Building Stones 4 - Metamorphic rocks

What are the differences between metamorphic rocks commonly used as building stones?

Give each small group of pupils a sheet of the photographs of metamorphic rocks, Point out that the photographs are all at natural scale (the 1p coin is 2 cm across). If you have any samples of real metamorphic rocks to display, they will greatly enhance the activity.

Using the natural scale photographs from the sheet, ask pupils to:

- state the evidence which shows that the slates and the gneiss are of metamorphic origin (i.e. formed from earlier rocks by heating and/or increased pressure in the Earth) and that they are not sedimentary or igneous.
- state which of the photographs shows a rock which would react with dilute hydrochloric acid.
- which of the rocks shown could possibly contain fossils.
- which of the rocks have the biggest crystals and were probably formed under the most intense heat and pressure deep within the Earth's crust.

Show the pupils the photographs from this page, either projected or printed, and ask them:

- what evidence in the gneiss at outcrop (1) and in the green slate (2) suggests that they have both been subjected to intense Earth movements.
- for their views on: a) the use of serpentinite as a facing stone (3). They should take into account the notes which accompany the sets of building stone photographs;
  b) the use of white marble for the grave of Robert John Evans in 1922 (4);
  c) the use of the Khuppiam Green gneiss for the bench seat (5).

1. Gneiss at outcrop, Isle of Coll, Hebrides, Scotland
(lens cap is 50mm diameter)

2. Reverse fault in green slate, Lake District. The flat surface on which the penny rests is a natural cleavage plane, (coin is 2cm diameter).

3. Serpentinite used as an ornamental facing stone, (Sheffield)

4. A marble grave, with lead lettering, once flush with the surface, now standing out by 2.5mm,
Ecclesall Churchyard, Sheffield

5. A bench seat made of Khuppiam Green gneiss from India (Peace Gardens, Sheffield – a space which is open to the public at all times) (Photos: *Peter Kennett*)

The back up

Title: Building Stones 4 - Metamorphic rocks

Subtitle: What are the differences between metamorphic rocks commonly used as building stones?

Topic: A small group activity using photographs of metamorphic rocks used for ornamental purposes. This activity follows 'Building Stones 1' and is intended for pupils to deepen their understanding of metamorphic rocks. A table showing how the series of Earthlearningidea building stone activities link together is given on the final page.

Age range of pupils: 12 -18 years

Time needed to complete activity: 20 minutes for the classroom activity; much more for an outdoor visit to a town/city centre or a graveyard.

Pupil learning outcomes: Pupils can:
- learn the criteria by which metamorphic rocks are distinguished from one another;
- judge the best rock to use for a given situation;
- express an opinion about the aesthetic value of different rocks.

Context: We have already introduced pupils to the range of rock types used as building stones or which are used in ornamental work, such as gravestones (See Earthlearningidea 'Building Stones 1 – a resource for several Earthlearningidea activities'). Now we are developing pupils' understanding of each of the three groups of rocks in turn.

Possible responses to the questions posed to pupils are -

1. Using the photographs of rocks at natural scale:
- state the evidence which shows that the slates and the gneiss are of metamorphic origin. – *The slates show colour banding, due to variation in the original beds of rock from which they were made. The cleavage produced by metamorphism is now at a high angle to this earlier bedding. The gneiss consists of large crystals of quartz, feldspar and dark minerals, formed by recrystallisation in the solid, without melting. The crystals show a strong alignment, demonstrating that they are not of igneous origin, which would result in a more random texture.*
- state which of the photographs shows a rock which would react with dilute hydrochloric acid. - *Marble. This is the only rock containing calcium carbonate. It has the same composition as the limestone from which it was formed by metamorphism.*
- which of the rocks shown could possibly contain fossils. - *The Welsh slate is of low metamorphic grade (i.e. not heated and squeezed as much as, say a gneiss), and it may contain fossils, even if they are distorted. Some low grade marbles may also contain 'ghosts' of fossils, affected by the heat of metamorphism. The green slate is formed from volcanic ash and would be unlikely to contain fossils.*
- which of the rocks have the biggest crystals and were probably formed deep within the Earth's crust. - *the gneiss (see above). The Verde Ematita is also coarse-grained and the presence of the mineral cordierite suggest that the rock from which it was made was subjected to high temperatures, but, again, not actually high enough to melt it.*

2. Using the photographs of rocks in the text above:
- what evidence in the gneiss at outcrop (1) and in the green slate (2) suggests that they have both been subjected to intense Earth movements. - *The contorted banding in the gneiss shows that it has been affected by major Earth movements, probably many kilometres deep in the crust. The reverse fault in the green slate shows that the rock was subjected to major compressive forces in the Earth's crust, forcing one section of the rock to override another.*
- pupils' views on: a) the use of serpentinite as a facing stone (3). - *The facing of Wake Smith's office in the photograph has been cleverly cut from a single block, to give a four-way 'book form' symmetry. Serpentinite is however, subject to more rapid weathering than most other metamorphic rocks.*
  b) the use of white marble for the grave of Robert John Evans in 1922 (4) - *When installed, this grave would have looked very impressive, with fresh gleaming white marble, with the lead letters hammered into grooves and smoothed off flush with the surface. Now however, it has been discoloured by algae and 2.5mm thickness of marble has reacted with acidic rain and has dissolved.*
  c) the use of the Khuppiam Green gneiss for the bench seat (5) –*The seat is attractive and arouses curiosity among those who sit on it! It is very strong and has resisted 13 years of rough usage.*

Following up the activity:
If at all possible, follow the work in class with a visit to a nearby graveyard or town/ city centre. Give each group of pupils a set of the metamorphic rock sheets (with the rocks named) and ask them to match as many as they can.

Underlying principles:
- Metamorphic rocks were formed by recrystallisation of earlier-formed rocks under conditions of raised temperature and pressure deep in the crust or in the upper mantle of the Earth, but without large-scale melting being involved.
- The arrangement of the crystals in most metamorphic rocks shows some alignment, because of the high compressional forces of the Earth movements involved.

- Rocks such as marble and quartzite are composed of just one mineral and seldom show any alignment, because they contain no clay minerals which would produce platy minerals when metamorphosed. Instead, re-crystallisation occurs at the edges of the minerals, joining them closely together to give an even texture.
- Marble is a geological term only applied to rocks formed by the metamorphism of limestones. The term is often misapplied: it does not apply to any rock just because it can be polished.

Thinking skill development:
- Pupils look for patterns within rocks to enable them to distinguish between them.
- Working out of doors provides a good opportunity to make a bridge with normal classroom studies.

Resource list:
In class or in a town centre or graveyard
- Per small group of pupils – one copy of each of the sheets of photographs of metamorphic rocks and their descriptions

Useful links: 'Will my gravestone last?' and 'Metamorphism – that's Greek for change of shape, isn't it?' from http://www.earthlearningidea.com

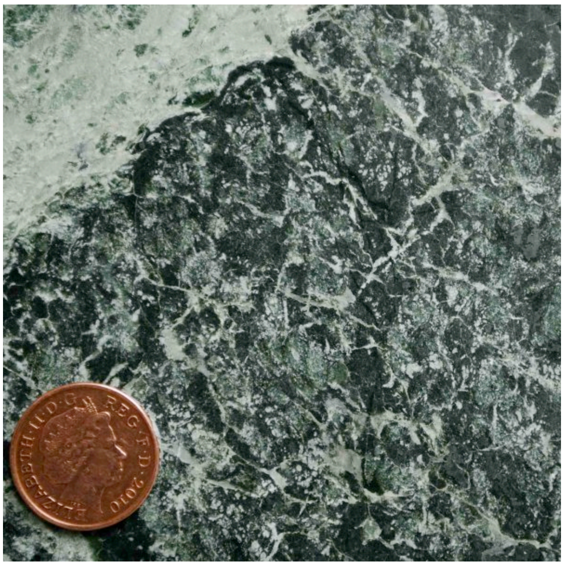
http://geoscenic.bgs.ac.uk/asset-bank/action/viewAsset?id=344745&index=96&total=110&view=viewSearchItem

Source: Source: Devised by Peter Kennett of the Earthlearningidea team, inspired by the enthusiasm of Eric Robinson and the set of sixteen postcards of Building Stones produced by Fred Broadhurst, Richard Porter and Paul Selden for the University of Manchester, and obtainable from Manchester Museum.

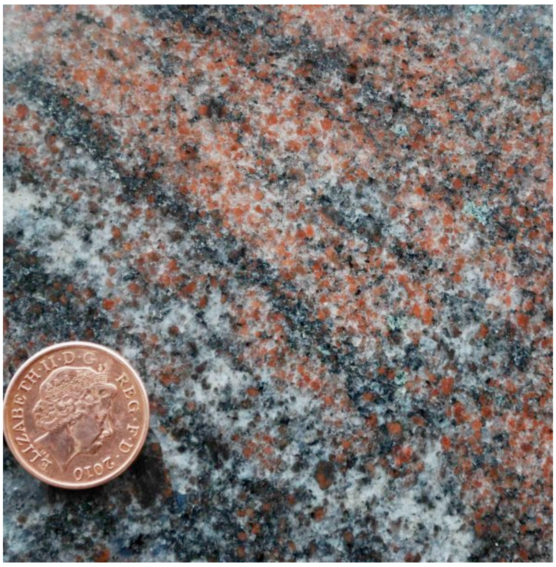
Metamorphic Rocks

Slate, with colour band from original bedding, North Wales

Broughton Moor Slate, Lancashire, England



Serpentinite, locality unknown



Gneiss, ('Paradiso classico'), India

Verde Ematita, Argentina

Marble, Carrara, Italy

(1p coin is 2 cm in diameter)

All photographs by Peter Kennett

Metamorphic Rocks

Slate, North Wales (from a loose specimen, 2012)
Slate is produced by the low grade metamorphism of an original mud-grade rock such as shale. Increased lateral pressure is normally considered as a more important factor than raised temperature. New platy minerals are formed at right angles to the direction of the forces involved. This may be totally different from the original bedding, so a slate will tend to split along the new cleavage planes, and not the original bedding. This is well seen in the specimen, where the bedding is picked out by a colour change, whilst the penny lies on a cleavage plane, along which the slate has been split by the quarry worker.

Broughton Moor Slate, Lancashire, England (Paving at the fountains in the Peace Gardens, Sheffield, 2012)
This slate could be classified as a sedimentary, igneous or metamorphic rock! It was formed when volcanic ash was blasted out of a volcano in Ordovician times (488-444 Ma). The ash settled in surrounding water, with the coarser particles settling first, grading up to the finer ones. It later underwent metamorphism at a destructive plate margin in the Caledonian Orogeny (mountain-building episode) and acquired a cleavage at a high angle to the original bedding.

Gneiss ('Paradiso classico'), India (Pisani plc, Cromford, Derbyshire, 2012)
By contrast with slate, gneiss is a high grade metamorphic rock, formed under higher temperatures and greatly increased lateral pressures deep in the Earth's crust. In spite of the extreme conditions, the rock never became molten, apart from localised patches within the overall rock mass. The distinctive banding of quartz, feldspars and ferromagnesian minerals is evident in this natural scale photograph. This is one of a wide variety of gneisses imported from India for use in ornamental work, such as gravestones. The rock takes a good polish and is resistant to weathering.

Verde Ematita, Argentina (Marks and Spencers' department store, Fargate, Sheffield, 2012)
At first sight, this attractive blue-green rock, with a texture resembling tapioca, looks as though it is of igneous origin. However, it is actually a metamorphic rock. The blue mineral is cordierite, which is associated with metamorphism at high temperatures, but without melting. Verde Ematita comes from the High Andes in Argentina, and was proposed for all major Marks and Spencer stores – until the quarries ran out of reserves!

Marble, Carrara, Italy (Ecclesall Churchyard, Sheffield, 2012)
The term 'marble' is often wrongly applied to any rock which takes a good polish. However, geologists restrict the word to metamorphosed limestones, whether this took place in contact metamorphism close to a major igneous intrusion, or whether increased pressure at a destructive plate margin was involved. This sample is typical of marble from Carrara in Italy. When fresh it is dazzling white, with subtle grey swirling marks ('marbling'), resulting from the metamorphism of impurities within the original limestone. It tends to suffer from weathering and this sample shows some algal staining.

Serpentinite, source unknown (office front of 18, Pall Mall, London, 2012)
The name serpentinite derives from the supposed similarity of the rock to snakeskin! It consists largely of ferromagnesian minerals, which have been altered considerably during Earth movements. It probably derives from an igneous origin in the Earth's mantle, but the alteration is so severe that serpentinite is justifiably classed as a metamorphic rock by most authorities. It is best used for ornamental work indoors, since it is badly affected by weathering and is often considerably paler than this fresh example.

Footnote:
The natural scale photographs of building stones were taken using a Nikon D60 digital SLR camera, with the lens on the 55mm zoom setting. The front of the lens was kept at a standard 23cm from rock surface, using a short stick cut to length. The 1p coin is 2 cm in diameter.

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The following chart shows the relationship between each of the activities on the theme of building stones. Each activity can be taken as a free-standing entity, since photographs and details of rocks are repeated. However, it is hoped that pupils will deepen their understanding of the topic and their enthusiasm for looking at the built environment around them by following all the activities in sequence, if this is appropriate to their local setting. The photographs were mostly taken using local opportunities in the U.K., but many of the building stones have come from across the world.

Title of activity	Topic	Resources provided	Indoor activity	Outdoor activity
Building Stones 1 - a resource for several Earthlearningidea activities. ("BS1")	Identification of building stones from each of the three groups of rocks.	Six sheets of photographs of building stones at natural scale, to be cut into separate photographs; Descriptions of all the stones; Key to the identification of building stones.	Identifying all the stones from the photographs, using the key; Competitive approach; opportunity for playing games with the photos.	Identifying building stones from the complete sheets of photographs, in a graveyard or town/city centre.
Building Stones 2 – igneous rocks	Using the photographs of igneous rocks to investigate their features in more detail and to comment on the conditions under which some of the rocks were formed.	Three sheets of igneous rocks, (taken from the whole set in BS1); Photographs of igneous rocks in use in a city centre; Descriptions of igneous rocks, as in BS1; A simple classification chart for the igneous rocks featured in the activity.	Grouping the photographs according to a) grain size; b) colour (and hence mineral content); Assessing the value of igneous rocks for ornamental or functional purposes.	Identifying building stones of igneous origin, from the sheets of photographs, in a graveyard or town/city centre; Explaining detailed features seen in igneous rocks used in buildings.
Building Stones 3 – sedimentary rocks	Using the photographs of sedimentary rocks to investigate their features in more detail and to comment on the conditions under which some of the rocks were formed.	Two sheets of sedimentary rocks, (taken from the whole set in BS1) Photographs of sedimentary rocks at outcrop, in use in a city centre and being processed for use as building stones; Descriptions of sedimentary rocks, as in BS1.	Relating the sedimentary rocks to their environments of deposition; Discussing their relative merits in resisting weathering; Showing how sedimentary rocks are cut for use, and why matching stones used in older buildings may be difficult.	Identifying building stones of sedimentary origin, from the sheets of photographs, in a graveyard or town/city centre; Explaining detailed features seen in sedimentary rocks used in buildings.
Building Stones 4 – metamorphic rocks	Using the photographs of metamorphic rocks to investigate their features in more detail and to comment on the conditions under which some of the rocks were formed.	One sheet of metamorphic rocks, (taken from the whole set in BS1) Photographs of metamorphic rocks at outcrop and in use in a city centre; Descriptions of metamorphic rocks, as in BS1.	Using evidence from photographs at natural scale and of metamorphic rocks outdoors to decide how they were formed and the factors affecting their use.	Identifying building stones of metamorphic origin, from the sheets of photographs, in a graveyard or town/city centre; Explaining detailed features seen in metamorphic rocks used in buildings.
Will my gravestone last?	Using a local opportunity to enable pupils to see a wide range of rock types and to investigate different scientific hypotheses.	An outline of how to conduct a graveyard survey, including suggested preparation and follow up activities; a plotting chart for pupils' observations; Hypotheses which might be tested are suggested. The sheets from Building Stones 1 should be used for this activity.	Preparing for the graveyard visit, by revising pupils' knowledge of sedimentary, igneous and metamorphic rocks. Following up the visit by assessing the validity of hypotheses about weathering rates etc and plotting graphs of data gathered during the visit.	Identifying ornamental stones from the complete sheets of photographs in a graveyard; Testing hypotheses regarding the rates of weathering of different rock types and the choice of different rock types over time.