Funded by Defra's Aggregates Levy Sustainability Fund, administered by English Nature.

☛ Individual groups will need 10x hand lenses, measuring tapes, compasses and clinometers if dip measurements are to be attempted, as well as clipboards, pencils, rulers and copies of the relevant field sheets for individual pupils. (See **SNA8 worksheets**).
Group Leaders will need a plastic bottle of dilute HCl, a small plastic bottle of water, goggles a geological hammer and a digital camera will also be useful.

☛Field leaders should have decided which combination of the following exercises the groups are to tackle before they arrive on site.

1. Snableazes Quarry
2. Snableazes Quarry in Section
3. Snableazes Quarry, West Crag
4. Cullernose Point
5. Long Heugh Crag
6. Summary Of Geological Events

NOTE: Worksheets may be used as appropriate to help pupils summarise the activities at any location, or to guide the discussions, or as a guide for pupils in small group activity.

INTRODUCTION

☛ Follow the directions to Snableazes Quarry given below. Due to the angle of the driveway to the quarry, it is advisable to approach from the north. **NOTE:** Access to this site is **only by prior permission**. (See **SNA3 Locaccess** for details).

Site 1:

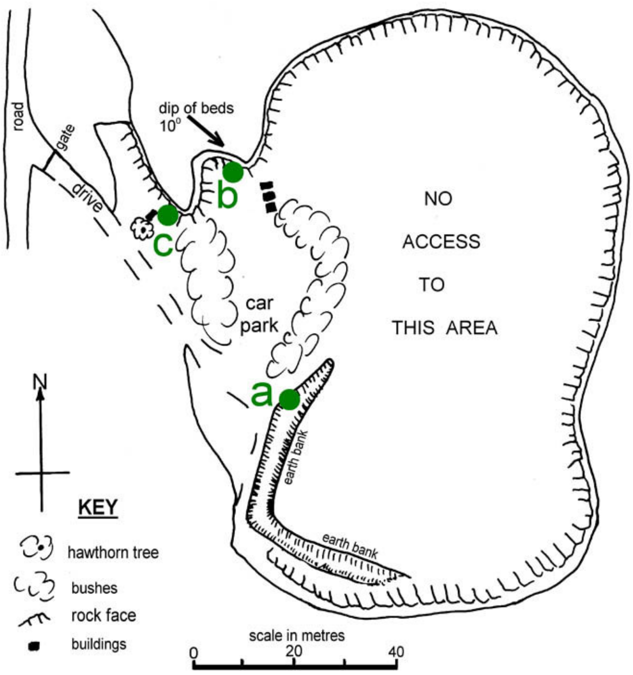


Figure 1. Map of Snableazes Quarry.

Site 1: Snableazes Quarry.

☛ Take the A1 towards the north eastern outskirts of Alnwick. Leave the A1 north of Alnwick at Denwick, and turn right onto the minor road eastwards, towards RAF Boumer, after passing through Denwick village. Continue 4.5 km on to Longhoughton. Take the left turn along the minor road signposted to Lesbury and Alnmouth. After 1 km the narrow, (and hard to spot), gated driveway to Snableazes quarry is on the left just before a slight dip in the road. It is immediately after Snableazes farm, which is on the right. Minibuses and cars may drive in and park **only by prior arrangement**. Coaches will need to drop off the group and return to pick them up after an hour.

Take the group to **Site 1a** the earth bank at the edge of the open area in the east of the quarry. **Under no circumstances** should you allow pupils to proceed past this point.

Site 1a. The East face of The Quarry (as seen from the earth bank). Here the emphasis is on careful observation and application of knowledge.

Worksheet 1. Snableazes Quarry.

Suitable questions at this site	**Acceptable responses.**
Look at the lower two thirds of the quarry face opposite. Can you see jointing in the rocks?	Yes, the jointing is near vertical.
Is it likely to be igneous or sedimentary?	In the absence of bedding the likelihood is that it is igneous.
Confirm to the group it is igneous, and ask, "How were the joints formed"? If the joints are near vertical where would you expect the cooling surfaces to be?	They were formed as the magma cooled, solidified, and continued to contract, causing brittle fractures to occur at right angles to the cooling surfaces. Approximately horizontally above and below.
Do the joints continue right to the top of the face?	No, the top couple of metres are not jointed in the same way.
Describe the top part of the face. Can you see the top contact of the igneous rock near the top of the face?	The top part appears bedded. These are sedimentary rocks lying on top of the igneous rock. They appear to be horizontal
Tell the group that in fact the beds are dipping away from them, and only appear horizontal. (Imagine looking at the edges of pages in a book, or on a clipboard, held so as to be dipping away from you. The edges appear horizontal, but the page surface is actually dipping.) See the section on **worksheet 2.**	
Tell the group that there are two options for a name for this igneous feature: a sill (intrusion) or lava flow (extrusion). What evidence would we need to be sure it was a sill and not a lava flow?	We would need to see the top contact and see that it had baked the overlying rock – something that a lava flow at the surface cannot do (since the overlying beds had not been deposited.).
Give the group the information that the beds above the igneous rock are shales and fine sandstones, which have been baked hard. What name would they give to the igneous feature?	Therefore it's a sill.
Where would you expect the bottom of the sill to be found?	Underneath: below the ground at the base of the quarry face.
Estimate the thickness of the visible part of the sill.	About 15 – 20 metres
Apart from metamorphism, what does this mean for the rocks **above** the dyke during the intrusion?	(They would be baked and altered metamorphosed) **but also** lifted by the thickness of the sill: i.e. about 15 - 20 metres.
Is the sill older or younger than the sedimentary rocks above and below it?	Younger. It was intruded into the layers long after they were deposited. This is an apparent reversal of the usual situation described in the **Principle Of Superposition.** Here it is **The Principle of Cross Cutting Relationships** which is relevant.
Where did the magma come from? [**NOTE**: basic magmas originate by partial melting of the upper mantle – which is otherwise solid].	Deep below ground, (upper mantle) probably along the fault which links this sill with the dyke at Boulmer, and then spreading out between the bedding planes.
How was the scree formed?	Physical weathering of the jointed rocks on the face
What kind of rock is the scree material forming – igneous, metamorphic or sedimentary. ?	Like the un-cemented sand on the beach this is also regarded as a sedimentary rock because it is made up of weathered fragments.
Using **worksheet 1**, ask the group to sketch and label the outcrop. Use the section on **worksheet 2** to help guide pupils through the rest of the quarry, and to realise that the rocks are continuous sheets dipping eastwards (**Principle of Lateral Continuity**).	

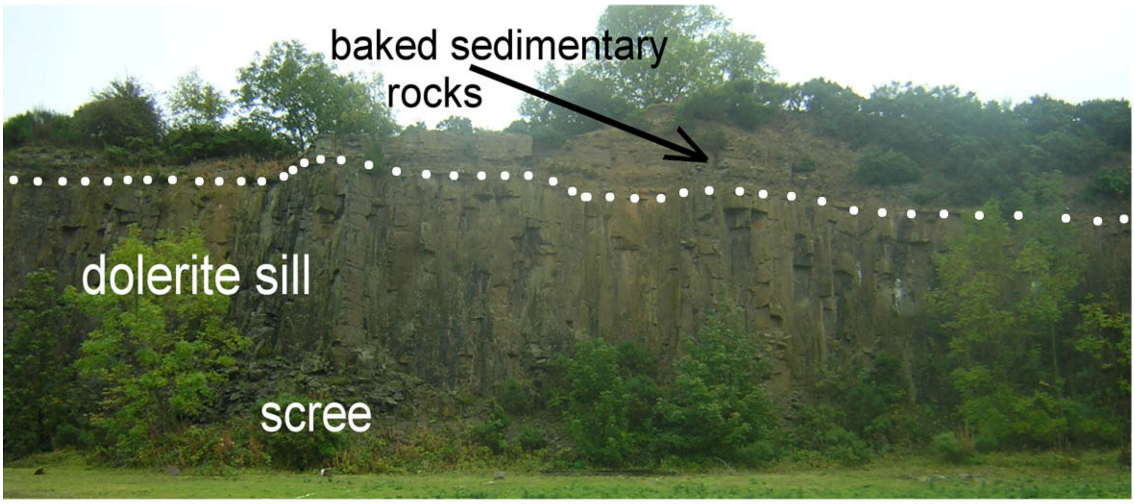


Figure 2. The East face of Snableazes Quarry

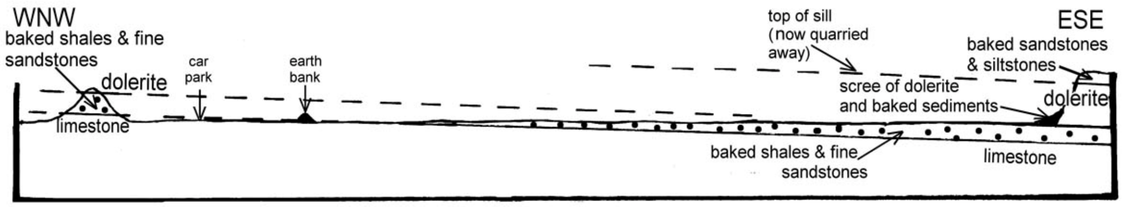
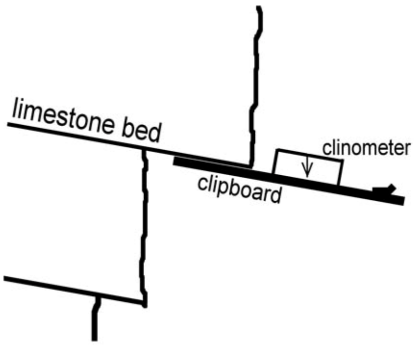


Figure 3. Section across Snableazes Quarry.

☛ Bring the group back to the car park and to **site 1b**, the face at the northern end. (See **Figure 1**). Here the sedimentary rocks below the dolerite are exposed.



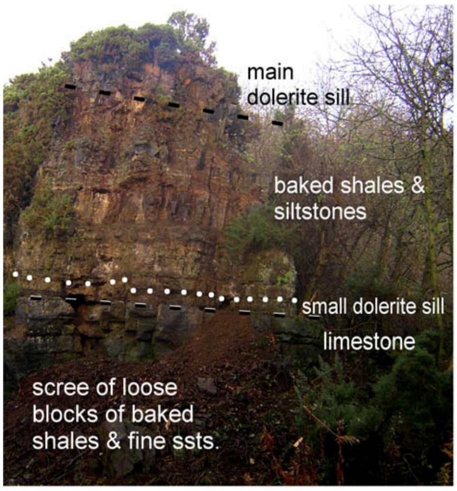
Very few top bedding planes are exposed here, so if a dip reading is to be taken, use a clipboard held to the bottom bedding surface, as shown.

NOTE: The dip arrow is already drawn on the pupil map of the quarry and the dip amount could be recorded there. However, if the dip arrow is to be measured and plotted by pupils this should be removed from the worksheet.

Figure 4. Taking a dip reading at Site 1b.

Worksheet 2: Snableazes Quarry in Section.

<table>
<tr><th>Suitable questions at this site</th><th>Acceptable responses.</th></tr>
<tr><td>Ask the group to describe the rock in the exposure.</td><td>Grey. It has bedding running across the face and some jointing.</td></tr>
<tr><td>What kind of a rock might it be, igneous, sedimentary or metamorphic?</td><td>Bedded rocks are sedimentary.</td></tr>
<tr><td>Ask them to approach the exposure and describe the rock type.</td><td>An impure (contains a lot of clay) limestone (effervesces slightly with dilute HCl).</td></tr>
<tr><td>Ask them to estimate its visible thickness (top and bottom are not seen.).
Don't climb the exposure.</td><td>About 3 metres thick.</td></tr>
<tr><td>Are the beds horizontal?</td><td>No, they appear to be dipping towards the main quarry face to the right (SE).</td></tr>
<tr><td>Were the beds deposited at this angle?</td><td>No, originally they would have been deposited horizontally. (Principle Of Original Horizontality)</td></tr>
<tr><td>What forces can tilt large sections of rock in the earth's crust?</td><td>Plate tectonic forces.</td></tr>
<tr><td colspan="2">The best place to get a good idea of the true dip is in the NW corner of the car park where apparent dips in the faces are to the left and to the right. In fact the true dip is directly out of the corner, roughly towards the SE (See the map on the worksheet). Ask the group to measure the dip of the sedimentary rocks (Remember the dip is measured in the direction of steepest gradient, i.e. the direction a drop of water would roll down the clipboard surface. In this situation hold the clipboard tightly against the lower bedding plane of a conveniently overhanging block and measure the dip of the board. (See Figure 4)). The dip should be around 10^0 (to $15^{0)}$ at 130^0 to the north. Record it on the worksheet.</td></tr>
<tr><td>Ask the group to work out if this limestone is above or below the dolerite sill?
Ask the group to use the section on worksheet 2 to help them understand the vertical dimension.</td><td>The angle of the dip carries it below the quarry floor, so it is below the sill.</td></tr>
<tr><td colspan="2">As they walk out of the car park and round to site 1c pupils should complete the table on worksheet 2 using their observations and the Principle of Lateral Continuity to help them.
NOTE: Locations "v", "x" and "z" form the crag at site 1c. Location "w" is the lateral continuation of layer "v".</td></tr>
<tr><td>Can the contact of the limestone with the bottom of the dolerite be seen?</td><td>No it can't, at least, not at this location. (In fact there are several metres of sediment between the limestone and the sill above).</td></tr>
<tr><td colspan="2">Tell the group there is a way to see the base of the sill. Ask the group to trace by eye the top of the limestone as they walk to site 1c. The contact is almost horizontal along the west face of the car park and around the corner and along the drive (not through the trees) to site 1c.</td></tr>
</table>



☛ Bring the group round towards the entrance gate to the quarry and stop by **site 1c,** the face just east of the hawthorn tree.
Hard hats should be worn here.

The lower part of the exposure is of 3 metres of grey muddy limestone with 6 metres of baked and altered sediments lying on top. Right at the top, the lower 1 metre or so of sill is (just) visible. However, only the lowest 3m, or so, of beds are directly observable from the ground.
Do not climb on the exposure.

Figure 5: Site 1c, The Western Exposure at Snableazes Quarry.

With larger groups it is advisable to split into two parties: one to examine the face up close and the other to observe it from a distance, and then swap over.
In this way no more than about 6 pupils are on the scree together.

Although the sketch on **worksheet 3** may be done on the scree, the rest of the exercise will be more safely completed on a flat space near the drive.

Site 1c: Overview.
☛ Assemble the group on the drive where they can see the whole crag, as in **Figure 5**.

Worksheet 3: Snableazes Quarry, West Crag

Suitable questions at this site	Acceptable answers
Ask the group why is there a quarry here at all? What was worth the effort of quarrying?	Road stone: dolerite (whinstone) was quarried for its physical and chemical resistance for road stone, and its ability to bond with bitumen (and the concrete coastal defence blocks at Boulmer). Also blocks of dolerite have been used in several local buildings.
Ask the group to describe the material accumulated at the base of the crag. How has it got there?	It is loose, angular material forming scree. It has been physically weathered and fallen from the face above (and will therefore contain samples of material out of reach from the ground.).
Tarmac finished quarrying here in 1987. How many years has it taken this scree to form?	About 20 years.
Ask the group to describe the lowest rock exposed at the base of the exposure.	Grey. It has bedding running across the face and some jointing. It is likely to be sedimentary. (It may be predicted that it is the same limestone as the one traced round from the car park)
Ask the group to describe what they can of the higher beds in the middle part of the crag.	Brown stained, (chemical weathering) with traces of bedding running through it. Jointed and breaking into small blocks. Again, likely to be sedimentary. (In fact they are fine sandstones and shales, baked by the sill and also weathered)
Ask the group to describe what they can “see” of the rock right at the top of the crag.	It is brown coloured (iron weathering) and jointed into blocks. Bedding is not obvious
Ask the group to use the **Principle of Lateral Continuity of Beds** and predict what the top layer might be. HINT: Use the section on **worksheet 2**.	Projection from the section on the worksheet suggests it is the base of the sill. Other observations do not contradict this: it has a contact parallel with the bedding in the sedimentary rock below; it has strong jointing and no sign of bedding.
Ask them if the contact is parallel or cutting across the bedding?	It has a contact parallel with the bedding in the sedimentary rock, so it not a dyke, but a sill.
Ask the group if this is the top contact of the sill or the bottom one?	Clearly it’s the bottom contact – and it is several metres above the top of the limestone seen at site **1b**. (Use the section on the worksheet to demonstrate the relationship to the top contact seen at **site 1a**.)
Ask the group to predict what rock types might be found on the scree slope?	Dolerite, baked shales, fine sandstones or siltstones, and maybe limestone are the ones possible.
Ask the group to examine the material on the scree slope to see what it is made of, and try to confirm their prediction..	It is made of a fine sandy soil, plus examples of baked sedimentary rocks. (Dolerite and limestone are quite rare on the scree).
Point out the “spotted” nature of fresh surfaces of the fine grained rocks and ask what the spots might be?	They are the beginnings of new crystals which started to form when the sediments were heated by the intrusion 295 million years ago.
Ask how this material got here? **SAFETY NOTE**: When breaking clean surfaces of pebbles teachers should wear goggles and use only a special geological hammer. Hammer **away** from group members.	Physical (frost action) and biological weathering of lumps of rock from the vegetated face above, but also chemical weathering to produce the clays.

Site 1c: Inspecting the Face

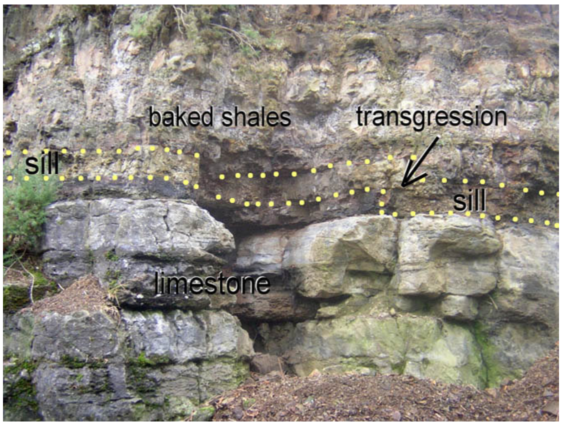


Figure 6: The Centre Lower Face At Site 1c

☛ The space on the scree is limited and individuals should take care not to lose their footing, or cause anyone else to do so. Here the task is to describe and interpret a small transgressive sill just above the limestone. It is an offshoot of the main sill, and is weathered to a yellowy colour. It has not been folded.

Apart from the field sketch on **worksheet 3**, the rest of the worksheet should be completed on the flat area by the drive, not on the scree. Divide the small group into two, one to the left and the other to the right of the group leader and approach the crag face.

Suitable questions at this site	**Acceptable answers**
Ask the group to describe and identify the lowest bed (If this is a group which has already done the overview, ask instead "What test will confirm it's a limestone"? Answer: effervescence with dilute HCl.)	It is grey, fine grained, with joints and clear bedding planes running across the face. It is therefore sedimentary. It effervesces with dilute HCl (not a great deal due to clay impurities) It is therefore a limestone
Ask what rock is immediately above the limestone?	The group on the left will report a 17cm bed of hard red and black fine grained rock. This is a baked (metamorphosed) shale. The one on the right will report a 20cm "layer" of yellowy rock with joints. (This is a thin leaf of the dolerite sill, about 6m below the main mass.)
Ask the groups to trace "their layer" into the centre of the face and describe what happens.	The red and black shale suddenly stops, whilst the yellowy (dolerite) suddenly steps up over the shale and continues to the left above the shale. [This is called a transgressive sill.] (See **Figure 6**).]
Ask the group to explain their observations, using geological principles. (Or ask: "How can a "bed " be at two different positions (older and younger) at the same time?") [**NOTE:** The suggestion of a liquid intrusive sill, emplaced along lines of weakness more-or-less along the bedding, when the beds were deep underground should be suggested to the group, if it is not forthcoming.]	Focus on hypotheses which refer to geological principles. One bed (yellow) clearly **cuts across** another (shale) and therefore must be later in origin**.** **(Principle Of Cross Cutting Relationships).** This suggests the yellowy bed is later and has displaced part of the shale bed upwards.
Find a small piece of the dolerite and inspect a broken surface. (There are many loose pieces. There is no need to damage the face). Ask why the inside is a dark blue colour whilst the outside is yellowy.	Chemical weathering of the minerals in the exposed surface of the rock. **SAFETY NOTE:** Only use a special geological hammer when trimming rock fragments, and wear goggles. Always hammer away from the rest of the group.
Ask the groups to predict if the crystal size of this dolerite would be smaller or larger than the crystals in the large sill they saw (from a distance) at **site 1a?**	Smaller, because being a thin sill (with greater surface area to volume) it would have cooled more quickly.
Draw the attention to the pieces of baked sediments on the scree and the differences between them and the un-altered specimens they have seen in the laboratory, prior to the visit. The "greasy" look, slightly reminiscent of broken porcelain, was caused by the heat from the intrusion as it cooled and baked the clay minerals. "Spots" of new minerals caused by the heat may also be seen. Ask the group to sketch the face and label it on the worksheet.	

☛ Finally, bring the group together on the drive and complete **worksheet 3.**
Summarise the events they have been investigating as a geological history. Use the rock cycle to help them sort out the sequence of events:
1. Deposition (oldest bed first), **2. Deformation** (including intrusions), **3. Uplift, weathering & erosion.**

Ask the group to summarise the geological events that they have seen evidence for at Snableazes. Geological convention is oldest event is listed at the bottom, youngest at the top 1 to 5)	5. quarrying for roadstone (Tarmac). 4. uplift weathering and erosion. 3. intrusion of dolerite sill, (both large and small) baking the rocks top and bottom. 2. deposition of fine sandstones in delta conditions. (Younger beds deposited on top) 1. deposition of limestone in marine conditions (oldest bed deposited first).

Directions to Cullernose Point.

☛Leave the quarry at Snableazes and continue northwards to the crossroads. (See Figure 1 in document **SNA3 locaccess**). At the cross roads turn right to Longhoughtonnd pass beneath the low bridge. At the crossroads at Longhoughton turn left onto the B1339 to Embleton. After 1.25 km, on a sharp left bend, take the right turn onto the minor road to Dunstan, which has a low bridge of 12 ft 6 inches across it. After 2km the road bends sharply left, and after a further 1km begins to diverge from the cliff top. The pathway to Cullernose Point is on the right where the emergency telephone is sited, and the lay by is on the left.

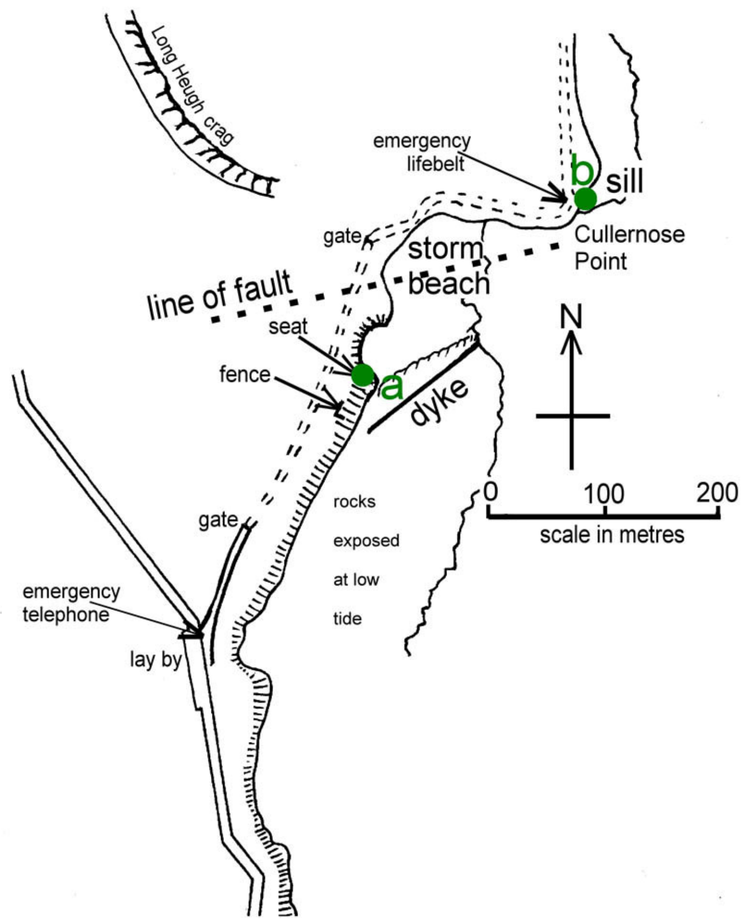


Figure 7. Site 2a and 2b: Cullernose Point.

These sites are along a public footpath which runs through land owned by the Northumberland Estates. Please follow the "Country Code".

☛Roadside parking is possible here on the left, but coaches should drop off their party and return to pick up the group after an hour and a half, or so. The descent to the beach is steep and often slippery, **so stay on the cliff top**. Take the footpath northwards along the top of the cliff.

The site is a nesting site for seabirds, so do not stray from the footpath and disturb them during the breeding season.

☛ Take the footpath northwards for about 300 metres, to the seat with a view of a small crag to the north. This is **site 2a**.

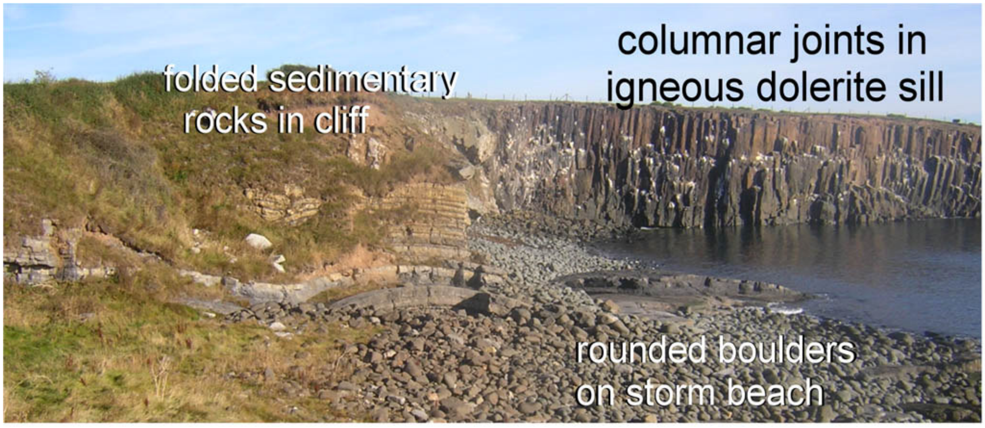


Figure 8. Site 2a: View to Cullernose Point.

The small crag (**Figure 8**) is of sedimentary rocks down faulted in front of the dolerite of Cullernose Point.

[The rocks on the foreshore to the **east** and **south** are sedimentary rocks with a dyke running through them (look southwards before high tide!).]

Worksheet 4: Cullernose Point.

Suitable questions at this site	Acceptable answers
What present day weathering and erosion processes are affecting this exposure?	Weathering – chemical, (weathering of iron minerals in it to hydoxides (brown) physical weathering (using the joints) and biological weathering (bird guano, and vegetation growing into it). Marine erosion.
Describe the beach material bellow the cliff, and explain how it got there	Well rounded and large boulders. They have been broken off from the outcrop, and rounded and moved up the beach by powerful storm waves.
Ask why there is no sand on this beach?	The waves are too powerful. Any sand will be washed away.
Ask the group to describe the rocks in the cliff just in front of them.	Layered and folded rocks in the lower two thirds. At the top, brown crumbly material with large boulders.
What kind of rocks are they likely to be igneous, sedimentary or metamorphic?	Sedimentary (layered and made of fragments)
Ask the group which way the sedimentary rocks are dipping in the cliff in front of them.	Generally towards the sea, although they are folded (and faulted).
Ask for a description of the rocks in the headland to the right and behind the cliff	Lack of bedding and strong vertical jointing.
What kind of rocks are they likely to be igneous, sedimentary or metamorphic?	Igneous. It is the dolerite they have already seen so much of.
Ask how the joints were formed in this igneous rock	As the liquid magma cooled it became solid (at about 800°C) As it continued to cool it contracted setting up stresses which caused brittle fracture in the solid rock.
Ask the group where the cooling surfaces would be to give those cooling joints?	Since the joints form at right angles to the cooling surfaces, they must have been almost horizontal, dipping slightly seawards. (i.e. approximately the same as the bedding planes)
What name should be given to this igneous feature	It is a sill since it does not cut (significantly) across the bedding planes.
Why can't we see the top surface of the sill?	It has been eroded away.
Why can't we see the bottom of the sill?	It is below ground (and sea) level.
Estimate the thickness of the sill (and therefore how much the rocks have been uplifted by the intrusion.)	Close to 20 metres.

Figure 9. Site 2b: Cullernose Point.

☛Walk along the Coastal Footpath to the top of the sill and continue until the exposure of dolerite appears in the foreshore by the emergency life belt. This is site **2b**. **Do not get too close to the sea.**

Figure 10: Dolerite with Vesicles

Figure 11: Dolerite Columns.

Suitable questions at this site	Acceptable answers
Ask the group to describe the shape of the joint blocks.	Polygonal: ideally hexagonal (6 sides), but varies 3 to 6 sides.
Ask the group to envisage what each joint block would look like in 3 dimensions?	A polygonal column at right angles to the cooling surfaces.
Where the surface is flatter to work on (See **figure 11**), select a column and measure the distance between the centres of each adjacent column. (Again these vary, indicating that cooling produced an uneven set of stresses through the, now solid and brittle, but still hot, rock as it cooled.)	

☛ Focus the group's attention on the smaller scale features of the dolerite.

Suitable questions at this site	Acceptable answers
Find a broken surface of the dolerite and ask the group to describe it.	Made of medium grained interlocking black crystals and having low porosity. No bedding, or fossils.
What does the crystal size tell you about the rate of cooling? (Compare crystal size with the small sill at Snableazes).	Medium rates of cooling (probably many thousands of years, rather than the few days in a lava flow.)
Point out the small holes, sometimes filled with minerals, in the dolerite. Ask for hypotheses on how they may have formed. NOTE: Vesicles are bubbles left over when the magma crystallised: probably of very watery gases.	Hypotheses will fall into two groups: those suggesting the holes formed <u>during</u> the formation of the rock, and those suggesting they formed <u>afterwards</u> e.g. by boring organisms, or weathering. The way to confirm they formed at the same time as the rock is to find one with no demonstrable connection to the outside by breaking it open. **Take the usual precautions when hammering**.
Ask the group to complete **worksheet 4** before returning along the coastal path towards the road.	

☛ Stop the group on the footpath about 100 metres beyond site **2a**. Turn the group around and ask them to view the skyline along the Long Heugh Crag. Use **worksheet 5** to summarise the main geological features on the area and relate them to the rock cycle.

☛ Finally ask the group to summarise the sequence of geological events they have seen evidence for today, using **worksheet 6.** The final **worksheet 7** could be used as a follow-up homework exercise. Return along the coastal footpath route to meet your transport on the road.

☛ The ESO-S materials for the sites at Boulmer Foreshore may be combined with this visit into an extended field experience, including modern sedimentary processes.