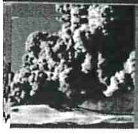

- **Pyroclastic flows (also known as nuées ardentes):** Very hot (over 800°C), gas charged, high-velocity flows made up of a mixture of gas and tephra. These usually hug the ground and flow down the sides of the volcano with speeds of up to 700 km per hour. The Roman city of Pompeii (Italy) was destroyed in 79 AD by such flows from Mt Vesuvius.
- **Lava flows.**
- **Volcanic gases:** These include carbon dioxide, carbon monoxide, hydrogen sulphide, sulphur dioxide and chlorine. In 1986, carbon dioxide emissions from the lake in the crater of Nyos (Cameroon) killed 1,700 people.

Secondary effects:

- **Lahars (volcanic mud flows):** Melted snow and ice as a result of the eruption combined with volcanic ash forms mud flows that can move down the course of river valleys at high speeds. In 1985, a lahar destroyed the Colombian town of Armero after an eruption of the volcano Nevado del Ruiz. Only a quarter of the 28,700 population survived.
- **Flooding:** When an eruption melts glaciers and ice caps, serious flooding can result. This happened in Iceland in 1996 when the Grimsvotn volcano erupted.
- **Volcanic landslides.**
- **Tsunamis:** Sea waves generated by violent volcanic eruptions such as those formed after the eruption of Krakatoa (Indonesia) in 1883. Tsunamis from this eruption are estimated to have killed 36,000 people. (For details on tsunamis see the section on seismic hazards, pages 203–204)
- **Acid rain:** Volcanoes emit gases which include sulphur. When this combines with atmospheric moisture, acid rain results.
- **Climatic change:** The ejection of huge amounts of volcanic debris into the atmosphere can reduce global temperatures and is believed to have been an agent in past climatic change.

Volcanic events become hazardous when they impact upon people and the built environment, killing and injuring people, burying and collapsing buildings, destroying infrastructure and bringing agricultural and other economic activities to a halt.

Management of the volcanic hazard

- **Prediction:** Locating volcanoes is straightforward, but it is very difficult to predict when activity will take place. The already mentioned Colombian volcano, Nevado del Ruiz, came to life in late 1984 with small-scale activity but volcanologists, although they knew the danger a major eruption would pose to the surrounding area, were unable to predict when that major event would take place. As the volcano continued with small-scale activity for several months, people stayed and worked in the area. When the final violent event took place, almost all the population had remained and devastating lahars swept down several valleys, killing over 20,000 people.

  A study of the previous eruption history of any volcano is important, along with an understanding of the type of activity produced. There are several ways in which volcanologists are seeking to give a fairly accurate timing for an eruption. These include the monitoring of land swelling, changes in groundwater levels and the chemical composition of groundwater and gas emissions. It is also possible to monitor seismic activity looking for the shock waves that result from magma moving towards the surface, expanding cracks and breaking through other areas of rock.
- **Protection:** In this case, protection usually means preparing for the event. Monitoring a volcano, as shown above, will possibly identify a time when the area under threat should be evacuated. The governments of several countries with volcanoes, such as New Zealand, have made risk assessments and from them produced a series of alert levels in order to warn the public of the threat.

Geological studies of the nature and extent of deposits from former eruptions and associated lahars and floods may also provide evidence for hazard assessment. Following this, it is possible to identify areas at greatest risk and land use planning can be applied to avoid building in high risk areas. Figure 5.15 shows the risk assessment made for the area around Mt Rainier (part of the Cascade Range in the USA), one of the most studied volcanoes in North America, which is not surprising as 3.5 million people live and work in proximity to it.

Once the lava has started to flow and is fairly viscous, it may be possible to divert it from the built environment. On Mt Etna in Sicily, digging trenches, dropping blocks into the lava stream and using explosives has been successful in slowing down the flow and, in some cases, diverting it. In 1973, the inhabitants of Haeimaey (Iceland) were able to divert a lava flow by pouring seawater on the front so it would quickly solidify. In parts of the Hawaiian Islands, barriers have been built across valleys to protect settlements from lava flows and lahars.

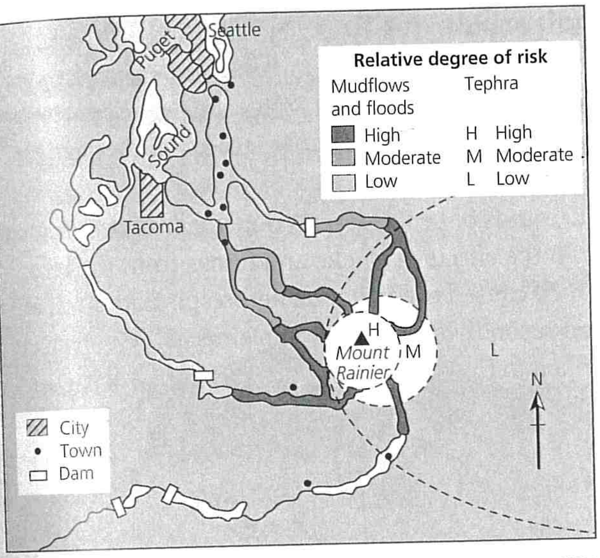

Figure 5.15 Risk assessment of Mt Rainier, Cascade Range, USA

Many devastated areas in poorer countries require aid for considerable periods of time as volcanic events can be prolonged and very damaging to the local economy. Such aid is needed for monitoring, evacuation, emergency shelters and food, long-term resettlement of the population and the restoration of the area's economic base and infrastructure.

Responses can also be seen as both short and long term. Immediate responses are those which take place just before or after the volcanic event such as warnings, evacuation and attempts to stop lava flows. In the long term, responses include the monitoring of a volcano, research into finding new methods of prediction and even building barriers in anticipation of the direction of lava flows and lahars.

Volcanic events

The eruption of Mt Nyiragongo, Congo, January 2002

Mount Nyiragongo lies in the Virunga Mountains in the Democratic Republic of the Congo (Figure 5.16) and it is associated with the African Rift Valley.

The main crater of the volcano is 250 m deep, two kilometres wide and often contains a lava lake. Since records of the area began in the nineteenth

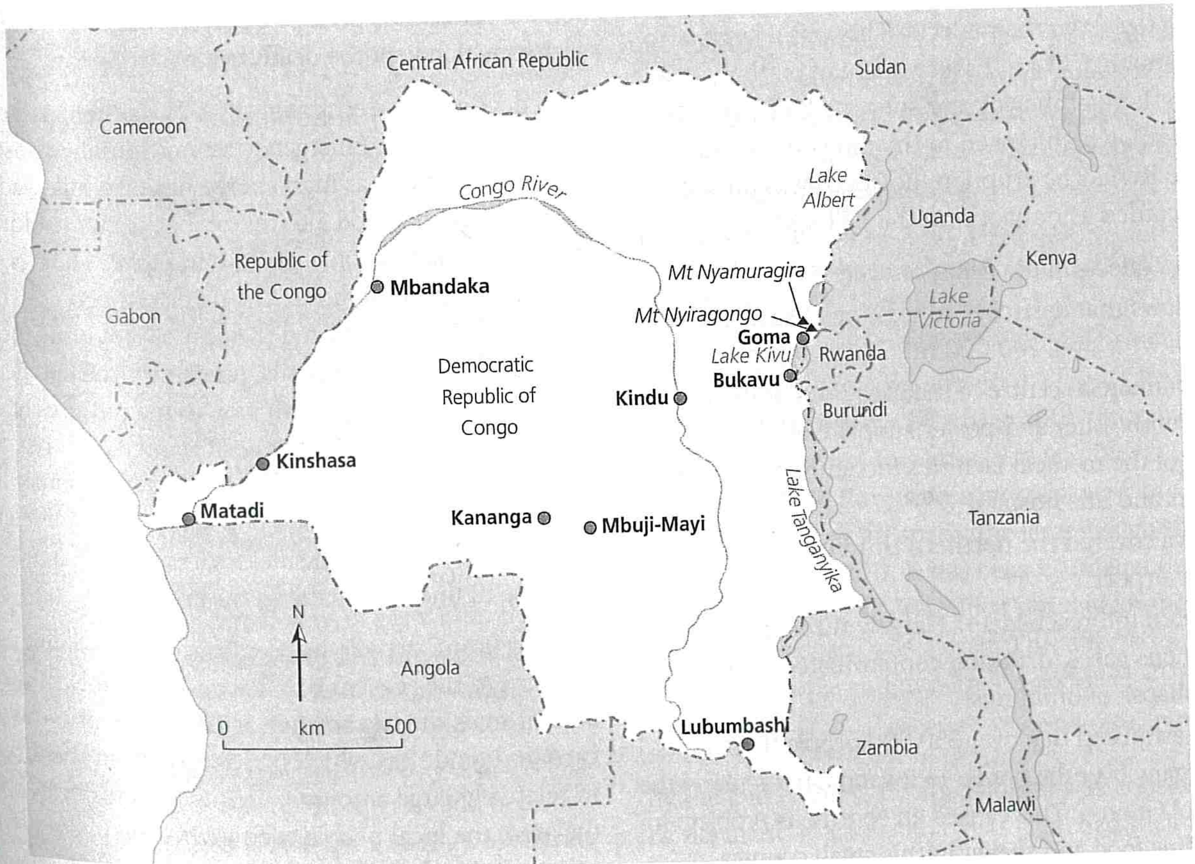

Figure 5.16 The location of Mt Nyiragongo