Case study: Mam Tor Landslips, UK

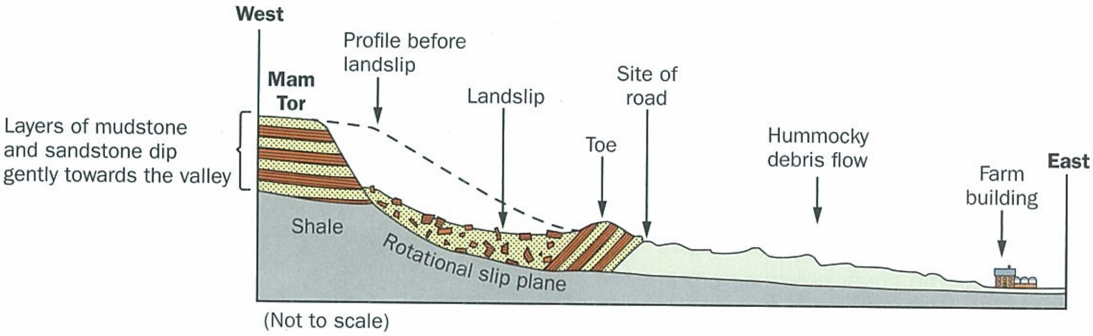

Fig. 9.32 Diagrammatic cross section through the mass movements at Mam Tor

Mam Tor is believed to have the largest landslip (slump) in Europe. It has totally physical causes: the mountain is composed of alternating permeable sandstones and impermeable shales which dip slightly towards the valley. The shales (very finely bedded mudstones) can be crumbled easily by a person's hand, so have very little strength. Their upper layer becomes slippery when wet and provides a lubricated layer for the rock above to slip down over it. About 3000 years ago, water saturated the sandstone beds adding weight, until the stress was so much that the rock mass broke along, and slid down a rotational concave slip plane. It left a 70-metre-high slip face with a typical arcuate shape and an up-tilted toe at its foot. There have been many slips since and they still occur. The most significant one was a hazard in 1979 when the major road between the cities of Sheffield and Manchester, which crossed the toe of the slip and had been repaired many times after smaller slips, was cut and abandoned, as it was no longer economic to repair it. Heavy vehicles now have to take a long detour.

The large scale of the slip is evident in Fig. 9.33. Each layer of the exposed remains of the road represents a repair after a slip. At least five are visible and in places the repairs are two metres thick. Broken shale is seen in the centre left where the material is still slipping, aided by a spring, which issues where the brown vegetation is. Wet shale is very slippery, so layers above easily slide over wet layers below them. In the face of the scar, composed of thin beds of permeable sandstone and shale, small mudflows indicate where the wet shale has turned back to the mud it once was.

Below the toe is a hummocky debris flow consisting of material from the landslip, which threatens to bury farm buildings in its path. The landslip and debris flow together are more than a kilometre long. The average flow movement is 250 mm per year, but is faster in wetter years. Recent research revealed that it has moved continuously by up to 500 mm per year since its formation.

Fig. 9.33 The slip face of the Mam Tor landslip

Fig. 9.34 The steep foot of the debris flow with the scar behind it

Case study: The Bingham copper mine landslide and rock fall

In April 2013 Bingham Copper mine in Utah, USA, experienced massive landslides when more than 135 million tons of rock and rubble moved three kilometres into the open pit. The slide was of solid bedrock that broke away from the upper half of the slope, together with waste rock from the mine that had been piled up above it, its weight putting additional stress on the slope. The rock slid down the shear plane, before free falling and flowing into the pit. The tremendous speed at which the rockslide hit the bottom caused a 2.5 magnitude earthquake.

Fortunately, slow movement in the side of the pit was noticed beforehand and sensors and radar monitored it for more than two months. The mining was stopped when movement reached 5 cm a day and the workforce was moved out of danger shortly before the landslide.

Although the landslide is thought to have been along a weak, thin, sedimentary layer within quartzite rock, possibly aided by an old fault line, it could not have happened without quarrying steepening the slope.

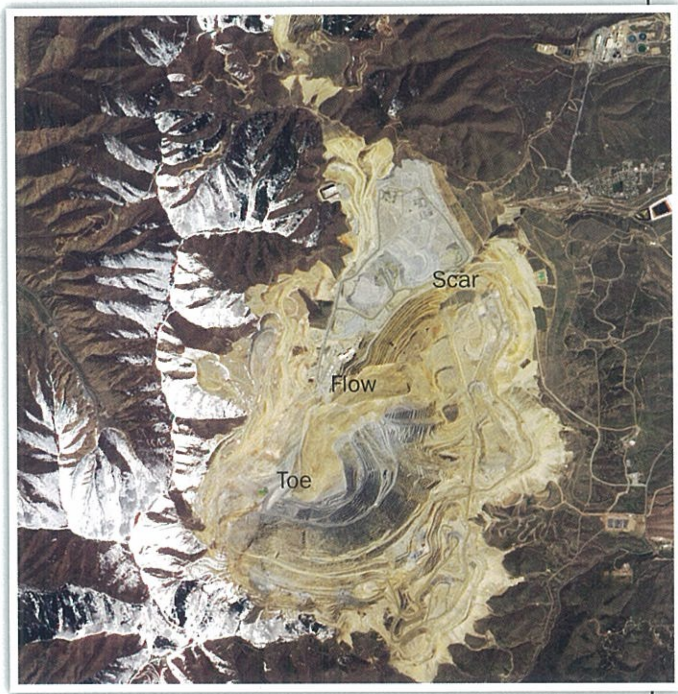

Fig. 9.36 Satellite image of the April 2013 landslide at Bingham copper mine

Fig. 9.35 The 970 metres deep Bingham Canyon Copper mine before the landslip. Excavated waste is piled up in the background

Effect on lives and property

The economic disruption made it one of the most expensive landslides, as the workforce had to be laid off while the mine was made safe. Buildings and the main access road were swept away and costly mining equipment crushed. The mining company, Kennecott Utah Copper, spent three million dollars on remote-controlled bulldozers to clear the rubble safely. Production for the year was reduced by about a half. The workforce had to be reduced, involving redundancy pay-outs. The local authority also lost a considerable amount in tax revenue, which the company would normally have paid.

This landslide shows that large rock slides caused by slope failure are predictable with considerable accuracy if warning signs are noticed and monitored. However, this slide had not been expected to fall as far as the lower part of the open pit.

Case study: Debris flows and landslides in Vargas, Venezuela

This area suffered the highest death toll from mass movements in recent times in December 1999 when approximately 30 000 people died in towns along the Caribbean coast. The actual number is unknown because many people were swept out to sea. Mass movements funnelled down steep valleys on the north side of the Sierra de Avila mountain range, which runs parallel to the coast, onto the towns below.

Factors influencing this mass movement hazard were both natural and human:

- The coastal area had become densely populated and mainly urban, despite being frequently affected by slides and flows. No one survived in the many shanty towns where flimsy shacks were easily destroyed.
- Many of the coastal towns were built on old debris flows.
- The very steep mountains behind the narrow coastal strip have many slopes steeper than the angle of repose for loose materials.
- The metamorphic rocks have planes of weakness along which landslides will occur where they are inclined towards lower areas.
- December 1999 was extremely wet, as 911 mm fell in 52 hours, equivalent to a year's average rainfall.
- The slopes had lost their protection and stability because trees had been cleared by local people.

The landslides and their effect on lives and property

Thousands of landslides triggered by the rain affected a 60 km stretch of coast. As the rock and soil slid down the mountains, added water turned them into debris flows, with high densities of rock, including large boulders, and mud. These moved very fast and were very destructive.

After the town of Caraballeda had suffered a similar experience in 1951, the channel that had been followed by the debris flow then was lined with concrete in an attempt to guide any future flow safely to sea. However, the 1999 flow left the channel at a bend and ploughed through the town, destroying houses and the first two floors of apartments. As further landslides were possible, 100 000 survivors were evacuated immediately.

All public services were lost from many areas and rebuilding has been slow. Thousands were still homeless nine years after the event and the value of surviving property had fallen by 70 per cent.

10. Comment on the degree of risk perception in the Vargas area of Venezuela in 1999.

Impacts of mass movements on lives and property

Many of the impacts on lives and property are similar to those of tectonic hazards but usually on a smaller scale, so they do not usually attract overseas aid.

11. Explain why the aftermath of a disaster is likely to be much worse in an LIC than in an HIC.

12. Describe the mass movement shown in Fig. 9.37. State the evidence for the type of movement. Explain why it was an unstable slope and the likely reasons for the movement.

Fig. 9.37 Mass movement destroying a car park built on sand and clay on the south coast of the UK

Fig. 9.38 Housing in a part of Quito, in the Andes of Ecuador, where many of the slopes are loose volcanic ash and landslips are a hazard

Fig. 9.39 This landslip near Zermatt, Switzerland, blocked 100 m of the road and only railway route from the main valley in 1991

13. Describe the effects of mass movements on lives and property.

Prediction, hazard mapping and monitoring of mass movements and perception of risk

Prediction and monitoring

Warning signs that a mass movement is likely to occur include cracks resulting from tension in buildings and in the ground, tilted structures, bulging walls and steep slopes, especially with deposited material above them. Arcuate-shaped cracks on ground above cliffs indicate the site of future slumps. Once noticed, the slopes can be closely monitored for change.

Large moving masses like Mam Tor's landslip are monitored by GPS and laser surveys to determine the amount of movement each year of a number of fixed markers on the surface of the landslip. GPS measures distance and direction very accurately. Arrows are then drawn on a map to show the direction and length of annual movements. By comparing movements with rainfall, it may be possible to determine how much water the slope can hold without moving.

Rainfall and changes in soil moisture are also monitored. Measurements in boreholes indicate changes in groundwater content and the pressure it exerts; the weight of additional water can trigger mass movements. Many drainage pipes have been placed in the Mam Tor landslip to remove water and reduce movement.

Delicate instruments such as tiltmeters, which record the amount of tilt occurring, and strainmeters, which record changes in the crustal strain to a very high degree of precision, are used in areas with active faults.

NOAA and the USGS operate a debris flow early warning system in California when heavy rain falls by monitoring areas where wildfires have removed the protective vegetation cover.

Landslide hazard mapping

Landslide hazard assessment maps are drawn up using factors that affect slope stability and knowledge of previous movements. Rocks are classified as having high, medium or low susceptibility to landslides and the degree to which they have been affected in the past is similarly classified. Maps of the routes taken by rock falls in mountain areas reduce the chances of building in their paths.

In the USA, geologist engineers are trained to recommend actions to mitigate for geological and geomorphological hazards and trained planners help local communities to undertake what is necessary to reduce the dangers. Mitigation measures are described in Chapter 3.

Perception of risk from mass movements

The degree of risk perceived varies according to distance from the site of the hazard, the amount of knowledge a person or group of people have and the length of time since a hazard last occurred. Insurance companies have a clearly defined assessment of the risk, whereas a visitor to the area may have no knowledge of risk at all. Government agencies are likely to be well informed and to take responsibility for educating the public about any risk in the locality. Private landowners also have a responsibility to inform the public about, and protect them from, any risks on their land. In the USA warnings are issued during national and local weather forecasts.