Geohazards

Clouds and large earthquakes (*May 2008*)

The press announced in April that the USGS and other western US geoscience institutes had issued the first ever comprehensive earthquake forecast for California , but it was cautiously phrased in terms of probabilities of destructive magnitudes (>6.7) over the next 30 years. That might be fine for administrators and civil engineers, but not so good for anyone who becomes a victim at the precise time this or that Californian fault 'goes off'. People world-wide have rarely chosen where to live based on knowledge of geological risks; indeed most threatened communities have little choice, for many reasons. What would be useful is being warned that a devastating earthquake is definitely due where one lives, and it will happen sometime in the next few days or weeks. Even an hour's warning will save many lives. But no geological survey will commit itself to that kind of pronouncement, except perhaps some of the many surveys in China. The fact that all kinds of phenomena, such as nervousness among animals, rising water levels in wells and so-on have been shown to occur shortly before many big earthquakes has prompted a kind of 'barefoot' monitoring that is officially co-ordinated in some parts of China. It is said that lives have been saved on a number or recent occasions.

It is easy for western scientists to make the analogy with homeopathy, and pooh-pooh such methodology. Also, there has been a succession of observations from space that could prove useful, such as 'earth lights' and magnetic-field fluctuations that accompany some seismic events (see *Remote signs of earthquakes* August 2003; *Early warning of earthquakes* December 2005). The latest odd, but conceivably useful connection is an association of unusual cloud formations with earthquakes in Iran (Guo, G. & Wang, B. 2008. Cloud anomaly before Iran earthquake. *International Journal of Remote Sensing*, v. **29**, p. 1921-1928; DOI: 10.1080/01431160701373762). The authors, from Nanyang Normal University in China, scrutinised free, hourly images from the geostationary Meteosat-5 satellite covering the whole of Iran, where seismicity is concentrated on a single large zone of deformation that trends NW-SE through the Zagros mountains. On several dates they found cloud formations parallel to the fault zone. Between 60 to 70 days later large eathquakes took place along the fault, including the highly destructive Bam earthquake of 26 December 2003. Indeed, a noticeable thermal anomaly in clouds directly above Bam occurred 5 days before the disaster.

How often do tsunamis occur? (*May 2008*)

Fortunately, truly destructive tsunamis on the scale of that of 26 December 2004 are rare events. So much so that nobody has a clear idea of their average frequency at different exposed shorelines; a vital statistic for risk analysis. Tsunamis produce high energy marine deposits, but unless they are preserved in accessible locations their incidence would be difficult to estimate, and they may be confused with tempestites generated by hurricanes. One characteristic of tsunamis is that they are waves that affect the entire ocean volume, which can create unique features, unlike wind waves whose effects are restricted to a few tens to hundred of metres. Canadian, US and Omani sedimentologists have examined a sediment deposited in Oman by a recorded tsunami generated by a large earthquake off Pakistan in 1945 and have discovered one such signature (Donato, S.V *et al* 2008. Identifying tsunami .deposits using bivalve shell taphonomy. *Geology*, v. **36**, p. 199-202; DOI: 10.1130/G24554A.1). The deposit, a coquina rich in bivalve shells, contains an unusually high proportion of still-articulated shells, suggesting that living animals were ripped from the seabed and then flung into a lagoon. Along with oddities in fragmentation of other shells and the sheer size and extent of the coquina, this feature seems to be characteristic of tsunamites. Features in the Oman example closely match those in another on the eastern shore of the Mediterranean Sea in Israel.

The Sichuan earthquake (*July 2008*)

Beneath the Longmenshan (Dragon's Gate) Mountains of Sichuan Province, China an apparently 'stuck' segment of a major fault complex failed on 12 May 2008 (Xie, F. *et al*. 2009. Preliminary Observations of the Faulting and Damage Pattern of M8.0 Wenchuan, China, Earthquake. *The Professional Geologist*, v. **46**, p. 3-6.). Unprecedented access to the world's media resulted in our exposure to the full horror of the effects on habitations, especially schools, of a major seismic event in mountainous terrain, where building standards were unable to withstand ground shaking. 80 thousand people died, thousands more are still unaccounted for and more than 1.5 million people have become refugees in a country that is rapidly emerging from Third World status. Now that aftershocks have subsided massive threats remain from the many landslide-blocked rivers and fractured dams. Yet we also witnessed enormous mobilisation of the People's Army within hours of the earthquake and truly heroic attempts to rescue as many trapped people as possible. Without that swift response the casualties would undoubtedly have been worse.

The aftermath of the Magnitude 8.0 Wenchuan earthquake.

China boasts one of the most sophisticated seismic warning systems outside of California and Japan, deploying robotic seismometers and GPS recorders in the most risky regions, and with a 10-thousand strong Earthquake Administration. Sadly, Chinese seismologists regarded the faults shown to be accumulating displacement most quickly as those most likely to fail. Yet it is generally 'stuck' segments that fail catastrophically. China has a reputation for gathering data generally regarded as 'non-scientific', such as well water levels, and animal behaviour, that might give empirical clues to impending earthquakes. The Tangshan earthquake of 28 July 1976, which killed a quarter of a million people 160 km from Beijing, was preceded by reports of shifts in the water table, odd 'earthlights' and unusual animal behaviour. Paying serious attention to reports by ordinary people of such oddities is reported to have avoided untold numbers of deaths in the period since Tangshan, but not in the case of Sichuan. Strangely, a Taiwanese weather satellite detected decreased electrical activity in the ionosphere above Sichuan hours before the recent earthquake. Geophysicists have noted increased emissions of radon in the period immediately preceding some major earthquakes which might conceivably have an effect on the ionosphere. Whatever methods have been used, prediction of catastrophic earthquakes has had very few successes in terms of lives saved, and the signal lesson from Sichuan, as from that which destroyed the Japanese city of Kobe in 1995, is that building standards in zones of active faulting must take account of the risk of ground movement.

See also: *Tibetan Plateau reviewed* (Tectonics September 2008); Stone, R. 2008. Landslide, flooding pose threats as experts survey quake's impact. *Science*, v. **320**, p. 996-997; DOI: 10.1126/science.320.5879.996.

Extraterrestrial impactors (*July 2008*)

June 30, 2008 was the centenary of the mysterious Tunguska event that devastated more than 2000 km^2 of forest 1000 km north of Lake Baikal in Siberia. Much of the mystery stems from there being no sign of a crater and therefore of the process involved. Speculation about the cause of a massive explosion between 5-10 km above the surface still goes on (Steel, D, 2008. Tunguska at 100. *Nature*, v. **453**, p. 1157-1159; DOI: 10.1038/4531157a). Ideas have ranged over a gamut of high-energy physical processes involved in the explosion: a deuterium-rich, fluffy comet that was ignited as a thermonuclear explosion by hypersonic atmospheric entry; a lump of antimatter; a miniature black hole; explosive release and ignition of natural gas; a 'Verneshot', and even an alien space craft involved in an accident. The chances are that the explosion was more mundane, and akin to what occurs inside a diesel engine. Compressive heating of the air in front of a small asteroid or comet travelling at more than 15 km s^{-1} would generate temperatures around 50 thousand degrees. Flash vaporisation of a small comet or asteroid would add to a massive shock wave at the epicentre, rather than by an intact projectile. It is thought that many small craters, such as Meteor Crater in Arizona, result from impacts by strong metallic asteroids, whereas stony ones or comets easily disintegrate. Whatever, research still goes on at the site, now completely reforested.

The centenary spurred *Nature* to devote pages 1157-1175 in its 26 June 2008 issue to impact-induced features from Earth and other planets, together with three Letters and two reviews. Topics covered include the search for near-Earth objects and the Spaceguard survey, which is beginning to suggest that humanity can concentrate on global warming for the next century or so, and truly monster impact structures from the Moon and Mars, including evidence for one that may have 'scalped' northern Mars. In one of the reviews it is said that a sci-fi novel (Niven, R. & Pournelle, J. 1977. *Lucifer's Hammer*. Harper Collins) inspired the Alvarez father-and-son team that first postulated an impact origin for the K-T mass extinction event. The second review is of a highly realistic sculptural depiction of a pope (John Paul II) knocked over by a meteorite: perhaps planetary science's first involvement, literally, in what some might consider *lèse majesté*. So, in many ways, quite an event…

Screening for arsenic contamination (*September 2008*)

For up to 20 years millions of people in Bangladesh and West Bengal have unwittingly drunk groundwater that is contaminated with arsenic as a result of natural processes. They are potential victims of the greatest mass poisoning in human history. Dreadful as the possible fate awaiting them may be – they may develop various cancers – discovery and ten years of research into their problems has alerted geoscientists to the hazard of environments like those in which they live. That arsenic poses great dangers is common knowledge, but until unmistakable signs of arsenic poisoning appeared in Bangladesh (black wart- and mole-like skin lesions), the hazard was thought to be restricted to former mining areas where oxidation of iron sulfides released the traces of arsenic locked within those minerals. From studies in West Bengal and Bangladesh has emerged a cause that was completely unexpected: it involves one of the commonest minerals at the Earth's surface, goethite or FeOOH. This yellow-brown colorant of many sediments has the remarkable property of being able to adsorb or 'mop-up' a large range of elements dissolved in water with which it comes into contact. Among these is arsenic. In the oxidising conditions that sponsor the formation of goethite as a coating on sedimentary grains the mineral actually prevents a great deal of natural, geochemical pollution. Yet, exposed to reducing conditions, commonly developed when buried organic material begins to rot, goethite may dissolve and release its potentially toxic load into groundwater. This is precisely the source of arsenic at levels more than 100 times the safe level in some wells on the Ganges-Brahmaputra plains. The story does not stop there, however.

When sea level stood about 130 m lower than now, at the last glacial maximum, rivers rising in the Himalaya cut deep valleys in the coastal areas. As sea-levels rose these rapidly filled with new sediments, most of which were stained with goethite. But they were interbedded with thick organic-rich peats that formed during periods of slow sea-level rise. It is the peats and more finely dispersed vegetable matter that caused the reduction and solution of goethite, and thus the arsenic that it carried. Especially high arsenic levels develop in sediments derived from specific areas in the Himalaya. So a suite of conditions conducive to arsenic hazard have emerged from unravelling the tragedy of the northern plains of the Indian subcontinent. It is possible to use that suite as a means of predicting other risky areas, one of the first to be revealed being in the Red River delta of northern Vietnam. The population of Hanoi is at risk from well water drawn from the Red River sands and gravels. Systematic computer screening of known geology, topography and soil conditions in Southeast Asia is beginning to throw up other problematic areas (Winkel, L. *et al*. 2008. Predicting groundwater arsenic contamination in Southeast Asia from surface parameters. *Nature Geoscience*, v. **1**, p. 536-542; DOI: 10.1038/ngeo254) where concentrations of arsenic in drinking water are highly likely to exceed the maximum recommended level of 10 $\mu g\ l^{-1}$ (parts per billion). The pilot study highlights the known areas, but also the deltas of Mekong River in Cambodia and southern Vietnam, the Irrawaddy in Burma (Myanmar) and the Chao Phraya basin of Thailand. Hopefully, geochemical testing will reveal in details which wells are at risk and which are not, in these three regions: it would be easy to reject perfectly safe groundwater that often occurs close to contaminated areas, as found in Bangladesh, without careful testing. The implicated mineral, goethite, is itself a cheap and abundant means of remediation if contaminated water is passed through goethite-rich filters. But the large areas at risk in SE Asia, together with others discovered by epidemiologists in northwestern India, the Indus plains of Pakistan and in Mongolia, create a chilling scenario for many other populous, sediment-rich areas elsewhere. Winkel *et al*'s approach surely needs to be refined and applied globally.

See also: Polizzotto, M.L. *et al*. 2008. Near-surface wetland sediments as a source of arsenic release to ground water in Asia. *Nature*, v. **454**, p. 505-508; DOI: 10.1038/nature07093. Harvey, C.F 2008. Poisoned waters traced to source. *Nature*, v. **454**, p. 415-416; DOI: 10.1038/454415a.

Cause of Javan mud volcano (*September 2008*)

The Lusi mud volcano on Java

Since May 2006 the largely urban Sidoarjo area of eastern Java has been plagued by continuous eruption of hot mud and steam from a vent that suddenly appeared. Around 7 km^2 have been buried by up to 20 m of noxious mud, giving a total emission of about 0.05 km^3 at a rate of 100 thousand m^3 per day. Although nobody has been killed, the mud volcano is an economic and social disaster, 30 thousand people having been displaced. The area is one of active petroleum exploration, and locals blame a blow out from a nearby gas exploration well, though scientists and the exploration company point to the eruption having begun a couple of days after a magnitude 6.3 earthquake in the area around the capital Yogyakarta, 250 km away. If the latter, economic losses may be difficult to recover from insurers; if the former, there will be a rare old furore. So, a thorough evaluation of what the cause may have been is welcome (Tingay, M. *et al*. 2008. Triggering of the Lusi mud volcano: Earthquake versus drilling initiation. *Geology*, v. **36**, p. 639-642; DOI: 10.1130/G24697A.1). Being a mix of Australian, German and British geologists, the authors have no axe to grind. They consider that seismic influence was highly unlikely, in this case, although many mud volcanoes have formed close to earthquake epicentres in other areas.

On the other hand, the well that was being drilled at the time suffered a loss of drilling mud shortly before the volcano began to erupt, suggesting escape to fractures at depth around the well. Moreover, the hole was not cased at depth. The most likely trigger was creating a passageway up the well for high-pressure fluids to escape from the 3 km deep target limestone sequence into shallower unconsolidated clays. They were liquefied and escaped as a lateral blow out

Evidence for past tsunamis (*November 2008*)

Since the Indian Ocean disaster of 26 December 2004, coastal areas world wide are increasingly examined for signs of past tsunamis. Much the most common focus is on large boulders on low-relief shorelines never subject to glaciation. On the Bahamas large blocks of coral scattered above sea level suggest past tsunamis perhaps caused by collapse of volcanoes on Atlantic islands such as the Canaries or Azores. Yet, ordinary storm waves, if focused by coastal inlets can literally blast large boulders from well-jointed outcrops and carry them hundreds of metres inland. So peculiar boulders on a coast do not necessarily show that a tsunami once struck, although many around the shores of eastern Britain may well have been dislodged by tsunami triggered by a submarine landslide off western Norway about 7 thousand years ago. In an attempt to get more reliable signs of past tsunamis, the devastated coasts of northern Sumatra and western Thailand have been searched for tangible signs of the 2004 event (Monecke, K. *et al*. 2008. A 1,000-year sediment record of tsunami recurrence in northern Sumatra. *Nature*, v. **455**, p. 1232-1234; DOI: 10.1038/nature07374. Jankaew, K. *et al*. 2008. Medieval forewarning of the 2004 Indian Ocean tsunami in Thailand. *Nature*, v. **455**, p. 1228-1231; DOI: 10.1038/nature07373).

Sand sheets between beach ridges, probably deposited by ancient tsunamis, on Phra Thong Island Thailand. (Credit: Jankaew 2008; Fig. 2)

Both teams homed in on boggy depressions or swales between fossil beach ridges on broad low-lying shores. There, debris carried by the huge 2004 waves could be trapped and then preserved by regrowth of vegetation. The generally low energy in the swales is also likely to prevent erosion, so that deep superficial sediment can build up that may preserve signs of past tsunamis. This focus paid dividends, in the form of coarse sand just beneath a regrown vegetation mat, with distinctive signs that the sand had been deposited by transport from the seaward side of swales. Coring and trenching then unearthed deeper, older sands with exactly the same structure. The surprise was the antiquity of the tsunami sands: layers carbon-dated around 1300-1400, 780-990 AD and 250 BC. Clearly, more extensive surveys of this kind are necessary wherever coastal conditions permit good preservation. That would give an idea of the periodicity of earthquakes and landslips energetic enough to produce coastal catastrophes around major ocean basins. Yet there is a danger: if, as suggested by the Thai and Indonesia data, several centuries have lapsed between such dreadful events, it presents an excuse not to install costly monitoring devices or permanently shift coastal townships to foretell or prevent future disasters.

See also: Bondevik, S. 2008. The sands of tsunami time. *Nature*, v. **455**, p. 1183-1184; DOI: 10.1038/4551183a.