.

4.1 Scientific discovery

The study of geology and geomorphology has enabled scientists to gain a greater understanding of our past, including the processes that have formed the Earth, the origins of life, evolutionary processes and extinctions. Much of the early knowledge of geodiversity was founded in the UK; indeed many of the periods of geological time were based on British geological sites (Wilson 1994) and are summarised in Table 9.

Table 9 Origins of geological time periods with defining countries

Eras	*Periods*	*Epochs*	*Country where defined*
Cainozoic	Quaternary		
(recent life)		Holocene	England
		Pleistocene	England
	Tertiary		Germany
		Pliocene	England
		Miocene	England
		Oligocene	Germany
		Eocene	England
		Palaeocene	Germany
Mesozoic	Cretaceous		France
(middle life)	Jurassic		Switzerland
	Triassic		Germany
Upper Palaeozoic	Permian		Russia
(ancient life)	Carboniferous		England
	Devonian		England
Lower Palaeozoic	Silurian		Wales
(ancient life)	Ordovician		Wales
	Cambrian		Wales

Adapted from Wilson (1994)

Geodiversity provides us with the means to understand the Earth and the processes which shape it. These discoveries have been applied to the mining, water, construction, and other industries. This knowledge has also been used to help develop contingency plans to predict flooding, environmental hazards such as earthquakes and volcanic eruptions, and environmental engineering.

A new area of geology, so called forensic geology, relies on aspects of geodiversity for solving crimes. For example, crimes have been solved by linking soil types to a crime scene (The Times 2002). An American geologist also identify the general location of Osama Bin Laden in 2001, when he recognised the sandstone caves shown in a video of Bin Laden (BBC 2004).

Fossils are also scientifically significant with new discoveries being made constantly. Recently, a new species of *Misionella didicostae* (a type of crevice weaver spider) was discovered in the Dominican Republic; this discovery was the first fossil record of the family *Filistatidae* (Penney 2005). In the UK, 330 million year old tracks left by *Hibbertopterus (Eurypterida)*, a type of giant water scorpion, were found in Scotland (Whyte 2005). The UK also has many important fossil sites. Table 10 provides a summary of some of the key scientific discoveries that have been made at three geological sites in the UK. The conservation of geodiversity is essential for these new discoveries to continue. Fossil collectors have described feelings of awe, and humbleness with fossil discoveries. There is a feeling that you are *"lucky to have found it"* and *"to be the first person to ever see it"*.

Table 10 Selected aspects of scientific discovery at Wren's Nest, Jurassic Coast and Isle of Wight

Wren's Nest NNR	Jurassic Coast	Isle of Wight
Silurian age rocks contains most diverse and abundant fossil fauna in British Isles, perfectly preserved 3D fossils including trilobites, sea lilies, worms	Fossils including vertebrates such as fish, amphibians, reptiles, most invertebrates except corals, plants.	National and internationally important fossils, including dinosaurs, ammonites, birds, plants, turtles, crocodiles, mammals, insects.
Type locality of 186 species of fossil, 63 not found elsewhere	Discoveries new to science continue to be made	All species of dinosaur represented, with potential for future finds
Many new species, particularly microfossils yet to be described	Near continuous sequence of rocks documenting 190 million years. Important site in the founding of historical geology and geomorphology.	Complete or near complete strata including the lower Greensand Group, Wealden Group and Gault and Upper Greensand
Other features of the site include patch reefs and ripple beds. Fossils important for study of evolution and past environments	Other features include barrier beaches, active landslides, cliffs with arches, stacks and bays and raised beaches	Rocks and fossils important for the understanding of the geological evolution of the Isle of Wight and Hampshire Basin. Geomorphological processes

The value of geodiversity to scientific discovery is very difficult to estimate, with new discoveries continually being made, and new theories being developed. The values of scientific information have been quantified in some studies. The Illinois State Geological Survey (2003) reported in their 2000 annual report that the cost of geologically mapping Kentucky was $90 million, and the benefits of this information are at least 25 to 39 times the cost. Another study developed a method of estimating the value of geological map information to the location of a waste disposal facility by comparing the economic impact of decisions made using new map information compared to existing maps (Bernknopf and others 1997). The net benefit of $0.34 million was calculated by subtracting the value of producing the new geological map ($1.16 million) from the benefits that the new map information will provide ($1.50 million) (Bernknopf and others 1997).

There are many socio-economic benefits of geological maps, the multiple uses and applications are important for assessing coastal erosion, flood hazards, soil and ground instability, groundwater resource development and contamination risk, and other planning activities.

4.2 Historical analysis

Geodiversity is essential to historical analysis. The geological record enables the 4,600 million year history of the Earth to be reconstructed and provides insight into the understanding of the origins of the planet, the origins of life, the changing landscape, the climate, evolutionary processes and extinction periods. Geodiversity provides us with a record of the way in which the Earth has changed and evolved as a result of surface processes. Geodiversity in the UK has been advanced by many historical figures in the field (Table 11).

Table 11 Selected historical figures in geodiversity

Wren's Nest NNR	Jurassic Coast	Isle of Wight
Sir Roderick Murchison	Elizabeth Philpot William Buckland William Conybeare Henry De la Beche Mary Anning	Gideon and Mary Mantell William Fox

The study of climate change, sea level change, past environments, landscape formation, evolution of species and planetary geology are all only possible due to our geodiversity. Where the UK's biodiversity is a snapshot of life today; the geological record provides a long term record of billions of years of history (English Nature 2002). The evolution of the continents has been studied extensively using the evidence provided by the geological record. The oldest rocks in the UK are 2,800 million years old, and since the Cambrian period, plate movement has moved the UK from south of the equator to its present position. The rock record illustrates that climate change occurs from these plate movements, and also from changes in atmospheric composition, ocean current circulation, and sea level rise and fall (English Nature 2004).

Fossils provide information about evolution and extinctions. Although dinosaurs can be considered the charismatic species of the geological world, fossils can be formed from many different species. Ammonites, for example, are common and popular fossils.

The public's perception of geodiversity knowledge is varied. Respondents in a series of focus groups undertaken for this research were in awe of geological time and plate tectonics. Respondents were amazed that environments were very different to the present day *"...Dudley was like Jamaica at one time…"*.

The value that people derive from fossil collecting was estimated using the choice experiments survey method at both the Wren's Nest NNR and on the Jurassic Coast. At Wren's Nest, the choice experiment examined three fossil collecting scenarios. Highest values were found for unlimited collecting from spoil heaps at Wren's Nest NNR (£5.18 per household per year) and collecting by geologists only (£6.58 per household per year). The survey revealed that the public had a higher preference for geologists collecting than being able to collect fossils from loose rock. A negative value (-£11.76) was found for collecting by the public in all areas (Table 12). This reflects the public's concern that the site would become spoiled by over-collection of fossils, indiscriminate collecting and damage to the resource, all of which may affect the aesthetic appeal of Wren's Nest. On the Jurassic Coast, fossil collecting by all via a code of conduct was highly valued (£57.73 per household per year). Restricting fossil collecting to geologists and collectors only and no fossil collecting was negatively valued (-£15.46 and -£42.27 respectively) (Table 12). This reflects the public's enthusiasm for fossil collecting, while also respecting the role of geologists and collectors in the area. The difference in values between the two sites is marked and may be explained by the greater familiarity of geology and fossils in Dorset as opposed to Wren's Nest.

Table 12 Value of fossil collecting at Wren's Nest NNR and Jurassic Coast

Fossil collecting	Implicit price per household per year (£)
Wren's Nest NNR	
Fossil collecting by geologists only	6.58
Fossil collecting in all areas by public	-11.76
Unlimited fossil collecting from loose rock/spoil heaps	5.18
Jurassic Coast	
No fossil collecting	-42.27
Fossil collecting in all areas by geologists/collectors only	-15.46
Fossil collecting via code of conduct by geologists/collectors, public collect on beaches	*57.73*

Historical analysis of geodiversity clearly provides much evidence on the history of the Earth and the Earth's processes. An understanding of these processes is essential for the successful management of human impact on the environment.

4.3 Environmental monitoring

The record of past climate change, soil formation, desertification, and the evolution of plants and animals can be applied to the present day situation (Ellis 1996). Past environments are represented in ice cores, peat bogs, lake, cave and marine sediments, and the fossil and rock record. The effects of human activities on the environment are also recorded (Ellis 1996). The study of geomorphological processes in rivers and coastal environments will also aid the prediction of future processes, these have implications to society, and for example monitoring sediment transport is useful for flood planning. Sediments in bogs, lakes and ice cores provide a record of human impacts such as pollution, vegetation clearance and soil erosion presenting a picture of past environments. This information can also be utilised to predict potential future impacts on climate for example.

Humphreys (2003) reports a number of case studies which examine environmental change in the past and demonstrate how these changes can be used to manage future environmental changes brought on by climate change, sea level rises and other catastrophic events. Holderness in Humberside is an area of high coastal erosion, the cliff top can retreat by several metres per year (Humphreys 2003). This erosion results in the supply of sediment to beaches and coastal habitats to the south. This process has been occurring for approximately 6,000 years and has resulted in the significant loss of land. There is no evidence of this retreat in the geological record due to the nature of the erosion, however their existence can be inferred by basal sediments represented by coarse-grained lag deposits. There is a gravel lag present on the sea floor which represents the early Holocene rise in sea level. The knowledge of these processes is invaluable for the management of these environments and to predict future changes (Humphreys 2003).

Other examples address accreting coasts, floodplains and changing river courses, unstable ground, rapid catastrophic events such as climate change, seal level change, and volcanic eruptions (Humphreys 2003). See Figure 5 for further case studies. All of these case studies use the geological record to provide evidence of environmental change and importantly use this information to predict future environmental change or disasters.

Environmental monitoring in Dorset

The geodiversity of Dorset is important in monitoring the environment. Landslides represent a serious hazard to human activities, by monitoring these landslides their processes and mechanisms can be understood (Humphreys 2003). The Black Ven landslide complex at Charmouth extends 4km west towards Lyme Regis, this represent one of the largest coastal landslides in Britain. Major engineering works are underway to remediate the effects.

The coast also provides evidence for beach formation and evolution. Chesil Beach is an internationally known feature. The beach is 28 km long and is famous for the volume, type and size-grading of its pebbles (Dorset County Council and others 2000). The Fleet, one of the most important lagoons in Europe, is enclosed by Chesil Beach and the sediments preserved provide information regarding late Holocene beach evolution and evidence for changes to sea levels, vegetation and climate (Dorset County Council and others 2000).

Figure 5 Environmental monitoring in Dorset

The value of geodiversity in environmental monitoring and forecasting to society is vital for the future. The value can be represented by the savings made from flood monitoring, and also from the restoration costs. The value is widely acknowledged and accepted, however few studies have attempted to quantity it. Of these, some studies have measured the economic impacts of climate change, sea level changes and pollution, (Mitchell and Carson 1989; Bateman and others 1991), however none have valued the contribution of geodiversity knowledge to this.

4.4 Educational resource

Geological sites are a very important educational resource, which are regularly used to teach school children on field trips and for training future geologists and geomorphologists. Sites are required by students and teachers to demonstrate the practical principles of geology and geomorphology (Ellis and others 1996). Field centres, visitor centres and geological organisations provide formal and informal opportunities for education. There are many areas of the UK which are studied for their relevance to geological education internationally; for example, Dorset, Dudley, Ludlow and the Lake District. Interpretation at geological and geomorphological sites also provides education to the wider public. Dove (1997) writes about the potential links between geology and art education.

Geodiversity features in the National Curriculum as part of science and geography; though geography is not a core subject (Department for Education and Skills 2003). Geology is taught at GCSE, A and AS level. Degree level geoscience courses are available at approximately 41 universities in the UK (Geological Society 2006).

Less formal educational resources for geodiversity include ‘Rockwatch’, which is the nationwide club (run by the Geologists’ Association) that provides an educational but fun experience for young geologists. The Urban Geology Activity Access Programme also exists to raise the profile of geoscience activities and encourage interest and participation across the multi-cultural youth groups in South London (Solanke 2005). Activities have included using urban music to deliver and present geology.

Geodiversity is essential as a resource for education, the value of which seems impractical to measure. There have been some studies which measure the public’s and academic’s perceptions of geology and the teaching of geology (Trend 2001; Dodick and Orion 2003). One aspect of the choice experiments studies undertaken at Wren’s Nest NNR and the Jurassic Coast included an assessment of the value of different levels of interpretative material provided at the sites. The key results from this study are reported in Table 13. The value of information per household per year is calculated as £15.15 at Wren’s Nest NNR and £38.66 in Dorset.

Table 13 Value of educational information at two geological sites

Educational information	Value of information per household per year (£)
Provision of educational material - Wren’s Nest NNR	15.15
Extensive educational material - Jurassic Coast	38.66

4.5 Research

There are many internationally important areas for research, such as palaeontological sites, areas of ancient volcanic activity, river systems and coastal outcrops. Many areas of the UK have been and continue to be important for research, both national and international. Research into geodiversity is ongoing as technology improves, new discoveries are made, and theories can be revised or supported by new evidence. Palaeontological study provides key insights into evolutionary biological processes. Hall (2002) stated that the fossil record is a record of the changes in patterns explained and related to biological, ecological, climatic and tectonic changes.

Geodiversity also prompted early research, and many important advances in research were made in the UK (Ellis 1996). The history of research in the UK is celebrated and recognised as pioneering to the advancement of geological and geomorphological science.

4.6 Summary of contribution that geodiversity has to knowledge

By conserving geodiversity we are ensuring that there will still be scope for future research to resolve current geological problems, support new theories and develop new techniques or ideas (Ellis and others 1996). The geodiversity of the UK provides tools for predicting future environmental changes and a resource for the education and training of students and teachers at all levels. Without the conservation of these resources there will be no opportunities for the essential hands-on education of children, future generations of geologists and amateur geologists (Gray 2004). Continuing research is fundamental with the onset of climate change and the other environmental changes predicted.

The public have a strong view on the knowledge value of geodiversity. Focus group participants recognised the educational and research value, and that geodiversity is part of our history and should be preserved for continued research and for future generations. The public see geodiversity as being *"about rocks and fossils"*, *about scientific testing on rocks and formations"*, *"seeing it in museums"*. Some perceptions of geodiversity were that it is a boring subject, stuffy, and not very interesting. Stereotypes were described for geologists: *"beard touting, tweed jacketed professors"*, *"middle aged or elderly men with tweed coats boring each other senseless", "young people are not prominent"*. The links between geodiversity and other area was also apparent. Participants identified links with biology, botany, industry, history, archaeology; *"geology underlies everything, plants, animals"*, and is *"fundamental to everything"*.

5 Products

Geodiversity provides many different products for society. These include food and drink, fuel and energy, construction material, minerals for industries, ornamental and other products and employment. These products are now examined in turn.

5.1 Food and drink

Geodiversity directly provides us with a number of specialist food and drink products such as mineral water and salt. The geodiversity of an area is also an important factor in the production of beer, whisky and wine (Maltman 2003).

Geodiversity is important for the supply and storage of water and ground water in aquifers and soils for drinking and the food production industry. Natural mineral water as described by the Natural Mineral Water, Spring Water and Bottled Drinking Water Regulations 1999 (HMSO 1999) is 'water that originates in an underground water table or deposit and emerges from a spring tapped at one or more natural or bore exits'. The Food Standards Agency (2003) lists 95 natural mineral waters in the UK. The UK mineral water industry produces 900 million litres of the 1,200 million litres of bottled water consumed annually accounting for £500 million per year, and growing at an annual rate of more than 10 per cent (British Soft Drinks Association 2001).

Geodiversity provides rock and mineral deposits such as halite, gypsum and liquid brines which are a source of salt. As well as being used for human consumption, salt is also used as a water softener, animal feed, industry, agriculture and for ice and snow clearance. The amount of brine/rock salt produced in the UK in 2001 was 6.1 million tonnes (British Geological Survey 2003).

Beer, wine and whisky production also rely on geodiversity to an extent. All three rely on water and water chemistry, physiography and soils to varying extents, from the water used in the brewing process, to the soils in which the hops and grapes grow (Maltman 2003). It is the differences in these characteristics that account for the varied flavours and local distinctiveness of the product. In France there is a wine called Kimmeridgien, grown on Kimmeridgian age rocks. Most areas of the UK have brewing and distilling industries accounting for an important contribution to industry.

The food and drink products associated with geodiversity are a significant economic activity and as such will bring significant income and employment benefits.

5.2 Fuel and energy

Geological resources are a key source of fuel and energy. These resources include reserves of coal, peat, petroleum, gas, uranium, geothermal and hydrothermal sources. Geodiversity is also an important factor in the production of hydroelectric power, and in the siting of wind farms.

Coal, peat and petroleum are extremely important as sources of fuel and energy. Table 14 below provides are overview of the level of extraction of these energy sources in the UK, as well as an estimate of the economic value of these products.

Table 14 UK coal, oil and gas production and value in 2001

	Million tonnes	Value £million
Coal: deep mined and opencast	31.5	1028
Oil: onshore and offshore	117.8	14732
Gas: onshore and offshore (oil equivalent)	105.8	8325

Source – BGS (2003)

Geothermal energy from volcanoes, hot springs, geysers, and fumaroles may also be used for heating and to produce electricity. Geothermal energy is currently being utilised extensively in America, Iceland and New Zealand. Although the use of geothermal energy in the UK is limited as the temperatures are not sufficient to produce electricity, these resources are being used for heating in Cornwall and Southampton. Total geothermal energy use (which includes active solar heating) in the UK amounted to 0.5% of total renewable energy use in 2002 (DTI 2003). This is equivalent to the amount of energy produced from 16,000 tonnes of oil (DTI 2003).

Geodiversity also contributes to hydroelectric and wind power since the topography of land is an important factor for the location of these plants. Wind and hydroelectric power respectively accounted for 3.4% and 12.9% of total renewable energy use in 2002 respectively (DTI 2003). Renewable energy comprised 1.4% of the total primary energy requirements (DTI 2003).

Geodiversity is valuable for the provision of both non-renewable and renewable fuel and energy. In particular, there has been much recent interest in developing renewable sources of energy such as wind, hydroelectric and geothermal energy as these represent significant economic and environmental benefits over the more traditional non-renewable sources.

5.3 Construction

Geodiversity provides an important raw material for the construction industries. Many different types of rocks are sought after for their aesthetic and structural properties. Materials used in the construction industries include clay, sand, gravel, gypsum, limestone, building stones and rocks/pebbles. These materials are used as building stones, aggregates for concrete, roads and railways, cement making, for the manufacture of tiles and bricks, for use in plaster, glass making, and dry stone walling. The quarrying of these materials can also produce important geological exposures.

It is interesting to note that many areas of the UK have distinctive building stone. For example, Portland Stone from Dorset, granites from Scotland, sandstone from Yorkshire. These materials have also given rise to characteristic and locally distinctive buildings and architecture; a result of the underlying geodiversity. Some rock types are used in distinctive buildings. For example, English Heritage uses specific quarries to restore historic buildings.

The use of different types of stone for buildings in the Dorset area has influenced the character of towns and villages. For example, Portland freestone is predominantly used on the Isle of Portland, Upper Greensand sandstone is used in the villages around Shaftesbury, and Sherborne is build predominantly from Inferior Oolite (Thomas 1998). Many of Dorset's villages and buildings are of historic or architectural interest and indeed some are now designated as Conservation Areas requiring original stone for repair and maintenance (Thomas 1998).

The value of construction materials produced in the UK is summarised in Table 15.

Table 15 Production and value of construction minerals in the UK in 2001

	Million tonnes	Value £million
Aggregates		£1,645
of which: Land-won sand & gravel	80.8	
of which: Marine-dredged sand & gravel	20.6	
of which: Crushed rock	153.0	
Cement raw materials (limestone & chalk, common clay & shale) (GB)	17.1	£138
Common clay & shale and Fireclay (for bricks) (GB)	8.0	
Gypsum, natural	1.7	
Slate	0.6	
Building (dimension) stone (GB)	1.0	

Source – BGS (2003)

The socio-economic value of geodiversity products for construction is difficult to gauge. The local distinctiveness that is provided by the diversity of building material is important and should be valued; however there are no studies to date. There have been studies on the value of built heritage; however the availability of the building stone for restoration or repairs at these properties is based on the availability of the material.

5.4 Minerals for industry

Many of the Earth's mineral resources are used in industry. Industrial, metal and precious minerals are used extensively in the manufacture of many products and materials. The global industrial mineral resource is extensive, and the economic value of these resources is significant. The UK however only has a limited mineral industry; the size of which is summarised in Table 16 below.

Table 16 Industrial, agricultural and horticultural minerals produced in the UK in 2001

	Million tonnes	Value £million
Limestone/dolomite/chalk (Industrial use) (GB)	9.6	717
Limestone/dolomite/chalk (Agricultural use) (GB)	1.6	
Brine/Rock salt	6.1	
Potash (refined potassium chloride)	0.9	
Silica (Industrial) sands	3.8	
China clay	2.2	
Ball clay	1.0	
Peat (million m^3)	1.8	
Other minerals including barytes, fluorspar, calcspar, lead ore, fuller's earth, iron ore, chert and flint, china stone and talc	0.2	

Sources – BGS (2003)

Some minerals were, however, important to the UK economy in the past. For example, the alum industry in Yorkshire and the Doulton clay pits in Dudley; further detail of history of the mineral industry in Dudley can be found in Figure 6.

Minerals in Dudley, West Midlands

The Dudley area was very important for the supply of coal, fireclay, ironstone and limestone in the past. Fireclay was historically used in the glassmaking industry for furnaces and melting pots in the area. The Doulton Clay pits were also used for fine china and sanitary ware. Limestone was used principally in agriculture, then later in the production of iron. Other materials such as dolerite and sandstones were also worked in the past. This was more important for the past local economy. The mining history of the area is celebrated by the local people (Prosser and Larwood 1994). Dudley and Tipton provided all the iron and glass for the construction of the Crystal Palace in London for the great exhibition of 1851 (Dudley Metropolitan Borough Council 2006). Many lime kilns survive as evidence of the industrial past of the area.

Figure 6 Geodiversity and industrial minerals in Dudley, West Midlands

Precious metals and minerals have also been used by man for thousands of years; evidence of this is present in archaeological finds. Gold has always been highly prized, and the current economic value of gold is approximately £229.053 per ounce (London Bullion Market Association 2004). Gemstones are also used in industry, for abrasives and drills.

Mineral resources clearly have a high economic value which is demonstrated by global markets. The social value of these resources is something that has not been explored.

5.5 Ornamental and other products

Geodiversity provides a wide range of fossils, minerals, gemstones, precious and semi-precious metals which are often used in jewellery and other ornamental uses. These products are bought by the general public, private collectors, museums, and other institutions.

Some fossils have great aesthetic appeal and may command very high prices – see Tables 17a and 17b for an illustration of selected fossil sales from Dorset and the Isle of Wight.. These fossils are sometimes termed 'décor fossils' and prices are largely based on the aesthetic value of the product (Rolfe and others 1988). Other significant fossils, such as the *Tyrannosaurus Rex* 'Sue' sold for $8.36 million in 1997 in New York (Forster 2001). Forster (2001) provides further evidence of the amounts that fossils have fetched at selected auctions.

Table 17a Palaeontological specimens from Dorset auctioned in New York (Forster 2001)

Year	Description	Price $
1997	Cluster of ammonites *Asteroceras obtusum* Lower Lias, Lyme Regis	600
1998	Collection of British ammonites *Promicroceras planicosta* and *Asteroceras obtusum* Lower Lias, Lyme Regis	375
1998	Ichthyosaur snout *Icthyosaur* sp., Jurassic, Lyme Regis	1500

Table 17b Isle of Wight Fossil Sales (Simpson 2001)

Year	Description	Sold to	Approx. price
1977	New genus of Wealdon crocodile	Stuttgart Museum	£4,000
1982	Partial *Iguanodon*	Natural History Museum	£2,000
1990	*Valdosaurus* leg	Belfast Museum	£5,000
1993	*Neovenator*	Sandown Museum	£20,000
1997	R.L.E. Ford Collection	Martin Simpson	£4,000

Ornamental stone is another product that command high prices. Such stone is used for stone carving and sculpture, and for stone facing on buildings. Fossils and geology also feature in architecture, ammonites in particular are used as decorative features in walls and paving.

The products offered by geodiversity represent social and economic benefits to society, with great importance to some individuals (Wood 1988) and areas such as Dorset, Yorkshire and the Isle of Wight for the commercial collection of these products (Larwood and King 2001).

5.6 Employment

Geodiversity provides employment on many levels. Jobs directly related to geodiversity include jobs in education, geodiversity-related industries, museums and other attractions. Other employment opportunities are created as a result of geotourism. These jobs are largely based in the service industries such as in hotels, restaurants and other associated sectors. Other

The extent to which geodiversity provides employment opportunities is a subject that has been little researched. Estimates could be made to determine how many people are employed directly with geology and geomorphology; however many more people will be employed indirectly.

5.7 Summary of products

Geodiversity provides us with many products such as providing food and drink, fuel, minerals for construction and industry, ornamental products, for example fossils and gemstones, and also by providing employment. Many of these products have market values and therefore can provide some comment on the overall values of geodiversity products. However, little or no research has been undertaken to explore the social values associated with these products, and this is an area that requires further research.

6 Ecosystem or natural system functions

Geodiversity provides an important contribution to the functioning of a wide range of ecosystem / natural systems, and hence has a vital role to play for the long term sustainability of the Earth's environments. This section, which is based on a framework developed by De Groot (1992), seeks to outline these functions and in particular those functions that have a direct benefit to society. As will be seen, many of the functions provided by geodiversity have local, nation and even global significance.

6.1 Global life-support services

Geodiversity provides essential functions in the environment. For example, the chemical composition of our oceans and rivers is influenced by volcanic activity, geological movements and by the weathering and erosion of bedrock and soils. In the global cycle of elements, the dissolved constituents of seawater are supplied by rivers, volcanic gas and hydrothermal systems (Open University 1989). Most of these elements can be accounted for by rock weathering, and oceanic crust is also a sink for these elements (Open University 1995).

Volcanic activity and weathering also influence the chemical composition of the atmosphere, and hence the climate. Soils, and especially peat bogs, provide carbon storage for the environment (Garnett and others 2001) and are therefore important for our atmosphere and climate. The amount of carbon in UK soils is estimated to be 9838 Mt (Milne and Brown 1997). The recycling of nutrients is also a factor related to volcanic fallout. Bedrock and bedrock lithology are also important in that they provide a substrate on which to live. Thus, geodiversity provides a significant foundation for life on the planet.

The value of geodiversity in global life support is clearly inherent for the well being of the environment. Although no specific valuation studies have been undertaken to value the contribution of geodiversity to global ecosystem services, Costanza and others (1997) estimates that the total annual value of global ecosystem services is in the region of $22,000 billion (Table 18).

Table 18 Global ecosystem services value

Service	**Total annual value of selected global ecosystem services (Billions of 1994 $US)**
Climate regulation	684
Water regulation	1115
Water supply	1692
Erosion control	576
Soil formation	53
Nutrient cycling	17075
Raw materials	721
Total	**21916**

Source – Costanza and others (1997)

6.2 Landscape formation or geomorphology

Many landscape features and geomorphological processes have fundamental implications for humans. Topography, that is relief and altitude, influence climatic conditions, run-off, water catchments and soil erosion (De Groot 1992). Weathering and erosion play an important part in the storage and recycling of nutrients and also influence the formation of soil. Run-off and river discharge causes sediment transport. Geological processes are fundamental to our enjoyment of the natural coastline, erosion of cliffs form features such as natural arches, stacks, caves and other landscapes. Distinctive landscapes form as a result of these processes (see Figure 7 for an illustration). The current landscape in the UK has evolved over the last 10,000 years as a result of ice ages (English Nature 2004).

Isle of Wight landscapes

The unique landscape of the Isle of Wight is due to the geodiversity of the area. The chalk downs and cliffs, the Undercliff, beaches and estuaries are all products of the processes that have taken place on the island. The landscape will continue to change through these processes and also with human influence. The coastline character is distinct and is a direct result of the coastal processes.

Dorset landscapes

The geodiversity of the Dorset area has a huge impact on the landscape and landscape formation. The river and coastal geomorphological processes have also shaped the landscape of the area. Landslides are an integral part of landscape formation and character of the coast, particularly in Lyme Regis. There is a huge variety of landscapes including the coastal landscapes of cliffs, stacks and arches. Inland there are rolling hills, steep sided valleys, limestone plateau, chalk ridge, bays and headlands, heathlands, Upper Greensand hills, chalk escarpment, marshes and estuaries. The distinctive landscape is a direct result of the geological characteristics.

Figure 7 An illustration of how geodiversity helps to create distinctive landscapes in the UK

The value of geomorphology in the formation of landscape and hence the benefit to society is not readily documented. However some research has been undertaken on the perceptions of landscape and landscape value (Garrod and Willis 1992a; b; Willis and Garrod 1992; 1993; León 1996; Hanley and others 1998; Bullen and others 1999; Scott 1999; 2002).

6.3 Flood and erosion control

Geological features and geomorphological processes form floodplains and therefore act as natural flood defences. The process of shingle and beach formation is also vital for coastal protection. Spit growth and on-shore and off-shore sand bar movement can also act as flood protection, for example Hurst Spit. Chesil Beach (see Figure 8 for further details) is an example of geomorphological processes working as a natural flood defence, protecting the Fleet behind it (Bray and Hooke 1995). Many natural flood features also provide essential habitats.

With the onset of climate change and the associated sea level changes, the understanding of geological and geomorphological features and processes for flood and erosion control will be essential.

Dorset flood control
Chesil Beach and Fleet Lagoon act as a natural flood control in the area. Studland Dunes also provide some protection of the land behind. The beaches act as a natural defence, however the coastline is continually eroded by the sea, and many coastal defence schemes are present to protect property. Offshore aggregates are dredged to replenish some beaches in the area. Floodplains provide natural flood protection, however many of these areas are developed and the floodplain no longer serves as temporary storage for river water.

Figure 8 Natural flood and erosion control

To examine how people perceive and value natural coastal erosion, the choice experiment study undertaken in Dorset examined public's values for alternative coastal defence strategies. The key results from this study are reported in Table 19. As can be seen, people tended to have negative values for the option to allow natural erosion to continue, while they had positive values for hard engineering solutions to coastal protection.

Table 19 Implicit prices of coastal defence options along the Jurassic Coast, Dorset

Attributes of the Dorset Jurassic Coast	Implicit price per household per year (£)
Coastal defence with hard engineering (use of concrete walls, pilings)	14.19
Coastal defence in gateway towns only (none in areas outside of towns)	-11.28
Allow natural erosion to take place	-2.91

Focus groups were also undertaken for this research to further explore the public's perception of erosion and flooding. Generally, views were mixed. Some participants thought it imperative to protect property and land from coastal erosion. However, others considered that erosion is a natural process that has been taking place for hundreds of years. They further argue that coastlines will continue to erode and evolve, and that we humans are unlikely to be able to change nature. Some key quotes from these discussions included: *"landscapes are evolving"*, *"we can't change it"*, *"you have to come to terms with it"*, *"places like Durdle Door will close and new doors will open"*.

The value of geodiversity in flood control has not been quantified. A study into the amenity value of alternative coastal defence schemes has been undertaken (Christie 2006). However, some scientists argue that the biggest threat to some geodiversity features are man-made flood defences and coastal protection schemes (Wilson 1994).

6.4 Water quantity and quality

Bedrock characteristics are important for water catchments and groundwater recharge. Aquifers form groundwater reservoirs. Common aquifers include: alluvial deposits; glacial deposits; fissured hard rock; confined or artesian groundwater; karst aquifers; sedimentary basins or permeable and porous rock (Bennett and Doyle 1997). The main aquifers in England and Wales consist of the Cretaceous chalk and the Permian and Triassic sandstones (Price 1996). Groundwater abstraction in the UK is 2400 million cubic metres per year (Price 1996).

Water quality is determined by many factors, including the natural filtration of water in aquifers (Price 1995). Topography and hydrogeology are also factors in the construction of reservoirs for water supply (Bennett and Doyle 1997).

There are a number of studies that have valued aquifers based on the quality and damage from pollution. For example, Kulshreshtha (1994) estimated that the economic value of maintain high quality aquifer water in Canada was worth between $85 million and $460 million. In the same study, Kulshreshtha also estimated that the high water quality aquifer helps to generate between $795 million and $4000 million to the economic activity in the area

6.5 Pollution control

Soils and rock act as a natural filter to reduce the negative effects of pollution from heavy metals and other sources. Some soils naturally attenuate contaminants through physical filtering, adsorption, biodegradation, and chemical precipitation (Brady and Weil 1999). The depth of soil, structure and composition of the soil, rocks and sediments greatly influence the affects of groundwater pollution (Gray 2004).

The value of soils in pollution control has not yet been documented. There are no studies that have quantified any economic benefits of soils and rocks as an aid to pollution control.

6.6 Soil processes

Bedrock is important for soil formation and influences many soil properties (Birkeland 1999) such as the texture and structure (Brady and Weil 1999), which in turn will affect resistance to erosion and drainage. Soil depth is an important parameter for watershed protection and water catchments as this influences infiltration of water (Price 1996). Bedrock lithology affects the soil mineral content (Brady and Weil 1999). Soil is the substrate for many plants and animals, and also an important resource for man for agriculture. Chalk and limestone bedrocks produce alkaline and usually well-drained soils, whereas sandstones, gravels and sands produce acidic well-drained soils. Fine grained rocks such as mudstones, shales and clays can produce poorly-drained soils. There is a large diversity of soil types in the UK. The local geology of an area determines the types of soils formed. The diversity of soils also influences the different landscapes and vegetation found.

6.7 Habitat provision

Geodiversity provides extensive and unique habitats. Limestone pavement, cliffs, caves, alpine environments, wetlands, salt marshes, intertidal zones and restored quarries all provide different environments for a range of plants and animals. Particular types of soils and soil processes define certain habitats. For example, chalk downs provide a unique habitat and biodiversity that are dependent on the lithology of the underlying bedrock for the conditions. The formation of Chesil Beach and the Fleet has resulted in the provision of an extensive habitat for wildlife.

Caves provide habitats for bats and invertebrates such as the freshwater crustaceans which live in underground water (Glasser and Barber 1995). Unique ecosystems develop in caves, particularly underground caves. Limestone pavements support rare species of plants (Webb 1995). Purvis (1993), Jenkins and Johnson (1993) and Pearce (1993) describe the unique biodiversity on spoil heaps, with the presence of rare and metal tolerant plants such as the lichens found at Parys Mountain, North Wales. Hydrothermal vents support biological communities in warm, chemical-laden waters (Glowka 2003).

In a public perception focus group undertaken for this research, participants recognised the links between geodiversity and habitats and identified that underlying geology and geomorphological processes dictate the plants and animals which are supported by these areas.

The value of geodiversity in providing habitats is not well documented. However the close link between geodiversity and biodiversity is now more acknowledged. English Nature (2004b) examined a number of cases studies to highlight the links between geology and biodiversity. There are studies which have valued selected habitats such as salt marshes, wetlands, lakes and rivers. For example, Constanza and others (1997) estimated the value that different biomes contributed had for global ecosystem services (Table 20).

Table 20 Value of global ecosystem services by biome

Biome	**Total annual value of selected global ecosystem services by biome (billions of 1994 $US)**
Wetlands	4879
Tidal Marsh/Mangrove	1648
Swamps/Floodplains	3231
Lakes/Rivers	1700
Total	**11458**

Source – Costanza and others (1997)

Other studies that have valued habitats include An (2000) who estimated that people were willing to pay between $162.73 to $323.79 to protect wetland habitats and wildlife in San Joaquin Valley, California. Van Kooten (1993; as cited in Nunes and van den Burgh 2001) stated the willingness to pay per household per year for the conservation of waterfowl habitat in Canada as $50 to $60 per acre. Nunes and van den Burgh (2001) provide an extensive review of studies that have valued ecosystem and natural habitat diversity and functions (Table 21). Values for habitats range from $8 to $101 and values for functions including wetland life-support and soil and wind erosion protection range from $0.4 to $1.2 million and $454 million respectively (Nunes and van den Burgh 2001).

Table 21 Value ranges for ecosystem and habitat diversity and ecosystem functions

Diversity level	**Biodiversity value type**	**Value ranges**	**Method(s) selected**
Ecosystems and natural habitat diversity	Terrestrial habitat (passive-use)	From $27 to 101	Contingent valuation
	Coastal habitat (passive -use)	From $9 to 51	Contingent valuation
	Wetland habitat (passive -use)	From $8 to 96	Contingent valuation
	Natural areas habitat (recreation)	From $23 per trip to 23 million per year)	Travel cost, tourism revenues
Ecosystems and functional diversity	Wetland life-support	From $0.4 to 1.2 million	Replacement costs
	Soil and wind erosion protection	Up to $454 million per year	Replacement costs, hedonic price, production function
	Water quality	From $35 to 661 million per year	Replacement costs, averting expenditure

There is however no data available that directly links the economic value of habitats to geodiversity. The value to biodiversity is exemplified by the nature and variety of species of plants and animals that rely on aspects of geodiversity. The conservation and management of biodiversity has implications for geodiversity conservation and hence it is important to integrate them to provide greater protection and understanding.

6.8 Summary of functions

The ecosystem or natural system functions that geodiversity provides are vital for the continued survival of our environment. The role of geodiversity in global life support systems, landscape formation, flood and erosion control, water quantity and quality, pollution control, soil processes and habitat provision varies, however the conservation of geodiversity is essential for these functions to be maintained.

7 Summary of economic values associated with geodiversity

In this report, the many benefits that geodiversity provides to society and where possible the value that society derives from these functions have been highlighted. Table 22 below provides a summary of the values associated with the various functions of geodiversity. Values are stated where possible, however, the Table also highlights areas where there has been little or no measurement of these values. Thus, current research does not enable the total value that geodiversity contributes to society to be measured. There are clearly gaps that need to be filled. Furthermore, the extent to which geodiversity influences the various types of social functions varies. In some cases, such as fossil collecting it has been possible to directly attribute all of the value to geodiversity, whereas other benefits, such as the value of a painting, the link is less direct and it is therefore difficult to know how much of the total value can be attributed to geodiversity.

Examining the four key functions of geodiversity, it is clear that 'appreciation' of geodiversity has both direct and indirect links. The 'knowledge' benefits tend to be directly linked to the geodiversity. Most of the 'product' values are also as a direct consequence of geodiversity, though the contribution to employment and food and drink varies. Some ecosystem and natural system functions, such as water quantity, can be directly attributed to geodiversity, whereas other functions such as global life-support services, geodiversity is an integral part of a global system.

The economic values of geodiversity are important as in conjunction with the social values more evidence for the conservation of these resources is provided.

Table 22 Summary of geodiversity values

	Component	Value/Measure
Appreciation		
Better living surroundings	Improvement to daily lives	Well being – qualitative evidence
Resource for recreational visits	Climbing	£31.15 per person per visit (Hanley and others 2001)
	Mountain biking trail	$205 - $235 per trip (Fix and Loomis 1998)
	Beach recreation	$33.93 consumer surplus (Bell and Leeworthy 1990)
	Access to Wren's Nest NNR	£7.83 - £21.26 per household per year (PhD research)
	Access to Jurassic Coast WHS	£23.69 - £62.35 per household per year (PhD research)
	Geotourism on Isle of Wight	£137 million per year, 39% of total tourism on IOW (PhD research)
Distant appreciation	Subscriptions	Entertainment and personal enjoyment – qualitative value
	Sales figures	
	Passive use value of Wren's Nest NNR and Seven Sisters Caverns	£7.59 - £19.17 per household per year (PhD research) Qualitative value of appreciation
Cultural, spiritual and historic meanings	Local meanings	Personal importance – qualitative value
Artistic inspiration	Works of art	Value of artefact Personal enjoyment
Social development	Pride, relationships, community spirit	Personal and social development Sense of pride
Knowledge		
Scientific discovery	Scientific information – geological maps	$2250 million to $3510 million in benefits (Illinois State Geological Survey 2003) Knowledge and understanding – social and economic value
Historical analysis		Knowledge and understanding
	Fossil collecting by geologists – Wren's Nest NNR	£6.58 per household per year (PhD research)
	Fossil collecting by geologists via code of conduct - Jurassic Coast	£57.73 per household per year (PhD research)
Environmental monitoring and forecasting	Geodiversity as a tool to manage changes	Knowledge and understanding – social and economic value
Educational resource	Knowledge and understanding	Qualitative value
	Educational material at Wren's Nest NNR	£15.15 per household per year (PhD research)
	Extensive educational material on Jurassic Coast	£38.66 per household per year (PhD research)
Research		Knowledge and understanding

	Component	Value/Measure
Products		
Food and drink	Mineral water	£500 million per year (British Soft Drinks Association 2001)
	Beer, whisky and wine industry	
Fuel and energy	Coal, oil and gas	£24085 million in 2001 (British Geological Survey 2003)
Construction	Minerals for the construction industry	£1783 million total in 2001 (British Geological Survey 2003)
Minerals for industry	Gold	£230 per ounce (London Bullion Market Association 2004)
	Limestone, rock salt, silica, clay, peat, other minerals	£717 million in 2001 (British Geological Survey 2003)
Ornamental and other products	Fossils and minerals	Social and economic value
	Fossil T. Rex	$8.36 million (Forster 2001)
	Fossil collecting from spoil - Wren's Nest NNR	£5.18 per household per year (PhD research)
	Fossil collecting via code of conduct - Jurassic Coast	£57.73 per household per year (PhD research)
Employment	Employment figures	Social and economic benefits
Functions		
Global life-support services	Ecosystem services:	(Costanza and others 1997)
	Climate regulation	$684 billion
	Water regulation	$1115 billion
	Water supply	$1692 billion
	Erosion control	$576 billion
	Soil formation	$53 billion
	Nutrient cycling	$17075 billion
Landscape formation	Understanding of landscape formation and diversity of landscapes	Social and economic value
Flood and erosion control		Safety and protection
	Coastal defence of Jurassic Coast	£14.19 per household per year (PhD research)
	Natural erosion of Jurassic Coast	-£2.91 per household per year (PhD research)
Water quantity and quality	Value of aquifers	$85 million to $460 million total economic worth (Kulshreshtha 1994)
Pollution control	Geodiversity as natural pollution control and attenuation	Social and economic value
Soil processes	Development of soils, substrate for agriculture	Social and economic value
Habitat provision	Geodivesity providing habitats	Social and economic value
	Global biomes	(Costanza and others 1997)
	Wetlands	$4879 billion
	Tidal marshes	$1648 billion
	Swamps	$3231 billion
	Lakes/Rivers	$1700 billion

8 Discussion and conclusions

The social and economic values of geodiversity are evident in many forms. These have been listed in the framework (Figure 1). The generic values have been described and summarised, however the extent to which actual values can be attributed is limited.

Documented values for the appreciation of geodiversity are in the form of studies which have valued geodiversity recreation or tourism. Implicit prices estimated from a choice experiment provided the value of access to two geological sites. Value was estimated as £7.83 - £21.26 per household per year for Wren's Nest NNR and £23.69 - £62.35 per household per year for the Jurassic Coast WHS, these values represent access to the sites without and with educational material in the form of interpretative panels and information centres. Multiplier analysis provided an estimate of the local economic impacts of geotourism on the Isle of Wight. Geotourism contributes £137 million per year, accounting for 39% of total tourism on the Isle of Wight. This generates between £33 million and £62 million of income and supports between 4038 and 5491 full time equivalent local jobs. The passive use value of Wren's Nest, that is, the value placed on the site by people with no actual or planned use of the site was estimated as £19.17 per household per year for access to Wren's Nest with educational material, and £11.37 per household per year for access and educational material in the Seven Sisters caverns. The passive use value of fossil collecting was £5.11 per household per year. Access without educational material was valued at £7.59 and £11.14 for Wren's Nest and the Seven Sisters caverns respectively. These demonstrate the value of a site existing for the sake of it, that the resource exists for other people to enjoy and is available for future generations. Qualitative evidence is also available to provide further social values of geodiversity appreciation.

The value of geodiversity knowledge is apparent; however there are limited studies which have been carried out. The value of the provision of educational material about the geology at Wren's Nest NNR and the Jurassic Coast WHS were estimated through choice experiments as £15.15 per household per year and £38.66 per household per year respectively. The value of fossils being available for geologists to collect and research was valued at £6.58 per household per year and -£15.46 per household per year for Wren's Nest and the Jurassic Coast respectively. Focus group data are also a valid tool providing descriptive evidence. The difference in values can be explained by the differences in the types of site. The geodiversity, particularly the fossils of the Jurassic Coast is generally better known than Wren's Nest, and hence this is reflected in a higher value being placed on fossils here.

When comparing the choice experiment results for Wren's Nest and the Jurassic Coast, differences in value are apparent. While each of the sites are valued highly for their scientific importance, it is clear from this research that the Jurassic Coast is valued higher than Wren's Nest. The Jurassic Coast is a prominent site which benefits from an established tourist trade, of which geodiversity plays a huge part. The area has also been the subject of many documentaries and features in the media frequently. The difference in the sites is apparent, however, each of the sites are unique in their own right.

The social and economic values of geodiversity products are evident. Materials for construction and industry, fossils and other ornamental products and power have a market value and these can be used to illustrate the values. Fossils are sold for considerable sums, and the sale of fossils is an important part of certain local economies (Isle of Wight, Dorset, Yorkshire). The value of fossil collecting in Wren's Nest was estimated at £5.18 per household per year and £57.73 per household per year in Dorset. Fossil collecting has been a popular activity in Dorset for hundreds of years and has become an integral part of the tourist trade here. A number of fossil shops are found in the area and new fossil finds often feature in the local and national media. This may account for the higher values than those found at Wren's Nest. Fossil collecting is popular in Wren's Nest, however the area is less well known.

The functional value of ecosystems and other functions has been estimated, however limited studies exist which value specific geodiversity functions. While it is clear that geodiversity is a major part of some ecosystems, the contribution of geodiversity is not readily stated. There is much overlap in the functions that geodiversity provides, illustrating the close relationship between the various components of geodiversity functions. For example, soil processes and pollution control and flood and erosion control with landscape formation. There are tenuous links between geodiversity and the functions provided.

This research aimed to provide estimates of the social and economic value of geodiversity in the UK. This is the first study to address geodiversity values using a variety of methods. These methods sought to provide a range of values to fill in some of the gaps in the knowledge. The benefits of using a variety of approaches allow for use and passive-use values to be measured, along with the descriptive values, these values are important for decision makers to consider. Public opinion is largely overlooked when defining policies and practices, experts are usually consulted, however the benefits of gaining local perspectives mean that policies are developed with all users in mind. The conservation of these features is essential to the future of geodiversity.

Future research needs to address the gaps in the knowledge. The appreciation of geodiversity, namely, the benefits to living surroundings, the distant appreciation, the cultural, spiritual and historic benefits need to be measured. There is also limited information on the value of artistic inspiration and social development. The value of knowledge is also little documented, the social and economic value of knowledge needs to be further explored. As knowledge and research are improved and gained, ongoing valuation is important. The value of environmental monitoring and forecasting and research are insufficiently estimated. Geodiversity is imperative for environmental monitoring, therefore by estimating the value, the conservation and management of these features will be further enhanced. The economic value of geodiversity products is documented. However the social values are less understood. There is limited research into the value of geodiversity functions. This is an area where further research would be essential to understand the links between geodiversity and biodiversity, and would also provide evidence of a holistic approach to management.

A key conclusion of this research is that people do value geodiversity, and while some of the benefits of geodiversity are not widely apparent, they are no less important. The main threats to geodiversity are development pressures for example quarrying, landfill, building construction and coastal defences, other issues include recreational pressures, the removal of geological specimens, climate and sea level changes, lack of information/education (Gray 2004). These threats are mostly due to human activity either directly or indirectly through influencing processes. The HM Treasury (2003) 'Green Book' on policy appraisal suggests that the wider social and environmental costs and benefits should be considered in policy and project appraisal. This research demonstrates that the social values of an environmental resource such as geodiversity may be significant and even though these social values may not be readily monetorised, they should still be considered and reported. These methods of estimating social and economic values have been widely applied to nature conservation with much success. While previously there was limited data available, decisions about the future of geodiversity resources need to take these social and economic values into account, to enable decision and policy makers to effectively manage and conserve the resource.

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Appendix 1 - Literature review

1.1 Introduction

This section contains technical information regarding the research into the social and economic value of the UK's geodiversity. Key points of the literature review, definitions, methodology, econometric results. The references are also included.

1.1.1 Geological and geomorphological conservation

Geology and geomorphology are the rocks, fossils, minerals, landforms and the natural processes which form and change them. The variety of these can be described as geodiversity, previously known as Earth heritage conservation, or the conservation of all things geological in the widest sense. This includes museum collections, building stones, geological data, maps and art (Prosser 2002a). Gray (2004) defines geodiversity as:

> "the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems".
>
> (Gray 2004, 8)

Geodiversity can be used to emphasise the link between geology, wildlife and people (Prosser 2002a; 2002b) and can be seen as the link between people, landscapes and culture (Stanley 2003). Earth heritage conservation is the area of conservation concerned with sustaining those physical resources of the Earth that best represent our geological and geomorphological heritage (Crofts 1994). Stevens (1994) defined Earth heritage conservation as 'concerned with sustaining the part of the physical resources of the Earth that represents our cultural heritage, including our geological understanding, and the inspirational response to the resource.' Geological and geomorphological conservation has been described as the conservation of geology and geomorphology in its natural setting (Prosser 2002a).

1.2 Background to geological conservation and legislation in the UK

The origins of geological conservation in the UK date back to the mid-nineteenth century in Scotland where *Lepidodendron* stumps from the Coal Measures were publicly protected and enclosed in a building in 1887 (Ellis 1996). Since then the conservation of geodiversity has progressed significantly with many notable landmarks

1887 - Protection of Scottish fossil tree stumps

1941 – Society for the Protection of Nature Reserves formed a conference to plan conservation in post-war Britain leading to formation of Nature Reserves Investigation Committee in 1943, dominating conservation until 1981

1947 – *Command 7122* report by the Wild Life Conservation Special Committee considers Earth heritage (Ministry of Town and Country Planning 1947)

1949 – Nature Conservancy (NC) created through Royal Charter to establish National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs)

1949 – National Parks and Access to the Countryside Act passed by Parliament lead to National Parks and Areas of Outstanding Natural Beauty in England and Wales. Local authorities given the power to create local nature reserves

1950s-1970s – SSSI and NNR series developed by NC and then the Nature Conservancy Council (NCC)

1977 – Geological Conservation Review commences audit of Earth heritage sites in Britain

1981 – Wildlife and Countryside Act (and amendment 1985) improved arrangements for conservation of SSSIs

1990 – NCC (1990) publish Earth Science conservation in Great Britain – A strategy

1990 – Environmental Protection Act and Natural Heritage (Scotland 1991) Acts splits NCC into Countryside Council for Wales, English Nature and Scottish Natural Heritage, Joint Nature Conservation Committee responsible for the three agencies and continues the GCR

1990 – Regionally Important Geological and Geomorphological Sites (RIGS) notified to local authorities by voluntary local groups

2000 – Countryside and Rights of Way Act provided better protection for SSSIs

2006 – Geological Conservation – a guide to good practice published by English Nature

Geological sites are classified into three types, namely exposure or extensive, integrity and finite (English Nature 2006). Integrity sites are all geomorphological sites and finites sites are those which contain geological features that are limited such that any removal may damage or destroy the resource. Exposure or extensive sites contain geological features which are relatively extensive beneath the surface. Integrity sites include static or active sites (Glasser 2001). Static sites include some glacial landforms (Gray 1997) or deposits (Larsen 1987; Gordon and Campbell 1991; Glasser and Lewis 1994). Active sites include dynamic processes and landforms such as karst and caves (Goldie 1996), coastal geomorphology (Carr 1983), fluvial geomorphology (Brazier and Werritty 1994) and mass movement.

Finite sites are unique mineral, fossil or geological feature sites (Norman 1992; Prosser 1994; Preece 1998) and some stratotypes (Prosser 1992). Exposure sites include exposures in active and disused quarries, cuttings and pits, exposures in coastal and river cliffs, foreshore exposures, mines and tunnels, inland outcrops and stream sections (Glasser 2001).

Geological sites could also be classified into two types according to the character of a site. There are sites which are generally well known for their geodiversity, for example the Dorset and East Devon Coast is famous for its fossils and fossil collecting. The other type of site is not particularly renowned for its geology, these sites often have overarching designations, national parks for example.

In England, the natural areas concept was developed by English Nature to ensure that Earth heritage is considered as an integral part of the total nature conservation resource (Prosser 1995). There are currently 120 Natural Areas identified, each characterised by their underlying geology, landforms and soils, vegetation types and species (English Nature 2003). Each Natural Area has a unique identity resulting from the interaction of wildlife, landforms, geology, land use and human impact (Prosser 1995).

In 2006 Natural England will be formed when English Nature, the environment activities of the Rural Development Service and the Countryside Agency's Landscape, Access and Recreation division form a single body with responsibility for enhancing biodiversity, landscapes and wildlife in rural, urban, coastal and marine areas (DEFRA 2006).

Geodiversity audits have occurred at county levels for example of quarries in Devon (Roche 2004). A number of Local Geodiversity Action Plans (LGAP) are now being produced. The purpose of LGAPs are to highlight the geodiversity of an area and to involve a wide range of people to set priorities and for geoconservation at a local level (English Nature 2004). LGAPs have been produced in many areas, for example Cheshire, Leicestershire and Rutland, North Pennines Area of Outstanding Natural Beauty and County Durham, and Warwickshire (Burek and Potter 2003). Many other areas are also producing these plans.

There are also international designations which are important for geodiversity in the UK. The United Nations Educational, Scientific and Cultural Organization (UNESCO) designate World Heritage Sites (WHS). These are cultural and natural heritage sites deemed to be of outstanding value to humanity (UNESCO 2006). There are currently two geological WHS in the UK, Giant's Causeway and Causeway Coast, and Dorset and East Devon Coast.

1.3 Environmental valuation

The environment has many functions to society, namely production processes, amenity and ecosystem or natural system services and these functions create waste which can arise from the production processes or from consumption (Hanley and others 2001b). These functions are therefore valuable to society and this can be reflected in monetary terms and in non-monetary terms. These functions provide people with utility and can have value.

The economic value of an environmental asset can be thought of as the change in utility if the asset is increased or decreased by a given amount. The total economic value of these changes is the sum of all the values and benefits gained (Figure 1).

total economic value	=	use values	+	Passive use values	+	option values	+	indirect values

Where:
use values = the direct use of a resource, this can be consumptive or non-consumptive
passive use values = existence (the resource exists with no actual or planned use)
bequest (the resource is available for future generations) and
altruistic values (the resource exists to be used by others in the present).

Option values = the future demand or supply of the resource (Ready 1995)
Indirect values = the functional value of the resource

Figure 1 The component parts of total economic value (adapted from Hodge 1995)

1.4 Environmental valuation uses

Geological and geomorphological resources can be considered as an environmental resource and therefore the total economic value, monetary and non-monetary value can be calculated using environmental valuation methods. See Section 3 and 4 of the main report for an investigation of the values and benefits that geodiversity provide.

The motivations for utilising environmental valuation methods to determine the value of geodiversity are:

To demonstrate all the values of geodiversity (socially and economically)

To raise awareness of geodiversity and its associated values

To provide evidence for continuing funding

To calculate replacement costs

To set charges/taxes/fines

Land use planning and policy tool for opposing development

1.5 Stated preference

The demand for environmental goods can be measured by investigating expressed or stated preference for these goods relative to their demand for other goods or services (Garrod and Willis 1999). Stated preference techniques of environmental valuation include contingent valuation and choice experiments and are considered direct methods.

Choice experiments

Choice experiments (CE) methodology is a relatively new concept in environmental valuation (Hanley and others 1998). The method can be used to examine the response of an individual to changes in the attributes that make up a hypothetical scenario. Therefore as well as eliciting a single value for an environmental scenario, the scenario can be broken down into component parts which make up the situation (Garrod and Willis 1999). As with the CVM, CE allows use and passive use values to be estimated. The underlying theory for CE comes from random utility theory and Lancaster (1966), who postulated that utility is derived from the characteristics of goods. Bennett and Blamey (2001) and Louviere and others (2000) provide a comprehensive review of choice experiments technique and case studies.

The model being used is the discrete choice multinomial logit model, based on random utility theory. The choice experiment data can be used to examine how the different levels of attributes affect the probability of choice. That is the model describes the probability of the choice being made by the respondents based on its characteristics. These models can derive estimates of the amount of money an individual is willing to pay to obtain some benefit from a specific action, in this case an improvement in access/interpretive material.

1.6 Economic impact - multiplier analysis

Multiplier analysis is a tool for measuring the impact of an introduction of expenditure into an economic system. Therefore, this method of measuring economic impacts can be used in environmental contexts as a means to look at impacts of certain environmental features or goods. Multiplier analysis has been used extensively to examine the economic implications of tourism in particular (Christie and others 1998), but has also been applied to environmental goods. In the case of a tourism resource, expenditures such as management costs for that resource (employment, wages, contractors, maintenance) and visitor expenditure. These expenditures stimulate economic activity which generates additional income and employment to areas.

Multiplier analysis is used to measure the size of these impacts and can be used in conjunction with traditional environmental valuation methods to support the valuation exercise. The relationship between one area of economic activity and the total additional activity this generates is called the multiplier effect, that is, the multiplier is the amount of additional economic activity results from the initial investment. Four main types of multiplier, namely: sales/transactions, input-output, income and employment. Multiplier analysis was used in a study associated with nature conservation (Rayment 1995). Direct and indirect expenditures give rise to induced effects of an increase in wealth of employees and employers and a rise in their expenditure. The multiplier coefficient, which is calculated by dividing the sum of the direct, indirect and induced effects with the direct effects, expresses the changes in these economies. The multiplier coefficients used can be calculated through surveys or borrowed from previous studies.

1.7 Qualitative techniques

Qualitative data deal with meanings (Dey 1993). Qualitative data are derived from people, that is, people are regarded as bodies of knowledge, evidence and experience. This provides descriptive evidence as the data are based on what the public think.

Qualitative data are data collected at focus groups and interviews. Focus groups have been long established in conducting market research, but they are equally as useful when views, attitudes and perceptions need to be understood. Focus groups can aid questionnaire design and when groups represent different ages and user groups for example, this allows for comparison of views. Qualitative data such as focus groups should be used in conjunction with other survey methods (Morgan 1997).

Focus groups have been used to study public perceptions of landscape (Scott 1999; 2002). Studd (2002) highlights the importance of public participation to stakeholders in nature-conservation decision-making. Benefits to stakeholders and participants are identified.

1.8 Summary

Figure 2 illustrates and summarises the values and benefits of geodiversity with appropriate environmental valuation methods according to De Groot, (1992) and Turner and others (2001; 2002). This illustrates that there are many different valuation methods that can be used to capture the different values of geodiversity.

In order to capture all the different values of geodiversity, a combination of techniques can be used. Choice experiments allow use and passive use values to be calculated and multiplier analysis using employment, income and expenditure multipliers can gauge the economic impact of geodiversity to local economies. Qualitative techniques will also capture the passive use values and perceptions associated with geodiversity presented in a descriptive or anecdotal form. By adopting this multi-method approach with qualitative and quantitative data collection, the studies will compliment each other and provide even greater evidence for the values of geodiversity and hence the conservation of geodiversity. The quantitative aspect can inform and support the qualitative aspect and vice versa.

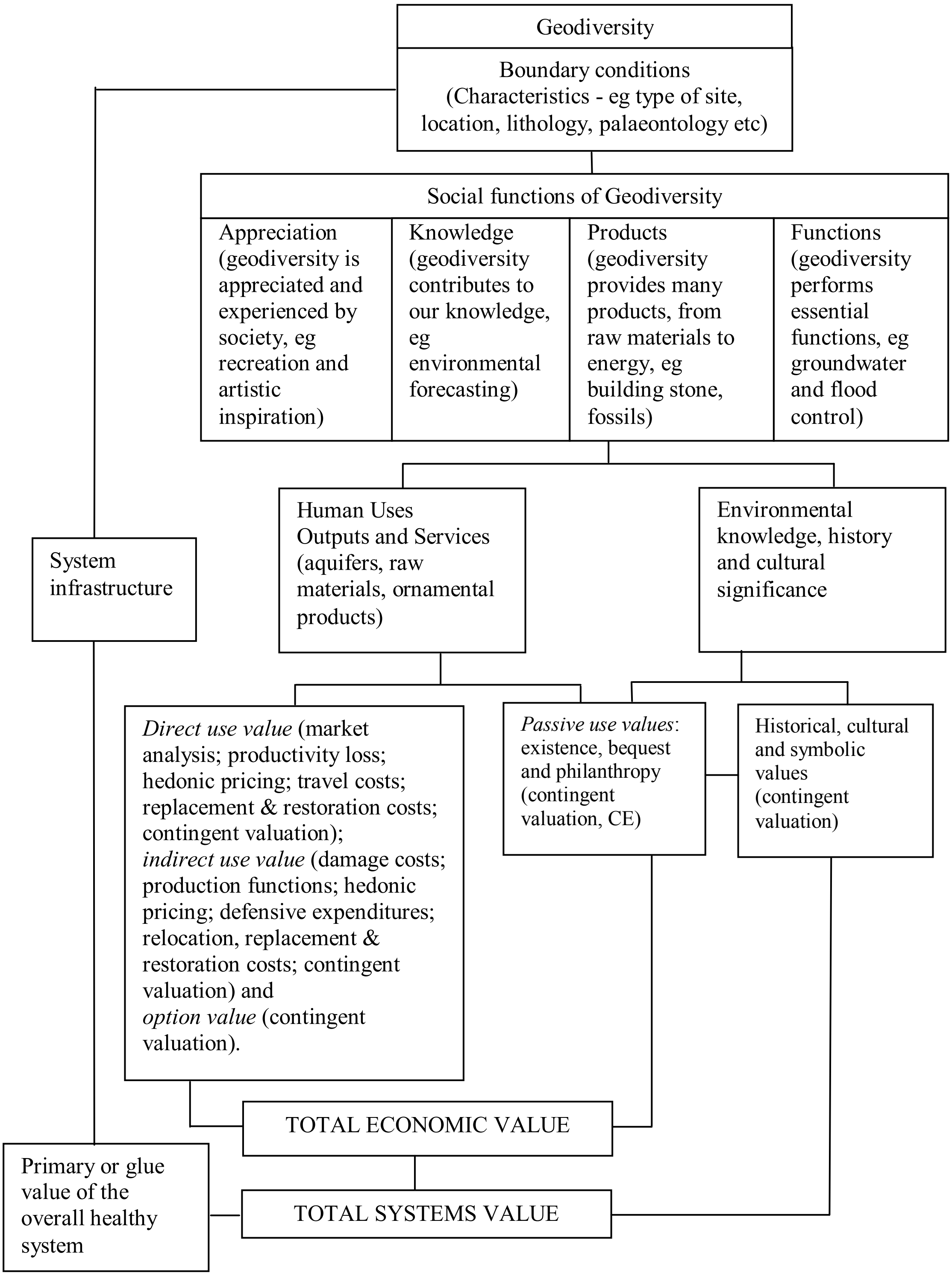

Figure 2 Revealing the value of geodiversity: geological and geomorphological structure and processes to social functions and values (adapted from De Groot 1992; Turner and others 2001; 2002)

Appendix 2 - Case study areas

2.1 Introduction

The case study areas for this research were chosen in consultation with English Nature, these were namely Dorset, Isle of Wight and Dudley. This section will briefly describe the areas and the geological interest. The framework in Section 2 of the main report (Figure 1) summarising the appreciation, knowledge, product and function values of geodiversity was applied to the case study sites and examples are presented where relevant in the main report.

2.2 Dudley

Dudley is a large metropolitan borough located in West Midlands, to the west of Birmingham. This area is also known as the 'Black Country' due to the areas former coal and iron industry. The geology of this area is characterised by Silurian Wenlock limestone and Westphalian Coal Measures (Prosser 1994). The area is internationally renowned for its fossils, particularly the Dudley Bug, a trilobite which featured in the town coat of arms (Bassett 1982). There are a number of sites designated for their geology (Table 2), with Wren's Nest designated the first geological National Nature Reserve (NNR) in the UK in 1956 (Cutler and others 1990). There are nine Geological Conservation Review (GCR) sites (JNCC 2006a). The rocks of the area have been mined and quarried for hundreds of years.

Table 2 Geological designations in Dudley (Adapted from Prosser 1994)

Site of interest	Designation
Brewin's Canal Section SSSI	SSSI
Bromsgrove Road Cutting, Tenterfields and Local Nature Reserve (LNR)	SSSI and LNR
Doultons Clay Pit (part of Saltwells LNR)	SSSI part of LNR
Ketley Clay Pit	SSSI
Turner's Hill	SSSI and LNR
Wren's Nest	SSSI and NNR
Fens Pools – shows evidence of past industrial and mining activity though is not notified specifically for geology	SSSI
Barrow Hill	LNR
Cotwall End (part of Turner's Hill SSSI)	LNR
Bumble Hole – shows evidence of past industrial heritage though is not notified specifically for geology	LNR

Wren's Nest NNR is a 35 hectare site situated amidst a residential area and comprises a limestone hill with steep sides and substantial wooded vegetation. The area was mined for limestone and the landscape reflects this industrial history. Geological outcrops are as a result of this mining and features such as trenches, quarries, spoil heaps, crown holes, caverns created by pillar and stall mining and lime kilns are present. A canal tunnel also exists beneath the site. The site is of open access and characterised by a network of footpaths and has a geological trail. A warden's office, visitor centre and car park are also present at the site. The site is renowned for its Silurian geology and fossils of corals, sea-lilies, shellfish, and trilobites are found in situ and among the loose rock, ripple beds are also visible in some areas.

Access to some areas of Wren's Nest NNR is restricted due to health and safety. The ripple beds have been fenced off, as have crown holes and the Seven Sisters caverns. The Seven Sisters have been the subject of recent debate regarding the future of the pillar and stall workings and underground caverns. The caverns were unstable and have been closed for some time. The Seven Sisters mine works have been infilled in order to prevent further collapses and rock falls.

There are a number of attractions which celebrate the local geology and industrial heritage of the area, including the Black Country Living Museum, Dudley Museum and Art Gallery and Dudley Canal Trust.

2.3 Dorset

The county of Dorset on the south coast of England displays Jurassic and Cretaceous geology. There are many SSSIs within the County which have been designated for geology and/or geomorphology, and also some sites where the geology has influenced the biodiversity. National and Local Nature reserves also feature in the county and the coast is classified as a Heritage Coast, and the area is also classified as an Area of Outstanding Natural Beauty. The area has exceptional rocks and fossils, geomorphological features such as landslides, a barrier beach and lagoon, cliffs and raised beaches (Dorset County Council and others 2000).

In December 2001, the Dorset and East Devon Coast was designated a World Heritage Site (Badman and others 2003) because it is as an outstanding example representing major stages of the Earth's history, including the record of life and ongoing geological processes. The rocks found on the Jurassic Coast illustrate 185 million years of geological time in the Triassic, Jurassic and Cretaceous periods. Dorset and East Devon's rich geological history was characterised by desert conditions, followed by tropical seas, swamps, forests and lagoons were formed, which then gave way to deeper marine conditions. Changes in sea level, earth movements, and ice ages shaped the area leaving the landscape we see today. Rivers deposited pebbles and sand, tropical seas formed clays, sandstones and limestones. Chalk was deposited in clear warm waters. Fossils such as insects, marine reptiles, ammonites, and plants are found here and are internationally important and found in museums. Dinosaur footprints are also found here.

The Jurassic Coast is visited by schools and universities and is also important for research. The coastal area is also used by the general public for recreation. People are drawn to the area to collect fossils. The environment also supports rare and important plants and animals. The area has also been very important for providing building stone both in the past and the present. Quarries form an integral part of the Jurassic Coast landscape. There are 'gateway' towns along the coast which are not part of the World Heritage Site, these include Sidmouth, Seaton, Lyme Regis and Weymouth. The landscape of the Jurassic Coast is varied and cliffs, barrier beaches, lagoons, stacks, arches, landslides and coves can be seen along the 95 mile long site.

The Jurassic Coast has a management plan in place which is supported by all the different organisations who have an interest and responsibilities for it. The National Trust own land, along with the Ministry of Defence and other public and private landowners. The Countryside Agency along with the county councils also has responsibility for the Jurassic

Coast. Other designations include SSSIs, Area of Outstanding Natural Beauty (AONB), LNRs, NNRs and heritage coast. There are 96 GCR sites in Dorset (JNCC 2006b).

There is also a Local Geodiversity Action Plan (LGAP) in place which aims to draw together existing information and ongoing projects concerned with the geology, geomorphology, soils and landscapes. The Dorset LGAP will 'lead to the conservation and enhancement of the geological resource and provide guidance to the planning authorities on sustainable policies in the geological context' (Dorset LGAP 2006).

2.4 Isle of Wight

The Isle of Wight is an island of 146 square miles in the English Channel off the coast of Hampshire. The island has a population of 132,731 (National Statistics 2006) and is a popular tourist destination attracting 2.5 million visitors per year (Isle of Wight Council 2006). Designations on the island include SSSIs, Heritage Coast, and nearly half of the island is an Area of Outstanding Natural Beauty (Table 3). There are also 40 GCR sites on the island (JNCC 2006c). An LGAP for the Isle of Wight is being developed.

Table 3 Isle of Wight designations

Site of interest	Designation
Brading Marshes to St. Helens Ledges	SSSI
Bembridge Down	SSSI
Bembridge School and Cliffs	SSSI
Whitecliff Bay and Bembridge Ledges	SSSI
Priory Woods	SSSI
Bouldnor and Hamstead Cliffs	SSSI
Prospect Quarry	SSSI
Headon Warren and West High Down	SSSI
Bonchurch Landslips	SSSI
Thorness Bay	SSSI
Colwell Bay	SSSI
Lacey's Farm Quarry	SSSI
Compton Down	SSSI
King's Quay Shore	SSSI
Compton Chine to Steephill Cove	SSSI
Isle of Wight	AONB
Tennyson	Heritage Coast
Hamstead	Heritage Coast

The geology of the Isle of Wight demonstrates three distinct periods, the Cretaceous, Palaeogene and Quaternary. The Cretaceous period is characterised by Wealdon sands along the south of the island, Greensand cliffs and Gault clay, and a chalk ridge in the centre, this extends to the Needles rocks in the west of the island. Clays and sands of the Palaeogene period are present in the northern coastal plain. The Quaternary on the Isle of Wight created the island when sea level rises separated it from Dorset. Gravel, peat and clays were deposited during the Quaternary.

The Isle of Wight is renowned for its fossils and 15 species of dinosaur are found including, *Iguanodon bernissartensis* and *Iguanodon atherfieldensis, Valdosaurus canaliculatus, Hipsilophodon foxi, Polacanthus foxi, saurapod, Baryonyx walkeri, Eotyrannus lengi*, and *Neovenator salerii*. Dinosaur footprints are also preserved on the island. Other fossils found include corals, ammonites, clams, lobsters, shells, reptiles and fish. The chalk is made from billions plankton remains

The landscape of the Isle of Wight is heavily influenced by the geology, for example the Chalk Downs, the Undercliff (landslip) and the coastal chines (deep narrow ravines).

Appendix 3 – Qualitative study

3.1 Qualitative study methodology

Qualitative methods can be used to gauge perceptions and understanding of key aspects. There are studies which have looked at the public perceptions of landscapes (Bullen and others 1999; Scott 1999; 2002). The Countryside Council for Wales (2001) is involved with a project known as LANDMAP, a landscape character assessment technique. Part of this project seeks to document the public perceptions of landscapes. Focus groups and interviews were used to identify which features and landscapes are of value to local communities, the sense of local identity with the landscape and how the public value landscapes and landscape features. The project also identified what the public consider as important to conserve, enhance and change in the landscape. Photographs were used as part of the LANDMAP surveys for the public to comment on.

This method can be adapted and applied to measure the public's perceptions of geodiversity. The methodology adopted in the study involved two phases of focus groups. These focus groups determined the public's perceptions of geology and aided the development of the choice experiment attributes (Appendix 5). Initial focus groups (Phase 1) were carried out in Dudley, Dorset and Snowdonia, with a total of four groups being held overall, two in Dudley and one each in Dorset and Snowdonia. Five focus groups were conducted in Dorset with specific user groups (Phase 2). These groups were represented by tourists, industry, education, fossil collectors, and children. Participants were recruited accordingly, and the recordings transcribed and analysed. Where appropriate participants were remunerated for their time/costs of attending as is the usual practice.

3.1.1 Survey design

Phase 1 focus groups were exploratory and to confirm the language and terms for the environmental valuation questionnaire aspect of the survey. Phase 2 was designed to address participants' opinions and preferences for landscapes and their opinions of specific geological landscapes. Photographs of particular geological landscapes were presented to the focus groups, and participants were asked to comment on these pictures. The photographs showed a variety of geological features from the UK.

Focus group transcripts were analysed and are presented as descriptive evidence for the public perceptions and values of geological heritage and for a basis for the environmental valuation aspect of the research (Appendix 5). The results are used to provide qualitative evidence in the revealing the value framework.

3.1.2 Focus group script

The questions posed at phase 1 of the focus groups concentrated on the following:

What do the general public think geology is? What do they think of when asked what geology is?

What terms have the general public heard of?

What experiences of geology had the focus group participants had? Had they visited anywhere in particular? What did they like about that place?

What uses do the general public think geology has?

What value do you think that geology has?

Do you think that it is important to conserve geology? Why do you think it's important? How do you think we should conserve geology?

Would the general public be willing to pay? If so, how much?

Participants were asked these questions as a means to ensure that discussions did not stray beyond the remit of the focus group. Discussions were based around these questions and participants were allowed a relative free rein. Phase 2 focus groups in Dorset followed a script asking participants questions about landscape and geology

3.1.3 Recruitment

Phase 1 of the focus groups were attended by 27 participants (Table 4). Phase 2 was attended by 29 participants from various user groups (Table 4).

Table 4 Phase 1 and 2 focus group participant numbers

Phase 1 - Location	Number of participants
Dudley (specialists)	6
Dudley (general public)	6
Snowdonia (general public)	7
Dorset (general public)	8
Phase 2 – Dorset – Group type	
Fossil collectors	6
Industry	5
Academics	5
Tourists	7
Children	6

The main issues and themes of the qualitative analysis are presented in Appendix 4.1 and provided values for the aspects of geodiversity in the 'revealing the value' framework in the main report.

3.2 Qualitative results

Quotes from focus groups have been used in the 'revealing the value' chapter in Section 3 of the main report to demonstrate the values and perceptions of geodiversity. The main themes and issues of discussion are highlighted in this Section.

Key themes that were apparent through the focus groups were: education; fossils and fossil collecting; coastal erosion; infrastructure (parking, roads, public transport, and visitor facilities) and access. Issues such as fossil collecting and coastal defence were discussed at length at the Dorset groups, the collectors and public in particular. Education, infrastructure and promotion were key themes in the Dudley groups.

All focus group respondents had certain landscapes or aspects of geodiversity which stimulated feelings and reactions. The appreciation of geodiversity is apparent and the way in which respondents valued it is varied. The well being and calmness evoked by the geodiversity was described at length by all groups. Participants feel a sense of pride and awe of the geodiversity and local landscapes.

Links between geodiversity and other aspects such as plants and animals was made, and also the links between archaeology and industry. Distinctive landscapes were also described in reference to the geodiversity and how different rock types influence the landform, soils and buildings.

The values of geodiversity suggested by participants were wide-ranging. Participants suggested many values for geodiversity such as educational value, wellbeing from rocks and crystals, that it is part of our history and is valuable for that reason, that geodiversity should be preserved for future generations. The scientific value of geodiversity was made apparent, however there was some issues with the communication of scientific information, and the concern that experts were not perceived to be approachable. The subject of geology as a science is old fashioned and needs to be updated. Stereotypes existed based on images in the media portraying geologists as *'men with beards'*.

Participants were asked which aspects of geodiversity and landscapes should be preserved for the future, the variety of responses reflected the different user types involved. Collectors, academics, the general public, tourists and children all had different opinions according to their personal use of the resource. Children were more general, suggesting that all landscapes, fossils and rocks should be preserved. Many threats to geodiversity were identified by the different groups: development, wind farms, erosion, pollution and climate change.

Issues such as coastal defence, location of caravan sites and infrastructure such as roads, parking and facilities were all raised. There is also a concern with the communication between the public regarding the issues such as coastal defence and planning. Participants felt that decisions were being made without involving local communities in the processes.

The focus group data were used to develop the choice experiment questionnaire and provide descriptive evidence for the value of geodiversity where other economic values are not readily evident.

Appendix 4 - Economic impact study

4.1 Economic impact study methodology

An economic impact assessment can trace spending through an economy and can also measure the cumulative effects of that spending. The aim of the economic impact study was to measure the employment and income impacts which are due to the geology on the Isle of Wight. The Isle of Wight was chosen as it is a traditional tourist destination, generally well known for its geology and visitors are attracted by the geological diversity of the island. The boundaries of the study area are defined by the island limits on the Isle of Wight, therefore this is defined as the local economy for this study. The elements of the design and development of the survey are described along with a description of the pilot study. The sampling framework is then described. The results of the survey are presented in Appendix 4.2.

4.1.1 Survey design and development

The survey instrument was a questionnaire designed using other examples of economic impact questionnaires. The questionnaire design was based on questionnaires used in other studies (Sherwood 1994; Christie and others 1998; Christie and others 2003) and is designed to ask respondents about their visit, asks specific questions relating to respondents expenditure and socio-economic questions about the respondent.

The first part of the questionnaire was designed to ask respondents about their visit to the area. That is, the duration of their visit and the type of accommodation if any. Respondents were asked why they chose to visit the area, what activities they had participated in, or planned to do and if they had visited previously. The next section then asked respondents about their expenditure relating to travel, food and subsistence, and other expenditure. Travel expenditure includes fuel, ferry crossing, parking, train and car parking. Food and subsistence relates to expenditure on accommodation, eating out in hotels, cafés, restaurants and any other food. Self catering respondents were asked about their spending on food in supermarkets. Other expenditure includes any expenditure directly related to geology, for example, a guided walk or a museum entry. Expenditure on other goods such as gifts, guides and crafts and other services, such as laundry. Other activities such as entrance to other attractions, museums, heritage sites were also recorded. The final section of the questionnaire asks for socio-economic information, that is marital status, level of education, employment status, age and household annual take home income. A pilot study verified the questionnaire. The final questionnaire used in the study was refined following the pilot study and minor changes took place. A section on perceptions and attitudes was included to gain some information on respondent's opinions of geological conservation.

4.1.2 Survey administration

The final survey took place on the Isle of Wight during August and September 2003, and April 2005. Sampling occurred in the summer holidays to capture visitors during the peak tourism season. Sampling also took place out of season, to ensure that a variety of visitors were targeted. Various locations around the Isle of Wight were chosen to carry out the surveys to ensure a variety of different types of visitor were interviewed face to face. Respondents were intercepted during their visit or approached in car parks at attractions. The questionnaire took approximately 5-10 minutes to complete. Groups of people were asked, and provided results for the entire group, the person with the next birthday was selected as the person to answer the questions.

4.1.3 Sample frame

The sample frame was to collect information from day and overnight visitors at a variety of locations around the Isle of Wight. Interviews were carried out at Dinosaur Isle, a geological museum in Sandown, Compton Bay (Shippards Chine); a National Trust beach used for general recreation as well as having a geological interest. Chilton Chine was also sampled. The Needles Park was also sampled to capture a variety of different people visiting a general tourist attraction which also has spectacular geological features, namely the Needles and Alum Sands.

A total of 150 interviews were undertaken for the survey, Table 5 summarises the sample breakdown.

Table 5 Sample breakdown for Isle of Wight survey

Location	Number
Compton Bay	21
Needles	20
Dinosaur Farm	16
Dinosaur Isle	72
Chilton Chine	21
Total	150

4.2 Economic impact results

The results of the economic impact study are presented for the Isle of Wight. Summary results are presented regarding the average group size, average length of stay, travel time, and expenditure (Table 6). Results for total expenditure for all respondents are calculated. The results are then provided according to the respondents' knowledge of the geology when choosing the Isle of Wight as a destination. Respondents were also asked about their opinions to statements regarding the conservation of the geological features on the Island.

Table 6 Summary of trip information and expenditure

	Isle of Wight
Average group size	3 people
Average stay	5 days
Average travel time	3.5 hours
Average travel expenditure (ferry, fuel, other)	£76.68
Average expenditure on accommodation and subsistence	£287.13
Average spending on geological activities (museum entry, fossil walks)	£28.77

Results are per group of visitors

The expenditure according to travel, subsistence, activities and other services are summarised (Table 7). Activities are divided into geological activities, such as entry to museum, guided walk, guide books, and other activities, which includes visits to the zoo, other heritage sites (castles, national trust properties). Expenditure on gifts is divided into geological and other gifts. Geological gift expenditure includes museum shop purchases, fossils, and any other related expenditure. Results are also presented according to whether the expenditure was local (Island expenditure) or non local (mainland expenditure). The direct geological spending, that is, the amount of expenditure on geological activities and gifts are displayed as a percentage of the total spending. Locally, 8.7% of the total expenditure is directly related to geological activities.

Table 7 Summary of total non local and local expenditures

	Non local	Local	Total
Total travel (fuel+ferry+other)	£9,016.00	£2,486.20	£11,502.20
Total subsistence (accom+meals+other food)	£3,355.50	£39,714.00	£43,069.50
Total geological activity	£0.00	£2,216.85	£2,216.85
Total other activities	£15.00	£2,020.10	£2,035.10
Total geological gifts	£0.00	£2,099.00	£2,099.00
Total other goods/gifts	£0.00	£903.00	£903.00
Total other services	£0.00	£15.00	£15.00
Total expenditure	£12,386.50	£49,454.15	£61,840.65
Total direct geological expenditure	£0.00	£4,315.85	£4,315.85
% geology expenditure	0.00	8.73	6.98

Respondents were asked whether they were aware of the geology of the Island and whether this influenced their visit (Table 8). 77% of respondents were aware of the geodiversity of the Island, 39% were influenced by the geodiversity, and 38% were not influenced. 23% of respondents were unaware of the geodiversity; however 14% of these respondents said that they would return in the future. 99% of groups also stated that geological heritage is important to preserve.

Table 8 Summary of responses to influence of geology on visit

Influence of visit	%
Aware of geology, influenced visit	39
Aware of geology, no influence	38
Unaware	9
Unaware, but will return	14

The expenditure results were then divided into four sub samples according to the influence that the geology of the Island had on respondents' decision to visit (Table 9).

Table 9 Expenditure of visitor groups according to influence of geology on visit

	Non local spend (£)	Local spend (£)	Total spend (£)	% of total expenditure
Aware of geology, influenced visit	4,829.50	19,278.50	24,108.00	39
Aware of geology, no influence	4,484.00	17,068.85	21,552.85	35
Unaware	1,761.00	5,722.80	7,483.80	12
Unaware, but will return	1,312.00	7,384.00	8,696.00	14
TOTAL	12,386.50	49,454.15	61,840.65	

Table 9 illustrates that of the £24,108.00 spent by respondents who visited because of the geodiversity of the Island, £19,278.50 was spent on the Island.

Spending by those visitors drawn by the geological features of the area provides significant benefits to the local economy. Multiplier analysis is an economic tool that can be used to measure the impact of an introduction of expenditure into an economic system. Multiplier coefficients can be used to estimate the income and employment generated by visitor spending.

The income and employment impacts of tourism related to geodiversity can then be estimated by multiplying the coefficient and the expenditure of visitors (Table 10). Multiplier coefficients for income impacts = 0.24 for lower, and 0.45 for higher bound (Rayment 1995). Employment impacts are estimated using £34,000 for the lower (Countryside Agency 2000) and £25,000 for the higher (Rayment 1995).

Table 10 Income and employment impacts of geodiversity

		Income impacts		**Employment impacts (FTE jobs)**	
	Local spend (£)	**Lower bound (£)**	**Higher bound (£)**	**Lower bound**	**Higher bound**
Aware of geology, influenced visit	19,278.50	4,626.84	8,675.33	0.6	0.8
Aware of geology, no influence	17,068.85	4,096.52	7,680.98	0.5	0.7
Unaware	5,722.80	1,373.47	2,575.26	0.2	0.2
Unaware, but will return	7,384.00	1,772.16	3,322.80	0.2	0.3
TOTAL	49,454.15	11,869.00	22,254.37	1.5	2.0

FTE – full time equivalent jobs

The expenditure related to geodiversity from this survey can be applied to the expenditure generated by tourism as a whole. Tourism on the Isle of Wight was estimated to be worth £352 million for the tourism year 2004/2005 (Isle of Wight Council 2006a). 39% of survey respondents who visited the Isle of Wight were influenced by the geodiversity and accounted for 39% of the total expenditure. This percentage is high due to the nature of the sample sites. A more conservative percentage can be derived from the number of visitors to the Dinosaur Isle Museum as a percentage of total visitor numbers to the Island. There were 81,486 visitors to Dinosaur Isle Museum in 2002/2003 (Pusey, pers comm 2005) and 2.6 million visitors to the Isle of Wight (Isle of Wight Council 2006a). Thus 3.13% of the total visitors can be considered as visiting the Island specifically for the geodiversity. Therefore applied to the tourism value, geodiversity accounts for approximately £11 million of this value. Applying the same income and employment multiplier coefficients, geodiversity generates between £2.6 million and £4.9 million in income and supports between 324 and 441 full time equivalent local jobs. The multipliers used are conservative as the Island relies on some goods and services from the mainland therefore, there will be leakages in the economy.

Questions which determined respondent opinions on the existence, bequest, altruistic and option values of the geological features were posed with a five point scale. Respondents were required to indicate whether they strongly agreed, agreed, were uncertain, disagreed or strongly disagreed with four statements regarding the above values of geological heritage. Results for the Isle of Wight are presented in Table 11.

Table 11 Results in percentages for visitors' opinions of the existence, bequest, altruistic and option values of the geological features of the Isle of Wight

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree	No answer
Important to conserve geological features for the sake of it	35	41	15	6	1	2
Important to conserve geological features for future generations to visit and enjoy	67	29	3	0	1	1
Important to conserve geological resources for other people to continue to use and enjoy the sites	62	34	2	0	1	1
Important to conserve so that I can use it again	58	35	5	1	0	1

The results are estimates of the economic impacts of geotourism on the Isle of Wight. The impacts are significant and clearly demonstrate that the geodiversity of the Isle of Wight, and hence the conservation of the geodiversity is of considerable importance to the local economy. There are no studies of a similar nature to compare the estimates with however, the multipliers used in the analysis are conservative and allow for leakages in the economy to the mainland.

Appendix 5 - Choice experiment study - Dudley and Dorset

5.1 Choice experiment methodology

The choice experiment was undertaken in two locations, namely Wren's Nest NNR, Dudley in the West Midlands and the Dorset and East Devon Coast World Heritage Site, known as the Jurassic Coast, on the south coast of England. The method was similar for both sites, and will be described in the following section. The differences in methodology are highlighted. The results for the two sites are presented in Section 5.2. Choice experiments can estimate the economic value of non market goods, in this case geological sites. The aim of this survey was to estimate an economic value for specific attributes of geological sites. The development, design and implementation of the survey are discussed briefly.

5.1.1 Survey design and development

The environmental valuation survey development process was undertaken through a variety of stages. Focus groups were used to explore issues at the chosen sites and to identify the attributes and levels for the choice task. The questionnaire was designed according to an accepted format, then piloted and refined as appropriate prior to the main survey. The pilot study data were analysed in order to ensure that the data could be modelled.

5.1.2 Design of choice tasks

Analysis of focus group transcripts highlighted access, fossil collecting, amenity and education as important issues at Wren's Nest NNR and the Jurassic Coast. Coastal defence was identified as a further attribute in Dorset. The levels were determined by addressing how it would be possible to vary the attributes. For example, access levels could be described according to limiting access and different levels of access with or without interpretative material. Fossil collecting could be restricted to different groups, and coastal defence levels could be based on different types of coastal defence, from using hard 'invasive' engineering techniques to allowing erosion to take place naturally. The attributes and levels used are shown in Table 12 for Wren's Nest and Dorset.

Table 12 Attributes and attribute levels for Wren's Nest and Jurassic Coast

Attribute	Wren's Nest Levels	Jurassic Coast Levels
Access to Seven Sisters caverns	No access to Seven Sisters caverns	No access to Jurassic Coast
	Guided access, no explanation of geology	Access, some explanation of geology
	Guided access, with explanation of geology	Access, extensive explanation of geology
Access to Wren's Nest / Coastal defence in Jurassic Coast	No access to Wren's Nest NNR	Hard engineering everywhere
	Access, no explanation of geology	Some engineering in gateway towns, but not in WHS
	Access with explanation of geology	Allow natural erosion to take place
Fossil collecting	Unlimited collecting from spoil heap	No collecting
	Geologists collecting	Geologists/collectors only
	Public collecting in all areas	Public collecting in all areas
Payment vehicle	Council tax (residents) – 5 levels	Council tax – five levels
	Entry fee (residents and visitors) – 5 levels	

Payment vehicles were in the form of a council tax for local residents and an entrance fee for visitors to Wren's Nest NNR. In Dorset, the payment vehicle was council tax. Using council tax or entry fees allows a realistic and familiar question to be posed to respondents, for example management of these types of sites would realistically be funded through taxes. Entry fee is also relevant as it is not unusual to be charged for access. The council tax payment vehicle was ideal as it corresponds with the area of the Dudley Borough and Dorset and East Devon County Councils. Levels of tax and entry fees were calculated using evidence from previous studies and the pilot studies (tax = £2.50, £5.00, £10.00, £20.00, £40.00; entry fee = £1.00, £2.00, £5.00, £10.00, £20.00). The attribute levels were developed and refined following the pilot studies.

The choice task was designed using the selected attributes and levels presented to participants. These choices are presented to participants as three policy/management options, one of which refers to the current situation which is common practice. A 3^3 x 5 orthogonal main effects experimental design was used to assign attributes to choice options using the statistical program SPSS. There are three attributes with three levels and one attribute with five levels, this would give a full factorial design of 135 combinations and would not have been practical to undertake in the field. Combinations were reduced using a fractional factorial design. This design is based on a subset or sample of the full factorial. SPSS generated the fractional factorial design which provided 25 profiles (sets of attributes and levels). These profiles can be generated into choice pairs by blocking the profiles using an extra variable with 5 levels. This gave a total of 50 choice tasks which were then split into five choice sets, with ten choice tasks or scenarios in each.

5.1.3 Design of the CE questionnaire

The CE questionnaire was developed and designed according to the format summarised by Bennett and Adamowicz (2001) and Louviere and others (2000). Bennett and Adamowicz (2001) suggest the following sub-headings for the structure of questionnaires.

- introduction to the survey
- frame or context of the issue should be established
- statement of the issue
- statement of potential solution
- option to choose alternatives
- introduction to the choice sets
- choice sets presented clearly
- follow-up questions
- socio-economic and attitudinal questions

The questionnaire was made up of a series of questions designed to gather essential information, set the scene and introduce the choice tasks. Finally there were socio-economic questions to enable analysis according to these socio-economic characteristics.

The questionnaire's introduction consisted of questions about the Wren's Nest NNR, and Jurassic Coast for the Dorset Survey. Respondents were questioned on the frequency of visits, the reason for visiting and the activities taken part in. The respondents were then presented with six statements relating to access, recreation, the rocks and fossils and the educational and scientific value of the site. Respondents were asked to state whether they strongly agreed or strongly disagreed with the statements. Respondents were then asked their opinion on whether rocks and fossils were important and their level of interest in geology.

The Jurassic Coast questionnaire included some extra questions. Respondents were asked what attracted them to the area, and alternatives, statements on coastal defence were also included.

These questions serve as an introduction to the survey, and the data collected would provide information on the visiting habits of respondents.

Information was then given about the geology of the site, information about the current health and safety issues and future options for the site were presented. Maps, photographs and pictures of fossils found at Wren's Nest NNR were also used in the questionnaire. A map was used in Dorset. The current situation (Table 13) was described, and the choice task was introduced and explained using an example choice scenario.

Table 13 The current situation at Wren's Nest and the Jurassic Coast

	Wren's Nest	**Jurassic Coast**
Access to Seven Sisters/Access to Jurassic Coast	No access to Seven Sisters caverns	Access to most of the Jurassic Coast with some interpretation at selected locations
Access to Wren's Nest nature reserve/Coastal defence	Access to most areas of Wren's Nest nature reserve with no access to Seven sisters, ripple beds and crown holes Some explanation of the geology is available	No increase in coastal defences in Jurassic Coast Coastal defence in gateway towns
Fossil collecting	Unlimited collecting from spoil heaps	Collecting via code of conduct by geologists/collectors Public collecting on beaches
Annual tax increase	No increase	No increase

Respondents were then asked to look at one of the five sets of ten scenarios for future management of the Wren's Nest NNR or the Jurassic Coast. These scenarios are based on different combinations of the attribute levels, with different tax values, each scenario has three options. It was explained that respondents were to choose their preferred option out of A, B or the current situation.

Following the choice task exercise, respondents were asked their main reason for the choices they made. Respondents were also asked how confident they were of those choices on a scale of one to five where one was not confident and five was very confident.

The final section of the questionnaire asked for standard socio-economic data such as gender, age, marital status, employment, education, dependants, level of education and household income. This data allows the survey data to be compared to the populations to determine if the sample was representative of the wider population. Respondents were also asked whether they live in Dudley or Lyme Regis, within 15 miles, or more than 15 miles from Dudley or Lyme Regis. Finally, respondents are asked if they would like to make any further comments and thanked for taking part in the survey.

5.1.4 Pilot survey

Pilot studies allowed for the final attributes (Table 14) to be determined, specific questions were changed or re-worded, and graphic icons were added to make each attribute level easily recognisable by respondents.

Table 14 Final attributes and levels following pilot studies

Attribute	Wren's Nest levels	Jurassic Coast levels
Access to Seven Sisters/ Jurassic Coast	No access to Seven Sisters caverns	No access to Jurassic Coast
	Group access to caverns with guide, no explanation of geology	Access to most Jurassic Coast, some explanation of geology
	Group access to caverns with guide with explanation of geology	Access to all of the Jurassic Coast, extensive explanation of geology
Access to Wren's Nest/ Coastal defence in Jurassic Coast	No access to Wren's Nest NNR	Allow coastal defence with hard engineering solutions in all areas
	Access to all areas except no access to seven sisters, ripple beds and crown holes, no explanation of geology	No increase in coastal defences in Jurassic Coast, Coastal defence in gateway towns
	Access to all areas except no access to seven sisters, ripple beds and crown holes with explanation of geology	Allow natural erosion to take place
Fossil collecting	Unlimited collecting from spoil heaps	No collecting
	Collecting by geologists only	Fossil collecting in all areas by geologists/collectors only
	Collecting by all in all areas	Collecting via code of conduct by geologists / collectors, public collecting on beaches
Annual council tax increase	£2.50	£2.50
	£5.00	£5.00
	£10.00	£10.00
	£20.00	£20.00
	£40.00	£40.00

The attributes will allow an estimate of use and passive use values of the case study sites. The value of access to the sites can be estimated, while the value of education can be estimated in the form of the preferences for the provision of interpretative material. Passive use values can be ascertained through analysis of the data from those respondents who have never visited the site.

5.1.5 Final questionnaire and choice tasks

The final questionnaire and choice tasks were developed following the pilot study. The structure of the questionnaire was as described in Section 5.1.3 previously. Firstly, there was an introductory section asking respondents about their visit, this was followed by a description of the site issues and introduction of the choice task, with example choice task, the choice task is then undertaken, this is followed up with questions on the respondents reasons for their choices and their confidence in answering the questions. The final section of the questionnaire asked socio-economic questions.

5.1.6 Survey administration

The survey was administered through personal interviews and workshops at a variety of locations for each study site. Personal interviews allow for higher response rates (Bennett and Adamowicz 2001). Data were collected during October and November 2004 at various locations around Dudley, Kidderminster town centre and Worcester city centre. This included the half term school holiday in October. Workshops took place in April 2005 in Dudley, Kidderminster and Worcester. In Dorset, respondents were interviewed in June and July 2005, this period also included a bank holiday. Valuation workshops took place at both case study sites to validate the main survey and explore issues in more depth.

5.1.7 Survey interviews

The main survey in Dudley and Dorset comprised of 700 and 200 personal interviews respectively, with each interview taking an average 15 to 20 minutes to complete which is sufficient time for the task to be understood. Each respondent had a set of show cards with the questions they were required to answer. Each respondent also looked at one of the five choice sets. Choice sets were cycled through one to five for participants to ensure that each choice set was used accordingly. Answers were recorded by the interviewer on a simplified answer sheet.

5.1.8 Sample frame

5.1.8.1 Dudley

The sampling frame of both the survey interviews and valuation workshops must take into account the objectives of the case study, that is, to estimate the economic value of the Wren's Nest NNR and the Jurassic Coast while being representative to the area and population. The sample frame and survey were designed to target users and non-users of the site and both visitors and local residents were questioned.

The survey took place at Wren's Nest NNR and Dudley Museum and Art Gallery. Sampling also took place in Merry Hill Shopping Centre (Dudley), Kidderminster and Worcester town centres to evaluate if and how the value of Wren's Nest NNR declined with distance from the site (distance decay) (Table 15).

Table 15 Sample breakdown and distance of sample sites from Wren's Nest NNR

Location (Distance from Wren's Nest, miles)	Number
Wren's Nest NNR (0)	150
Dudley Museum and Art Gallery (1.3)	100
Merry Hill, Dudley (4.0)	225
Kidderminster (13.0)	112
Worcester (30.0)	113
Total	700

5.1.8.2 Dorset

The survey took place on the Jurassic Coast during June and July 2005, this period also included a bank holiday. Sampling took place at Lyme Regis, Charmouth, West Bay and other locations to ensure that a variety of people were interviewed along the length of the Jurassic Coast (Table 16).

Table 16 Sample breakdown for Jurassic Coast survey interviews

Location	Number
Lyme Regis	39
Charmouth	51
West Bay	45
Others:	
Bridport	5
Burton Bradstock	5
Beaminster	13
Abbotsbury	10
Weymouth	11
Broadwindsor	21
Total	200

5.2 Choice experiment results

Results of the choice experiment study carried out at Wren's Nest NNR and the Jurassic Coast are presented (Section 5.2.1 and 5.2.2). The results of the preliminary questions are reported for each site, followed by the choice model results. Implicit prices and consumer surplus are calculated. The Wren's Nest NNR results are also analysed to determine distance decay. The socio economic characteristics of the respondents in the Dudley and Dorset surveys were representative of the survey areas.

5.2.1 Dudley

There were a range of introductory questions at the beginning of the CE questionnaire. These questions were designed to elicit visiting habits and attitudes to various aspects of Wren's Nest NNR. A summary of responses is now presented. The results of the choice analysis are also presented.

5.2.1.1 Visiting information

Of the 700 respondents questioned in the Wren's Nest NNR Survey, 261 had visited Wren's Nest NNR and 439 people had never visited (Table 17). At the valuation workshops, of 34 participants, 20 had visited Wren's Nest NNR and 14 had not.

Table 17 Frequency of visits to Wren's Nest NNR (main survey)

Frequency of visit	Number
Never	439
Once	61
First time	69
Daily	13
Once a week	10
More than once a week	14
Once a month	8
Once a year	14
Twice	19
Frequently	29
Infrequently	11
When younger	13
Total	700

Activities which the 261 respondents had taken part in during their visit and in the past to Wren's Nest NNR are summarised in Table 18, the most popular activities were 'walking' (48%), though this was usually combined with 'looking at geology' and 'collecting fossils' (43% and 35% respectively). 'Looking at plants and wildlife' was 30%. A low proportion of respondents took part in 'dog walking' and 'other' activities (both 7%).

Table 18 Activities at Wren's Nest NNR

Activity	Today	% of people	Past	% of people
Walking	124	48	142	54
Dog walking	19	7	27	10
Playing	1	0	14	5
Looking at plants and wildlife	79	30	92	35
Looking at rocks and fossils	111	43	170	65
Collecting fossils	91	35	139	53
Other	17	7	18	7
Total	442		602	

In the Dudley survey, 2% of respondents maintained they had a 'professional' interest in geology, 13% of respondents had an 'amateur' interest, 65% had a 'casual' interest, and 20% had 'no interest' (Table 19). Overall this indicates that 80% of respondents have some interest in geology.

Table 19 Interest in geology

Level of interest in geology	Number	%
Professional	14	2
Amateur	94	13
Casual interest	454	65
No interest	138	20
Total	700	100

5.2.1.2 Attitudes towards Wren's Nest NNR

Respondents were questioned on their attitudes to various statements about Wren's Nest NNR (Table 20).

Table 20 Summary of respondent preferences (Wren's Nest NNR survey)

	Agreement with statement (%)				
Statement	Strongly disagree	Disagree	Neutral/ don't know	Agree	Strongly agree
There should be unlimited public access to Wren's Nest	5	12	25	29	29
It is a space for recreation	2	11	17	35	35
The rocks and fossils are important	0	0	5	13	81
The educational use is important	0	0	1	18	80
The scientific value is important	0	2	3	15	80
There should be no public access to Wren's Nest	80	13	5	2	0

Respondents were asked whether the rocks and fossils of Wren's Nest were important and should be protected. Of the 700 people asked, 684 respondents agreed and 16 respondents disagreed. Reasons for these disagreements from respondents were due to a lack of interest, that 'in the scale of things, it's not important', some respondents 'don't think about it', others said that it is interesting but not important.

Respondents' attitudes to unlimited public access were varied, with 58% of people agreeing or strongly agreeing, weaker preferences are also demonstrated by neutrality (25%) and disagreement (17%). Conversely, attitudes to no public access were more marked. Attitudes to Wren's Nest NNR being a space for recreation are also mixed. However, the opinion that rocks and fossils are important is almost unanimous. The scientific and educational value is also highly regarded.

5.2.1.3 Choice analysis

The choice tasks from the CE questionnaires were analysed using the specialist econometric software LIMDEP. Estimation is made using the discrete choice multinomial logit model. This section reports the results of the aggregate choice model for the whole sample and sub-samples for each of the case study sites. The attributes are then investigated along with the reasons respondents gave for their choices. Implicit prices and consumer surplus are calculated. Finally policy values are presented where applicable. The attributes and levels are shown in Table 21.

Table 21 Description of attributes and levels for the Dudley survey

Attribute	Level
Access to Seven Sisters caverns	No access to Seven Sisters caverns Group access to caverns with guide, no explanation of geology Group access to caverns with guide with explanation of geology
Access to Wren's Nest	No access to Wren's Nest NNR Access to all areas except no access to seven sisters, ripple beds and crown holes, no explanation of geology Access to all areas except no access to seven sisters, ripple beds and crown holes with explanation of geology
Fossil collecting	Unlimited collecting from spoil heaps Collecting by geologists only Collecting by all in all areas
Annual council tax increase	£2.50 £5.00 £10.00 £20.00 £40.00

5.2.1.4 Model specification

Choice analysis is based on the estimates of coefficients of variables. The utility is assumed to be linear and model specification is therefore;

$$U = bac1 * accseva + bac2 * accsevb + baw1 * accwrea + baw2 * accwreb + bco1 * collecta + bco2 * collectb + btax * tax$$

Equation 1 Model specification for choice analysis

Where accseva and accsevb are the recoded access to Seven Sisters variable; accwrea and accwreb are the recoded access to Wren's Nest NNR; collecta and collectb are the recoded fossil collecting variable and tax is the tax increase variable. Associated with the variables are the estimates of the β coefficients; bac1; bac2 etc.

The current situation coefficients, standard errors, t-ratio and significance were estimated by recoding the variables and running the model with these coded as 1. This does not change the overall model.

5.2.1.5 All respondents choice model - Dudley

Analysis using the multinomial logit (MNL) choice model produces the aggregate or average choice across all respondents in survey (Table 22) and the sub-samples (Dudley, Kidderminster and Worcester) (Table 23). The model is discussed in Section 5.2.1.6.

Table 22 Estimates of coefficients, standard errors and significance for main survey

Variable	Coefficient β	Standard error	t-ratio (B/SE)	P-value (Z>z)
Constant	-1.3169	0.0879	-14.9813	0.0000
BAC1 Access to Seven Sisters, no explanation of geology	0.3778	0.0369	10.2278	0.0000
BAC2 Access to Seven Sisters, explanation of geology	1.0255	0.0393	26.1258	0.0000
BACS1 No Access to Seven Sisters - CS	-1.4034	0.0483	-29.0623	0.0000
BAW1 Access to WN, no explanation of geology - CS	0.5895	0.0374	15.7664	0.0000
BAW2 Access to WN, explanation of geology	0.6730	0.0429	15.6695	0.0000
BAWS1 No access to WN	-1.2625	0.0461	-27.4107	0.0000
BCO1 Public collecting in all areas	-0.5673	0.0402	-14.0979	0.0000
BCO2 Unlimited collecting from spoil - CS	0.2498	0.0406	6.1572	0.0000
BCOS1 Collecting by geologists	0.3175	0.0369	8.6137	0.0000
TAX	-0.0482	0.0025	-19.5575	0.0000
Log likelihood function	-4609.031			
Log likelihood for choice model	-4609.0305			
Log likelihood (constants only)	-6176.8399			
Rho square	0.25382			
Adjusted rho square	0.25339			
Chi-square	3135.6188			
Completed iterations	7			
Observations	7000 (0 skipped)			

Note: CS refers to the current situation. For access to Wren's Nest NNR, the current situation is referred to as access with no explanation because access with explanation is explained as having improved facilities and interpretation.

Table 23 Estimates of coefficients and significance for sub-samples (Dudley, Kidderminster and Worcester)

Variable	Dudley Coefficient β	Dudley P-value	Kidderminster Coefficient β	Kidderminster P-value	Worcester Coefficient β	Worcester P-value
BAC1 Access to Seven Sisters, no explanation of geology	0.3505	0.0000	0.9980	0.0000	0.2583	0.0000
BAC2 Access to Seven Sisters, explanation of geology	1.0920	0.0000	1.3648	0.0000	0.8853	0.0103
BACS1 No Access to Seven Sisters - CS	-1.4425	0.0000	-2.3627	0.0000	-1.1436	0.0000
BAW1 Access to WN, no explanation of geology - CS	0.5331	0.0000	1.0053	0.0000	0.7083	0.0000
BAW2 Access to WN, explanation of geology	0.7483	0.0000	0.6853	0.0000	0.4530	0.0000
BAWS1 No access to WN	-1.2815	0.0000	-1.6906	0.0009	-1.1614	0.0003
BCO1 Public collecting in all areas	-0.4541	0.0000	-1.0786	0.0000	-0.8943	0.0000
BCO2 Unlimited collecting from spoil - CS	0.1747	0.0000	0.4473	0.0000	0.5219	0.0000
BCOS1 Collecting by geologists	0.2795	0.0003	0.6313	0.0009	0.3724	0.0000
TAX	-0.0470	0.0000	-0.0541	0.0000	-0.0635	0.0002
Constant	-1.0796	0.0000	-3.8026	0.0000	-1.1017	0.0000
Log likelihood function	-3335.344		-428.351		-664.966	
Log likelihood for choice model	-3335.3444		-428.3513		-664.9663	
Log likelihood (constants only)	-4479.9584		-666.0712		-923.6577	
Rho square	0.2555		0.3569		0.28007	
Adjusted rho square	0.25487		0.35459		0.27752	
Chi-square	2289.228		475.4398		517.3828	
Completed iterations	7		9		7	
Observations	4750	(0 skipped)	1120	(0 skipped)	1130	(0 skipped)

5.2.1.6 Analysis of model for all respondents - Dudley

There are comprehensive methods to assess the model in terms of its performance in terms of whether the model conforms to the assumption that choices reflect utility maximising behaviour, the statistical significance of the model, the significance of the individual coefficients and the fit of the model.

The model should reflect the loss or improvement of an attribute with negative and positive coefficients respectively. The direction of the coefficients is as expected. The TAX coefficient was negative as expected indicating that respondents were less likely to choose an option that was associated with a higher tax payment.

The significance of the model was determined by testing the model against the hypothesis that all the coefficients other than the ASCs are equal to zero (Ben-Akiva and Lerman 1985).

$$-2\,(L(c)-L(\beta))$$

Equation 2 Significance test

Where L(c) is the log likelihood for the model with only ASCs and L(B) is the log likelihood for the estimated model. This assumed X2 distributed with K-J+1 degrees of freedom where K is the number of parameters and J is the number of choices in the set. In this model there are eight parameters and three choices per task giving six degrees of freedom. The calculated statistic is 3135.6188. Which exceeds the critical values of X2 at both the 95% (12.59, $p<0.05$, 6d.f.) and 99% (16.81, $p<0.01$, 6d.f.) levels. The null hypothesis is rejected and the estimated model is considered to be significantly different from one of constants only.

Results for the whole sample indicate that all ten of the coefficients are highly significant from zero ($p<0.01$). This means that the coefficients were all significant in the model. The null hypothesis that the coefficients equal zero is rejected for all variables. Overall, the test of the individual attributes provides general agreement with the test of significance of the model.

The value of rho square is a measure of the fit of the MNL model. Rho square is reported as 0.25382 and adjusted rho square is 0.25339. Values between 0.2 and 0.4 are considered acceptable (Bennett and Adamowicz 2001), therefore the overall fit of the model is good.

Results of the three sub-samples were fairly consistent with the main sample. The results indicate that all the attributes are highly significantly different from zero. This means that the attributes are significant in the model. The Dudley sub-sample results are particularly similar to the full sample results as are the directions of the coefficients. Adjusted rho square are reported as 0.25487, 0.35459 and 0.27752 for the Dudley, Kidderminster and Worcester sub-samples, all are within the accepted ranges.

5.2.1.7 Implicit prices – Dudley

The coefficients can be used to estimate the implicit price for the changes in the attributes using the formula (Equation 3):

$$IP = -\frac{b_{Attribute}}{b_M}$$

Equation 3 Calculation of implicit prices

Where IP is the implicit price of an attribute at level 1, $b_{Attribute}$ is the estimated coefficient of the attribute at level 1 and b_M is the estimated coefficient for the tax attribute.

Implicit prices for the whole sample, and the three sub-samples (Dudley, Kidderminster, Worcester) are shown in Table 24. The implicit prices are per household.

Table 24 Implicit prices of separable attributes for all data and sub-samples

Attribute and level	Implicit prices (£)			
	All data	Dudley	Kidd'r	Worc'r
Access to Seven Sisters Caverns				
No access to Seven Sisters Caverns - CS	-29.09	-30.69	-43.66	-18.01
Group access to caverns with guide, no explanation of geology	7.83	7.46	18.44	4.07
Group access to caverns with guide with explanation of geology	21.26	23.24	25.22	13.95
Access to Wren's Nest NNR				
No access to Wren's Nest NNR	-26.17	-27.27	-31.24	-18.29
Access to all areas, no explanation of geology - CS	12.22	11.34	18.58	11.16
Access to all areas, with explanation of geology	13.95	15.92	12.66	7.14
Fossil collecting				
Collecting by geologists	6.58	5.95	11.67	5.87
Collecting in all areas by public	-11.76	-9.66	-19.93	-14.09
Unlimited collecting from spoil heaps - CS	5.18	3.72	8.27	8.22

The implicit prices estimated for the attribute levels are as expected, that is, the levels which reflect some loss of access or amenity, have a negative implicit price, whereas the attributes which demonstrate an improvement have positive implicit prices. The fossil collecting attribute displays negative implicit prices for collecting in all areas by the public.

These prices were then aggregated to the 124,988 households in Dudley, 40,281 households in the Wyre Forest District and the 39,060 households in Worcester (Table 25) (National Statistics, 2005; 2006a;b).

Table 25 Aggregated implicit prices for all data, Dudley, Kidderminster and Worcester

Attribute and level	Aggregated implicit prices (£)			
	All data	Dudley	Kidd'r	Worc'r
Access to Seven Sisters Caverns				
No access to Seven Sisters Caverns – CS	-3,635,543	-3,836,290	-1,758,697	-703,634
Group access to caverns with guide, no explanation of geology	978,804	932,101	742,824	158,910
Group access to caverns with guide with explanation of geology	2,656,744	2,904,178	1,015,873	544,726
Access to Wren's Nest NNR				
No access to Wren's Nest NNR	-3,270,530	-3,408,011	-1,258,382	-714,555
Access to all areas, no explanation of geology – CS	1,527,183	1,417,824	748,272	435,817
Access to all areas, with explanation of geology	1,743,344	1,990,187	510,105	278,740
Fossil collecting				
Collecting by geologists	822,543	743,227	469,881	229,126
Collecting in all areas by public	-1,469,760	-1,207,701	-802,855	-550,259
Unlimited collecting from spoil heaps – CS	647,215	464,473	332,974	321,132

5.2.1.8 Consumer surplus - Dudley

The consumer surplus can be calculated from the implicit price and is defined as the difference in welfare achieved through a change from the current situation and the other proposed alternatives (Bennett and Adamowicz 2001), that is, welfare is assessed through the marginal value of a change away from the present situation.

Table 26 Consumer surplus for all data and three sub-samples

Attribute and level	Consumer surplus (£)			
	All data	Dudley	Kidd'r	Worc'r
Access to Seven Sisters Caverns				
No access to Seven Sisters Caverns (CS)	0.00	0.00	0.00	0.00
Group access to caverns with guide, no explanation of geology	36.92	38.15	62.10	22.08
Group access to caverns with guide with explanation of geology	50.34	53.93	68.88	31.96
Access to Wren's Nest NNR				
No access to Wren's Nest NNR	-38.39	-38.61	-49.82	-29.45
Access to all areas, no explanation of geology (CS)	0.00	0.00	0.00	0.00
Access to all areas, with explanation of geology	1.73	4.58	-5.91	-4.02
Fossil collecting				
Collecting by geologists	1.40	2.23	3.40	-2.36
Collecting in all areas by public	-16.94	-13.38	-28.20	-22.31
Unlimited collecting from spoil heaps (CS)	0.00	0.00	0.00	0.00

Note: CS refers to the current situation. For access to Wren's Nest NNR, the current situation is referred to as access with no explanation because access with explanation is explained as having improved facilities and interpretation.

Table 27 Aggregated consumer surplus per household for all data and three sub-samples

Attribute and level	Aggregated consumer surplus (£)			
	All data	Dudley	Kidd'r	Worc'r
Access to Seven Sisters Caverns				
No access to Seven Sisters Caverns (CS)	0.00	0.00	0.00	0.00
Group access to caverns with guide, no explanation of geology	4,614,347	4,768,392	2,501,522	862,545
Group access to caverns with guide with explanation of geology	6,292,287	6,740,468	2,774,571	3,994,628
Access to Wren's Nest NNR				
No access to Wren's Nest NNR	-4,797,714	-4,825,836	-2,006,655	-1,150,374
Access to all areas, no explanation of geology (CS)	0.00	0.00	0.00	0.00
Access to all areas, with explanation of geology	216,161	572,363	-238,167	-157,077
Fossil collecting				
Collecting by geologists	-818,671	-689,933	-627,439	-796,173
Collecting in all areas by public	-2,688,491	-2,309,778	-3,109,701	-2,915,970
Unlimited collecting from spoil heaps (CS)	0.00	0.00	0.00	0.00

Note: CS refers to the current situation. For access to Wren's Nest NNR, the current situation is referred to as access with no explanation because access with explanation was explained as having improved facilities and interpretation from the current situation.

5.2.1.9 Policy values

These results can be utilised to calculate policy values, the consumer surplus associated with a particular bundle of attributes and levels which make up different plans. For example, the best value plan overall, the best value plans associated with and without the provision of information, and plans based on different levels of fossil collecting have different consumer surplus associated with them for all data (Table 28).

Table 28 Consumer surplus per household for different plans

Best value	Best value with no information	Best value collecting by geologists	Best value collecting by public
Access to Seven Sisters Caverns with explanation	Access to Seven Sisters no explanation	Access to Seven Sisters Caverns with explanation	Access to Seven Sisters Caverns with explanation
Access to WNNNR with explanation	Access to WNNNR no explanation	Access to WNNNR with explanation	Access to WNNNR with explanation
Unlimited collecting from spoil heaps	Unlimited collecting from spoil heaps	Collecting by geologists	Collecting by public
£52.07 (£6,508,125)	£36.92 (£4,614,556)	£53.48 (£6,684,358)	£35.14 (£4,392,078)

Aggregated consumer surplus in parentheses

The value of providing information is calculated as the difference between the best value plan and the best value plan with no information. Therefore the value of providing information at Wren's Nest and the Seven Sisters caverns is £15.15 per household per year. The value of providing information is 29% of the consumer surplus of the best value plan.

5.2.1.10 Passive use value

The passive use value can be estimated using the data of those respondents who have not visited Wren's Nest NNR. 493 respondents had not visited Wren's Nest NNR.

Table 29 Estimates of coefficients and significance for respondents not visited

Variable	Coefficient β	P-value (Z>z)
BAC1 Access to Seven Sisters, no explanation of geology	0.4065	0.0000
BAC2 Access to Seven Sisters, explanation of geology	1.0266	0.0000
BACS1 No Access to Seven Sisters - CS	-1.4331	0.0000
BAW1 Access to WN, no explanation of geology - CS	0.5964	0.0000
BAW2 Access to WN, explanation of geology	0.6092	0.0000
BAWS1 No access to WN	-1.2055	0.0000
BCO1 Public collecting in all areas	-0.6966	0.0000
BCO2 Unlimited collecting from spoil - CS	0.2735	0.0000
BCOS1 Collecting by geologists	0.4231	0.0000
TAX	-0.0536	0.0000
Constant	-1.5109	0.0000
Log likelihood function	-2741.602	
Log likelihood for choice model	-5741.6021	
Log likelihood (constants only)	-3713.1260	
Rho square	0.26165	
Adjusted rho square	0.26097	
Chi-square	-4056.9522	
Completed iterations	7	
Observations	4390 (0 skipped)	

Note: CS refers to the current situation. For access to Wren's Nest NNR, the current situation is referred to as access with no explanation because access with explanation is explained as having improved facilities and interpretation.

Implicit prices are then calculated from these results per household and aggregated to the households in Dudley MBC. These can also be translated to consumer surpluses.

Table 30 Aggregated passive use values

Attribute and level	Implicit price (£)	Aggregated IP (£)	Consumer surplus (£)	Aggregated CS (£)
Access to Seven Sisters Caverns				
No access to Seven Sisters Caverns - CS	-26.76	-3,344,528	0.00	0.00
Group access to caverns with guide, no explanation of geology	7.59	948,630	34.35	4,293,158
Group access to caverns with guide with explanation of geology	19.17	2,395,903	45.93	5,740,431
Access to Wren's Nest NNR				
No access to Wren's Nest NNR	-22.51	-2,813,389	-33.64	-4,205,163
Access to all areas, no explanation of geology - CS	11.14	1,391,775	0.00	0.00
Access to all areas, with explanation of geology	11.37	1,421,612	0.24	29,837
Fossil collecting				
Collecting by geologists	7.90	987,519	2.79	349,288
Collecting in all areas by public	-13.01	-1,625,752	-18.11	-2,263,983
Unlimited collecting from spoil heaps - CS	5.11	638,231	0.00	0.00

Note: CS refers to the current situation. For access to Wren's Nest NNR, the current situation is referred to as access with no explanation because access with explanation was explained as having improved facilities and interpretation from the current situation.

5.2.1.11 Distance decay

Distance decay refers to the observation that people living further away from the site being valued care less about it and therefore express lower valuations. The distance decay from Wren's Nest NNR can be explored using the sub-sample results. The value should decrease from Dudley, to Kidderminster and Worcester. Kidderminster is 13 miles from Wren's Nest NNR and Worcester is 30 miles. The respondents in Dudley would potentially know of the site and value it more than someone living further away.

The results for the sub-samples indicate that value decreases for some of the attributes. However, the Worcester sub-sample results are higher than the Kidderminster results and in some cases higher than the Dudley sub-sample. The attributes: group access to the Seven Sisters Caverns with no explanation of the geology, no access to Wren's Nest NNR and access to all areas of Wren's Nest NNR with an explanation of the geology decrease with distance from Wren's Nest NNR.

Distance decay for the Jurassic Coast was not explored. The normal concentric pattern of distance decay does not apply due to the linear characteristics of the site.

5.2.1.12 Reasons for choices

Reasons for the choices that respondents made in the main survey are presented in Table 31. The majority of respondents stated that they chose A or B because they thought it was important to preserve geological features and were willing to pay. However, this does not compare with the fact that only 34% of the choices were for Option A or B, and the current situation accounted for 66% of the choices made.

Table 31 Respondents reasons for choices made in the choice task

Reason for choice	Number	%
Chose A or B because thought important to preserve geological features and were willing to pay	485	69
Did not consider that preserving features is good use of money	20	3
Do not think that increases in tax should be used to fund changes	127	18
Already contribute to similar causes as much as can afford	7	1
Other	61	9

Other reasons given were that their preferred combination was not available. Most people picked one attribute and level and used this for the basis of their choices. For example, some thought education was important therefore they picked the option where an explanation of geology was available.

5.2.1.13 Workshop discussions

The workshops presented the opportunity for discussion of any issues brought up by the participants. There was also more time to deliberate on the choice tasks. Participants were all supportive of the idea to improve Wren's Nest NNR and open the Seven Sisters caverns. Although the scenarios presented to participants were theoretical, the participants of the Dudley workshops said that the residents of Dudley should not pay extra council tax for the improvements to Wren's Nest/Seven Sisters as was suggested in the questionnaire. Communication issues were also raised by the participants of the Dudley workshops, in that they do not feel like they are being kept up to date with the issues/progress with the Seven Sisters project. There was also a strong opinion that the Wren's Nest NNR is for the community as well as other people who visit. Participants identified the impact that developing Wren's Nest NNR and the Seven Sisters would have on the local area, such as jobs being created for local people and money being spent in the area by visitors. There were also some concerns that money was being spent elsewhere in the Borough on issues that are perhaps less important.

Participants also recognised that education should play an important role in the future of Wren's Nest NNR and the Seven Sisters. Both formal education of children, and the education of the other people about what Dudley Borough and particularly Wren's Nest NNR have to offer for a recreational, educational and historic point of view. The issue of Wren's Nest NNR becoming an 'attraction' was also discussed. The Dudley participants were concerned that if an entry fee were charged, the fee may be too expensive and would exclude local people.

Issues that were discussed in the Kidderminster and Worcester groups were fairly similar. Participants were concerned about the infrastructure of Wren's Nest/Seven Sisters, and would want to ensure that if people were going to visit there was sufficient facilities to accommodate these visitors.

5.2.2 Dorset CE results

There were a range of introductory questions at the beginning of the CE questionnaire which were designed to elicit visiting habits and attitudes to various aspects. A summary of responses is presented followed by the results of the choice analysis.

5.2.2.1 Visiting information

The Jurassic Coast sample consisted of 122 visitors and 78 residents. 92 % of respondents knew that the area was designated as a World Heritage Site. Of the 200 respondents questioned, 196 had visited the Jurassic Coast and 4 people had never visited (Table 32). The majority of people questioned visit the Jurassic Coast daily (24%). At the valuation workshops, all of the participants had visited the Jurassic Coast.

Table 32 Frequency of visits to Jurassic Coast (main survey)

Frequency of visit	Number	%
Never	4	2
First time	30	15
Daily	48	24
Once a week	20	10
More than once a week	13	7
Once a month	28	14
Once a year	22	11
Other	35	17
Total	200	

Activities which the 196 Jurassic Coast respondents had taken part in during their visit and in the past are summarised in Table 33, the most popular activities were 'enjoying the scenery' (85%), though this was usually combined with 'walking', 'nature watching' and looking at rocks and fossils (60%, 35% and 42% respectively). 'Fossil collecting' was 30% (both casual and professional). A low proportion of respondents took part in 'dog walking' and 'playing' activities (11% and 14% respectively).

Table 33 Activities on the Jurassic Coast

Activity	Today	% of people	Past	% of people
Walking	118	60	160	82
Enjoying the scenery	167	85	168	86
Dog walking	22	11	64	33
Playing	28	14	31	16
Nature watching	68	35	80	41
Looking at rocks and fossils	82	42	96	49
Fossil collecting - casual	56	29	69	35
Fossil collecting - professional	2	1	2	1
Other	163	83	132	67
Total	706		802	

'Other' activities account for 83% of activities, these other activities include eating out, water sports including swimming, photography, shopping and sun bathing.

The Jurassic Coast survey identified 1% of respondents who maintained they had a 'professional' interest in geology, 17% of respondents had an 'amateur' interest, 62% had a 'casual' interest, and 20% had 'no interest' (Table 34). Overall this indicates that 80% of respondents have some interest in geology.

Table 34 Interest in geology

Level of interest in geology	Number	%
Professional	2	1
Amateur	33	17
Casual interest	124	62
No interest	41	20
Total	200	100

5.2.2.2 Attitudes towards the Jurassic Coast

Respondents were questioned on their attitudes to various statements about the Jurassic Coast (Table 35).

Table 35 Summary of respondent preferences

	Agreement with statement (%)				
Statement	**Strongly disagree**	**Disagree**	**Neutral/ don't know**	**Agree**	**Strongly agree**
There should be unlimited public access to the Jurassic Coast	0	1	16	22	61
There should be no access to the Jurassic Coast	74	7	19	0	0
The rocks and fossils are important	0	1	33	37	29
The rocks and fossils should be protected	0	5	55	29	11
Coastal defences are essential	1	8	35	21	35
The coastline should be allowed to erode naturally	23	9	58	8	2

Respondents' attitudes to unlimited public access were distinct, with 83% of people either agreeing or strongly agreeing. The reasons given by respondents for agreeing with unlimited public access have common themes. Access is seen as a public right, and that the *'Jurassic Coast belongs to everybody'* and is part of our heritage. Respondents raised the issue of public safety and are concerned that any access provided should warn visitors about cliff falls and tides. Some respondents indicated that *'we pay for it [access]'*. Respondents also identified that access to the Jurassic Coast is good for tourism and the local economy.

Attitudes to no public access were also marked with 81% of respondents disagreeing with the statement that there should be no access to the Jurassic Coast. The reasons given are similar to those given for unlimited access to the Coast, namely that access is a public right, though should be restricted in dangerous areas. Some respondents questioned the feasibility of restricting access.

The attitudes towards rocks and fossils being important and protected are positive with 66% of respondents agreeing that they are important and 40% agreeing that rocks and fossils should be protected. The explanations for respondents' agreement include that rocks and fossils are important for education, history – learning about the past, their scientific and research value, for evolution, new discoveries, and that rocks and fossils are interesting and important for their own sake. Some respondents suggested that the rocks and fossils *'bring in tourists'* and that they are the *'whole point of the World Heritage Site'*. Reasons given for those respondents that disagreed were *'not [important] to me personally'*, and that there are *'plenty of them'*, and *'loads in Charmouth and museums already'*.

Respondents gave a variety of explanations for their attitudes to the statement that rocks and fossils should be protected. Rocks and fossils should be protected for future generations and should be available for education and research. Some respondents suggested that rocks and fossils should be protected for museums, while others said they should be protected otherwise they would be *'lost to the sea'*. Some respondents stated that rocks and fossils are protected by geologists and scientists, and that not all should be protected because they are not all important. Reasons for disagreeing with the statement that rocks and fossils should be protected include *'they have lots in museums'* and there are *'too many'*.

Attitudes to coastal defence are more varied, with 56% of respondents agreeing with the statement that coastal defences are essential, however weaker preferences are also demonstrated by neutrality (35%) and disagreement (9%). Conversely, respondents disagreed with the coastline eroding naturally (32%), with 58% of people being neutral. 10% of the respondents agreed.

Most respondents' reasons agreed that coastal defences are essential, especially around towns. Respondents were particularly concerned about protecting property and businesses. Some respondents also said that coastal defences are needed especially in London and the South East of England. Concern was that *'we will disappear into the sea'*. The reasons given for disagreeing with the statement were that the sea is stronger than man, that it is not practical everywhere, and a waste of money. Some respondents said that they preferred the natural coastline.

Some respondents disagreed with the statement that the coastline should be allowed to erode naturally. One of the main reasons given was that there is the need for lives and land to be protected. Other reasons include that it is just not an option and respondents were *'not sure where it would end'*. Some respondents stated that natural erosion could be allowed to take place away from settlements, in the countryside, in remote areas or farming areas. Many respondents stated that erosion is *'happening anyway'*. Responses in agreement include that nature must take its course, it is a *'natural process'*, and that allowing erosion unearths more fossils.

5.2.2.3 Choice analysis – Dorset

The choice tasks from the CE questionnaires were analysed similarly to the Dudley data (Section 5.2.1). This section reports the results of the aggregate choice model for the whole sample and sub-samples. The attributes are investigated along with the reasons respondents gave for their choices. Implicit prices and consumer surplus are calculated. The attributes and levels are shown in Table 36.

Table 36 Description of attributes and levels for the Dorset survey

Attribute	Level
Access to Jurassic Coast	No access to Jurassic Coast Access to most of Jurassic Coast via beaches with some explanation of geology Access to all of the Jurassic Coast with extensive explanation of geology
Coastal defence	Coastal defence with hard engineering Coastal defence in gateway towns only Allow natural erosion to take place
Fossil collecting	No collecting Collecting in all areas by geologists/collectors only Collecting via code of conduct by geologists/collectors, public collecting on beaches
Annual council tax increase	£2.50 £5.00 £10.00 £20.00 £40.00

5.2.2.4 Model specification

Choice analysis is based on the estimates of coefficients of variables as discussed in Section 5.2.1.4 previously. The utility is assumed to be linear and model specification as in equation 1 for Wren's Nest NNR, with different attribute descriptions.

5.2.2.5 All respondents choice model – Jurassic Coast

The multinomial logit (MNL) choice model produces the aggregate or average choice across all respondents in survey (Table 37) and sub-sample of visitors and residents (Table 38). The sample was not analysed according to the sampling locations as the sample sizes would be too small for this. The model is described in Section 5.2.2.6.

Table 37 Estimates of coefficients, standard errors and significance for main survey

Variable	Coefficient β	Standard error	t-ratio (B/SE)	P-value (Z>z)
BAC1 Access to most of Jurassic Coast, some interpretation - CS	0.6137	0.2009	3.0554	0.0022
BAC2 Access to all of Jurassic Coast, extensive interpretation	1.6153	0.2022	7.9902	0.0000
BACS1 No access to Jurassic Coast	-2.2290	0.3495	-6.3776	0.0000
BCD1 No coastal defence in WHS, some engineering in gateway towns - CS	-0.2923	0.1705	-1.7145	0.0864
BCD2 Allow natural erosion	-0.0753	0.2299	-0.3276	0.7432
BCDS1 Hard engineering in all areas	0.3677	0.1932	1.9031	0.0570
BCO1 Fossil collecting by geologists only	-0.4006	0.1777	-2.2548	0.0241
BCO2 Geologists collect via code of conduct, public collecting on beaches - CS	1.4956	0.1458	10.2584	0.0000
BCOS1 No fossil collecting	-1.0950	0.1791	-6.1127	0.0000
TAX	-0.0259	0.0115	-2.2567	0.0240
Constant	-4.4156	0.5638	-7.8312	0.0000

Log likelihood function	-470.4873
Log likelihood for choice model	-470.4873
Log likelihood (constants only)	-617.2832
Rho square	0.23781
Adjusted rho square	0.23628
Chi-square	293.5918
Completed iterations	9
Observations	2000 (0 skipped)

Note: CS refers to the current situation.

Table 38 Estimates of coefficients and significance for sub-samples (visitors and residents)

	Visitors		Residents	
Variable	**Coeff. β**	**P-value**	**Coeff. β**	**P-value**
Constant	-1.7511	0.0000	-1.9314	0.0000
BAC1 Access to most of Jurassic Coast, some interpretation	*0.4960*	*0.0837*	*0.7563*	*0.0071*
BAC2 Access to all of Jurassic Coast, extensive interpretation	1.7920	0.0000	1.3447	0.0000
BACS1 No access to Jurassic Coast	-2.2880	0.0000	-2.1009	0.0000
BCD1 No coastal defence in WHS, some engineering in gateway towns	*-0.3159*	*0.1918*	*-0.3018*	*0.2205*
BCD2 Allow natural erosion	-0.1975	0.5555	-0.0161	0.9593
BCDS1 Hard engineering in all areas	0.5134	0.0996	0.3179	0.1808
BCO1 Fossil collecting by geologists only	-0.2443	0.3509	-0.4365	0.0747
BCO2 Geologists collect via code of conduct, public collecting on beaches	*1.7868*	*0.0000*	*1.1620*	*0.0000*
BCOS1 No fossil collecting	-1.5425	0.0000	-0.7254	0.0014
TAX	-0.0409	0.0258	-0.0124	0.3882
Log likelihood function	-257.111		-207.050	
Log likelihood for choice model	-257.1111		-207.0497	
Log likelihood (constants only)	-368.7022		-248.4854	
Rho square	0.30266		0.16675	
Adjusted rho square	0.30037		0.16246	
Chi-square	223.1822		82.8714	
Completed iterations	9		9	
Observations	(1220	skipped)	780 (0	skipped)

NB: sample sizes = 122 and 78 for visitors and residents respectively.
Rows in italics represent the current situation.

5.2.2.6 Analysis of model for all respondents - Jurassic Coast

The model for the Jurassic Coast is assessed according to the tests as utilised in Section 5.2.1.6 for Wren's Nest.

The results for all the data indicate that most of the attributes are highly significantly different from zero ($p<0.01$). This means that these attributes are all significant in the model (BAC1, BAC2, BACS1, BCO2, BCOS1). BAC1, BAC2 and BACS1 refer to access to the Jurassic Coast, and BCO2 and BCOS1 refer to fossil collecting. The variables BCD1, BCD2, BCDS1, BCO1 are not significantly different from zero ($p>0.01$). BCD1, BCD2 and BCDS1 refer to the coastal defence attributes and BCO1 refers to fossil collecting by geologists only.

The direction of the coefficients, that is, whether they are positive or negative are generally as expected. Two of the coefficients associated with coastal defence (BCD1 and BCD2) are negative illustrating that respondents did not prefer these attributes. Conversely, BCDS1 (allow hard engineering solutions in all areas of the Jurassic Coast) is positive, indicating that respondents valued this attribute higher than the other two attributes.

The coefficients for fossil collecting are negative for BCO1 and BCOS1, this means that respondents valued 'no collecting' and allowing 'fossil collecting by geologists only' less than allowing 'collecting via the code of conduct by geologists and collectors, and by the public on beaches'.

The tax coefficient was negative as expected indicating that respondents were less likely to choose an option that was associated with a higher tax payment.

The significance of the model was determined using the Ben-Akiva and Lerman test (1985) (Equation 2). The calculated statistic is 293.5918. Which exceeds the critical values of X2 at both the 95% (12.59, $p<0.05$, 6d.f.) and 99% (16.81, $p<0.01$, 6d.f.) levels. The null hypothesis is rejected and the estimated model is considered to be significantly different from one of constants only.

Results for the whole sample indicate that most of the coefficients are highly significant from zero ($p<0.01$). This means that the coefficients were significant in the model. The null hypothesis that the coefficients equal zero is rejected for all variables. Overall, the test of the individual attributes provides general agreement with the test of significance of the model.

Rho square is reported as 0.23781 and adjusted rho square is 0.23628. Values between 0.2 and 0.4 are considered acceptable (Bennett and Adamowicz 2001), therefore the overall fit of the model is good. Overall, fits are all well within acceptable limits, coefficient signs are logical and conform to the focus group findings.

The results for the sub samples are fairly consistent with the main sample, however there is some variation in the magnitude of the coefficients. Many of the attributes are highly significantly different from zero ($p<0.01$). With the exceptions of BAC1, BCD1, BCD2, BCDS1 and BCO1 in the visitors sub sample and BCD1, BCD2, BCDS1 and BCO1 in the residents sub sample. The directions of the coefficients for both sub samples are consistent with the main sample coefficients.

Adjusted rho square are reported as 0.30037 and 0.16675 for the visitors and residents sub samples respectively. The residents sub sample is not within the accepted range of 0.2 and 0.4. However this is most likely due to the sample size.

The variations of the MNL models in the sub sample from the main survey can again be explained by the relatively small sample sizes (122 and 78 respondents) compared to the main survey (200 respondents). However, the implicit prices and consumer surplus results presented in the following sections provide a valid means to compare the sub samples and will also reflect localised attitudes to the various attributes.

5.2.2.7 Implicit prices - Jurassic Coast

Implicit prices (Equation 3) were calculated for the whole sample, and the two sub samples (visitors and residents) and are shown in Table 39. The implicit prices are per household.

Table 39 Implicit prices of separable attributes for all data and sub-samples

Attribute and level	**Implicit prices (£)**		
	All data	**Visitors**	**Residents**
Access to most of Jurassic Coast via beaches with some explanation of geology	*23.69*	*12.12*	*61.15*
Access to all of the Jurassic Coast with extensive explanation of geology	62.35	43.79	108.73
No access to Jurassic Coast	-86.04	-55.91	-169.88
Coastal defence in gateway towns only	*-11.28*	*-7.72*	*-24.40*
Allow natural erosion to take place	-2.91	-4.83	-1.30
Coastal defence with hard engineering	14.19	12.55	25.70
Collecting in all areas by geologists/collectors only	-15.46	-5.97	-35.30
Collecting via code of conduct by geologists/collectors, public collect on beaches	*57.73*	*43.66*	*93.95*
No collecting	-42.27	-37.69	-58.66

Note: Rows in italics represent the current situation.

The implicit prices estimated for the attribute levels for all the data are as expected, that is, the levels which reflect some loss of access or amenity, have a negative implicit price, whereas the attributes which demonstrate an improvement have positive implicit prices. This is particularly true for the access attributes, but not easily discernible for the coastal defence attribute. Allowing natural erosion, and coastal defence in the gateway towns only have negative implicit prices (-£2.91 and -£11.28 respectively), whereas hard engineering has a positive implicit price (£14.19). The fossil collecting attribute displays negative implicit prices for no collecting and collecting by geologists only, with collecting via the code of conduct by geologists and on beaches by the public displaying a positive implicit price.

The implicit prices for the sub samples are similar to the main survey. The magnitudes of the sub sample implicit prices also vary to the main sample which is quite marked in some cases.

These prices were then aggregated to the 202,399 households in Dorset and East Devon (National Statistics 2005a;b;c;d;e;f) (Table 40).

Table 40 Aggregated implicit prices for all data and two sub samples

Attribute and level	Aggregated implicit prices (£)		
	All data	Visitors	Residents
Access to most of Jurassic Coast via beaches with some explanation of geology	*4,794,782*	*2,453,178*	*12,376,429*
Access to all of the Jurassic Coast with extensive explanation of geology	12,618,913	8,863,203	22,006,558
No access to Jurassic Coast	-17,413,719	-11,316,357	-34,382,987
Coastal defence in gateway towns only	*-2,283,851*	*-1,562,209*	*-4,939,116*
Allow natural erosion to take place	-588,365	-976,944	-263,300
Coastal defence with hard engineering	2,872,212	2,539,152	5,202,421
Collecting in all areas by geologists/collectors only	-3,129,619	-1,208,074	-7,144,141
Collecting via code of conduct by geologists/collectors, public collect on beaches	*11,684,326*	*8,837,287*	*19,016,250*
No collecting	-8,554,715	-7,629,208	-11,872,125

Note: Rows in italics represent the current situation.
Prices are shown with no decimal places.

The aggregated implicit prices show the willingness to pay for all households in the Dorset and East Devon areas. These prices illustrate the magnitude of the value of the respective attributes and hence how much improvements or changes to these attributes are worth in monetary terms. For example, access to the Jurassic Coast with extensive information is worth £12.6M to households in Dorset and East Devon and fossil collecting via the code of conduct for geologists and collectors and on the beach by the public is worth £11.6M.

5.2.2.8 Consumer surplus - Jurassic Coast

Consumer surplus was calculated for the Jurassic Coast data from the implicit prices (Table 41).

Table 41 Consumer surplus for all data and two sub samples

Attribute and level	Consumer surplus (£)		
	All data	Visitors	Residents
Access to most of Jurassic Coast via beaches with some explanation of geology	*0.00*	*0.00*	*0.00*
Access to all of the Jurassic Coast with extensive explanation of geology	38.66	31.67	47.58
No access to Jurassic Coast	-109.73	-68.03	-231.03
Coastal defence in gateway towns only	*0.00*	*0.00*	*0.00*
Allow natural erosion to take place	8.38	2.89	23.10
Coastal defence with hard engineering	25.47	20.26	50.11
Collecting in all areas by geologists/collectors only	-73.19	-49.63	-129.25
Collecting via code of conduct by geologists/collectors, public collect on beaches	*0.00*	*0.00*	*0.00*
No collecting	-100.00	-81.36	-152.61

Note: Rows in italics represent the current situation.

Table 42 Aggregated consumer surplus per household for all data and two sub samples

Attribute and level	Aggregated consumer surplus (£)		
	All data	Visitors	Residents
Access to most of Jurassic Coast via beaches with some explanation of geology	0.00	0.00	0.00
Access to all of the Jurassic Coast with extensive explanation of geology	7,824,131	6,410,025	9,630,130
No access to Jurassic Coast	-22,208,501	-13,769,535	-46,759,416
Coastal defence in gateway towns only	0.00	0.00	0.00
Allow natural erosion to take place	1,695,486	585,265	4,675,816
Coastal defence with hard engineering	5,156,063	4,101,361	10,141,536
Collecting in all areas by geologists/collectors only	-14,813,946	-10,045,361	-26,160,391
Collecting via code of conduct by geologists/collectors, public collect on beaches	0.00	0.00	0.00
No collecting	-20,239,041	-16,466,495	-30,888,375

Note: Rows in italics represent the current situation.

The consumer surplus for all data and the two sub samples are generally comparable. Attribute implicit price values which were already negative are obviously negative when converted into the consumer surplus and vice versa. The coastal defence consumer surpluses vary between the main survey and sub samples. The fossil collecting consumer surpluses are generally similar with the sub samples.

The passive use value of the Jurassic Coast was not calculated as only two out of the 200 respondents who had not visited.

5.2.2.9 Reasons for choices in choice task - Jurassic Coast

Reasons for the choices that respondents made in the main survey are presented in Table 43. 7% of respondents chose A or B because they thought it was important to preserve geological features and were willing to pay. 8% of respondents stated that they did not consider preserving these features was good use of their money. 43% of respondents thought that tax should not be used to fund these changes.

Table 43 Respondents reasons for choices made in the choice task

Reason for choice	Number	%
Chose A or B because thought important to preserve geological features and were willing to pay	14	7
Did not consider that preserving features is good use of money	16	8
Do not think that increases in tax should be used to fund changes	85	43
Already contribute to similar causes as much as can afford	8	4
Already contribute to other more important causes as much as I can afford	0	0
Other	77	38

Other reasons given were that their preferred combination was not available and that the current situation seems fair and reasonable. Most people picked one attribute and level and used this for the basis of their choices. For example, some thought education was important therefore they picked the option where an explanation of geology was available.

5.2.2.10 Jurassic Coast workshop discussions

Discussion in both groups confirmed the selection of attributes for the choice tasks. Access, fossil collecting and coastal defences were raised, unprompted by the facilitator. More direct questioning revealed that participants thought the attributes and the levels they were presented at were appropriate. Several participants mentioned their frustration that their *'ideal choice'* was not available and that they were *'forced to compromise, either by choosing the current situation or losing something else'*. While such frustration is understandable (it is a common response by those completing such tasks) it is a component of the CE method in emulating real world compensatory choice. The simulation of *'real world'* decision making was accepted, understood and, in several cases, appreciated by respondents.

Of importance to the correct functioning of the survey instrument is information processing and decision making strategy by respondents. Consistency of both, rather than conformity to a theoretically correct form, is important in confirming the efficacy of the information provided. There appears in the difference in the choices made by Group 1 that there is some question over consistency.

The cause of a change to choice making strategy by two respondents is due to poor understanding of 1 attribute each. The first was knowledgeable on the environmental issues but remained unsure of his/her opinion on coastal defences due to limited understanding of the socio political implications, for example the rationale behind the use of French stone in their construction. The respondent therefore ignored the attribute in each task; effectively employing a form of heuristics. Information furnished in the discussion led to consideration of the sea defence attribute; effectively a change in strategy to compensatory choice. The second respondent was unsure of the meaning of 'interpretation'. She was concerned over public access without information on safety, history and culture but failed to realise that interpretation was exactly that. Her choice making strategy was modified with the realisation that information and interpretation, in this case, are synonymous.

One respondent changed towards a heuristic strategy. Discussion confirmed her concerns that more access would lead to uncontrolled fossil collecting and increased pressure on the environment and infrastructure of the area. Her strategy was then to reject any scheme which increased access.

The respondent making the greatest number of changes considerably revised her views due to the discussion. She was greatly influenced by the information and discussion on coastal defences. She thought that her prior opinions had been influenced by *'bad information'* and *'hearsay, not fact'*.

Some discussion in both groups raised local concerns. For example, some suspicion that sea defences in West Bay were *'...the thin end of the wedge...once building starts on them then other stuff will follow'*. The respondent was referring to the ongoing *'saga'* of a development being granted planning permission, but never being built. The participant questioned if the sea defences would be *'...the final piece in the puzzle needed to get building started'*. While such issues are likely beyond the scope of the study some comment to reassure respondents that planning processes are not subverted by the proposed polices is necessary.

Participants were asked for their views on the choice tasks. The frustration over ideal choices and the points above notwithstanding it was considered to be understandable and a fair representation of the issues, addressing the above points adds theoretical validity to the survey.

Research Information Note

English Nature Research Reports, No. 709

The social and economic value of the UK's geodiversity

Report Authors: Michelle Webber, Mike Christie and Neil Glasser
University of Wales, Aberystwyth Date: September 2006
Keywords: geodiversity, geological conservation, social and economic value, choice experiments, multiplier analysis

Introduction

Given its relatively small size, the UK is one of the most geodiverse countries in the world. Our heritage of rocks, fossils, minerals, geomorphological features and processes includes a sequence of rock including every major period of geological history for the last 700 million years. This rich geodiversity is important in itself, for scientific and educational reasons, and international, national and local schemes to conserve, manage and promote this resource are in operation across the UK. Although it is widely accepted that geodiversity and the conservation of geodiversity is of social, economic and cultural benefit, these benefits have never previously been described. The aim of this report is to describe the social and economic value of geodiversity using a variety of methods.

What was done

The social and economic value of geodiversity is explored using a variety of methods. First, a review of existing research was undertaken to identify existing knowledge on the value of geodiversity, and also identify where gaps in this knowledge exist. This resulted in a qualitative review of the evidence about social benefits. New empirical research was then undertaken to provide information on where gaps in the knowledge occurred. This research included a series of interviews and focus groups with members of the public and specific user groups to collect descriptive and anecdotal evidence of the way in which people value geodiversity. A number of case studies were explored to illustrate in greater detail the social functions provided. Empirical research was also undertaken to specifically explore the economic values of geodiversity. In particular, the choice experiments method was used to assess how much people would be willing to pay to protect and enhance two geological sites: Wren's Nest National Nature Reserve (NNR) and the Jurassic Coast World Heritage Site (WHS). Economic impact analysis was also carried out on the Isle of Wight to determine the size of the local economic impacts that geodiversity brings to the Island.

Results and conclusions

The value of different elements of geodiversity was examined using two choice experiments valuation studies: one at Wren's Nest NNR near Dudley and the other at the Jurassic Coast World Heritage Site in Dorset. The value of 'knowledge' of geodiversity was explored by comparing the value of access to different geological sites both with and without the provision of interpretative material. Significant positive 'willingness to pay' values were found at both the Wren's Nest NNR and at the Jurassic Coast WHS. In both cases the provision of educational material on geodiversity (and hence 'knowledge') clearly enhances the value that people attain from visiting a geodiversity site. The value that people placed on the opportunity to collect fossils was also explored at both case study sites.

A multiplier analysis study was also undertaken to provide an estimate of the local economic impacts associated with geodiversity on the Isle of Wight. This research found that 39% of tourists in this survey

Continued .....

had visited the Isle of Wight specifically for the geodiversity. Average daily spend by these visitors was £73.86. The estimated expenditure related to geodiversity can be applied to the expenditure generated by all tourists to the Isle of Wight. Tourism on the Isle of Wight was estimated to be worth £352 million for the tourism year 2004/2005 (Isle of Wight Council 2006a). Geodiversity was therefore estimated to account for approximately £11 million of this value. Applying income and employment multiplier coefficients, it is argued that geodiversity generates between £2.6 million and £4.9 million in local income and supports between 324 and 441 full time equivalent local jobs.

Qualitative data, collected during focus groups and interviews, were also collected to provide descriptive evidence of the values that the general public hold for geodiversity. The evidence collected here was indicative of the high values that the public place on geodiversity resources and when considered alongside the findings from the choice experiments, provide strong evidence in support to the continued management and conservation of these resources.

This study demonstrates that the use of environmental valuation techniques, such as choice experiments, can be utilised to estimate the non-market benefits that geodiversity provides. These techniques, combined with qualitative and economic impact methods allow for the wider values associated with geodiversity to be identified. These values should now be used to develop policies and provide future management and conservation strategies for geodiversity.

English Nature's viewpoint

This is the first published attempt at placing a value on the social and economic value of geodiversity. As such it makes a major contribution to the thinking surrounding conservation of geodiversity, offering an additional approach to be used alongside more established means of conservation such as conservation and planning legislation. It provides valuable evidence on both a qualitative and quantitative basis. English Nature has always urged caution in interpretation of 'willingness to pay' and economic impact studies. We believe this research to be well constructed and to contain some innovative features in its methodology. Nevertheless, we suggest that the qualitative figures be used as broad indicators of positive economic value and impact rather than be quoted as exact figures.

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