Knockan Crag Education Pack - Teacher's Notes

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INTRODUCTION

Who are these resources for?

This education pack has been assembled to support teachers and pupils who want to visit Knockan Crag and understand fully the remarkable significance of this site for all who study Earth Science. Although many of the resources are targeted principally at the Upper Primary and Lower Secondary stages, there is much in the pack that may be relevant to visits by younger or older pupils.

The pack has also been designed to be a useful teaching resource for teachers and pupils who may be unable to visit Knockan Crag in person. If you live in the NW Highlands, some of your local rock outcrops may be of the same type as those at Knockan Crag. Note, however, that this education pack comes with a warning! There is no real substitute for seeing at first hand the relationships between the rock units at Knockan Crag and for using the well equipped interpretation centre there to learn how ancient geological events have shaped the dramatic landscapes of the NW Highlands.

Overview of a possible teaching approach

The resources in this pack are designed to guide your pupils through the following sequence of learning activities:

	Topic Description	Activities	Suggested Time Allocation
1	***Layer Upon Layer*** - learning about the processes involved in the formation of the most common types of sedimentary rock	Teacher-led introduction followed by information handling activity	Approximately 1.5 hours
1a	***Imitating Nature*** - making models to show some of the processes involved in making sedimentary rocks	Teacher-led demonstration and/or pupil experiments	Approximately 1.5 hours; a selection should be integrated with the above information handling activity
2	***Which Came First?*** - applying the logic of what pupils have learned so far to the interpretation of rock sequences	Information handling activity	Approximately 0.5 hour
3	***Which Rock Is Which?*** – learning to examine and describe rocks; using the supplied Rock Specimen Collection to study the particular sequence of rock strata at Knockan Crag	Teacher-led introduction leading to practical activities focusing on developing observation and recording skills	At least 1 hour in total with pupils working individually and then in groups or as whole class

Topic Description	Activities	Suggested Time Allocation
4 ***Knockan Crag Visit*** - learning about the special relationships revealed in the rocks there and gaining an understanding of the processes involved in creating local landscapes	Field trip	At least 2 hours on site
5 ***Alternative (or Extension) Activities*** - for those unable to visit Knockan Crag or for reinforcement after visit	Creating timeline display; viewing CD-ROM; interacting with BBC website	Depends on selection made – if any

If the above approach is adopted, the total time commitment in the classroom is likely to be at least five hours. This time estimate could easily be doubled if a detailed approach is adopted and extension activities are undertaken. Alternatively, depending on the desired level of understanding, the activities could be selectively streamlined to reduce the total time commitment.

Links to 5-14 Environmental Studies Guidelines

The teaching approach described above enables many 5-14 targets and outcomes to be achieved by your pupils. A detailed analysis of various links with the *Environmental Studies* 5-14 guidelines is provided in **Appendix One**.

What is included in this education pack?

The components of the pack are described and listed in the table on the next page.

Resource	Description	Purpose
Teacher's Notes	These notes include suggested teaching approaches, together with advice about how to ensure practical activities and demonstrations are carried out successfully. They describe links with the 5-14 Guidelines and also provide background information at a level suitable for teachers who may be unfamiliar with the concepts that necessarily underpin any study of Knockan Crag.	These notes are intended to provide detailed guidance on how the supplied resources may be used to best advantage.
Pupil Activity Sheets	Activity sheets have been prepared for three main activities. The Word files for these activity sheets are also supplied to enable you to modify them to suit your own specific circumstances.	The three activities have been designed to help pupils explore the concepts needed to understand the story told by the rocks at Knockan Crag.
Rock Specimen Collection	One good quality specimen is provided to represent each of the eight rock formations exposed in the Knockan area. Use of the specimen collection is supported with clue cards, information cards and an identification key.	Pupils need practice in examining carefully selected specimens if they are to develop an understanding of how different rocks are formed.
A copy of *Northwest Highlands – a landscape fashioned by geology*	A 40+ page booklet with particularly fine illustrations and diagrams providing background information about the geology and landscapes of the NW.	This is a resource for those enthusiastic students and teachers who wish to learn more about the general context of Knockan Crag.
The CD-ROM used in the interactive display at the Knockan Crag centre.	The story of the rocks at Knockan Crag is presented in a lively and readily accessible manner using animated diagrams.	This CD-ROM is especially suitable for reinforcing concepts previously explored during classroom activities and a visit to Knockan Crag.
Leaflets	Two SNH leaflets describing Knockan Crag and its satellite sites are provided.	These leaflets provide an overview of the key locations
Pre-printed diagrams and cards	Where appropriate, diagrams and information cards used in pupil activities are provided in this convenient format.	Using these will minimise your preparation time.
Library of computer files on CD-ROM	All the files created in developing the education pack have been copied on to a CD-ROM. A hyperlink list of websites is also supplied to enable further research into any of the topics likely to be covered while studying Knockan Crag.	Access to these files will enable you (if so inclined) to adapt and modify some of the supplied resources and to design a range of extension activities.

SUGGESTED TEACHING APPROACHES

Topic One

Layer Upon Layer

This topic is designed to develop your pupils' understanding of how sequences of sedimentary rock strata are formed. This understanding is not only necessary for grasping the significance of the rocks exposed at Knockan Crag. Sedimentary rock strata outcrop prominently throughout the NW Highlands and underlie most other parts of Britain. Understanding how the three main rock families (sedimentary, igneous and metamorphic) are formed is also one of the Attainment Targets at Level D within the *Materials from Earth* Science strand of the 5-14 Environmental Studies Guidelines.

The topic will involve your pupils in an information handling exercise which is supported by a number of practical modelling activities. Many of these may be tackled by the pupils themselves while others are more suited as teacher-led demonstrations.

A suitable starting point for the topic would be an exploration of your pupils' pre-knowledge of how local rock strata were formed and/or their understanding of how their local landscape is continually evolving as the passage of time and constant erosion take their toll.

The materials needed for the information handling activity are provided in **Appendix Two** and as separate pre-printed cards. A sequence of ten diagrams and their associated captions illustrates one common way in which sedimentary rocks can be formed. The diagrams and captions can be used flexibly. Three possibilities would be:

1. Sorting a jumbled list of the captions (ie no diagrams) into a meaningful sequence. Pupils could then be given the diagrams and asked to match each caption to an appropriate diagram. On the backs of the pre-printed cards of the captions letters could be added which spell the word SEDIMENTARY when they are correctly sequenced.

2. A less demanding version of this would be to sort out the sequence of diagrams each already captioned.

3. A more demanding version would be for pupils to correctly sequence the ten uncaptioned diagrams and write their own explanation of the processes represented. Note that there are one or two diagrams and captions whose order could reasonably be reversed when they are studied in isolation. Lettering on the reverse of the captions (as above) could give an indication of the <u>intended</u> order.

Imitating Nature

Appendix Three provides Teacher's Notes on eight possible modelling activities. A selection of these should be incorporated into the work of the class as appropriate. Some are dependent on the availability of local resources, although all of them are capable of adaptation and modification to suit your particular circumstances.

Topic Two

Which Came First?

The purpose of this information handling activity is to reinforce the key principle used to interpret sequences of rock strata. It is the straightforward concept that, in any sequence of sedimentary rocks, the oldest beds should be at the bottom of the sequence and the youngest at the top.

This is always the case unless something strange has happened – like you find at Knockan Crag. It would be undesirable to reveal to pupils the conundrum at Knockan in advance of the their visit, but <u>you</u> should be warned that the sequence of strata there does not appear to obey the 'Law of Superposition', as the above principle is known. The topmost rock in the sequence at Knockan is an ancient metamorphic rock, which simply should not be sitting on top of an otherwise normal sequence of younger strata.

In fact, the metamorphic rock is NOT part of the local sequence of strata even though it gives every appearance of being so. It has arrived at its present position after being pushed a long way westwards over the top of the younger rocks. Knockan Crag is an important site in the development of geology as a science because it was the first place in the world where this kind of relationship was clearly demonstrated. The realisation that such a thing was possible was an important breakthrough in leading to our present-day understanding of how continents 'drift' about the surface of our planet and create so many major topographic and geological features.

For pupils to understand what they are going to see at Knockan Crag, it is important that they fully grasp the principle underlying the 'Law of Superposition'. Since it is so intuitive and obvious, the suggested activity *Which Came First?* **(see Appendix Four)** should not take too long to complete.

Depending on the pupils' previous experience, you may wish to reinforce the distinction between <u>plan</u> and <u>section</u> drawings. Analogies with layered cakes or plasticene models might be appropriate!

The terms <u>limestone</u> and <u>conglomerate</u> are used in the diagram and may need further explanation or research. Limestones are sedimentary rocks that are made up of carbonate minerals such as calcite. The carbonate often comes from fossilised marine organisms. Many limestones are therefore indicators of ancient marine life, even though recognisable fossils may be absent or visible only under a high powered microscope.

Conglomerates (also known as pudding-stones!) are formed from coarse sediment full of pebbles and even boulders. They are associated with fast-flowing rivers and beaches exposed to strong wave action.

Topic Three

Which Rock Is Which?

This final pre-visit topic is designed to help pupils learn to look at actual rock specimens and become familiar with the main rock types that outcrop in the Knockan Crag area.

All our evidence about the Earth's geological past comes from studying rocks and the fossils and minerals they contain. Although professional geologists have devised many technologically advanced ways of observing and measuring the properties of rocks, simply looking closely at a rock specimen is still one of the best ways of gathering information about its origins and about the processes that created it. Even young pupils (and their teachers!) can learn a surprising amount by examining rock specimens and using 'common sense' to answer some of the questions that spring to their minds.

However, before leaping ahead to <u>interpret</u> clues about the origins of rocks, it is important simply to learn how to <u>describe</u> them. Activity One is a good starting point that involves pupils in <u>making observations</u> and <u>recording</u> them. It has the advantage that it can be carried out by a few pupils at any one time, thus relieving the pressure when there are more pupils than there are rock specimens.

Activity One – *Collecting The Evidence*

The aim of this activity is simply to get pupils to look closely at rocks and to get some practice at describing what they see.

Because rocks are so incredibly varied in their appearance, describing them effectively is not as easy as might be first imagined. Before starting the activity, it is suggested that you establish with your pupils some form of structured approach to describing rocks. Support materials for this have been provided in Appendices Five and Six. Although the terms suggested are all everyday words, it is important that their particular meanings in the context of describing rocks are explored and understood.

Appendix Five consists of a sheet setting out suitable headings that pupils can use to structure their descriptions together with advice on how to focus their observations on meaningful properties. The sheet itself is not particularly suitable for pupil use but it should prove useful as the basis of a teacher-led discussion on what to look for when examining rocks.

Appendix Six consists of a standardised *Rock Description Form* that pupils can use to describe rocks. It is based on the rock properties explored in Appendix Five.

Since there are only eight rock specimens in the collection provided, the following strategy for examining them may prove useful. Each pupil can be asked to examine at least one of the specimens in their own time and complete a *Rock Description Form*. Once everyone has had a chance to produce at least one written description, the forms can be passed around for others to try and match the correct specimen to the description they have been given.

Alternatively, you may wish to use your own collection of rock specimens for this activity. Since the object is simply to <u>describe</u> rocks, there is no need to know anything at all about the specimens you use. The only criteria should be that the rocks selected are clean, fresh and varied in their appearance. In many ways, it is preferable that pupils practise on your self-collected specimens since Activity Two focuses on the eight specimens in the collection.

Activity Two – *Identity Parade*

The aim of this activity is to introduce pupils to the rather strange and obscure (as they must seem to non-geologists!) long-established names given to the rock units in the NW Highlands. It also provides an opportunity to gain further practice in examining the properties of rock specimens.

Appendix Seven consists of a key that can be used by pupils to identify each of the eight specimens provided with this pack, using the rock properties explored in Activity One. A pre-printed version of this key is provided separately in the kit.

Appendix Eight consists of a set of display cards each with the name of one of the eight rock units. These cards are for displaying with the specimens after they have been identified using the *Identity Parade* key. On one side is a list of particular features to look for in the identified specimens. On the other side is a series of bulleted items explaining the name and origin of the rock unit from which the specimen was collected. Again, pre-printed versions of these cards are supplied separately.

It should be emphasised that the names given to the specimens in this kit are those of the local rock <u>formation</u> from which they were collected. This name may not include the common name of the rock <u>type</u> that makes up the formation. For instance, the rock specimen from the *Fucoid Beds* is a ***mudstone***, a common type of sedimentary rock. Similarly, the specimen representing the *Pipe Rock* formation is a type of hard **sandstone**. The other local rock formations from which specimens have been collected all include the main rock type in the formation name eg *Durness <u>Limestone</u>.*

Emphasis is placed on the formation names because these are the names used in all the displays at Knockan Crag.

Note About Naming Rocks

Many teachers lack confidence in naming rocks and somehow feel 'inadequate' as a result. However, be reassured - even experienced professionals cannot always identify hand specimens of rock by just looking at them. Some rocks may require examination under a microscope or even chemical analysis before an accurate name can be given to them. Naming (as opposed to describing) <u>pupil-collected</u> rocks can be a very tricky (and usually very speculative) business. It is also a rather pointless exercise for teachers and pupils if naming is regarded as an end in itself. It is much more valuable for pupils to learn how to describe a rock and perhaps recognise features that may shed light on its origin.

The reality is that it is <u>not</u> always easy or even possible to allocate a rock to membership of one of the three rock 'families' – igneous, metamorphic and sedimentary. While it is necessary for pupils to understand the ways in which rocks belonging to these families are formed (*5-14 ES Guidelines* page 49), it will never be possible realistically for them to be able to pick up a random specimen and be definite about whether it is igneous, metamorphic or sedimentary.

Note also that there are no igneous rocks in the Knockan Crag collection since igneous rocks do not feature in the Knockan Crag story. Instead, the initial focus is on the formation of sedimentary rocks, with additional information about the formation of metamorphic rocks coming towards the end of the story. A separate mini-project on volcanoes might be a good way of introducing and studying igneous rocks.

Topic Four

Visiting Knockan Crag

Access Details

Knockan Crag lies on the east side of the A835 about twelve miles north of Ullapool. Turn off the main road and drive up to the car park, which is suitable for cars and coaches. Toilet facilities are available at the car park. There is also a picnic area nearby.

There is a choice of trails to follow and an interpretation centre called the Rock Room to explore. To get the full benefit of their visit, pupils should be taken round the route marked as the 'Strenuous Trail' on the above map. This trail involves some locally steep gradients but gives good access to the rock formations and provides some rewarding views of the local landscape.

The main interpretation centre (Rock Room) is reached by following a short trail from the car park. This trail is suitable for wheelchair access. The Rock Room has several interactive displays. These explain why Knockan Crag has played such an important role in helping geologists to understand some of the major processes that have shaped the Earth's crust as we know it today. Other displays explain the spectacular landscape features that can be viewed to the west.

The centre is not normally manned. However, school parties are encouraged to seek the assistance of a Ranger. Try phoning the SNH office at 17 Pulteney Street in Ullapool at an early stage in planning your visit to see if the services of a Ranger will be available. The phone number is 01854 613418.

After visiting the Rock Room and learning why the local rock outcrops generated so much debate among geologists in the latter half of the 19th century, set off along the crag-top trail to view the evidence for yourselves. This trail is a circular loop starting at the centre and finishing back at the car park. It involves quite a lot of single-file walking, some of it over steep rocky terrain. It is vital for their own safety that your pupils should be well supervised. Having a Ranger to accompany the party has much to recommend it!

There are several points of interest along the route, each with information explaining the significance of what can be observed. There are also sculptures and other imaginative installations for stimulating discussion and questions.

List Of Practical Details

1. Allow at least one and a half hours for your visit. Two hours would be more appropriate, especially if you include time for a snack and toilet visits. Be sure to take any litter away with you.

2. There is no shop or café on the site.

3. The trail is well made and well surfaced. Since it crosses exposed terrain, however, sensible footwear and outdoor clothing are advised. The penalty paid for the outstanding panoramic views is of course that users of the trail may well be exposed to wind and rain driving in from the west.

4. The crag-top trail itself could take anything from 30 minutes to an hour depending on the number of stops and the time spent at each point of interest. Allow 45 minutes for a comfortable round trip.

5. You may well wish to revisit the interpretation centre after completing the crag-top trail to help clarify your pupils' understanding of what they have seen.

6. Remember to take a camera! There will be lots of 'photo-opportunities'. Binoculars would also be well worth carrying.

List Of Key Concepts Illustrated At Knockan Crag

The following are the key ideas that should be brought out during a trip to Knockan Crag. Although nearly all of them are covered by the displays in the Rock Room, it is only while following the trail (ideally with a Ranger) that the full meaning of most of them becomes obvious.

1. The rocks at Knockan Crag contain information that can be used to work out how they were formed and what has happened to them since.

2. The succession of rock formations that outcrop at Knockan Crag is unusual because older metamorphic rocks can be seen resting on top of younger sedimentary rocks. *(The file 'Rock Formation Thicknesses' in the Other Graphics folder in the CD-ROM Files Library shows an idealised vertical slice through these formations)*

3. The older rocks were pushed over the top of the younger rocks when the Earth's crust in this part of the world was violently compressed about 400 million years ago.

4. This violent compression occurred when two 'drifting' continents collided with each other creating many of the fractured, folded and altered rocks that are found throughout northern Scotland and elsewhere today. *(The file 'Colliding Continents' in the CD-ROM Files Library illustrates how this could have happened.)*

5. The Moine Schists that are now seen at the top of Knockan Crag were originally formed at least 50 kilometres to the east. They are separated from the younger rocks below by what is known as the Moine Thrust. *(The file 'Knockan Vertical Cross-section' in the CD-ROM Files Library illustrates the relationship between the Moine Schists and the younger rock formations below)*

6. The Moine Thrust is an excellent example of a very low angle fracture or thrust fault. There are many other major faults and thrusts cutting across the rocks of northern Scotland. *(The file 'NW Highlands Geological Map' in the CD-ROM Files Library shows the regional context of the rocks at Knockan Crag)*

7. As elsewhere, the present-day landscape at Knockan Crag is the product of millions of years of erosion acting with varying degrees of success on local rock formations. High summits and ridges occur where hard resistant formations have slowed the relentless downward erosion that has elsewhere created valleys and low-lying areas. *(The first few diagrams in the sequence provided for the Endless Cycle activity illustrate the erosion and removal of rock debris from mountain outcrops)*

8. Active agents of erosion today include wind, rain, frost, rivers, the sea and people. Of these, rivers in flood and ocean storms are undoubtedly the most powerful.

9. The combined effect of all of these agents of erosion, however, is relatively small when compared with the dramatic re-shaping of our mountains and valleys during the last Ice Age, which ended only 10,000 years ago.

10. The characteristically steep-sided valleys and mountains of the NW Highlands were created by the ice's grinding action as it made its way westwards. The deposits of gravel and rock debris that blanket much of the low ground today are just the remnants of the eroded materials left behind when the ice finally melted.

Knockan Crag Worksheet

A worksheet for use during visits to Knockan Crag is provided in **Appendix Nine**. It is designed to focus attention on the key ideas and to provide a structured format for recording important information about the local rock formations. Much of the information can be gleaned from the Rock Room displays. It is assumed, however, that the Ranger or party leader will supply required information during the visit. The table under the heading ***The Northwest Highlands Through Time*** on page 14 of these notes provides nearly all of the background information needed.

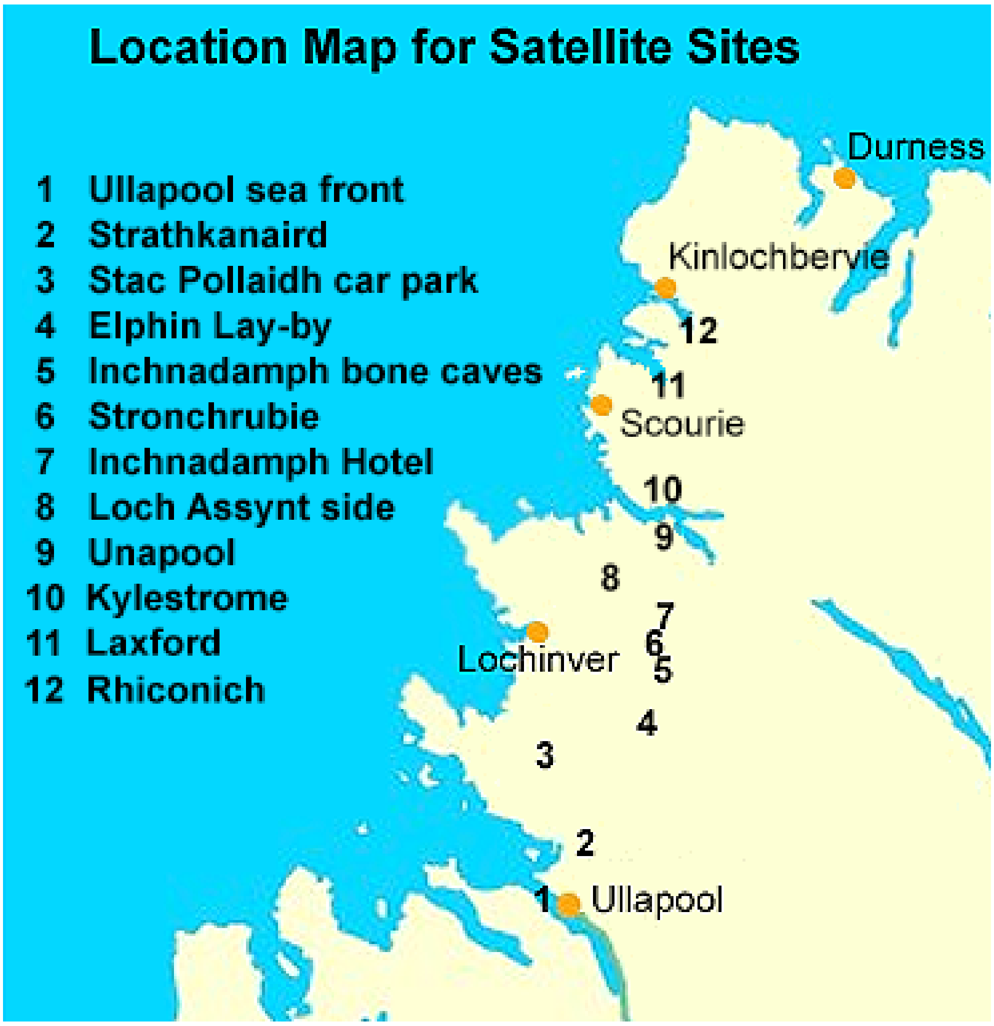
Note that, as with all of the text and graphics in this education pack, this worksheet is provided as a Word file in the CD-ROM Files Library. This gives you the option of making modifications to ensure that the worksheet is suitable for use with your pupils.

Extend Your Visit By Taking In Some Satellite Sites

Knockan Crag is the most accessible single location for interpreting the amazing story told by the rocks of the north-west Highlands. However, it is certainly not the only location where the details of the story can be unravelled.

Once the relationships between the main rock formations have been worked out during your visit to Knockan Crag, there are several large-scale features of the local landscape that will begin to make sense. A number of special satellite sites have been identified where it is possible to park and study some of these outstanding 'mega-features' of the local geology. Each site has a display board that helps you to pick out these features and understand the relationships between the various components of the panorama in front of you. The details that follow below are summarised in the *Rock Route* leaflet enclosed with this pack.

Try to visit some of these sites if your route and time permit. Their locations are indicated on the map below. The table that follows the map indicates what is to be seen at each site. All of the locations, except the one in Ullapool, are in lay-bys immediately adjacent to main roads. The Ullapool site is on the sea front and parking may have to be a few minutes away during the height of the visitor season.



The table below summarises what can be seen at each satellite site:

Satellite Site	Location	What can be seen in the adjacent landscape
Ullapool sea front	Facing over Loch Broom near pier.	The line of a 'thrust plane' on the other side of the bay where one set of rocks has been pushed over the top of another set. Also evidence of glaciation and sea level changes.
Strathcanaird – lay-by	NC157 035	An example of a landscape shaped by the action of moving ice sheets.
Stac Pollaidh car park	NC108 095	Frost shattered rock. Erosion caused by walking boots.
Elphin - lay-by	NC 212 106	Fertility created by underlying limestones. Two contrasting types of ancient sandstones visible on Suilven and Cul Mor.
Inchnadamph Bone Caves - one mile from car park	NC 253 179	Evidence of post-Ice Age animals and their hunters provided by bones in caves about a mile from car park.
Stronchrubie – lay-by	NC 202 247	Examples of glacial erosion and ongoing river erosion. Also glacial moraine deposits.
Inchnadamph Hotel – car park	NC 252 216	This display pays tribute to the geologists who first worked out the amazing story of the local rocks and made this spot a mecca for succeeding generations of Earth scientists.
Loch Assynt side – lay-by	NC 201 261	A rare example of erosion revealing an ancient landscape last seen 1000 million years ago before Torridonian Sandstones buried a range of low hills made of ancient Lewisian Gneiss.
Unapool – lay-by	NC 235 321	Two lines are visible in the rock outcrops on the other side of Loch Glencoul. These represent two major 'thrust planes' which have completely rearranged the original sequence of the rock strata.
Kylestrome – car park	NC 212 350	This site provides a view over Assynt and introduces travellers to the geological significance of the spectacular mountain landscape in front of them.
Laxford – lay-by	NC 232 488	Ancient Lewisian Gneiss is spectacularly exposed in a road-side cutting. Three different ages of rock can be distinguished here. Pale grey gneisses represent the original rock into which once molten sheets of dark basaltic magma were later forced. The streaks of pink granite must be the youngest of the three rock types since they can be seen cutting through both of the older types.
Rhiconich – lay-by	NC 245 513	Examples of large glacial 'erratics' – boulders carried from their source by ice and dropped when it later melted.

Topic Five

Alternative (or Extension) Activities

The following activities are suggested for those unable to enjoy a field trip to Knockan Crag, as well as for those wanting to reinforce what their pupils learned during their visit. The activities make use of three sources of information:

1. The booklet *Northwest Highlands – a landscape fashioned by geology.* A copy of this booklet is provided with this pack. Some of the information contained in it has also been extracted and simplified below.

2. The *Scotland's Journey CD-ROM* prepared for one of the Rock Room displays is also included in this pack.

3. The BBC Education website *Essential Guide to Rocks.* This excellent source of information does not focus specifically on the NW Highlands but does contain a lot of well presented information about the geological history of the whole of Britain. It can be found at:
   www.bbc.co.uk/education/rocks

Activity One *The Whole Story*

One of the important ideas developed in this education pack is that all rocks contain evidence about their origin and that this evidence can be interpreted to provide an insight into the geological past. A huge amount of scientific effort has gone into interpreting the evidence contained in the rocks of the NW Highlands and one of the best ways of presenting this is as a '**timeline**' of geologically significant events.

Your pupils could construct their own timeline using data from the three sources above, plus any others that their researches uncover. There are obvious opportunities for developing measurement and scale-drawing skills as well as artistic and creative presentational skills. Planning and designing a timeline is in itself a valuable activity. Decisions have to be made about the following:

- the overall format to be used
- whether to present the information vertically or horizontally
- whether to have the same scale throughout or to compress the early part
- what information to select for display
- how best to display the different pieces of information

Page 2 of the booklet *Northwest Highlands – a landscape fashioned by geology* sets out a fairly detailed timeline for the NW Highlands. The table on the following page is a condensed version of the information presented there:

The Northwest Highlands Through Time

When	What happened
10,000 years ago up to present time	• the land recovers from the Ice Age • peat develops during wet periods • trees, animals and people inhabit the area
2 million years up to 10,000 years ago	• the Ice Age affects the whole planet • periods of glacial conditions alternate with short warmer periods
65 to 2 million years ago	• volcanoes erupt off the west coast as the North Atlantic Ocean continues to widen • most of chalk limestone removed by erosion as sea level falls • climate cools
140 to 65 million years ago	• climate warm and humid • sea level much higher than today • thick layers of chalk limestone laid down on seabed over much of what is now Scotland
200 to 140 million years ago	• climate warm and humid • opening of North Atlantic Ocean begins • sea levels much higher than today
400 to 200 million years ago	• no rocks of this age in NW Highlands • evidence elsewhere in Scotland of inland deserts with tropical swamps on the coast and reefs offshore • widespread volcanic activity in rest of Scotland
500 to 400 million years ago	• Durness Limestone deposition ends about 490 million years ago as land is pushed up and sea retreats • major mountain chain created where Highlands are now • rapid erosion of uplifted land • Moine Thrust formed as rocks from the east (Moine Schists) were pushed westwards, sliding over the top of NW Highlands rocks
550 to 500 million years ago	• beach sands laid down on coastal fringes of large continent (to create Basal Quartzite, Pipe Rock and Salterella Grit formations) • mudstones (Fucoid Beds), and limestones (Durness Limestone) laid down when sea level rose and water was deeper • worms burrowing in beach sands leave first evidence of life in this area
3500 to 550 million years ago	• Lewisian Gneisses represent ancient rocks formed up to 3000 million years ago • much later, around 800 to 1000 million years ago, the rocks that are now the Moine Schists were laid down away to the east as layer upon layer of sand and silt; they were then pushed down into the Earth's crust and changed into their present form • at about the same time, Torridonian Sandstones were laid down to the west as river sands and gravels in a desert environment; unlike the Moine Schists, they escaped being altered

Activity Two *Using The Scotland's Journey CD-ROM*

This CD-ROM was developed for the interactive display in the Rock Room at Knockan Crag. An animated sequence explains in simple terms the series of geological events during the last 600 million years that created the rocks that form most of present-day Scotland.

The CD-ROM could be used in at least three different ways in your classroom:

1. As a simple presentation of geological facts; note that interaction during the animated sequence is mostly limited to clicking on a 'continue' button.
2. As a reference source from which information can be gleaned for activities such as the one outlined above in Activity One *The Whole Story*.
3. As a source of answers to questions devised by you to match the abilities of your pupils.

Activity Three *Creating A Knockan Crag Wall Display*

Creating a wall display is probably one of the most effective ways of pulling together the various threads of the Knockan Crag story. A collage of various maps, diagrams and illustrations could be created that would summarise the pupils' understanding of what they have been studying. Alternatives might include individual pupil reports or folios, or group presentations. For those pupils well acquainted with IT facilities, another alternative would be to put together a *Powerpoint* or similar presentation on what they have learned.

A number of graphical items are included as JPEG files on the Education Pack CD-ROM Files Library. These could be made available for pupils to copy or modify and incorporate into displays or presentations. The files include simple geological maps and vertical sections as well as photographs of appropriate rocks and fossils. Other suitable sources of information for creating a display or presentation include standard classroom reference books (many in the Dorling Kindersley range are relevant) and the internet. One web-site described below (BBC Education's *Essential Guide to Rocks*) has a wealth of relevant materials both for reference and for copying.

Activity Four *Using The BBC's 'Essential Guide To Rocks' Web-site*

This is a first-class site for learning about and revising many aspects of rocks and their origins. All of the pages, and even the animations, can be saved as 'web archive' files. This means that they only need to be downloaded once. They can be viewed off-line thereafter. They could even be saved on floppies or CDRs and used at several workstations simultaneously. The *Essential Guide To Rocks* web-site is located at:

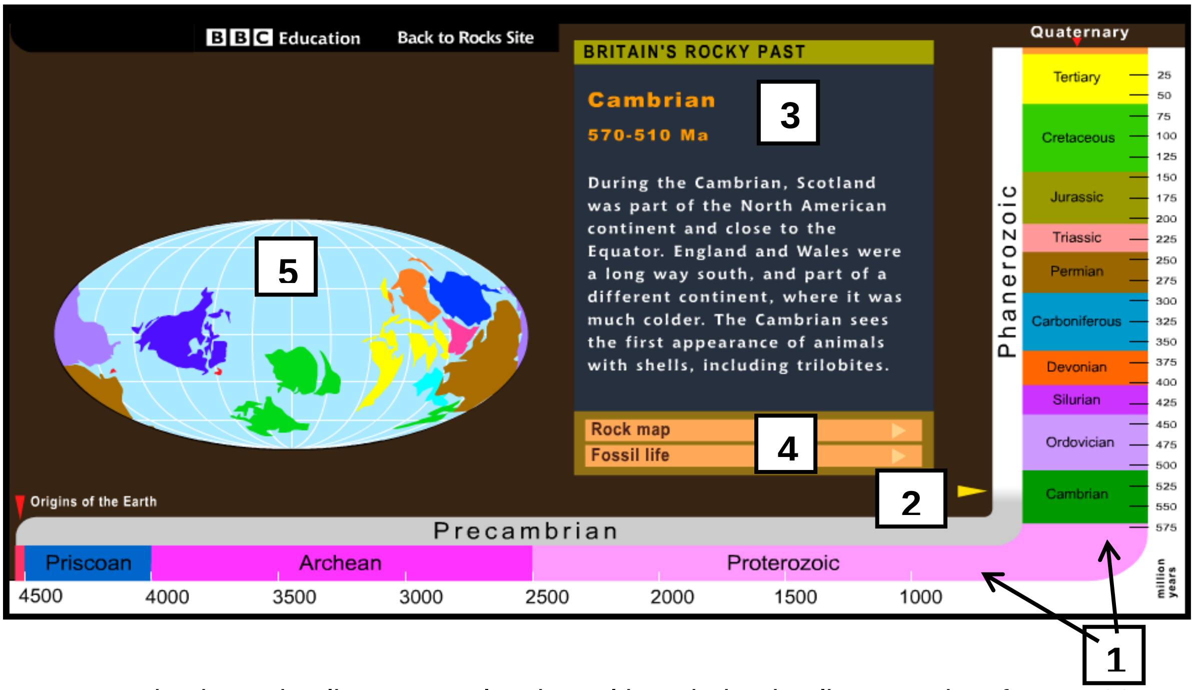
www.bbc.co.uk/education/rocks

Depending on the reading levels of your pupils, you may find the *Rock Primer* page useful as a general introduction to rocks. This page provides very brief descriptions of the most common rock types arranged in the three rock 'families' - igneous, sedimentary and metamorphic. You will find a link to it on the opening page of the above site within the *Walk With Rocks* area.

Much more stimulating and informative is the *Interactive Timeline Animation.* This is found by opening the *Britain's Rocky Past* link on the opening page as above. There are two ways of getting into this animation, one of which locks you into viewing a sequence of images about the formation of planet Earth before giving you access to the timeline. This one is accessed by the link that simply says *Go to animation.* The other link labelled *Go to interactive timeline* by-passes the Earth formation and animated plate movement sequence.

There is merit in using both animations at some stage, although the one that starts with the Earth formation sequence includes words like 'amorphous' and 'planetismal', which may need some explaining! This one also races uncontrollably through the plate movement sequence before grinding slowly through several ice ages. The second link, on the other hand, allows pupils to interact straight-away with the timeline.

The interactive timeline allows pupils to call up information for each of the main periods into which the geological timescale has been divided. An image of one of the screens of information is provided below with one or two appended notes to explain how it can be used:



1. Note the 'bent' timeline! Note also that, although the timeline stretches from 4500 million years ago to the present, the span of time is not represented uniformly. Since relatively little is known about the Precambrian era (the time from 4500 to 575 million years ago), the scale for this section of the timeline has been compressed.

   The names given to different periods are widely used by professional geologists and some pupils may wish to memorise the sequence from Cambrian to Quaternary - a good opportunity for a clever mnemonic! Every pupil will know the term 'Jurassic' already, but may not appreciate its full meaning as representing a particular period of geological time.

   Information about each period is accessed by pointing and clicking on the coloured areas of the timeline.

2. A yellow arrow-head indicates the active period whose information is currently displayed.
3. A brief summary of the main features of each period is displayed here. Scrolling is needed to reveal all the information about some periods.
4. The menu here provides access to maps and sketches of typical fossils. There are two types of map. One represents the calculated positions of the continents at the selected time. The other shows the major outcrops in the UK of rocks of this age. The distracting red dots on the UK maps indicate localities that featured in the *Essential Guide to Rocks* series of programmes. Note that summaries of each programme item can be accessed from the main web-page via the *Archive* link.
5. This is where the maps and fossil sketches are displayed. There are also some useful diagrams associated with certain periods. These show the local disposition of oceans and continents in a more detailed way.

Suggested Activities Using The *Interactive Timeline*

There is a wealth of information incorporated within this interactive timeline. A number of different activities could be tried depending on the age and research skills of your pupils:

1. If you feel that there is merit in your pupils becoming familiar with the names of the geological time periods, you may wish to create a word search or other activity to focus their attention on these or other technical words displayed on the *Interactive Timeline*. You can download a free program for creating word searches from the following web-site:

   http://www.worksheetfactory.com/

2. Pupils could explore the *Rock Maps* that can be displayed for each geological period shown in the *Interactive Timeline* to discover the age of the rocks of their local area. This activity could, of course, be extended to an exploration of the ages of rocks near other selected localities in the UK.

3. There is also information about typical fossil organisms associated with each geological period. Although the examples tend to be from England and Wales, they could be a starting point for researching about fossils. The following web-site has some outstanding photographs of trilobite fossils. Trilobites are perhaps the most interesting of the fossil organisms associated with the period when the later Knockan Crag rocks were deposited. Be patient while down-loading – the graphics files are quite large.

   http://www.geocities.com/trilobitologist/trilobites.html

4. The World Maps displayed for each geological period could be used to answer questions such as:

   During which geological period did the Atlantic Ocean first begin to form?

   During the Cambrian period, the parts of the Earth's crust that would later become England & Wales and Scotland were widely separated. They are shown as small bright red areas on the World Map. During which period did they join together?

   Note that graphical images and text can be copied for pasting into presentational materials from web-pages or any other screen displays using programs like the excellent (and free!) ScreenPrint Gold which can be downloaded from:

   http://www.softwarelabs.com/

Appendix One – Links to 5-14 Environmental Studies Guidelines

Study: Knockan Crag Visit

Curriculum areas:

Main focus: Environmental Studies ***Others:*** *ICT* *Language*

Components: Science Social Subjects

Levels: D to F

Main aim of study: To study the origins of the physical environment of the Northwest Highlands

Attainment outcomes: Materials from Earth People and place

Key strands:

- Materials from Earth
- The physical environment
- Using maps

Key questions for exploration:

- How old are the rocks of Northwest Scotland?
- How are rocks formed?
- How are landscape features such as mountains and valleys formed?
- What information can rocks and fossils provide about past environments?
- What have scientists learned from studying the rocks at Knockan Crag?
- Why is Knockan Crag such an important site for the international scientific community?
- How would this part of Scotland change if we could travel backwards through geological time?

Learning outcomes (relating to knowledge and understanding):

Through this study the pupils will:

- understand in simple terms the processes that lead to the formation of sedimentary and metamorphic rocks
- understand that sequences of sedimentary rocks contain a record of changing physical environments
- know that, in normal sequences of sedimentary rocks, rocks get younger going upwards through the sequence
- know that the distribution of continents and oceans has changed dramatically through geological time

- know that continents can collide and produce major mountain chains, volcanoes and earthquakes
- know that the rocks of northern Scotland provide clear evidence of a continental collision around 400 million years ago
- understand that present-day landscape features have been formed by the geological processes of erosion and deposition acting over long periods of time

K&U assessment:

Pupils should be able to:

- describe selected rocks in terms that may help to explain their origin
- interpret in simple terms the sequence of events that created a sequence of sedimentary rocks as illustrated in a simple labelled vertical section diagram
- describe in very general terms how the metamorphic rocks of northern Scotland were formed as a result of two continents colliding over 400 million years ago
- explain how older rock has come to rest on top of younger rock at Knockan Crag
- describe in general terms the processes that have produced the spectacular landscapes of Northwest Scotland

Skills assessment:

Pupils should be able to:

- demonstrate that they can select sources and successfully extract and process relevant information
- present information about the physical environment using appropriate maps and diagrams
- make detailed observations and record them in a logical and appropriate format
- apply information provided about straightforward scales to make useful measurements on maps and diagrams
- use search engines intelligently to locate appropriate web-sites
- capture images and text from web-sites for copying and pasting into presentational materials

Developing informed attitudes:

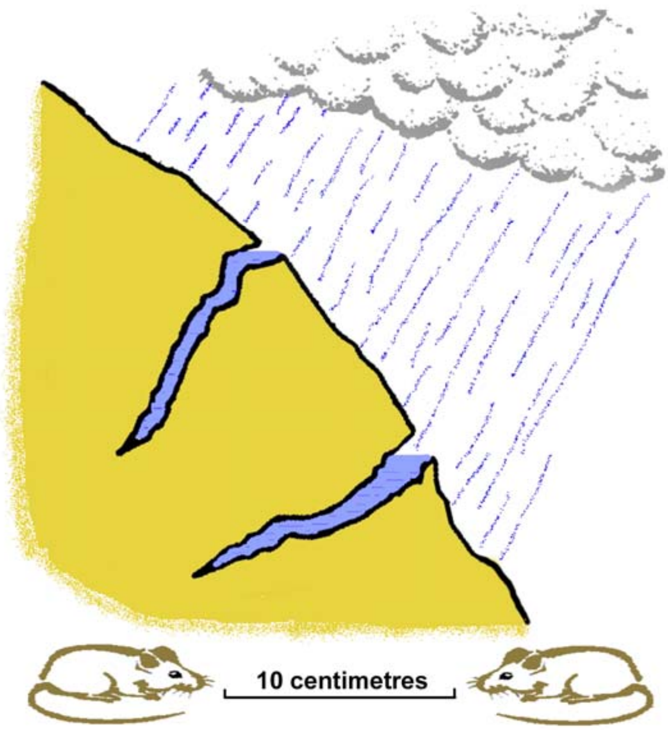
Pupils should be encouraged to:

- discuss the way in which the scientifically important site at Knockan Crag is being presented to the general public
- discuss how people long ago had different understandings of the origins of our physical environment

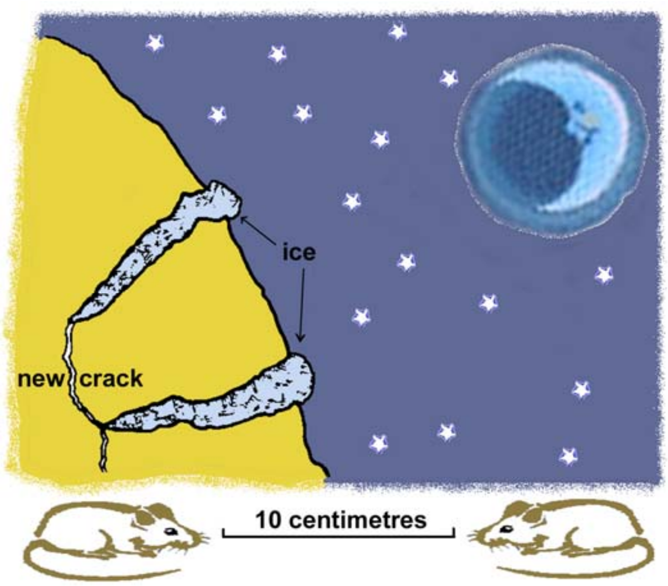
Appendix Two – *Layer Upon Layer* Activity

Diagrams <u>with</u> captions version

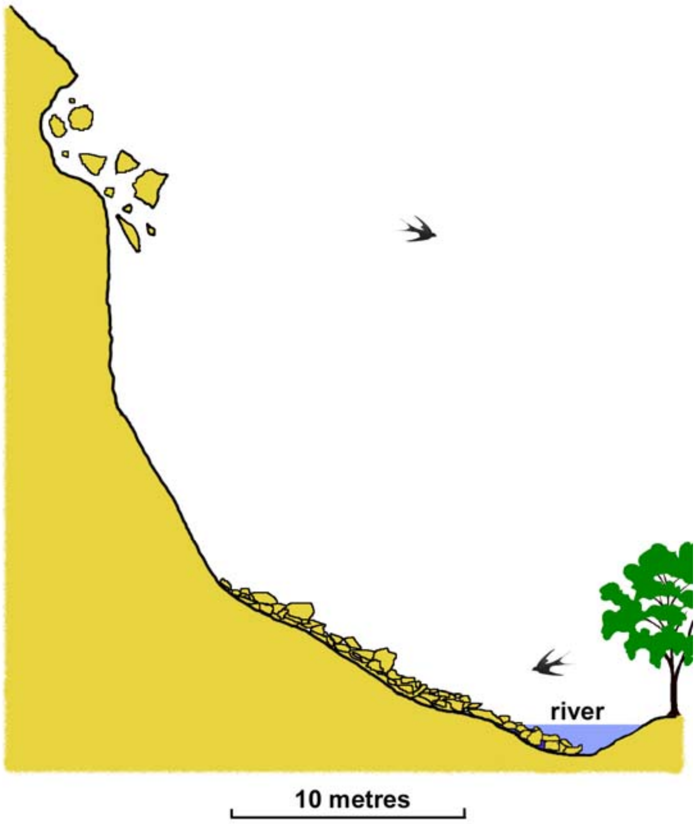
1. Imagine some rocky outcrops at the side of a valley high in the mountains. Cracks in the rock fill with water when it rains.



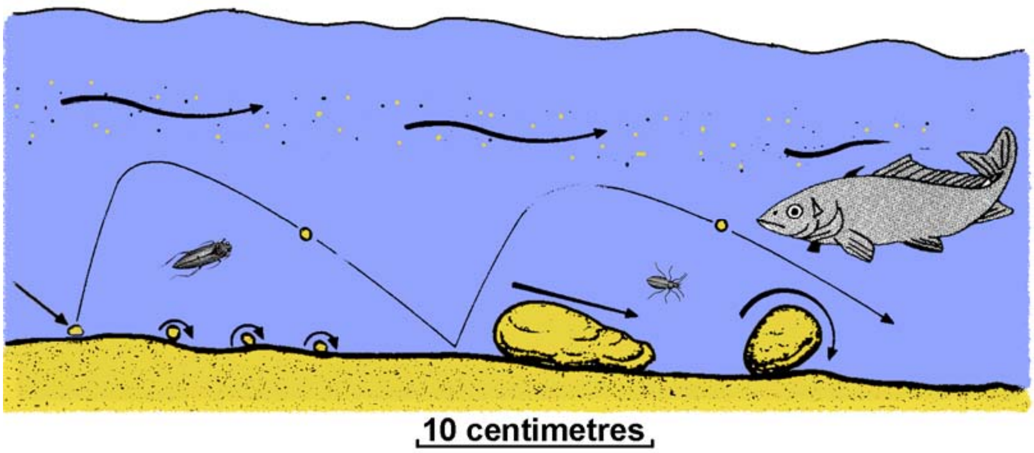
2. When it is cold, the water changes to ice. As it forms, the ice expands and makes new cracks in the rock.



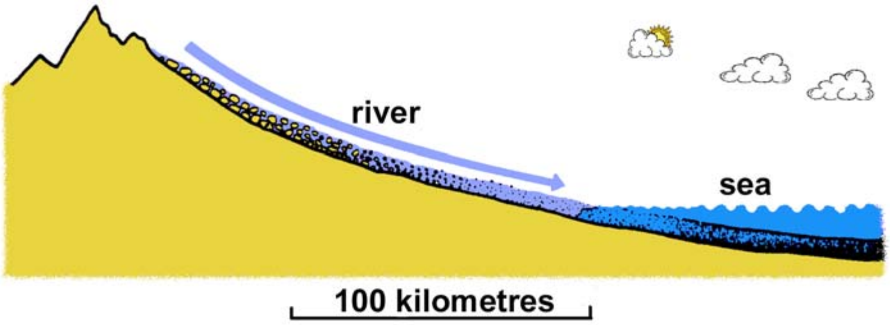
3. After this happens a few times, pieces of rock are loosened and fall from the outcrop. They slide downhill and eventually land up in the river flowing along the valley floor.



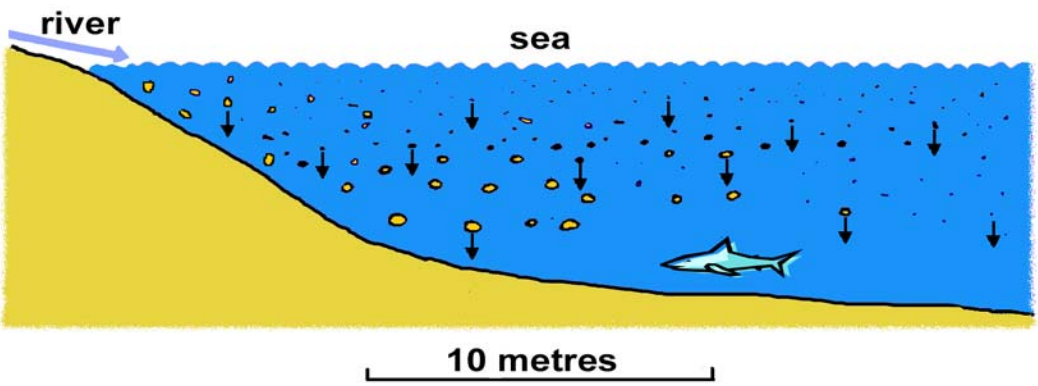
4. Once in the river, the pieces of rock tend to slide, roll and bounce downstream as they are forced along by the flow of water.



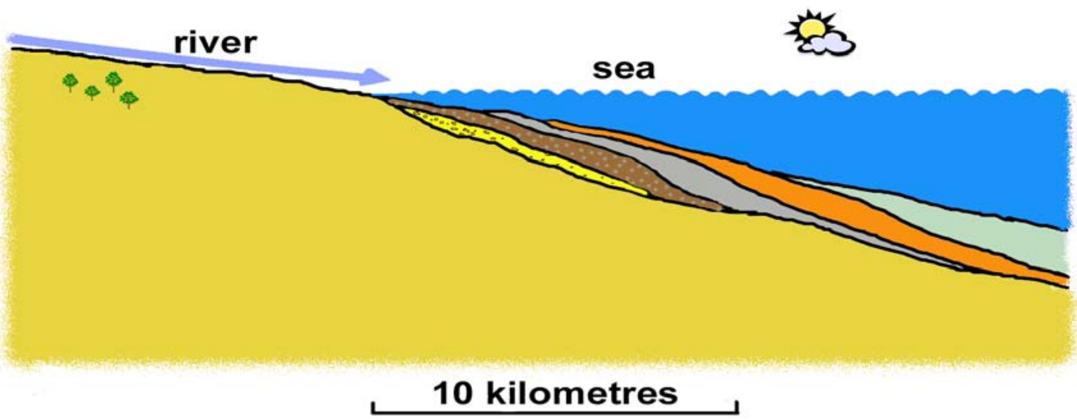
5. As they travel downstream, they get broken up into smaller sand grains and mud particles.



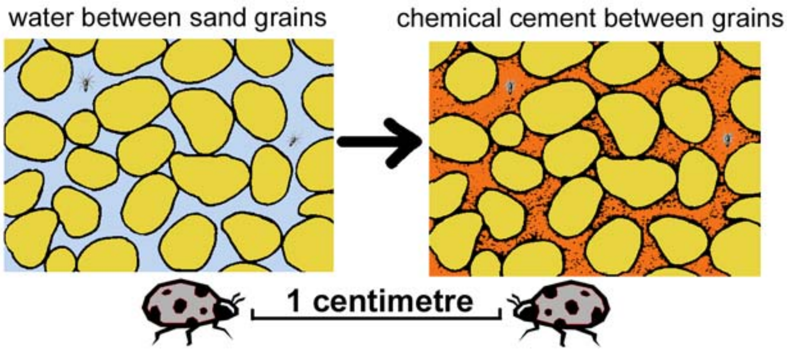
6. When the river flows into the sea, all the rock fragments fall to the sea bed as the flow of water slows and stops.



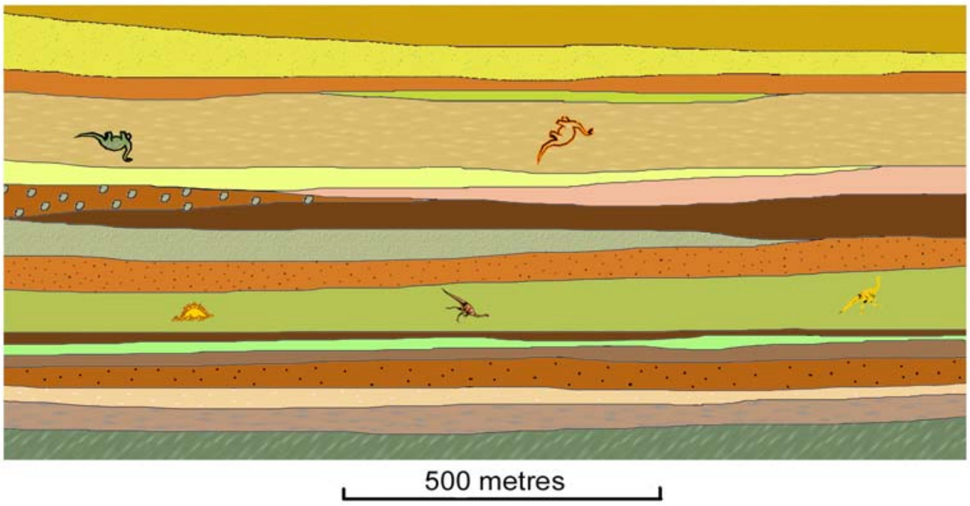
7. Over long periods of time, layers of pebbles, sand and mud build up on the sea bed at river mouths.



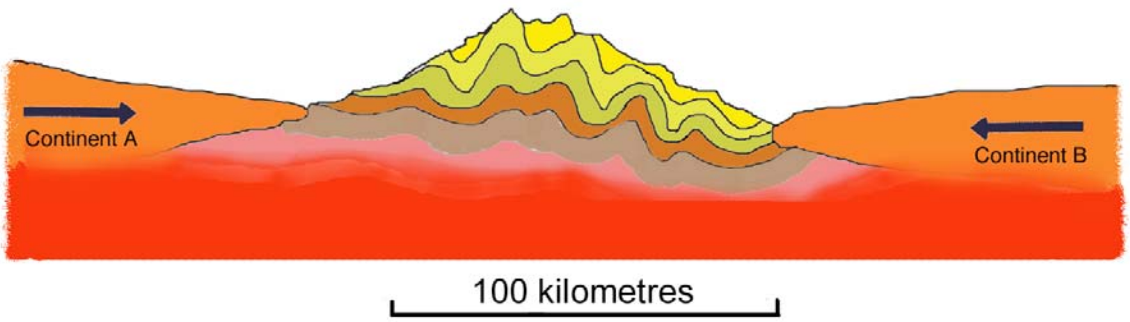
8. Water circulates in the tiny spaces between the rock particles in these layers and slowly deposits chemicals that cement the particles together. Sediments such as sand and mud eventually become sedimentary rocks called sandstone and mudstone.



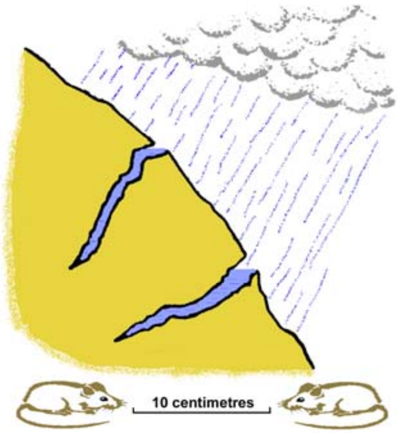
9. Over millions of years, layer upon layer of different sedimentary rocks pile up on top of each other to create rock formations hundreds of metres thick. These formations often lie undisturbed for hundreds of millions of years.



10. Sometimes, however, they get squeezed between colliding continents and get pushed up to form mountains.



11. As soon as the rocks rise above sea level, they are attacked by rain and frost and start breaking up. The endless cycle of making new rocks from old ones has started all over again.



Captions only version

Imagine some rocky outcrops at the side of a valley high in the mountains. Cracks in the rock fill with water when it rains.

When it is cold, the water changes to ice. As it forms, the ice expands and makes new cracks in the rock.

After this happens a few times, pieces of rock are loosened and fall from the outcrop. They slide downhill and eventually land up in the river flowing along the valley floor.

Once in the river, the pieces of rock tend to slide, roll and bounce downstream as they are forced along by the flow of water.

As they travel downstream, they get broken up into smaller sand grains and mud particles.

When the river flows into the sea, all the rock fragments fall to the sea bed as the flow of water slows and stops. The largest rock fragments are only carried into the sea during floods. These are the first fragments to get dumped on the sea bed. Smaller fragments tend to get carried farther out to sea before they too settle out of the water.

Over long periods of time, layers of pebbles, sand and mud build up on the sea bed at river mouths.

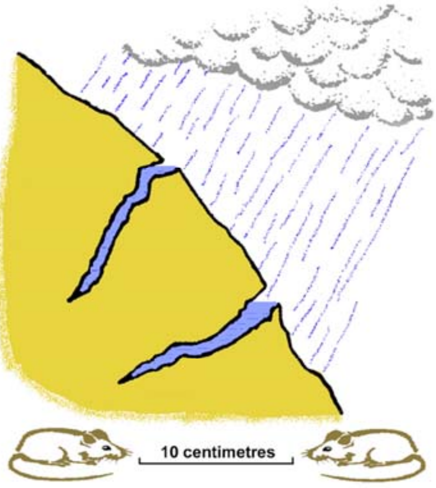
Water circulates in the tiny spaces between the rock particles in these layers and slowly deposits chemicals that cement the particles together. Sediments such as sand and mud eventually become sedimentary rocks called sandstone and mudstone.

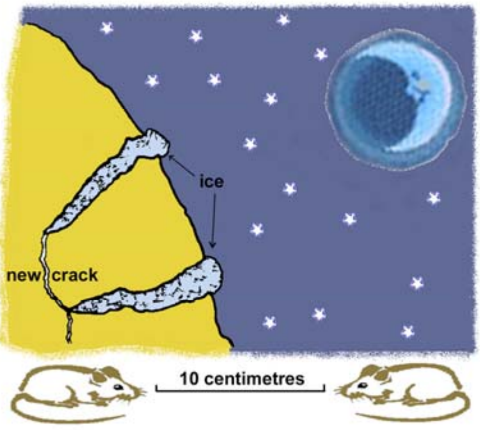
Over millions of years, layer upon layer of different sedimentary rocks pile up on top of each other to create rock formations hundreds of metres thick. These formations often lie undisturbed for hundreds of millions of years.

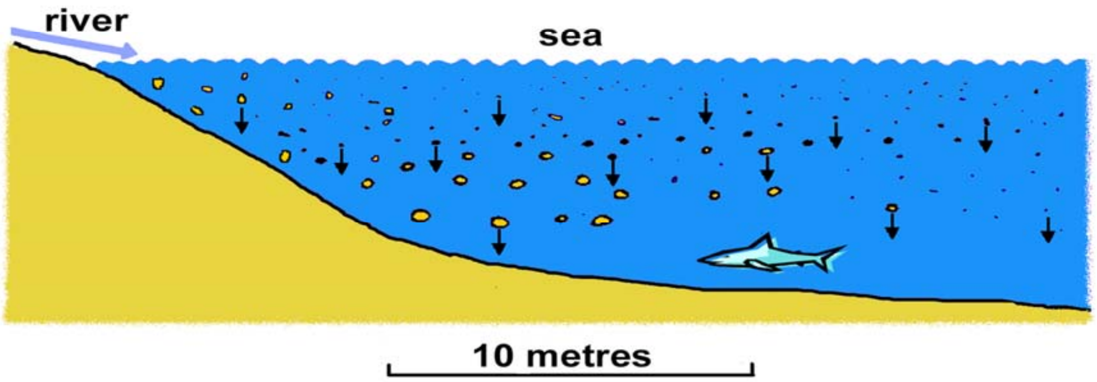
Sometimes, however, they get squeezed between colliding continents and get pushed up to form mountains.

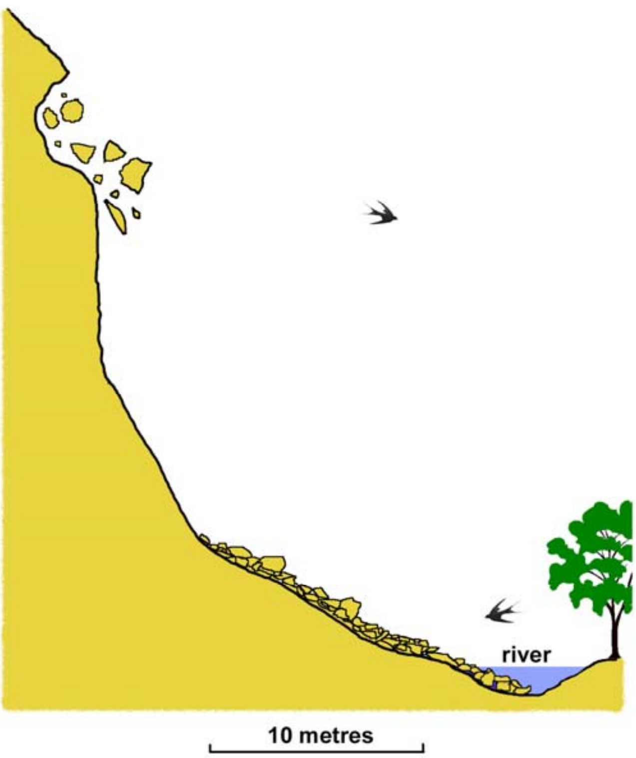
As soon as they rise above sea level, they are attacked by rain and frost and start breaking up. The cycle of making new rocks from old ones has started all over again.

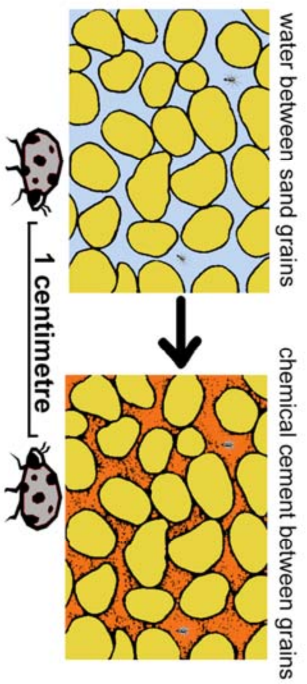
Diagrams <u>without</u> captions version



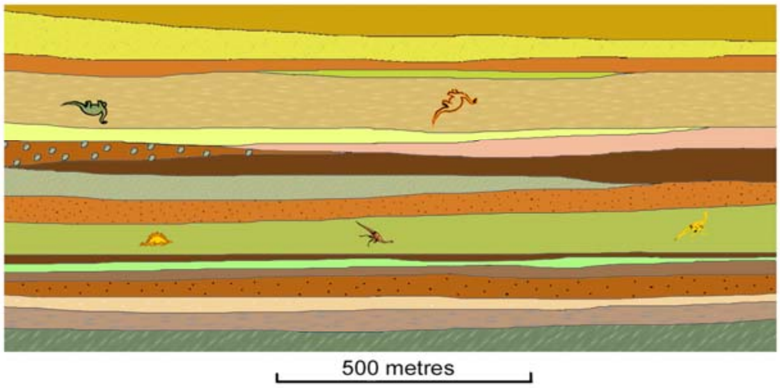


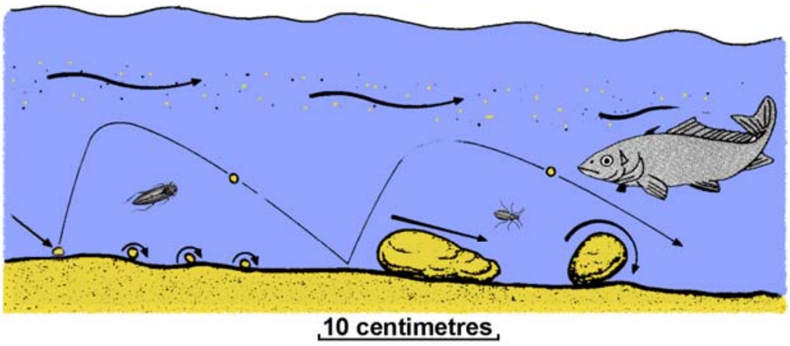


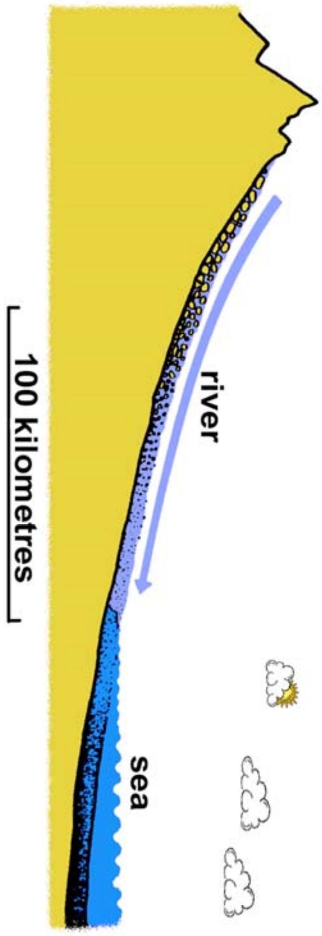


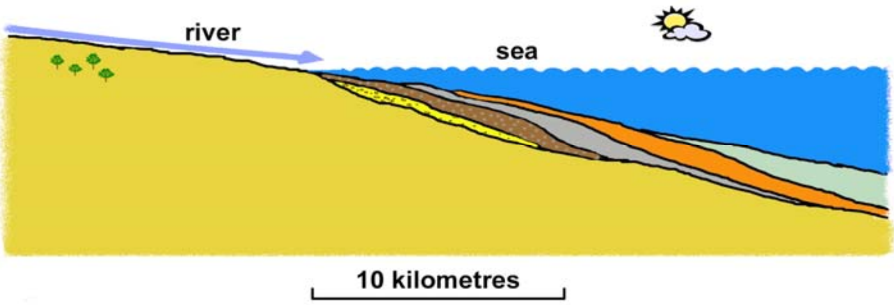


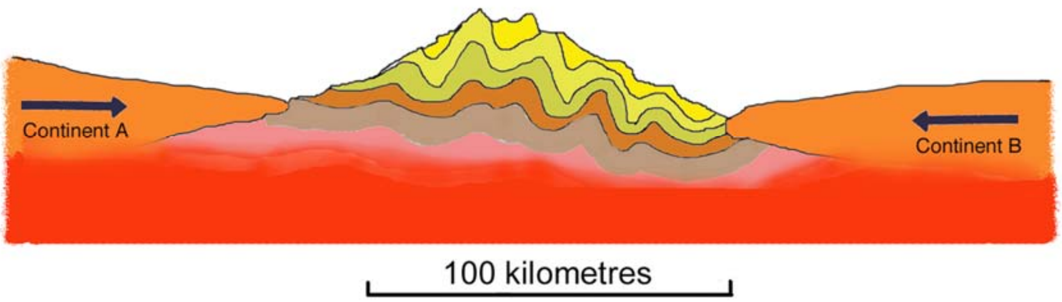
Diagrams without captions version











Appendix Three – *Imitating Nature*

Modelling the Formation of Sedimentary Rocks

A number of simple experiments can be used to model the processes described in the *Layer Upon Layer* activity. Many of them are probably best carried out as demonstrations, although pupil involvement is easily worked into all of them.

a) Expanding Ice

The aim of this experiment is to model the way in which freezing water can shatter rock. Unfortunately, freezing saturated specimens of real rock does not always produce convincing results even when repeated several times. Instead, it is probably better to fill a glass bottle with water, seal it tightly and place it in a thick polythene bag in a freezer overnight. Provided there is little or no trapped air in the bottle, it should shatter convincingly as the water freezes. Obviously, the shattered glass should be observed but not touched.

Jars with large lids may also work although the expansion may be achieved by doming of the lid rather than shattering of the glass. Note that the volume increase when water freezes and turns to ice is about 9%.

Everyday examples of this phenomenon include burst water pipes and shattered plant containers in frosty weather. Although rarely seen happening, frost shattering of rock is a very common phenomenon in Scottish hills and mountains. Most scree slopes are maintained by the constant addition of angular rock fragments through this process.

b) Landslides

The way in which frost-shattered rock fragments slide downhill can be modelled fairly easily. All you need is a heap of gravel piled up as steeply as possible. 10mm aggregate chips for road surfacing are ideal, although any similar material will do. For every material, there is a maximum angle of slope beyond which instability and sliding occurs. Sand is also good for demonstrating slope instability. Different sands will have different maximum angles, as do wet and dry samples of the same sand.

The best way to induce a landslide in the model is to remove material from the foot of the slope. This would happen in nature, for instance, when a flooding river eroded the bottom of an unstable slope. It also happens when roads are constructed through mountainous regions and was a major concern for engineers rebuilding the A9 road in the 1970s.

c) Sediment Transport In Rivers

This activity could generate a lot of fun and interest! Provided you have access to a bridge over a reasonably flowing river or stream, this could be less of a modelling activity and more of a real-world experiment. The aim is to observe how flowing water is able to transport various sizes of rock material downstream. Simply drop various batches of mud, sand and pebbles from the bridge and record what happens. It is important that pupils are able to see what is happening and that they are able to do so safely.

Only the finer grained materials such as mud, silt and fine sand are likely to be washed away as soon as they are dropped in the water. Coarser materials will migrate more slowly and may require regular monitoring over an extended period. It is likely that coarser materials will only move downstream when the river or stream is in flood. In a real flood, all but the largest boulders may be swept away entirely.

To make the materials more visible, try using pale-coloured sand and pebbles. It might even be desirable to paint larger pebbles to make them stand out from the material already in the river bed. Use emulsion paint which will be relatively short-lived. This may not be such a good idea, however, if the location is a local beauty spot.

Clearly, this is an activity that needs to be thought out in detail, especially from the safety angle. It would be inadvisable to use anything coarser than sand if pupils are likely to return to the site at a later date and try to investigate progress at close quarters in the river.

A different approach that should avoid all risk to pupils would be to take a sequence of photographs over a long period of a specific area of river bed. This would be a genuine experiment with an outcome that would depend very much on local conditions and the timescale of the experiment.

Yet another approach would be to model the action of flowing water on sand and pebbles in the playground using beach materials, a sloping surface and lots of water. This could be a good opportunity for pupils to design their own investigation. Control will need to be exercised over the flow rate and angle of slope if meaningful results are desired. On the other hand, a lot can be gained from simply observing the processes without being too rigorous and scientific.

d) Breaking Down Rock Fragments

Because of the timescale involved, there is no simple way of showing how rivers break down the rock materials they transport into ever smaller pieces. If there is a local river with which pupils are familiar, it may be possible to make the observation that the large boulders and cobbles that tend to fill the river bed near its source are reduced to sand and gravel at the river mouth. With luck, pebbles near the river mouth should be of the same rock types as upstream but of smaller size.

e) Deposition Of Sediment

This is a standard activity that generally works well. It involves the use of clear jars or plastic containers. If glass jars are used, precautions should be taken to avoid injury should a jar be dropped. The aim is to observe how sediment of different grain-sizes is carried around by moving water.

Pupils can add their own sediments to jars, fill them with water and then seal them. Alternatively, they can experiment with a range of prepared jars each containing different sediments. These might include clay, mud, silt, fine sand, coarse sand, grit, and fine gravel, all as discrete samples and as mixtures. Many soils are natural mixtures containing sediment of various grain sizes.

When the water in the jars is made to swirl around, it should be possible to observe that fine grained materials get carried around in suspension, coarser materials may jump up briefly and fall back again, while pebbles simply slide or roll along the bottom of the jar. This models quite closely what happens to sediment in a fast-flowing river.

An additional observation is likely to be that, as motion ceases, sediment settles out of the water in order of grain size with the finest material settling out last. This can explain why grain sizes are sometimes seen to get smaller upwards in beds of sedimentary rock. As with the material in the jar, a bed of rock may represent a single episode of deposition of mixed grain sizes carried by water that ceased to flow.

f) Converting Sediment Into Rock

In nature, this process can take a very long time and involve complex chemical reactions. As layers of sediment accumulate one on top of the other, the lower layers are subjected to increasing pressures and temperatures. Water contained in the spaces (pores) between the grains of sediment gets squeezed out and slowly carries dissolved minerals through the rock as it escapes upwards. These dissolved minerals often precipitate in the colder layers above and act as a cement, binding the grains of sediment to form a durable rock.

Although various materials such as dissolved sugar and plaster are sometimes suggested to model this process in the classroom, the most reliable 'cement' for making DIY sedimentary rocks is diluted PVA glue. It has the advantage of remaining transparent and thereby allowing the nature of the component rock fragments to be seen. Pupils should add about one part water to four parts glue and stir some into a little gravel in a plastic cup. The best results are obtained when there is just enough glue to wet all of the gravel. The mixture should be left to harden overnight before peeling off the plastic cup. Gravel is preferable to sand which soaks up a lot of glue and produces less rock-like specimens.

g) Building Up Layers Of Rock

The *Law of Superposition* is crucial to the understanding of rock sequences such as those exposed at Knockan Crag. Fortunately, perhaps, pupils do not need to identify the 'law' as such! All that matters is that they fully appreciate that, as layers of sedimentary rocks are laid down, each new layer is younger than any below it.

Although the point is a very obvious one, it may still be worth making a simple model by adding layers of different sediment to a clear-sided container. Different coloured sands are very effective. Try to avoid adding sand on top of coarse gravel since it will trickle down into the voids below and obscure the layering.

Piling sheets of paper on top of one another is another way of modelling sedimentary layers. Bricks or building blocks in a wall clearly demonstrate the *Law of Superposition* as well.

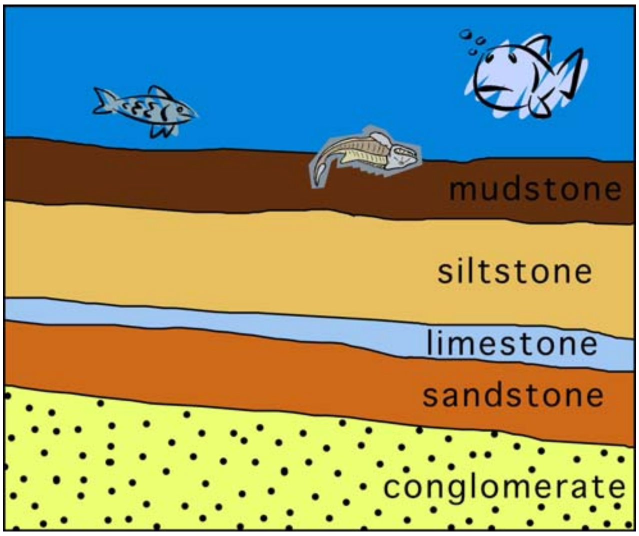
h) Mountain Building

Plasticene or modelling clay can be used to show how mountain chains are created when thick sequences of rock strata are squeezed between advancing continents. One problem with this model is that it is difficult to show that real strata get pushed downwards as well as upwards. Many of the rocks exposed in the Highlands today show obvious evidence of high temperature conditions in the 'root zone' of an ancient mountain chain as they were pushed downwards into the hotter regions of the Earth's crust.

Another problem with this model is recovering the plasticene for future use!

Appendix Four – *Which Came First?*

Which came first?



1. *Which of the rock strata shown is the oldest? Explain why you think this.*

2. *Write out the following sentences filling in the missing words:*

   In the rock strata diagram above, the limestone is older than the ___________ and the ____________ but is younger than the _____________ and the _____________.

   In a normal sequence of sedimentary rocks, the oldest rock is always at the ___________ of the sequence and the youngest rock is at the ________.

3. *Make a list of everyday examples where things are built up or piled up with the oldest layer at the bottom. Here is an example to get you started – a brick wall.*

Appendix Five – *Learning To Describe Rocks*

Learning to Describe Rocks

Here is some advice on what to look for and what to focus on when describing rocks:

Fresh or weathered?

- *ignore rock surfaces with a weathered crust and look only at fresh surfaces*

  Any rock that sits out in the sun and rain gradually develops a 'crust' of altered material, which makes it difficult to see what the rock is really made of. Geologists carry hammers to break open rocks so that they can look at freshly exposed surfaces. The specimens provided are nearly all freshly broken. Be very careful when looking at other rocks, however, since weathered surfaces are common and prevent you from seeing inside the rock.

Rough or smooth?

- *does the rock feel smooth or rough when you handle it?*

  When a piece of rock breaks away from its original outcrop, it is likely to be rough and sharp-edged. It may be very jagged and irregular in shape. If it gets carried along by a river or washed around by the sea, the roughness gradually gets smoothed off. River gravel and beach pebbles tend to feel smooth and rounded when they are handled.

Colours

- *the colours you see in a rock will depend on how far away it is*

The closer you get, the more likely you are to make out details of several different colours. Common patterns of different colours are listed separately below.

- *shades of colour are important*

For instance, few rocks are pure white. There are lots of rocks, however, that are very pale in shades of grey, brown, pink and green. Be sure to indicate whether colours are pale, or very pale or dark etc.

Layers

- *many rocks have obvious layered or banded patterns*

You really need to look at all the surfaces of a rock before deciding whether or not it is layered. Layers may be flat and regular or they may be crumpled or curved. The layers may be close together (thin layers) or far apart. They may be irregular or streaky. They may also be vague or very prominent. It is important to describe as much as you can about the colours and appearance of layers.

Crystals

- *rocks made of crystals tend to sparkle and reflect light from crystal faces*

It is obvious that a rock is made of crystals (crystalline) when there are lots of large shiny crystal faces. It may be less obvious if the crystals are very small or if the surface of the rock has been weathered. If you see any obvious crystals, be sure to describe their size and colour in your description.

- *sometimes, you will be able to see the regular shapes of well-formed crystals*

The simplest way to describe crystal shapes is to make an outline sketch of the shape.

Grains, fragments and pebbles

- *many rocks are made of bits of other rocks*

The sizes of these 'bits' are very important. The sand grains in a sandstone are very small fragments of older rocks that have been recycled to make a new rock. Larger fragments can be called pebbles if they have a smooth or rounded outline or simply 'fragments' if they are irregularly shaped or have sharp corners.

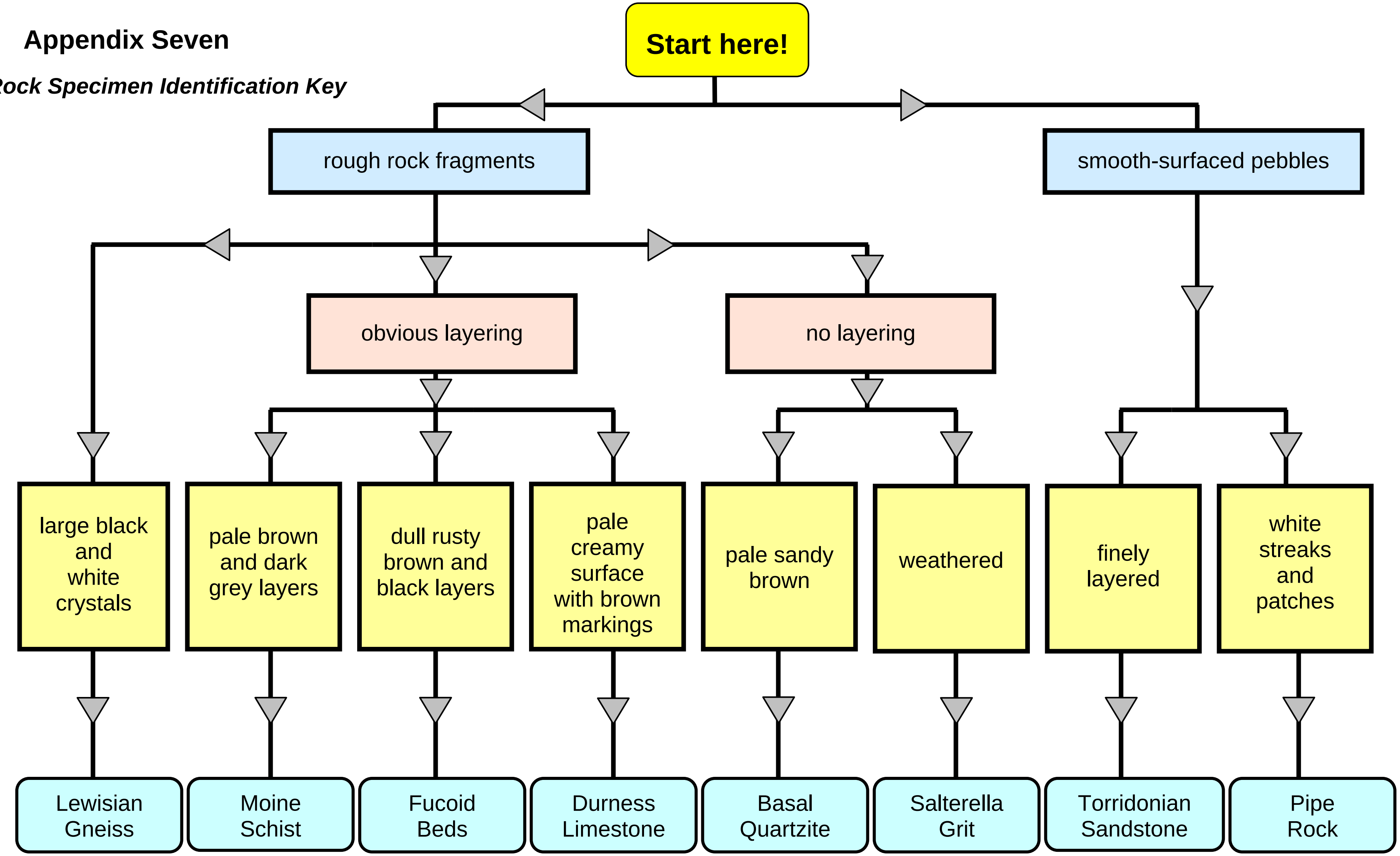
Appendix Six – *Rock Description Form*

Rock Description Form

Things to look for	Describe what you see
Rough, smooth or in-between?	
Colour from 2 metres?	
Colour(s) from 30 centimetres?	
Describe any obvious crystals	
Describe any obvious layering	
Describe any grains, pebbles or rock fragments inside the rock	
Describe anything else that you notice (use a hand lens if you need to)	

Appendix Seven

Rock Specimen Identification Key



Appendix Eight – *Specimen Display Cards*

Side One of cards 1 to 8:

Lewisian Gneiss

Things to look for:

1. Hold the specimen up to the light and move it around. Can you see the shiny crystal faces as they reflect the light?

2. In parts of the rock, the greyish white and very dark-coloured crystals are arranged in irregular bands which have a streaky and patchy appearance.

Torridonian Sandstone

Things to look for:

1. If you look closely at a wet surface using a hand-lens, you should see that the rock is made up of lots of fairly thin flat layers.

2. You should also be able to make out grains of sand of various colours in some of the coarser-grained layers.

Basal Quartzite

Things to look for:

1. If you look at the rock using a hand-lens, you should be able to see individual sand grains making up most of the rock.

2. On some surfaces on some specimens, very faint pale and dark banding can be made out. These bands represent the layers of sand that originally made up this very hard type of sandstone.

Pipe Rock

Things to look for:

1. There are the remains of burrows made by ancient sand-worms in this rock. These burrows stand out because they are now filled with white quartz. A vertical slice through a burrow looks like a long white 'worm' – although the worm itself has not been preserved at all. A horizontal slice through a burrow produces a circular white patch usually less than a centimetre in diameter. If you turn the specimen round and look at different surfaces, you should be able to see differently shaped sections cutting through burrows at different angles.

Fucoid Beds

Things to look for:

1. Some of the layering is very thin and regular, although broken and disturbed layers may be present in places.

   (The grains of silt and mud that make up this **mudstone** are usually too fine to be visible even through a hand-lens.)

Salterella Grit

Things to look for:

1. This rock contains tiny conical tubes that represent the fossil called 'Salterella'. Because they are small, the fossil tubes are not easy to see clearly. They tend to be most obvious where the rock has been weathered. They are best examined using a hand-lens and stand out as the small ochre-brown markings with a circular or conical outline.

Durness Limestone

Things to look for:

1. This rock is easily recognised because of the pale creamy brown colour of its weathered surfaces.
2. Bedding layers are sometimes obvious as darker brown parallel lines that stand out on these surfaces.
3. Other angular lines cut across the bedding layers and represent cracks that have split the rock in the past.

Moine Schist

Things to look for:

1. There are very few obvious crystals in this rock but you should be able to spot quite a lot of tiny crystal faces that sparkle as you hold the specimen up to the light and move it around.
2. Regular flat layering can usually be seen on some of the specimen's surfaces. The layers are defined in shades ranging from very pale brown to dark grey.

Side Two of cards 1 to 8:

Lewisian Gneiss

- ***gneiss*** *is the name given to a changed (****metamorphic****) rock made up of quite large crystals*
- *the crystals were formed when an older rock deep in the Earth's crust was squeezed and heated up until it almost melted*
- *this type of gneiss is named after the Isle of* ***Lewis*** *in the Western Isles.*
- *Lewisian Gneiss is the oldest kind of rock in Britain*
- *it is not actually seen at Knockan Crag, where it lies hidden beneath much younger rocks*
- *it is very common throughout the NW Highlands and in the Outer Hebrides*
- *it is typically coarsely crystalline and streaked into bands of contrasting colours*

Torridonian Sandstone

- *this type of sandstone is named after the* ***Torridon*** *area of the Northwest Highlands*
- *it is common all along the west coast from Skye northwards*
- *in some areas, this rock formation is more than 600 metres thick*
- *it was laid down when flash floods swept down sand and gravel from high mountains that used to exist to the west before the Atlantic Ocean was formed*
- *all this happened when the area was an arid desert more than 800 million years ago*
- *Torridonian Sandstone is commonly a reddish chocolate brown colour and sometimes contains lots of ancient pebbles washed in with the sand when it was formed*

Basal Quartzite

- *this rock was originally a sandstone made up almost entirely of **quartz** grains*
- *these grains are now cemented firmly together by more quartz, which has turned the sandstone into a very hard, tough quartzite*
- *it is called **Basal** Quartzite because it forms the bottom or basal layer of the local sequence of sedimentary rocks*
- *it was laid down as seas flooded over an ancient sinking landmass about 500 million years ago*
- *the ancient landmass was made of much older Lewisian Gneiss and Torridonian Sandstone rocks*
- *this rock layer is about 70 metres thick at Knockan Crag*

Pipe Rock

- *this sandstone has white markings at right angles to the original layering; these are the fossilised burrows (or 'pipes' as they used to be called) of a type of ancient marine sandworm*
- *in some outcrops, the 'pipes' are trumpet-shaped with diameters up to several centimetres and lengths up to 40 centimetres or more; most of the pipes, however, are straight-sided, narrower and much shorter than this*
- *the Pipe Rock represents inter-tidal beach sands and provides the first evidence of life in this part of the world*
- *Pipe Rock outcrops over much of the NW Highlands and now consists of hard sandstones forming a rock layer almost 100 metres thick*

Fucoid Beds

- *the unusual name 'fucoid' refers to a type of seaweed that was thought to be present in this mudstone as fossils*
- *the markings are now known to have been made by worms and other burrowing creatures that lived in this rock when it was still soft mud*
- *the term 'beds' is often used for outcrops of sedimentary rocks that occur in distinct layers*
- *the Fucoid Beds have a total thickness of about 15 metres at Knockan Crag*
- *they are rich in potash and are quarried at Loch Awe for making into a fertiliser used in farming*
- *they represent fine-grained silt, which accumulated in deeper sea water than the rocks above and below it*

Salterella Grit

- *this rock is a hard, gritty sandstone that gets its name from a type of fossil (Salterella) that occurs abundantly within its layers*
- *Salterella seems to have been a snail-like animal that lived in the shallow waters in which this sandstone was laid down*
- *all that remains of the animal are small cone-shaped tubes that are presumed to have been their shells*
- *unlike other rocks in this collection, this specimen has been left with an outer 'crust' of weathered material, which can look very different from the fresher rock inside*
- *the Salterella Grit at Knockan Crag is about 10 metres thick*

Durness Limestone

- *this type of limestone is named after Durness where it is very common*
- *the Durness Limestone formation outcrops more or less continuously from Durness to Skye, reaching a maximum thickness of 500 metres*
- *it was deposited as lime-rich mud in sea water that was shallow, warm, clear and rich in primitive marine organisms*
- *recognisable fossils of ancient sea creatures are very occasionally found in it*
- *Durness Limestone strata were laid down over an extended period of about 30 to 40 million years about 500 million years ago*

Moine Schist

- *the name* ***schist*** *is given to finely layered* ***metamorphic*** *(changed) rocks*
- *schists like this specimen can be formed when sedimentary down into the Earth's crust*
- *there they are heated and squeezed until the original sand and mud grains are changed into crystals*
- *when we see metamorphic rocks like this, they have come back up to the Earth's surface and cooled down again*
- *Moine schists are found over large areas of the Highlands*
- *they are named after an area in North Sutherland known as A' Mhoine, Gaelic for 'the peat bog'*

Appendix Nine – Worksheet For Visit To Knockan Crag

Rock Facts

During your visit, you will see outcrops of six different rock formations as you follow the crag-top trail. One of your tasks will be to record some information about each formation in the table on page 2. The information will come from displays in the Rock Room and from various displays along the trail itself. You may also be told some of the information by the leader of your group as you visit some of the outcrops.

Although you do not see them at Knockan Crag itself, there are two older formations that lie at deeper levels beneath the six formations you will be studying. These are the **Lewisian Gneiss** and the **Torridonian Sandstone** formations, which outcrop very widely to the north and south of Knockan Crag. They have been included in the table to help you build up a complete picture of all the important rock formations in this part of Scotland.

The Great Knockan Crag Puzzle

One of the six rock formations that you have seen appears to be in the wrong place. Answer the following questions about this geological puzzle:

1. Which one is it?

2. What are the names of the two geologists who finally solved the puzzle by making detailed geological maps of the area?

3. What is the accepted explanation of how this particular rock formation came to be where you saw it?

Carving Out The Present Landscape

Make a list below of the main **agents of erosion** that have created the very three-dimensional landscape that you overlook from Knockan Crag.

Name of rock formation	Place in sequence of outcrops (1 at bottom; 8 at top)	Approximate age of formation (in millions of years)	Main rock type(s) in formation	Conditions at the time when the rock was formed
Torridonian Sandstone	2	800	sandstone conglomerate (sedimentary)	Laid down as sand and gravel by flash-flooding rivers in a desert environment.
Lewisian Gneiss	1	2800	gneiss (metamorphic)	Very ancient rocks that have been pushed deep into the Earth's crust and totally recrystallised to form different rock types.