When are soft rocks tough, and hard rocks weak?
A discussion about the toughness/resistance of rocks in different places

Normally, the toughest and most resistant rocks (often called harder rocks) would be found at the tops of mountains, hills and plateaus (because they are most resistant to weathering and erosion) and the weaker, less resistant rocks (often called softer rocks) are at lower levels – but this doesn't always happen. Why should this be?

Sorting out the words

Geoscientists often say 'hard' for tough rocks and 'soft' for weaker rocks – but most people use the word 'soft' differently. An internet search shows that to most people, 'soft' to the touch means: spongy, fluffy, delicate, smooth or flexible, but to a geoscientist it simply means a rock weaker than most rocks. Geological 'soft rocks' include clay, shale, chalk, etc. Meanwhile 'hard rocks' to a geoscientist are most igneous and metamorphic rocks and well-cemented sedimentary rocks.

Another possible confusion is that some geoscientists use the term 'hard rocks' to mean all igneous and metamorphic rocks (even though some of these are less 'hard') and the term 'soft rocks' for all sedimentary rocks (even though some are pretty tough).

But even when you use the terms in the same way as geoscientists do, we still find that some 'soft rocks' make hills and some 'hard rocks' form valleys. How can this be so?

Soft rock high land and cliffs

The fine white limestone called chalk is so 'soft' that it can be used to write on a chalkboard or slate, but nevertheless, is tough enough to form high cliffs and ridges across the country. This is because, although the rock itself is readily broken apart, it has lots of cracks and fractures, allowing rainwater to drain through it quickly, so reducing the erosive effects of the water. Other 'soft rocks' can be similar.

A ridge of chalk and a chalk cliff, with weaker rocks in the foreground, Tyneham Gwyle, Dorset, England.

Image by Phil Champion CC BY-SA 2.0 from the Geograph project under the Creative Commons Attribution-Share Alike 2.0 Generic license.

Railway tunnel into a chalk cliff, Le Treport, Normandy, France.

Image licensed by Philippe Alès under the Creative Commons Attribution-Share Alike 4.0 International license.

Hard rock low land

Although igneous rocks are usually very tough and resistant, and so make higher land, the minerals that make up darker-coloured igneous rocks can be less resistant to weathering and erosion than minerals in the surrounding rocks, so forming lower land.

A weathered basalt dyke in tougher surrounding rock, Orkney, Scotland.

Peter Kennett.

Softer rock in hills and mountains

Weaker rocks can be found in highland areas, because they have been protected by the surrounding tougher rocks. This often happens in areas of 'inverted topography' when downfolds or synclines form the mountains (because the rocks in the downfolds were tightly compressed during folding) while upfolds or anticlines form valleys (tension at the tops of upfolds caused cracks, allowing weathering and erosion at greater rates) (see diagrams in the *Context* section below).

Inverted topography – the lower region in the centre is an eroded anticline, the higher region on the left is a syncline; Wilpena Pound in the Flinders Ranges, Australia.

Rick Ramsdale.

The high snow-covered Alps in Europe with older, often harder rocks, on either side.

Image in the public domain - solely created by NASA.

Harder rock in lowland areas
Where plate tectonics has formed mountain ranges in the recent geological past, the mountains are formed of different types of relatively young rock, some soft and some hard. The rock of the surrounding areas is a lot older and may have been involved in more than one mountain-building episode in the distant geological past, and so it is often formed of harder sedimentary, igneous and metamorphic rocks.

These examples all show that geoscience can be complicated and confusing and that we must not jump to conclusions when we try to relate landscape structures to the rocks and structures beneath.

……

The back up

Title: When are soft rocks tough, and hard rocks weak?

Subtitle: A discussion about the toughness/ resistance of rocks in different places.

Topic: The simple idea, which generally holds, of tough rocks forming hills and headlands and weaker rocks, valleys and bays, does not always apply, so we need to look for evidence of how these features form.

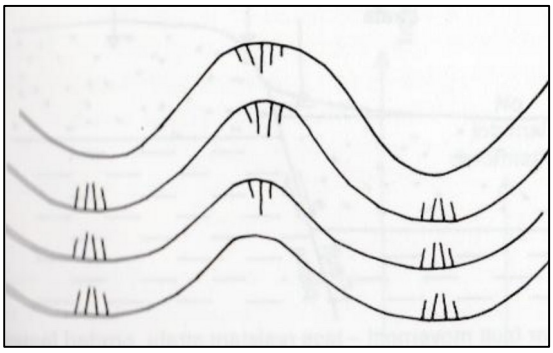
Age range of pupils: 11 years upwards

Time needed to complete activity: 10 minutes

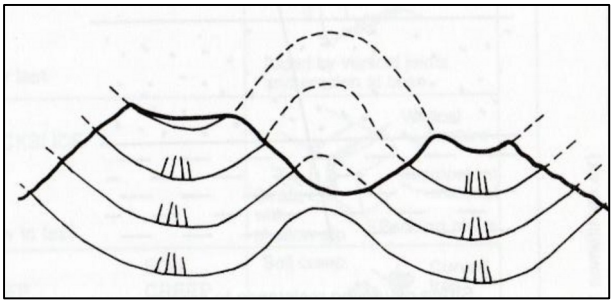
Pupil learning outcomes: Pupils can:
- explain instances of apparently weaker rocks forming hills, headlands and highland areas;
- explain instances of apparently stronger rocks forming valleys, bays and lowland areas.

Context:
Upfolds or anticlines in folded rocks are often weak at their crests (because tension splits the rock, forming joints) and the adjacent synclines are tough in their troughs, (because compression makes the rock stronger there), so that, when the area is eroded, the anticlines can become valleys and the synclines hills or mountains, as the diagrams show.

One well-known example is the syncline which forms Snowden, the highest mountain in England and Wales.



1. Rocks are folded into anticlinal crests and synclinal troughs; the joints on the crests result from the tension caused by the bending of the rock.



2. Weathering and erosion are most effective on the fractured crests, and slower in the compressed troughs, resulting in anticlinal valleys and synclinal hills.

Note that the ‘chalk’ used to write on chalkboards nowadays is made of gypsum.

Following up the activity:
Put “inverted topography” into an internet search engine and click ‘images’ to see other examples of this process.

Underlying principles:

- Usually, tougher rocks make higher land and weaker rocks form lower land, but in certain conditions, this is not the case.
- Landscape features have to be examined carefully to discover the importance of the rocks and their structures in their formation.

Thinking skill development:

Cognitive conflict is caused when general principles relating to tough and weak rocks appear not to apply.

Resource list:

- none

Source: Chris King of the Earthlearningidea Team.