The Earth in our hands

- how geoscientists serve and protect the public

3 LANDSLIDES

The where, when and how of landslides

After earthquakes, landslides are the most destructive process on Earth, killing hundreds of thousands of people in the last 100 years. Landslides occur when rock, soil or waste become unstable and move under the influence of gravity. As the material slides or flows, it may engulf buildings, bridges, roads and people. Landslides may be triggered by earthquakes, volcanic eruptions, heavy rain and flooding. Underwater landslides may also create tsunamis (see Note 6 in this series).

Specialists recognise different types of landslides depending on:

- material involved
- depth and style of movement
- shape of the surface along which material moves.

Two things are important in creating a landslide:

- development of a surface along which the slide can move
- changes in the balance of forces between those that resist movement and those that may drive it.

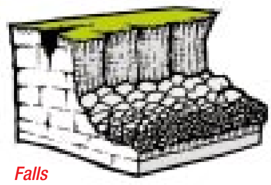
'After earthquakes, landslides are the most destructive process on Earth, killing hundreds of thousands of people in the last 100 years.'

When the strength of a soil or rock is insufficient to withstand the forces that can cause movement, a landslide occurs. Because water pressure in the spaces between particles in soil or rock reduces its resistance to sliding, prolonged or intense rainfall is the most common trigger. The sea or a river, nibbling into the foot of a slope, can remove support. Earthquakes may induce failure by changing pore pressures within soils or rock. Volcanic activity can push the ground upwards and cause landslides. Some eruptions melt ice at volcano summits and so cause catastrophic flows of mud ('lahars').

There are four different types of landslide:

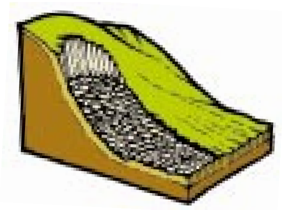
- **Falls:** collapse of steep (usually rocky) slopes where the initial movement is that of a falling object
- **Slides:** detachment occurs by sliding along an inclined surface
- **Flows:** water-saturated material moves like a liquid, sometimes at very high speed
- **Topples:** material becomes detached from an exposed vertical face with a rotational outward movement.

Landslides are often triggered by human activity, such as excavations cutting into the toes of slopes, making them unstable. Slides can also result from loading the top of a slope (e.g., with spoil tips, civil engineering embankments or buildings), by allowing water to drain uncontrolled into a slope, or not draining slopes properly after cutting, e.g., for roads or railways.



Falls

Slides



Flows

Topples

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Some examples

Steep-sided mountainous areas such as the Alps are prone to landslides. In October 2000, Swiss rescuers had to dig through 2m of mud and rocks to recover bodies buried in Gondo village, near the Italian border. A month later 1500 people were made homeless by a landslide in the village of Romagnano, near Trento, N. Italy.

On a far greater scale, a landslide caused one of the greatest natural disasters ever recorded. In 1556 a large earthquake in the Shensi province of China triggered the collapse of hills made of soft wind-blown soil called loess. Inside the hills was an intricate maze of tunnels where people lived. When the hills collapsed, the inhabitants were buried alive. The final death toll may have reached a million.

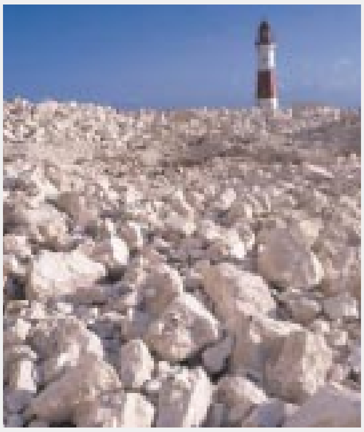
Pictured: The Holbeck Hall Hotel, built in 1883, was destroyed by this coastal landslip near Scarborough, Yorkshire, in June 1993

The worst landslide of the 20th Century occurred in Peru in 1970. Triggered by an earthquake, the unstable and overhanging peak of the Andean Huascaran Mountain collapsed and crashed down on the villages and towns on its flanks. There was no warning, and within minutes 18,000 people died, their towns and villages buried beneath the mud and rock. A similar event had killed 4000 people only eight years before.

The 1980 eruption of Mt St Helens was triggered by a landslide. Increased pressure from within the volcano caused the side of the mountain to bulge, steepening the slope. When this mass failed the sudden release of pressure caused the volcano to erupt explosively as gases trapped in molten rock bubbled out like beer from a shaken bottle.

Pictured: A woman died in January 2001 when her car was swept over the cliff by this landslide at Nefyn, Lleyn, N. Wales

Lethal landslides may also be triggered by humans. In 1963 a reservoir behind the then newly constructed Vaiont Dam (NE Italy) was being impounded. Movements were detected in the steep flank of the valley, but despite lowering the water level (which for complex reasons made things worse) over 2km of the valley wall slid into the reservoir in less than 30 seconds. A wave over 250m high surged up the valley side, overtopping the dam by 90m. Over 2000 people were killed as four villages in the path of the flood were destroyed.



Pictured: The Beachy Head rockfall of January 1999

Landslides in the UK

Fortunately large-scale landslides are rare. Although rainfall-induced landslides are relatively small they can nevertheless block roads and railways or affect the embankments on which they sit. Larger landslides that may move during very wet periods are well documented and occur along slip planes that have been in existence since the last Ice Age, which ended about 10,000 years ago.

The construction of cuttings and embankments, quarries and spoil heaps, can create severe dangers. In the Aberfan disaster (1966) 116 children and 28 adults were buried by a flow slide of mining waste from a tip above the village. The potential for similar disasters to occur has now been greatly reduced by improved methods of spoil heap construction, and by removal of older tips.

Many hundreds of small landslides resulted from the sustained wet weather in the autumn and winter of 2000/01. The soil on the slopes of a number of railway cuttings and road embankments became waterlogged and unstable. Sliding led to closure of coastal paths and blockage of roads and railways. No rail service operated between Darlington and York for more than two months while the lines were cleared of landslide debris. Five trunk roads were blocked; the Horseshoe Pass and the main road out of Rhondda (Wales) will remain closed for several months while repairs are made.

There are many thousands of ancient landslides in the UK, concentrated in particular areas such as the Pennines, Cotswolds, South Wales and many coastal areas. Although stable in dry periods, these ancient landslides can be reactivated by construction work or heavy rain. Between 80% and 90% of today's active landslides are the result of the reactivation ancient slides.

Pictured: Damage to a road caused by the Leith Hill landslip (Surrey), which was reactivated by heavy rainfall in December 2000. Photo: Mike Stephen.

Areas prone to landslides

Areas of the UK prone to landslides, with those highlighted below mentioned in the text.
Source - British Geological Survey National Landslide Database.

1 Mam Tor, Derbyshire
2 Lleyn
3 Aberfan
4 Black Ven, Dorset Coast
5 Beachy Head

The Pennine pass over Mam Tor, Derbyshire, has been closed permanently as continued slipping of interbedded sandstones and impermeable clays proved too much for road maintenance to cope with. The recent Leith Hill landslide (Surrey - picture, left) was only the most recent event in a long history of movement where poorly consolidated sands overlie impermeable clay.

A woman died and her husband was critically injured when their car was swept 10m down a cliff by a landslide at the village of Nefyn, Lleyn (N. Wales - picture, far left) on 2 January 2001.

Many areas of England's Eastern and Southern coasts are prone to landslides. Over 250,000 tons of chalk fell in two major cliff collapses near Dover, on 31 January 2001 and the following day. On 28 December 2000, nearly 1000,000m^3 of rock collapsed along a 2km stretch of coastline at Black Ven, near Charmouth (W. Dorset) continuing a process that began with sea level rise at the end of the last Ice Age. These processes will continue if predicted rises in sea level occur. West Dorset District Council is proposing £20 million worth of works over seven years to protect Lyme Regis from coastal instability.

Counting the cost

Direct costs of landslides include damage to agricultural land, loss of property and damage to buildings and communications. The indirect costs are those caused by delays and disruption, loss of economic activity and reconstruction.

Economic losses due to landslides in Japan alone account for US$4 billion annually and the aggregated annual economic losses in Italy, India and United States range from US$1 billion to US$2 billion. Given the pressures for increased urbanisation and the seeming inevitability of climate change, these losses are likely to rise.

Although the worldwide average number of fatalities per year caused by landslides is estimated at c. 600 (1971-74) this may be vastly exceeded by occasional events. For example, in the Venezuelan landslide of 1999, that year's most lethal natural disaster, 30,000 were killed and more than 100,000 made homeless. The economic loss was estimated at US$10bn (around 10% of the GDP of Venezuela).

In the UK, several million pounds are lost annually - mainly by the reactivation of ancient landslides. The costs of temporary road and rail closures can run to several thousands of pounds a day and repairs and stabilisation works often cost hundreds of thousands of pounds. Engineers estimate that repairs to roads in North Wales as a result of recent landslips will cost c. £2m.

Reducing risk

Geoscientists play a key role in managing landslide risk. Where a landslide has occurred, or where construction is planned, they investigate ground conditions with boreholes and various site surveys and laboratory tests in order to assess landslide risk and to formulate methods to prevent or minimise loss of life and property.

Remedial action includes earthworks to reduce slope angles, surface and groundwater drainage, and measures to provide support for slopes structurally.

Systematic mapping of ancient landslips is vital, as these may be reactivated by construction or drainage works.

The British Geological Survey publishes maps showing the location of some landslide areas. The Department for the Environment, Transport and the Regions (DETR) has sponsored several projects aimed at establishing more specialised methods of landslide hazard mapping suitable for use in the UK.

In order to construct hazard maps both geological and recent histories must be studied. Hazard maps highlight areas where there is no risk of landslides and development is safe, as well as areas where the risk is high. Between these two extremes, planners must negotiate a path based on sound science. Allowing development in safe areas and forbidding it in risky areas is relatively simple. For the rest, planners must be able to call on the best geological and engineering advice.

As an example of what can be done, Hong Kong is now the world leader in landslide hazard assessment. During the 1960s and 1970s 200-300 people were killed each year by landslides, due mainly to rapid growth in construction. In response the Geotechnical Control Office (with over 1000 staff) produced a set of controls and recommendations for planning and development and cut deaths by 90%.

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About these briefings

The Earth is a dynamic planet. It is active and productive, offering humanity enormous opportunities. However, living on it also presents us with many dangers; some of our own making.

In our interaction with the Earth, geoscientists are in the front line. They seek and find the raw materials we use for agriculture, roads, buildings, energy, water supply and all the industries that provide wealth and health.

Geoscientists help society understand natural hazards and mitigate their effects. Such dangers include floods, landslips, volcanic eruptions and earthquakes.

Geoscientists also help to minimise hazards we have created (or made worse) by our activities. These include subsidence, and the disposal of waste.

With their unique understanding of the immensely long time spans over which Earth processes operate, geoscientists help communities world-wide to learn how to use the planet's resources safely, wisely, and sustainably.

This series of Briefings is dedicated to bringing this role to public attention.

Further information and useful contacts

Bell, F. G., 1999. *Geological hazards: their assessment, avoidance and mitigation* (Spon, London. 648 pp)

McGuire, W. *Violent Earth: the threat from geohazards* (Geological Society of London, 2000).

Turner, A. K. and Schuster, R., 1996. *Landslides: investigation and mitigation.* Transportation Research Board, National Research Council, Special Report 247, Washington DC. ISBN 0 309 06151 2.

Managing ground instability in urban areas: a guide to best practice (Centre for the Coastal Environment, Isle of Wight Council)

PPG14 Development on Unstable Ground (http://www.planning.detr.gov.uk/ppg/ppg14/pdf/ppg 14.pdf)

Information, fact sheets and historic data including photos and video images can be found on various web sites linked to **www.geolsoc.org.uk**

Other useful sites:

http://www.dur.ac.uk/~des0www4/cal/slopes/index.html An overview of landsliding

http://www.cira.colostate.edu (Colorado University Flash Flood Laboratory)

http://www.info.gov.hk/hko/wservice/warning/landslip.htm Hong Kong Observatory Landslip Warnings

http://landslides.usgs.gov/ for good coverage of landslide matters

http://gldpsp.cr.usgs.gov/slumtrip/slumtrip.htm for a virtual fieldtrip around a landslide

http://www.bgs.ac.uk/ The British Geological Survey

http://www.homecheck.co.uk/ Check your property for landslide risk

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