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Future Geological Hazards

Most of geology, like archaeology, is concerned with the interpretation of past events. There is, however, a branch of geology concerned with the prediction of geological events in the future: Geological Hazard Assessment tries to use geological information to predict the location, timing and size of future geological events that could affect people. It is essential to be precise in these predictions as they cannot otherwise be used constructively.

The term geological hazard is here taken to include both geological events whose occurrence is little influenced by human activities, such as earthquakes, and those commonly provoked by humans, such as landslides. In both cases the effects of these phenomena are strongly influenced by human activities. Earthquakes do not generally kill people directly, but they frequently cause buildings to collapse or catch fire. Some of these hazards have already been discussed briefly in earlier chapters.

Volcanic eruptions

Volcanic activity can produce many different geological hazards, including lava flows, explosions, ash falls, ash flows and lahars (mud flows). Some earthquakes and tsunamis are associated with volcanic eruptions; they will be discussed separately below.

Non-explosive eruptions of lava can cause considerable destruction of forests, fields and buildings, but they are not usually dangerous to people as most lavas move slowly. Flows of andesite, the most common lava composition in the Aegean, will typically move only a few tens of metres each day.

Explosive eruptions, however, can cause considerable destruction, especially when accompanied by hot volcanic ashes. A particularly dangerous form of ash-flow is the *nuée ardente*: clouds of hot, sometimes glowing, ash and gases roll down the sides of the volcano at speeds of up to several hundred kilometres per hour engulfing and incinerating anything in their path. They can even cross the sea.

Another dangerous type of flow is a lahar or mud-flow, which forms when ash on the sides of the volcano is combined with rainwater, lakewater or melting snow, to from a thick, commonly hot, mud. Lahars can flow rapidly down valleys, destroying anything in their path and burying the landscape where they settle. The resulting rock can be very hard and difficult to distinguish from ash-flow deposits.

An important volcanic hazard is the gas produced by eruptions: the amounts are commonly not related to the quantity of lava or ash produced. The submarine eruption of the Colombo Bank volcano (7 km north-east of Thera) in AD 1650 produced large amounts of gas which killed 50 people and 1,000 animals on Thera.

Volcanic activity in the Aegean region during the last 5,000 years is thought to have been confined to the South Hellenic volcanic arc.[258] On the Thera island group volcanism since the famous Minoan eruption 3,500 years ago has occurred in the centre of the caldera, on the islands of Nea and Palaea Kameni. There has been little loss of life as these islands have been sparsely inhabited or uninhabited. The time interval between eruptions has been decreasing for the last 2,000 years, and we can expect another within the next fifty years, although it is unlikely to be very explosive.[88] Explosions on Nisyros about 100 years ago produced a new crater, but no lava or ash was produced. However, it is believed that Nisyros has potential for major explosive activity in the future.[254]

Earthquakes

The Aegean region has the highest incidence of earthquakes (seismicity) in Europe.[266] Most of these earthquakes are ultimately connected to large-scale tectonic movements, such as the Hellenic subduction zone and the regional crustal extension. There are many ways of expressing potential earthquake risk.[36, 167, 202] The most useful, from a cultural point of view, is the maximum observed earthquake intensity (hereafter maximum intensity; Fig. 17.1), as this expresses the potential destructiveness of an earthquake in that region (see Chapter 1).[120] Unfortunately such data is only available for Greece.

The high maximum intensity of the Ionian islands and south-western Peloponnese is due to the subduction of the ocean floor (albeit thicker than normal) beneath the Aegean sea. The ocean floor must bend to go down the subduction zone, and this movement causes the earthquakes. High maximum intensities on Crete and Rhodes are also related to the same plate motions, but here the direction of movement is almost parallel to the Hellenic arc, and hence the two plates slide past each other along transform faults.

Most of the other zones of high maximum intensity are related to crustal extension north of the Hellenic arc: this has produced a series of approximately east/west grabens. There are still important movements on the Corinthian and Euboean gulf grabens, hence their high maximum intensity. The high intensity of many of the island in the eastern Aegean is probably related to grabens that stretch from the Aegean sea itself deep into the mainland.

Just before many earthquakes there are changes in the environment which have been used to try to predict the timing of the earthquake. The water level in wells changes and springs may dry up as the stress builds up on the fault. The amount of gas in these waters may change also. The general level of ground noise (very small earthquakes) may change before the earthquake. Lastly, many people have noticed unusual behaviour of animals in the period before an earthquake. This may be related any of the effects listed above or to changing magnetic and electrical fields. As yet there has been little success in the prediction of most earthquakes.

Tsunamis

Tsunamis are extraordinary ocean waves which can become very high close to land. They have been called tidal waves, but this is a misnomer as they have nothing to do with the tides. Each tsunami typically has only a few cycles of rising and falling water, but can be reflected off the coast and hence repeated. In the open sea tsunamis are not very high, typically less than 50 cm, travel fast at speeds up to 200 km per hour and have a very long wavelength, of the order of tens of kilometres: hence they are not noticed generally by people in boats. Near to the coast their character changes dramatically: as the sea becomes shallower the wave slows down and energy is concentrated towards the surface. The height of the wave increases, and may exceed 50 metres. Such waves can be extremely destructive of coastal communities.

Most tsunamis are produced by undersea earthquakes (see above). Earthquakes change the height of parts of the sea-bed. These moving blocks then generate a wave in the overlying water. In the Aegean region tsunamis are mostly produced by shallow (less than 70 km deep) earthquakes with magnitudes greater than 6.5 on the Richter scale.[192] Even then only 25% of the earthquakes in the Aegean region of this type produced tsunamis and of those only 25% were destructive.

Tsunamis produced by volcanic eruptions are commonly rather small, although the submarine Colombo Bank eruption of AD 1650 produced a tsunami up to 20 m high on the coast of Thera. This event may have been caused by collapse of the roof of the volcano. The great Minoan eruption of Thera is though to have been closely associated with a major tsunami that devastated settlements on the northern shore of Crete (see Chapter 15).[14, 203]

However, this tsunami must have been produced by a tectonic earthquake at about the same time and not by the eruption itself.

Finally, tsunamis can be produced by underwater landslides. These occur when sediments deposited in the sea adjacent to the mouth of a river become too steep and start to slide. These underwater slides can have an enormous extent. A slide of this type in the western part of the Gulf of Corinth in AD 1963 produced a tsunami 5 m high.

Although the tsunami hazard is generally low in the Aegean region there are coasts more affected by tsunamis (Fig. 17.1). These are areas near earthquake zones where the shallowness of the sea-floor and the shape of the coastline may augment the height of the tsunamis. Ten such zones have been found, to which must be added those areas affected by volcanism, such as Thera.

Finally, if you are on the beach and the level of the sea suddenly goes down, do not stop to admire the new landscape, but run for your life to higher ground, as a tsunami may be on its way!

Landslides

The term landslide refers to a large number of different geological events, but all involve the movement of solid materials without the participation of large amounts of water, such as in

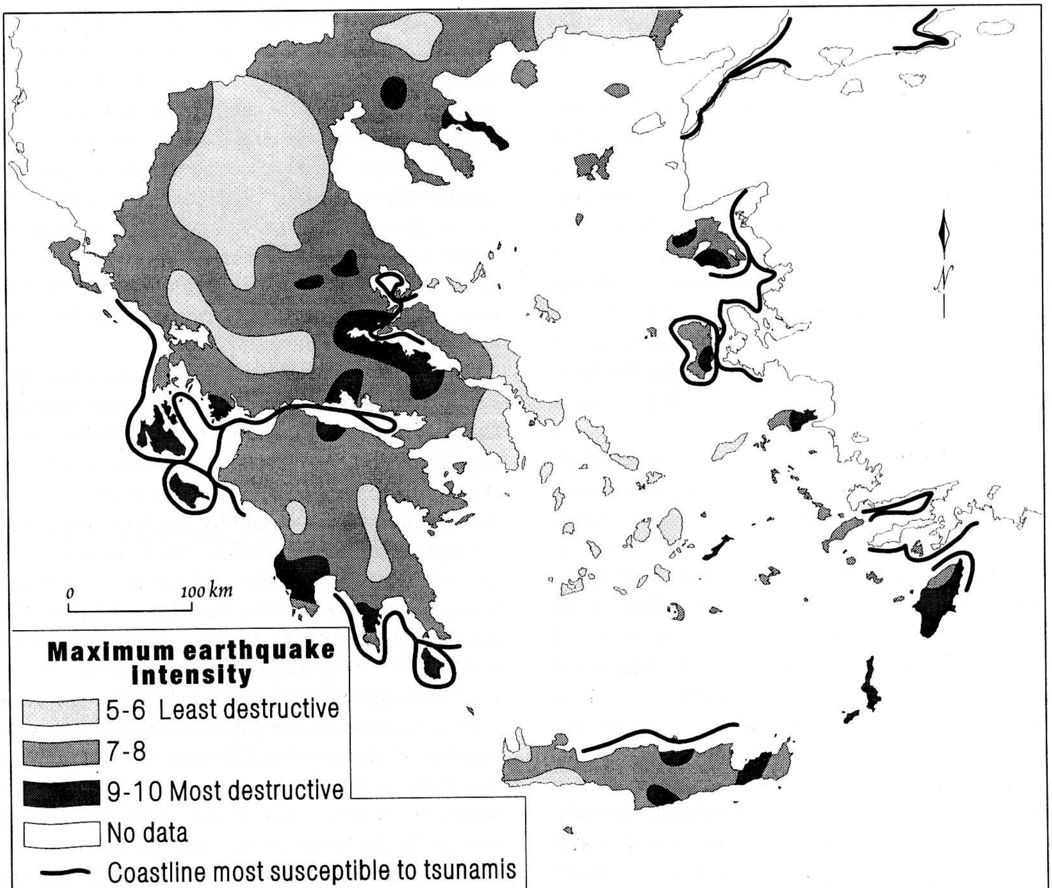

Fig. 17.1. Maximum observed earthquake intensity and coasts most commonly affected by tsunamis (after 120 and 192).

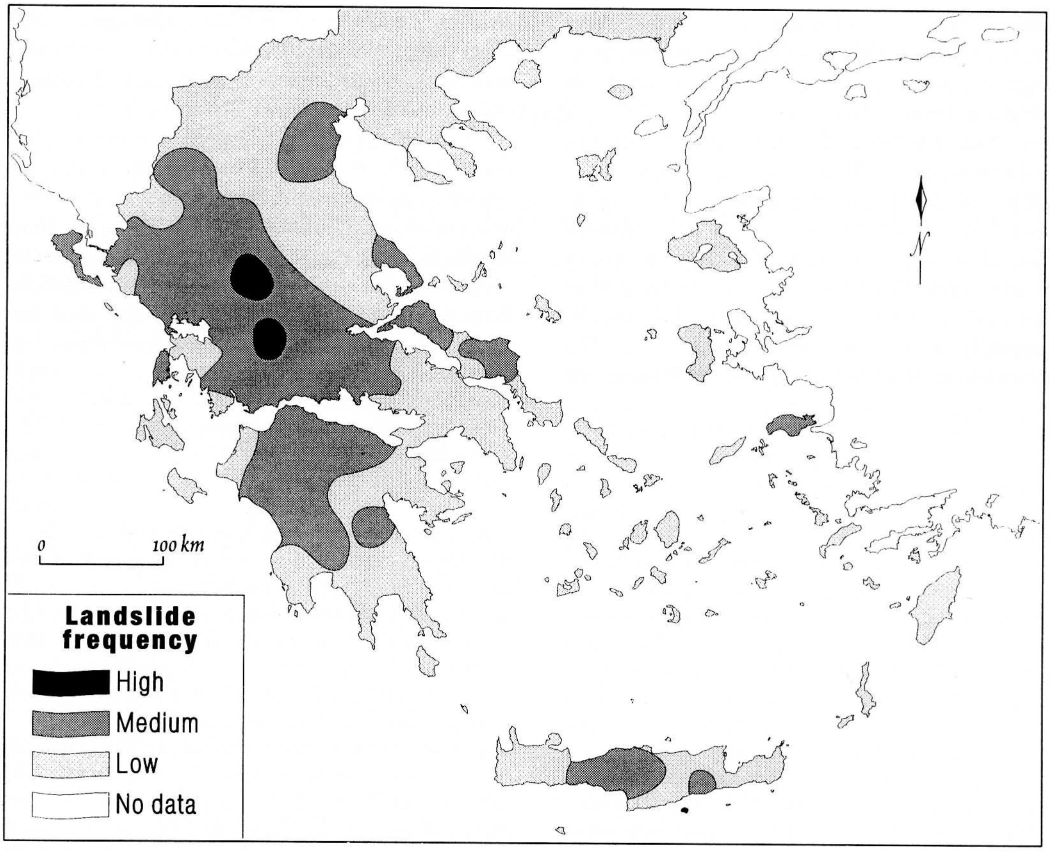

Fig. 17.2. Landslide frequency (after 144).

a river. Movements can be fast, as in the case of a rock-fall or rock avalanche, or slow, as in the downward creep of soil or blocks of rock a few metres a week or year. The movements can disrupt the rock into small pieces or the whole hillside can rotate away as a single block.

Landslides are fairly common in Greece, but most are quite small or surficial.[144,145] However, about 500 villages have been relocated during the last 30 years as a result of actual or potential landslides, and considerable damage has been done to roads and other structures. The occurrence of landslides is principally controlled by three factors: climate, relief and local geology.

Many landslides are triggered by rainfall, human activities and earthquakes. Saturation of rock masses with water increases their weight and lubricates the potential failure surface. Landslides tend, therefore, to occur in winter when rainfall is highest, and in the regions of greatest precipitation – the mountains of the west and central regions. Formation of ice can expand cracks and wedge off blocks of rock.

Local relief is an important factor: the average elevation of landslides in this region is 500 m, and the average slope is 25°. Relief is strongest in western and central Greece, because this is where active thrust faulting is now occurring. Over 80% of landslides occur in the western and central parts of Greece, because of the combination of relief, rainfall and geological conditions (Fig. 17.2).

The geological environment of landslides is rather different in the western and eastern parts of Greece. Although in the west they occur in rocks of widely different ages, the most dangerous are Late Cretaceous limestones and overlying flysch sediments. The limestones have thin, tightly folded beds and hence are easily fractured. The flysch contains weak rocks such as shale and clay. Another detrimental factor in this region is the common siting of villages close thrust faults, because of the availability of water. The scree slopes that commonly cover such faults can slide easily, especially when there is an earthquake. The situation in the east is quite different: the basement rocks are less folded, and many comprise thick, strong beds. Most of the landslides, therefore, occur in the fine-grained Neogene sediments and the loose Quaternary rocks.

Human activities frequently enhance the possibilities of landslides: tree roots can tie slopes together, and deforestation removes this restraint. Undercutting of slopes for road or house construction increases the apparent slope, and hence the possibility of a landslide. Irrigation and dam construction can load the rocks with water and produce landslides (as well as earthquakes).