# Teaching the Time: Physical geography in four dimensions

The brevity of life is a particular problem for the physical geographer. What can convince a 14-year-old that the Earth was old before she was born? How can our teaching bridge the chasm of time between last week's flood and the formation of the vast Ganges delta? **Chris Pyle** discusses some ways of making timescales accessible in our teaching.

I was watching a colleague's lesson on coastal erosion. 'So Miss', piped up one GCSE student. 'If you sat on the edge of a cliff for long enough, would you fall in?' He was almost serious. His question tried to span the gulf between a teenager's lazy afternoon at the seaside and the immensity of land-forming time.

One of our vital tasks as geographers is to open these doors to the fourth dimension. We are in the time-travel business.

It is helpful to have three timescales in view. Millions of years are the loose change of geological time – an awesome perspective which sets the context for much of our physical geography. However, most landforms develop on timescales of millennia, and the British landscape is strongly marked by the imprint of environmental change since the last ice age. Most geomorphic work is not done gradually over those periods, but takes place intermittently in events which often last days or hours.

## Deep time: millions of years

The eighteenth-century geologist James Hutton is often credited with discovering the immensity of geological time. As Macfarlane (2003) writes: 'To be with Hutton was to inhabit a world with a past so deep as to be terrifying'.

Hutton took the scientist John Playfair to Siccar Point in Berwickshire, where gently-dipping sandstones overlie vertical mudstone beds. He showed that the lower rocks must have been deposited on an ancient sea bed, tilted and uplifted by vast forces, and then over countless ages must have been eroded flat and eventually overlaid by sandstones formed on a new sea floor. This is an unconformity, a point at which rocks of very different ages are in contact. Playfair commented: 'The mind seemed to grow giddy by looking so far into the abyss of time'.

Our teaching about people's place on the Earth is not complete if we do not aim occasionally to take students to look into that abyss of 'deep time'. This is difficult to deliver in the classroom. Like Playfair, students are most likely to experience that sense of awe and wonder if they can visit and see striking geological sites.

Groups of year 7 students use gun clinometers to estimate the thickness of the conspicuous chalk and red sandstone layers in the cliffs at Hunstanton, Norfolk. Encouraged to visualise these rocks stretching for miles below the cliff-top seaside town, they are told that this chalk formed 100 million years ago on the floor of shallow tropical seas. How could that be true of this spot? Students gradually arrive at sensible ideas. Plate tectonics is a less cosy theory when it isn't just about far-off Everest or Japan, but about a journey made by solid rocks we can see and touch. Students root through fallen blocks to look for fossil bivalves. It is pleasing when they leave the beach asking: 'Do you really think that's true?'.

Large numbers are difficult to grasp. They are not just a 'wow' factor, though – geologists are making precise and factual claims. The analogy of distance is one successful way in. Briefly brainstorm things that have changed over the last year. Then choose a landmark a kilometre from your classroom – in my case, a nearby railway bridge. One millimetre represents a year. A million years takes you to the railway bridge – a slow snail's creep over pavement, gravel and grass. Tell them to look at every millimetre on the way, to see what it means to think of the Earth going a million times around the sun.

A more literal way of seeing large numbers is to fill an A4 sheet with lines of asterisks. With a small font size, 10,000 asterisks will fit on a page. I have not yet felt the need to stick 99 more pages to the wall so that students can see a million objects at once – but it is a possibility!

Another highly successful visual way of showing the length of Earth's history is to prepare a PowerPoint presentation marking major points in Earth history, setting the timings for each slide to correspond to the intervals between events. Figure 1 gives a suggested list of dates, using the scale of 1 second = 10 million years. The last few are so close together that they need to go as objects onto the same slide, rather than as separate slides. Figure 2 shows one attempt to compare Earth history with the length of a single day.

Face to face with 'deep time' at Hunstanton, Norfolk. Photo: Duncan King.

| Event | Years ago | Seconds |
|---|---|---|
| Earth begins | 4.6 billion | 80 |
| First single-celled life | 3.8 billion | 60 |
| First large fossils | 3.2 billion | 270 |
| Many life forms appear | 500 million | 4 |
| First land plants | 460 million | 6 |
| First ferns and sharks | 400 million | 5 |
| Coal starts to form | 350 million | 4 |
| Winged insects | 310 million | 4 |
| Beetles appear | 270 million | 4 |
| First dinosaurs | 230 million | 3 |
| First mammals | 200 million | 5 |
| First birds | 150 million | 1 |
| First flowers | 140 million | 5 |
| *Tyrannosaurus rex* appears | 90 million | 2.5 |
| Extinction of the dinosaurs | 65 million | 1.5 |
| Himalayas start to form | 50 million | 3 |
| First apes | 20 million | 1.4 |
| First hominids | 6 million | 0.36 |
| The ice ages begin | 2.4 million | 0.24 |
| End of last ice age | 10,000 | 0.001 |
| Today | 0 | |

*Figure 1*: Some key dates in Earth history. Timings use the scale: 1 second = 10 million years.

Let us attempt to transform the 4.5 billion years into something we can cope with on a more human scale. Suppose we set the entire 4.5 billion years equal to a single year. One second will then represent 143 years.

At midnight, when the new year starts, the earth is born.
At midnight on December 31 we reach the here and now.

The experience is rather sobering. The length of recorded human life, if we stretch it, comes to 30 seconds. The diverse life of higher plants and animals did not develop until the last of November. The part of earth history we know fairly well ...is less than two months long.

*Figure 2*: Earth history represented as one year. *Source*: van Andel (1985), p. 31.

## Post-glacial time: millennia

Hardknott Fort in Cumbria is a spectacular place which vividly illustrates millennial timescales of change. Walking round the bath-house walls, it is easy to imagine Roman soldiers shivering on this outpost (and outcrop) of empire. You can almost touch 2000 years. Hardknott's ruined walls stand on bedrock scoured by glaciers, with striations probably less than 20,000 years old and possibly close to half that age. If we can reach 2000 years, then we can see 10,000: the ice is not so much more distant than the Romans.

Most landscapes can be understood in terms of thousands of years. The major land forming agent for many of Britain's landscapes has melted in this timeframe; most landforms are formed at millennial rates; and unlike deep time, these are accessible in human terms.

The last glacial maximum, 18,000 years before the present, sets the backdrop for today's landscapes. Global civilisations and the peopling of Britain also belong to this post-glacial period (Diamond, 1997; Stringer, 2006). The ice ages should never be lumped into the same category as coal seams or dinosaurs; they are measured in thousands, not millions. (To see something of your students' mental timelines, try some of the events from Figure 1 as a card sort!) Late Quaternary history shows the climate system to be a highly changeable beast, and geography teachers have a major role in informing the climate change debate by teaching students their environmental history.

The most pervasive impacts of our glacial history are the three 'S's of slopes, sediments and sea-level change. Within the limits of the last glacial (Devensian) ice, slopes have often been oversteepened by glacial erosion; while outside those limits, periglaciation has left distinctive marks such as scree formation, chalkland dry valleys and solifluction deposits. The sediment legacies of the ice ages are not only the boulder clays and direct products of glacial deposition; to the south, many floodplains are composed of coarse gravels laid down by spring snowmelt floods during the late-glacial period. The effects of sea-level change go beyond the familiar landforms of emergent and submergent coastlines. In ways less easy to trace, it has meant a rise in base level for river long profiles, leading to aggradation (sediment build-up), so that many former river channels lie buried deep beneath their present courses; and it has meant the reoccupation of coastlines which for tens of thousands of years following the previous interglacial had been stranded up to 125m above sea level.

Is there evidence for past environmental change in your students' local or regional landscape? The question is easier to answer in Cumbria than in Cambridge or Camberwell, but well worth pursuing. How might these places have looked during glacial times – and how have they become as today?

A millennial timeframe also means appreciating the gradual pace of many natural changes. An excellent internet map exercise is to compare current features with the First Edition OS maps (www.old-maps.co.uk). It is difficult to find appreciable changes in river channel position, for example, even on some of our most dramatic meandering sequences. Average rates of change today are hardly visible over a hun-

Roman walls meet roches moutonées, Hardknott Fort, Cumbria. Photo: Chris Pyle.

dred-year period. Channels were probably more active at times in the past when river regimes were more seasonal and flows unregulated by people. The significance of 'hotspots' of faster erosion is also enhanced by understanding these typical rates of change. What should this mean for the way we teach landscape change?

## Event time: hours and days

Come rain, come shine, the rivers wear away their banks; the cliffs crumble; the glaciers slide. Or do they? Most land-forming processes are in reality highly episodic. Floods, storms, droughts and seasons are the drumbeat of landscape change, and our teaching and textbooks should convey these unpredictable rhythms.

Appreciating temporal variability is a higher-order skill than memorising the names of coastal erosion processes (for example). It can be made accessible at different levels:

- by identifying extreme events
- by considering the magnitude and frequency of different events
- by seeing how landform change involves a combination of both gradual and sudden processes.

The simplest way to add temporal texture is explicitly to identify the conditions which do most geomorphic work in a given environment. One suggested list is given in Figure 3. For example, rivers are jerky conveyor belts for sediment transport through the drainage basin; most of the stones on the channel floor will only be mobilised in the very largest storms.

The imagination is a powerful tool for understanding extreme events. During fieldwork, encourage students to envisage such an event. Most landscapes spend much time doing very little, and students need to understand the temporal sampling implicit in a single field visit. What would that stream be like on a stormy night? Rain lashing down, brown waters rising, stones rumbling in the churning torrent.

As well as photo and video, literature can be a highly effective way of bringing extreme events to life. Try Mark Twain's lively descriptions of floods and meander cut-offs in *Life on the Mississippi* (Twain, 1985) and the dramatic reconstructions of wave power in Junger's *The Perfect Storm* (Junger, 1998).

The magnitude–frequency concept develops this idea further. Does most landscape change occur in rare, large events (low frequency, high magnitude) or during everyday environmental remoulding (high frequency, low magnitude)? The truth lies somewhere in between for many British landscapes. High-magnitude events are more likely to dominate in areas of strong seasonality (e.g. major snowmelt) or tectonic activity.

| Environment | High-magnitude events |
|---|---|
| Rivers | Floods generated by rainfall and snowmelt |
| Coasts | Wind-generated storms<br>Spring high tides |
| Glaciers | Summer erosion episodes when warm-based glaciers slide, lubricated by meltwater |
| Weathering | Winter/summer and day/night cycles of freeze–thaw weathering |
| Landslides | Collapse triggered by saturation<br>Earthquake-triggered landslides |
| Soil erosion | Wind storms, rain storms, especially when soils are bare, e.g. after harvest |
| Desert | Sandstorms<br>Rainstorms |

*Figure 3*: High-magnitude events in different physical environments.

Students tend to focus on high magnitude landscape events which may occur in days or less, such as cliff collapse or volcanic eruptions. They are generally less good at appreciating the importance of the long-term processes which precede these – the centuries of weathering and undercutting of the coastal stack; the melting of the slowly subducting plate.

In this context, a helpful mnemonic to encourage students in particular to develop written explanations of landform change is 'SPEED', standing for *Sequence, Processes, Example, Evolution, Diagram*. *Evolution* is a prompt for students to mention:

- lengths of time ('the last ice age reached its peak 18,000 years ago')
- rates of processes ('Holderness is losing 2m per year, but chalk cliffs in Sussex erode at less than 2cm per year')
- whether change is gradual or intermittent ('the meander bend becomes gradually more pronounced over many years, until cut-off occurs during a flood').

The relationship between short and long-term landscape change is a problematic area for geomorphological researchers (Brunsden and Thornes, 1979; Lane and Richards, 1997). A focus on short-term events is at least a start in bridging the gap between the clean pages of the textbook and the muddy, murky world outside the window.

## Conclusion

This article was motivated by the observation that students often find it difficult to access the different magnitudes of time involved in physical geography. The division of timescales into millions of years, millennia and hours or days is one way of bringing a clearer understanding of these.

Much of physical geography is concerned with rates of change, and these issues of temporal depth and texture are important. An ultimate goal would be a generation of young people better able to unearth the complex timescapes embedded in the land. ■

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