# Key Question Enquiry

Outline plan – for adaptation as required by schools

***How is the English Riviera Global Geopark affected by geohazards and how should they be managed in the future?***

**Objectives** and anticipated learning **outcomes**

- Identify, describe and explain how *hazards* are classified and categorised;
- Understand the rationale for subdividing natural hazards into four further categories;
- Recognise how one natural hazard may be a trigger for another through understanding 'primary' and 'secondary' effects;
- Understand why some locations around the world such as the English Riviera in South
- Devon are designated as UNESCO Global Geoparks and that some of these are at risk from geohazards of one kind or another;
- Through observation and reasoning understand the kind of geohazard that is most likely to impact on the English Riviera Global geopark;
- Reach conclusions and make judgments about the causes and effects of the cliff failure at Oddicombe within the English Riviera Global Geopark;
- Understand the difference between 'hazard' and 'risk' and predict the level of threat posed by the coastline at Oddicombe;
- Evaluate the costs and benefits of both short and long term management strategies for the coast at Oddicombe and make informed judgements and recommendations regarding the most sustainable long term option.

**Key question led learning and teaching activities and curriculum progression**

***Key Question 1: How do geographers categorise hazards?***

Divide the pupils into pairs or groups of 3 or 4 and give each group a set of the photographs in **Resource 1**. Explain to the pupils that geographers identify *hazards* as any event or process that presents a threat to life, health, property and the environment. The task for the pupils is firstly to try to identify each of the hazards shown in the photographs. When each of the groups has finished take time to discuss and share opinions between the groups and make a list of the hazards on the board. Now set the pupils the next task of categorising the hazards. Tell the pupils that all of the hazards shown in the photographs can now be divided into two categories or sets and that they are going to have a few minutes to do this. How have they decided to classify the hazards? What criteria did they use? Did all of the groups use the same criteria? Support the pupils to see the hazards as *natural* and *human* generated threats.

**Human generated hazards**

Oil spills
Fire at nuclear power point
Industrial gas leak
Toxic waste dump
Petrochemical smog
Effluent river pollution

**Naturally generated hazards**

Volcanic eruption
Earthquake
Tsunami
Landslide
Disease (Malaria)
Disease (Flu inoculations)
River flood
Drought
Hurricane
Tornado
Sandstorm
Avalanche (Snow)
Debris avalanche
Wildfire
Sinkhole
Storm sea surg

The next activity is for the pupils to now study again all of the hazards in the 'natural' category. Explain that geographers further divide natural hazards into four more categories:

- *Geohazards*: hazards which are caused by geological conditions or geophysical processes especially tectonic activity around the world;
- *Meteorological*: hazards generated by atmospheric conditions particularly variations in pressure, temperature and wind movements;
- *Hydrological*: driven by and associated with the movement of water;
- *Biological*: caused primarily by biological processes and particularly infectious and contagious diseases which can be spread from one person to another.

As a final activity in this initial enquiry ask the pupils to separate the following six hazard photographs: Earthquake, Volcano, Hurricane, Tsunami, Landslide and Storm Surge. Challenge them to reflect on why you have asked them to separate out these hazards? What do they think they might have in common? Encourage discussion and speculation. Now ask the pupils to make three pairs of the six photographs. What criteria did they use when doing this? If they haven't already made the link then tell them that the three pairs are: Earthquake and Tsunami; Volcano and Landslide and Hurricane and Storm Surge. In what ways are these connected? Encourage the pupils to see a 'cause and effect' link between the two photographs in each pair and to understand that one natural hazard such as a volcano which threatens humans directly through emitting gas and ash and lava flows may also trigger secondary natural hazards such as landslides (or avalanches). Similarly a subterranean earthquake can cause a Tsunami such as that which occurred in the Indian Ocean on Boxing Day 2004 and a hurricane generate a storm surge and coastal flooding such as the flooding which occurred in New Orleans as a consequence of Hurricane Katrina in 2005.

***Key Question 2: How is the English Riviera in Torbay linked to the Mount Unzen volcanic natural hazard in Japan?***

Explain that in Japan in 1991 the Mount Unzen volcano located in the south of the island of Kyushu erupted (see map in **Resource 2**) and also the photograph of the volcano in **Resource 3**. The consequences for the population of the local town were devastating with 43 deaths. Tell the pupils that you are now going to show them a very short (understandably) film (**Resource 4**) of the eruption (useful to do this at least twice) with the objective of identifying what the eruption was like and exactly what it was that caused the deaths. Encourage discussion and reasoning. What the film shows is a *pyroclastic flow* (a very fast moving mass of ash, stones and pebbles and large boulders) which careered down the mountain side into the town. Pyroclastic flows can sometimes be super-heated and the main cause of death id suffocation. Explain that when pyroclastic flows mix with water (from melting snow usually) they create something even more hazardous. Distribute copies of **Resource 5** and support the pupils to write a few lines describing and explaining what occurred on Mount Unzen to cause the release of the pyroclastic flow. Show the three short films in **Resource 6** (the first is of the Unzen eruption of 1991) and invite the pupils to describe and explain what this product of the eruption is. Geographers call these mud flows of rock and water *lahars*. They can cause catastrophic destruction and globally it is estimated that lahars have been responsible for 17% of all deaths from volcanic eruptions over the last 200 years. Lahars can be compared with the consistency of concrete – fluid when moving but setting hard very quickly when they stop. Next, pupils can analyse the satellite image in **Resource 7** to identify the extent of the pyroclastic and lahar flows (shown as orange/brown down the eastern side of the volcano) and then mark the equivalent area on the outline map of the region in **Resource 8**. This flow area is also shown in the photograph in **Resource 9**.

So, what is the connection between Torbay and this event? Encourage the pupils to speculate. Torbay doesn't have volcanoes now but did it in the past? Were people from Torbay amongst the dead and injured? Did ash and dust blown up into the atmosphere from the eruption eventually mix with rain which fell on Torbay? All of these, and more, are possibilities but the link we are looking for is revealed in **Resource 10** look especially at the names and locations of the two places numbered 71 and 104!

Since 2001, UNESCO (United Nations Educational Scientific and Cultural Organisation) has designated sites around the world of particular geologic importance as Global Geoparks. The English Riviera Torbay is one of just 104 such Global Geoparks located in 32 countries around the world. Being a Global Geopark is not just about having important rocks! All Global Geoiparks are places with both a very important geological record and where that geology can be seen to have had (and continue to have) an important influence on the lives of the people who live in and around it – such as how people are able to earn a living, the materials used to build houses and the distinctiveness of the environment which people have an emotional attachment to. More

detailed information about the reasons for the designation of the English Riviera as a Global Geopark can be found at
http://www.englishrivierageopark.org.uk

So both Unzen and the English Riviera at Torbay belong to an elite club of locations around the world known as Global Geoparks. Divide the pupils into pairs and support them to select one Global Geopark from http://www.globalgeopark.org/homepageaux/tupai/6513.htm ensuring as many countries as possible are represented. Each pair can then prepare a six slide PowerPoint presentation to describe and explain:

- Key facts about the particular Global Geopark e.g. location, size, physical and human characteristics;
- Reasons why it has been designated as a Global Geopark – i.e. its geological importance;
- Similarities and differences to and from the English Riviera.

***Key Question 3: How might the English Riviera Global Geopark be vulnerable to geohazards?***

Remind pupils of the exercises they undertook in Key Question 1 to categorise and classify *hazards* from the photographs in **Resource 1** first into naturally generated and human generated hazards and then to further divide the naturally generated group into four types: geohazards, meteorological hazards, hydrological hazards and biological hazards. Before moving on review in particular which threats it was agreed at the end of discussions should be included in the **geohazards** category i.e. hazards which are caused by geological conditions or geophysical processes especially tectonic activity. Explain to the pupils that the designation of the English Riviera Global Geopark is based on the international importance of 32 locations. Create a Powerpoint slide show from the images in **Resource 11** which will reveal that many of these 32 locations have something in common. What is the similarity? Most are found around the coastline of Torbay or at quarries where cliff faces have exposed the rich rock record. This is borne out by the sites map in **Resource 11** which can be used at the end of the Powerpoint slide show to make this point. Given that many of the English Riviera geosites are at such locations which of the following geohazards threats do the pupils feel could pose a risk? Allow time for the pupils to discuss this in groups and to ask questions, Stimulate discussion by asking probing questions such as Is the English Riviera Global Geopark in an active earthquake or volcanic area of the world? Focus discussion by telling the pupils that each group must decide on the one geohazard they feel is most likely in their view to present a threat to the Global Geopark, Take the feedback from the groups and write the decisions on the board. Now show them the photograph in **Resource 12**. How many of the pupils felt that landslides could form the greatest threat?

***Key Question 4: How has the coastline at Oddicombe changed in the past?***

Explain to the pupils that one coastal location in particular within the Geopark has clearly been impacted upon by a geohazards for a long time - the cliffs at Oddicombe (see location maps and satellite photograph in **Resource 13**). Changes during recent history are illustrated in the images in **Resource 14**. Divide the pupils into small groups and provide each group with a set of the images but without an indication of the date of each one. Challenge the pupils to create a timeline of the images from the oldest to the most recent. Having completed this exercise provide the pupils with the date of each image so that they can check that they have the correct sequence. Now encourage the pupils to identify the main changes to Babbacombe Cliffs and Oddicombe beach from the evidence in the images. How has the coast changed here over the past 200 years or so?

***Key Question 5: How is the coastline at Oddicombe continuing to change today?***

The photographs in **Resource 15** together with the BBC film report and text at http://www.bbc.co.uk/news/uk-england-devon-22020762 and the short video composed of cross dissolved still photographs by Kim Aldis in **Resource 16** provide evidence of what happened at Babbacombe cliffs on April 2nd 2013. Within a week *Frederick Sherrell Ltd* a company of consulting engineering geologists and geotechinal engineers http://www.fslgeo.co.uk/ who have been advising Torbay Council on the stability of the cliffs at Oddicombe for 39 years produced a report of the incident which included the following figures:

*"Over 100,000 tonnes of rockfall debris fell down across the whole beach at Little Oddicombe and the north end of the beach at Oddicombe effectively burying the former coastal landscape"* – see photographs in **Resource 17**.

*"We estimate that the cliff top has regressed by about 30-40m over a length of approximately 140m, leaving a new cliff face about 5-15m in height extending south from the remains of Ridgemount House to the bottom of the garden"* – see photographs in **Resource 18**.

*"Subsidence/collapse of the majority of the garden area to the southeast of Ridgemount House at the top of the cliff"* – see photographs in **Resource 19.**

Encourage the pupils to examine the photographs, report text and film footage in order to describe the extent of the cliff failure that occurred. Next extend this activity to pupils working in small groups to begin to consider the possible reasons which might explain the causes of such a catastrophic collapse. Provide each group with a piece of A3 plain paper to draw and annotate a diagram (or diagrams) of what might have been responsible for the landslide based on the evidence they have accumulated so far. This is an important speculative and intuitive exercise based deliberately on a limited range of evidence at this stage.

***Key Question 6: How might the geology of Oddicombe cliffs have contributed to the landslide?***

The rocks that comprise the cliffs at Oddicombe were formed during the Permian era approximately 299 – 252 million years ago by when the action of the Earth's crustal plates had fused most of the world's land area into one supercontinent know as Pangea (see world map in **Resource 20**). This single land mass stretched from the north to south pole. It was surrounded by just one big super ocean called Panthalassa. The interior regions of Pangea became very dry because they were so far from the moderating influence of the sea and rain bearing winds. It was in this desert environment (not dissimilar to the deserts of Nevada and Utah today as shown in the photographs in **Resource 20**) that the rocks which today make up Oddicombe cliffs were formed.

Ask the pupils to examine the close up images of the rocks of Oddicombe cliffs in **Resource 21**. How would they describe its composition and texture? The rock is called Permian breccia (pronounced '*brechia'*) and sandstone and is a *conglomerate rock* which means that it is made up of fragments of pre-existing rocks held together by a 'cement' of finer grained sediment. Most of the fragments of rock within the breccia at Oddicombe are either limestone (found to the north of Oddicombe Beach) or slate (found to the south).

Ian West who works within the Faculty of Natural and Environmental Sciences, University of Southampton and who writes the Geology of the Wessex Coast website at http://www.southampton.ac.uk/~imw/Torquay.htm describes the breccia at Oddicombe as:

*Both porous and permeable which means that it both absorbs rain water and allows it to flow* *through it. It is notorious for subsidence problems because it is so prone to loss of strength on wetting and consequently can be twenty times more likely to fail than more consolidated rocks such as limestone.*

Now ask the pupils to revisit and review their annotated diagrams of the possible cause of the landslide. How could they now update and add more detail to this given what they now know about the geology of the cliffs? How might the breccia have reacted when it became saturated with rain water? What might have happened to its fine grained cement holding the pieces of limestone and slate together? What would the bedding planes and joints in the breccia and sandstone have been like with water percolating through them? Would this have made them unstable? If so why?

***Key Question 7: What evidence is there that heavy rainfall may have also contributed to the landslide?***

Give each pupil a copy of the rainfall and temperature data shown in the graph in **Resource 22** compiled by Dr Andrew Merritt, Lecturer in Engineering Geology at the University of Plymouth. Ask them to identify the dates of major land sliding events at Oddicombe and also the pattern of rainfall over the four months shown. Look particularly at the pattern of rainfall in the days preceding the major landslide of April 2$^{nd}$. Now ask the pupils to look at the pattern of temperatures over the four months shown on the graph and in particular during the month prior to the major landslide. What do they notice about the minimum daily temperature recorded on a significant number of days before the major landslide – the temperature dropped below freezing? How might this factor also contribute to the cliff collapse? Allow time for the pupils to speculate. What would happen to the rainwater in the cracks in the brecchia when the temperature dropped below freezing? What happens to liquids when they freeze? Expansion occurs. How might this process contribute to causing the cliff failure?

***Key Question 8: How might variations in temperature also have contributed to causing the landslide?***

When temperatures drop below freezing then rock can be exposed to freeze – thaw weathering (sometimes referred to as frost shattering) a process which if it occurs repeatedly over many years can cause exposed rocks to change and break down. Direct the pupils to the online animation of this process at http://www.bbc.co.uk/schools/gcsebitesize/geography/rock_landscapes/processes_rev1.shtml and then support them to update their individual A3 annotated diagram of what they considered caused the landslide at Oddicombe with the new information relating to both rainfall and temperature patterns.

***Key Question 9: Why is the cliff failure at Oddicombe a good example of a 'slide type' landslide?***

Explain to the pupils that there are different causes of landslides. Distribute the 'before' and 'after' cliff failure diagrams in **Resource 23**. The landslide at Oddicombe is a *slide type* landslide. From the evidence in the diagrams and from the British Geological Society website at http://www.bgs.ac.uk/discoveringGeology/hazards/landslides/rotationalSlides.html can the pupils describe what a *slide type* landslide is? What do they think a 'slip surface' is and how might it have contributed to the collapse? Water percolating through the breccia creates a lubricated slip surface on the bed rock below and it is along this surface that the unstable breccia above eventually moves down slope. As the blocks of breccia moved downwards some also rotated forward – a process known as *overtopping*.

***Key Question 10: How should the hazard at Oddicombe be managed most effectively in the future?***

Write the two words 'hazard' and 'risk' on the board and ask the pupils to consider the difference in meaning between the two. Understanding the difference is very important when deciding upon how locations such as Oddicombe should be managed in the future. A hazard is a potentially dangerous event such as earthquake, volcanic eruption, flood (and in the case of Oddicombe a landslide) which can happen. Risk on the other hand is the level of likelihood or probability of the hazard event happening. The higher and more imminent the risk then the more critical it is for the hazard to be managed in a way that reduces to a minimum the potential consequences for people.

Distribute copies of the aerial photograph and map of the landslide at Oddicombe (**Resource 24**). Based on this evidence what potential consequences can the pupils identify for people if another sudden and serious landslide were to occur resulting in the cliff line receding inland further and more debris on the beach? What can be seen in the aerial photograph and map that might cause a concern for members of Torbay Council? Encourage discussion and feedback. What have the pupils identified – the homes along Redcliffe Road, potential risk to visitors walking the footpath or visiting the beach and café and perhaps even the vicinity of the funicular railway?

Now ask the pupils to read through the following extract from the *Torquay Herald and Express* newspaper June 6th 2013 which quotes an unnamed Torbay Council spokesman as saying:

*"Following the recent collapse of a property and ongoing concerns about cliff stability at the end of Redcliffe Road at Oddicombe, we are taking steps to ensure public safety. "This includes requiring owners of properties at the seaward end of Recliffe Road to take appropriate measures to prevent access to adjoining land approaching the cliffs. "We are aware children have been gaining access to play on land near the cliffs. We are, of course, concerned for their safety and we are working with the police to get over the message that it is unsafe for anyone to trespass on to the land. "We would strongly advise parents to ensure their children do not go on to the private land and put their safety at risk. "We are looking, in consultation with local residents, at putting up a gated entrance at a suitable point in Redcliffe Road to prevent vehicles gaining access to the seaward end of the cul de sac."*
Read more: http://www.westernmorningnews.co.uk/killed-Torquay-cliff-houses/story-19193260-detail/story.html#ixzz3cB9d807g

Explain to the pupils that responses to managing the risk of hazards need to be both short term (immediately and in the first few weeks after the event) and then longer term over months and years which are carefully considered and planned for. Is the council spokesman describing a short or long term response?

The photographs in **Resource 25** are of the cliffs at Oddicombe at different points along about 1 km to the south of the landslide. Ask the pupils to describe and explain what they can see. What has been done to the cliffs here over the years and can it be described best as *short* or *long term* management of the potential risk of the hazard? How exactly does each method of cliff protection or stabilisation work? The report drawn up for Torbay Council by Frederick Sherrell Ltd in April 2013 describes this section of the cliff in this way:

*Strengthening works using rock anchors were carried out to the cliff behind the café and the sailing club in 2004 and 2011. As part of our recent inspection we could not see any visible signs of recent distress (rock falls, opening of clefts, spalling, unravelling etc.) along the whole section of the cliff. We also checked the area at the top of the cliff for any tell-tale signs of developing instability (ground subsidence, tension cracks etc.) and there were no visible signs of distress to the ground. We therefore conclude that this section of the cliff is unaffected by the recent cliff* *failure further to the north.*

Explain to the pupils that the risk of further land sliding where the cliff has already failed is high as the rock face is very unstable. The 'toe' of the landslide (see diagram in **Resource 23**) is being eroded by sea waves and the porous and permeable breccia sandstone will continue to be affected by both periods of heavy rain and occasions when it dries out during dry spells. Once cold weather returns in late autumn and winter then freeze – thaw weathering will occur again. Given these circumstances what would be an appropriate long term strategy for managing this section of coastline? Divide the pupils into groups of four and ask them to discuss what the 'best' approach should be. What must their priorities be? What are the implications in particular for the homes along Redcliffe Road where No 14 has already been abandoned due to concerns about ground instability (see photographs in **Resource 26** and newspaper report describing Redcliff Road as the 'most dangerous cul de sac in Britain' at http://www.dailymail.co.uk/news/article-2337012/Cliff-cul-sac-Britains-dangerous-street--home-collapsed-sea-evacuated-safety-fears.html As a final outcome the pupils could write a letter to Torbay Council suggesting a long term plan for managing the hazard at further landslides at Oddicombe.

Acknowledgements

The English Riviera Global Geopark would particularly like to thank Torbay Council, Plymouth University especially Andrew Merritt, Torbay Library Services and Frederick Sherrell Ltd, Tavistock www.fslgeo.co.uk for their particular help and support in the design and resourcing of this learning enquiry.

The English Riviera Global Geopark would also wish to thank the following for permission to re-produce photographs, illustrations and other graphics as attributed below. Every effort has been made to source additional images from those within the public domain and to attribute these according to the wishes of the contributors. We will gladly receive any information enabling us to rectify any error or omission at the first opportunity.

**Resource 1**

| | |
|---|---|
| Volcano | United States Geological Survey |
| Tsunami | David Rydevik |
| Landslide | Orlovic |
| Earthquake | United Sates Geological Survey |
| Oil spill | Pauk |
| Nuclear accident | Japan Times (Fukishima) |
| Gas release (Bhopal) | Luca Frediani |
| Toxic waste | United States Environmental Protection Agency |
| Petrochemical smog | Saperaud |
| River pollution | Shubert Ciencia |
| Malaria | Jim Gathany |
| Wildfire | RIANbot |
| Flu (injection) | Pete Souza |
| River flood | Louisiana GOHSEP |
| Drought | Virtual Steve |
| Hurricane | NASA |
| Tornado | Daphne Zaras |
| Sandstorm | Alicia Garcia |
| Avalanche | Scientif38 |
| Debris avalanche | G310 Luke |
| Water effluent | BetacommandBOT |
| Sinkhole | Wiki-feet |
| Storm surge | David Weatherly |

**Resource 2:** Oregon State University
**Resource 3:** 663highland
**Resource 4:**
Geography Video 4 the UC (University of Canterbury You Tube series on Environmental Hazards uploaded at https://www.youtube.com/channel/UCzhCJ3LEhztniW__HiDAyLg
**Resource 5:** B.Meyers, United States Geological Survey
**Resource 6:**
Apolline Project uploaded to You Tube at https://www.youtube.com/watch?v=kznwnpNTB6k
**Resource 7:** NASA
**Resource 8:** pixgood.com
**Resource 9:** United States Geological Survey
**Resource 10:** http://www.globalgeopark.org/
**Resource 11:**
All English Riviera Global Geopark http://www.englishrivierageopark.org.uk/
**Resource 12:** Torbay Council Beaches Team

**Resource 13:**
© Crown copyright and database rights 2011 Ordnance Survey [100017955]
https://earth.google.co.uk/
Image produced from the Ordnance Survey Get-a-map service
**Resource 14:**
Reproduction of all images courtesy of Torbay Council Libraries Service
**Resource 15:** All images David Weatherly
**Resource 16:** Kim Aldis
**Resource 17:** All images © Frederick Sherrell Ltd
**Resource 18:** All images © Frederick Sherrell Ltd
**Resource 19:** All images David Weatherly
**Resource 20:**
Map of Pangea super continent: This image comes from the Tethyan Plate Tectonic working group of the Institut de Mineralogie et Petrographie, Université de Lausanne.
Colorado plateau: Citypeek
All other images David Weatherly
**Resource 21:** All images David Weatherly
**Resource 22:** Andrew Merritt, University of Plymouth
**Resource 23:** Andrew Merritt, University of Plymouth
**Resource 24:**
Andrew Merritt, University of Plymouth and https://earth.google.co.uk/
**Resource 25:** All images David Weatherly
**Resource 26:** All images David Weatherly