Geohazards

Is volcanic eruption predictable? (*January 2002*)

Inhabitants of the eastern Congolese town of Goma have suffered three disasters in 8 years - the aftermath of the Rwanda massacres of 1994, the episodic war centred on control of Congo's immense physical resources since 1995, and now the devastating eruption of the Nyiragongo volcano that threatens half a million people. The last is a grim reminder of the difficulty in predicting geological disasters, and follows closely on claims that spotting impending volcanic eruptions is now "sorted" (Marshall, T. 2002. There she blows. New Scientist 12th January 2002, p. 29-31; Horizon, BBC2 17th January 2002, Volcano Hell). There are four phenomena that have been investigated as signifying threats of eruption. Most obvious are increases in temperature at existing vents that can easily be measured using infrared images from daily orbits of meteorological and environmental satellites. A remote sensing approach is so cheap that it ought to be applicable world-wide, yet most devastating eruptions emerge with insufficient time following thermal signs for emergency evacuations to begin. Fundamentally the clearest evidence that magma beneath a volcano is rising is that the edifice swells. Interferometric radar can detect millimetre-scale changes in surface topography, and such pre-eruption inflation is detectable (see *Interferometric radar and faults of the Mojave Desert*, December 2001). However, the lengthy periods between overpasses by radar imaging satellites (two images are a minimum for radar interferometry), and the need for immensely powerful computer processing has rendered this approach one of retrospection rather than early warning. Individual volcanoes' ground motions, and the minute changes in their gravitational potential that also relate to magma movements can be monitored at permanent ground stations, but apart from a select few on which volcanologists conduct long-term research, some thousands of dangerous volcanoes go unwatched.

Parts of Goma, Democratic Republic of Congo, inundated in 2002 by fast-flowing lava from Nyiragongo (in distance); note: image in false colour. (Credit: One Planet Education Network)

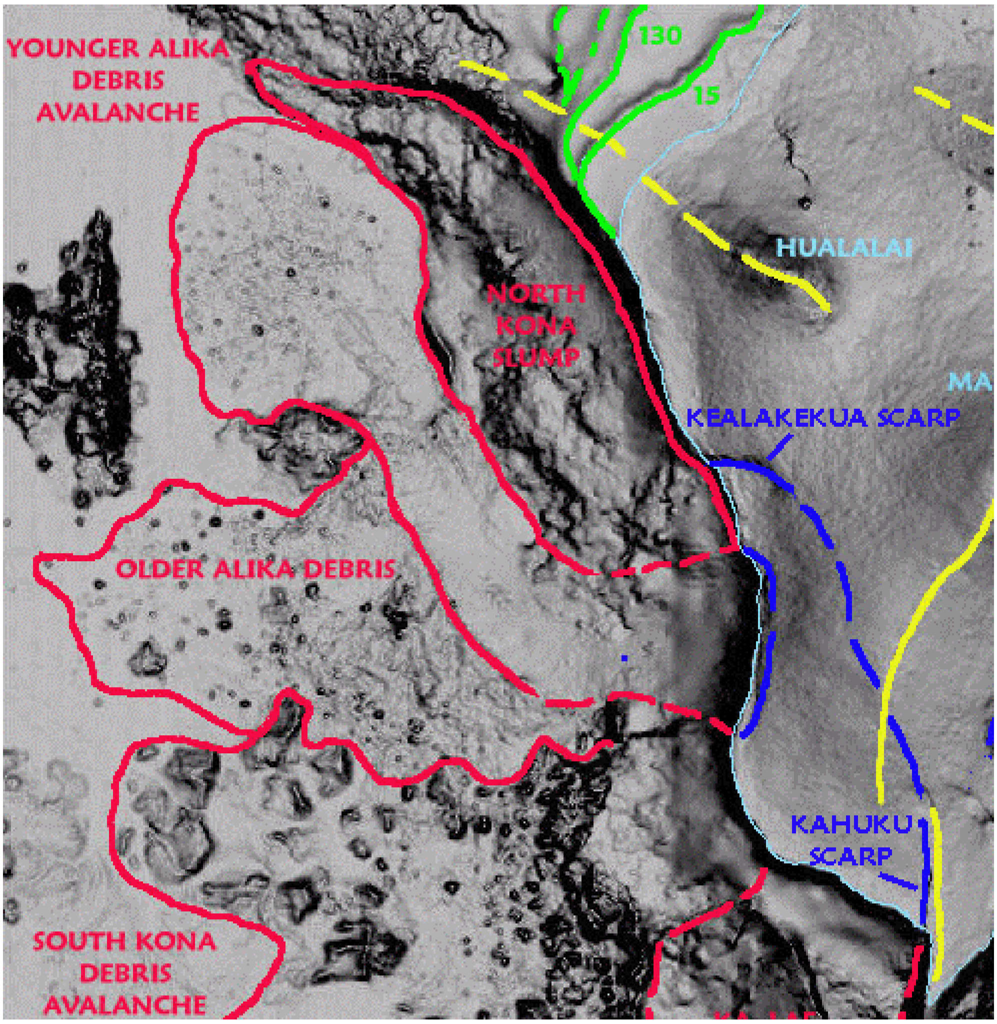
The central theme of both the Horizon programme and the *New Scientist* article was a method based on monitoring low-energy seismicity emanating from magmatic movements. The observation of low-frequency, long-period seismicity by US Geological Survey volcanologists while Mount St Helen's was active in 1980 is probably connected to a natural resonance of each volcano as magma begins to move. Follow-up work at a small number of volcanoes has fine tuned such signals to the timing of eruptions, with sufficient confidence levels that believable warnings are possible. Believability is essential, for a mass evacuation followed by no threat to life could deter future responses by endangered people, on the "crying Wolf" principle. Mexican volcanologists were able to give two day's warning of the immense eruption of Popocatapetl on 18th December 2001, and evacuation prevented any loss of life. However, none would have been threatened, as it happened, for the eruption on the vast massif was far from habitations. Yet so spectacular were the fire fountains, that the exercise served to habituate locals to take such warnings very seriously indeed.

Nyiragongo volcano and its companions in the western African Rift regularly erupt low-viscosity lavas that flow quietly over long distances. They pose less violent threat to life than explosive volcanoes, such as those around the Pacific rim, but chance may channel such flows through inhabited areas disrupting communications and destroying buildings. Many of the 45 confirmed deaths in Goma arose when people tried to rescue belongings from their engulfed homes. The current Goma disaster is not one primarily of volcanic origin, but of poverty, poor communications and fragile provision of basic necessities, such as unpolluted water and emergency food supplies. After the 1994 humanitarian tragedy, and threats from Nyirangongo to the 800 thousand Rwandan refugees camped around Goma, the US Geological Survey and Japanese volcanologists set up seismometers to monitor the volcano's internal activity. Five days before the eruption, only two remained functional, yet transmitted signs of abnormal seismic activity (Clarke, T. 2002. Seismic rumbling foretold Congo eruption. *Nature*. v. **415**, p, 353; doi: 10.1038/415353a). Despite that, warning did not get through to Goma in time for local people to flee, or any assistance to arrive. There was nowhere for the victims to go and relief followed only days and weeks after the event, when the damage was done. The same fate hangs over millions of people living in volcanic areas in poor countries - they favour such risky areas to live because of the richness of soils and the encouragement of rainfall by high mountains.. As things stand, communities in volcanic areas of North America, New Zealand, Japan and a few of the richer 3rd World countries stand a good chance of escaping magmatic events because of believable warnings and efficient communication. For the majority, survival is a matter of luck alone.

Collapsing islands (*February 2002*)

Lots of attention has focused on impacts by Earth-crossing asteroids and comets as potential causes of economic and biological catastrophe, as too on hazards from climate change induced by major volcanic activity. To these fears can be added the effects of tsunamis, but not those caused by even the largest conceivable earthquake. Oceanic islands can fall apart by a process that is identical to, though vastly bigger than a landslip, thereby displacing their equivalent volume of seawater.

Britain has experienced the effects of tsunamis driven by collapse of part of the Norwegian continental slope, triggered by massive methane release from gas hydrates in sea-floor sediments. The last of these was when its shores were colonised by Bronze Age people, and left its mark in the form of high-level sand beds on the flanks of eastern Scotland's firths. The north-east part of the Isle of Skye preserves spectacular results of landslips of volcanic rocks, that represent the largest mass movement known in Europe. However both examples are dwarfed by features off the Hawaiian islands, that sonar has revealed. There are some 70 debris fields that date back to 20 Ma, some of which contain up to 5 000 cubic kilometres of rock from collapses of the flanks of the growing volcanic islands. Surveys around other large oceanic islands of volcanic origin suggest that such flank collapses occur around every 10 000 years. Movement of masses so large involves energy equivalent to the world's arsenal of nuclear weapons, so flank collapses are comparable in magnitude with moderately sized impacts. They would generate tsunamis waves as high as 30 metres, which would devastate coastal areas around large ocean basins.



Sonar image of massive blocks on the ocean floor west of Hawaii's "Big Island" (Image ~80 km across). (Credit: Ken Hon, University of Hawaii at Hilo; Geology 205 course notes)

One area on Hawaii is indeed liable to collapse, and in November 2000 it moved, only to stop short of a full collapse. Geoscientists from the US Geological Survey and Stanford University used GPS receivers to monitor movement on the southern flank of Kilauea, and after a series of barely detectable earthquakes they recorded slips of up to 6 centimetres per day (Cervelli, P. *et al*. 2002. Sudden aseismic slip on the south flank of Kilauea volcano. *Nature*, v. **415**, p. 1014-1018; DOI:10.1038/4151014a). Careful analysis of many kinds of motion sensors suggests that the moving block sits on top of a low-angle fault or detachment, that may eventually carry the block seawards to unleash tsunamis. It is uncertain how much warning there would be of a fully fledged collapse, but is does seem sensible to establish such monitoring on active volcanic islands in the world's oceans. Since expansion of humanity following the retreat of the last continental ice sheets would have largely been along coasts, with their easy terrain and abundant food supplies, tsunamis would have been an ever present, but never suspected risk. Britain's example is minor in comparison to those that would stem from flank collapses, and perhaps the near-miss of November 2000 may encourage searches for the scars that huge tsunamis generate in relation to maritime archaeological records.

Prediction of earthquake periodicity founders (*September 2002*)

In a number of well-studied areas of chronic seismicity it appears from historical records that earthquakes recur with regularity. If that was so, it might be possible at least to prepare to throw many methods of detecting imminent movements at such areas, when they are "due" to go off. The theory behind time-predictability is that earthquakes relieve tectonic stresses along faults, and that if the forces are maintained, stress builds up again, to be released after a roughly fixed time (the same might apply to volcanism where magma production stays constant). A corollary is that high-magnitude events have longer periodicities than those lower on the Richter scale. One of the best cases thought to support this view is a 25-km stretch of the San Andreas Fault near Parkfield in California. The area has had 5 or 6 earthquakes greater than magnitude 6 since 1857, roughly every 22 years, the last being in 1966. There ought to have been one in 1988, but the poor statistics give an uncertainty either way of 10 years. By now there should have been a magnitude-6 event in the area, but it hasn't happened. Jessica Murray and Paul Segall of Stanford University have analyzed the physics of the last event, and of the period that followed it. (Murray, J. & Segall, P 2002. Testing time-predictable earthquake recurrence by direct measurement of strain accumulation and release. *Nature*, v. **419**, p. 287-291; DOI: 10.1038/nature00984).

Their work involved using precise geodetic measurements obtained over the last four decades to assess the 1966 Parkfield earthquake's size, which combines the movement then along the San Andreas Fault, the area involved in the slip and how "stiff" the crust is locally. Comparing this with geodetic data since then suggests strongly that the strain released in 1966 must have recovered between 1973 and 1987. They have shown that another Parkfield earthquake is long overdue. Their method rigorously allows for the effects of movements along other nearby fault, and inherent unpredictability seems inescapable. While other tests of the time-predictability principle, theoretically the most plausible approach, will continue, most devastating earthquakes continue to occur without forewarning. That reflects the fact that there are only enough seismologists with fancy equipment to cover threatened areas in a few extremely rich countries. Most people who live along active fault zones know whether or not high-magnitude earthquakes occur in their vicinity, yet will not have the privilege of scientists and equipment to provide warnings of this kind for a very long time, for simple economic reasons. Perhaps some effort and funds should be diverted to providing warnings within days of a serious event, using less "robust" methods.

See also: Stein, R.S. 2002. Parkfield's unfulfilled promise. *Nature*, v. **419**, p. 257-258; DOI: 10.1038/419257a.

British Geological Survey sued over arsenic (*September 2002*)

The world's largest ever class action has been launched in London against the British Geological Survey, over claims that it failed to spot arsenic contamination during a 1992 water survey in Bangladesh. As many as 40 million Bengalis risk arsenic poisoning, following a major groundwater development programme in the 1970s and 80s. Arsenic poisoning at non-fatal doses often shows first as water blisters on hands and shins. Long-term exposure via drinking-water causes cancer of the skin, lungs, urinary bladder, and kidney.

Aid agencies, led by UNICEF sank four million wells deep into alluvium, in the hope that groundwater use would alleviate the chronic problem of heavily polluted surface water in Bangladesh. The arsenic is of natural origin, and stems from leaching of the toxic element from sulphide minerals by deep, reducing waters. The case hinges on BGS' failing to test for arsenic, which is easily detected using low-cost semi-quantitative methods, only 3 years after they had completed a comprehensive evaluation of groundwater quality in Britain that did include arsenic measurements. Accusations of double standards have been flying. However, UNICEF also failed to test for arsenic during the original drilling, because they did not expect to find it in the water. World Health Organization guidelines are very clear that arsenic does pose a threat in groundwater, but most cases in the past have been associated with former mining areas.

Considerable work on measures to clean up well water has been conducted since the Bengal arsenic crisis surfaced. Under oxidizing conditions, arsenic is adsorbed by ferric hydroxide, and a simple remedy is passing the water through iron wool or over ground-up rust or natural ochres.

More confusion over Bangladesh arsenic crisis (*November 2002*)

Millions of Bangladeshi people risk arsenic poisoning if they drink water drawn from tube wells (see *British Geological Survey sued over arsenic* above). Since the disaster first came to light, UNICEF has tested 1.3 million of the estimated 10 million tube wells that are potentially hazardous. Those deemed safe are painted green, while those which are risky are now red. Unfortunately, doubts are being cast on the reliability of the commercial test kits that UNICEF use to estimate dissolved arsenic concentrations. It is claimed that the analytical method have never been validated by controlled field experiments, and also that the minimum level of arsenic that they can detect is ten times higher than the safe level set by the World Health Organisation. A positive contribution to solving the problem is to drill deeper, since it seems as if the condition for release of arsenic from bonding in sedimentary iron minerals is related to bacterial action that creates reducing conditions. Although deep by comparison with traditional hand-dug wells, the tube wells go down only 50 to 80 metres and do not penetrate the zone in which reducing bacteria survive.

Source: Pearce, F. & Hecht, J. 2002. Flawed water tests put millions at risk. *New Scientist*, 16 November 2002, p, 4-5.

Seismic bathymetry and Mediterranean debris flows (*November 2002*)

Tsunamis are an ever present threat in coastal areas, and can be set in motion by submarine debris flows as well as by earthquakes. As more evidence for ancient tsunamis emerges on coastlines, such as characteristic features in Alaska (seismically induced), the Hawaiian islands and Bahamas (induced by landslips on unstable volcanic islands), and even the east coast of Britain (submarine debris flow off western Norway) their perceived threat has grown. A team of oceanographers from Spain, Canada, Belgium, Britain and France has re-examined seismic reflection data from the western Mediterranean, to extract detailed topography of the sea floor (Lastras, G. and 6 others 2002. Seafloor imagery from the BIG'95 debris flow, western Mediterranean. *Geology*, v. **30**, p. 871-874; 10.1130/0091-7613(2002)030<0871:SIFTBD>2.0.CO;2). Although the western Mediterranean is seismically quiet, compared with around Italy and Greece, it is floored by products of turbidity flows. A particularly large example (BIG'95) off the Spanish coast has an estimated volume greater than 26 km^3. Lastras *et al*. provide exceptional detail of the internal structure and surface shape of this debris flow, which enables them to suggest how it formed. It coincides with an interface between deep volcanic rocks and a thick cover of soft sediments, along which gradual detachment eventually resulted in a normal fault propagating to the sea floor. The mechanical instability seems to have been due to rapid deposition from the Ebro river system at a time of low sea level in the Mediterranean around the beginning of the Holocene. The flow is marked by fluid escape structures, which the authors suggest may have been connected with a rise in bottom-water temperatures. Is this another example of gas hydrate being involved, as seems likely for the Storegger slide that caused tsunamis along Britain's east coast (see *Collapsing islands* above) about 7200 years ago? The authors do not speculate on that. However, the detail that they provide about the conditions that culminated in BIG'95 should provide a benchmark for seeking areas prone to such massive and potentially catastrophic events.