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A Summary of Earthquakes in 2003

David Galloway and Bennett Simpson present a summary of seismic activity in 2003

Contents

OVERSEAS

This year was not exceptional in terms of the number of worldwide earthquakes (Figure 1). There was 1 'great' earthquake (magnitude over 8.0), 15 'major' earthquakes (magnitudes between 7.0 and 7.9) and 141 'strong' earthquakes (magnitudes between 6.0 and 6.9). These numbers are comparable with the long-term averages for these magnitude ranges, which are 1, 18 and 120, respectively. The number of people killed by earthquakes during 2003 was 46,021 (Table 1), which is considerably more than the long-term average of around 10,000. The majority of the fatalities (over 93%) occurred as a result of a magnitude 6.6 Mw earthquake in southeastern Iran on December 26.

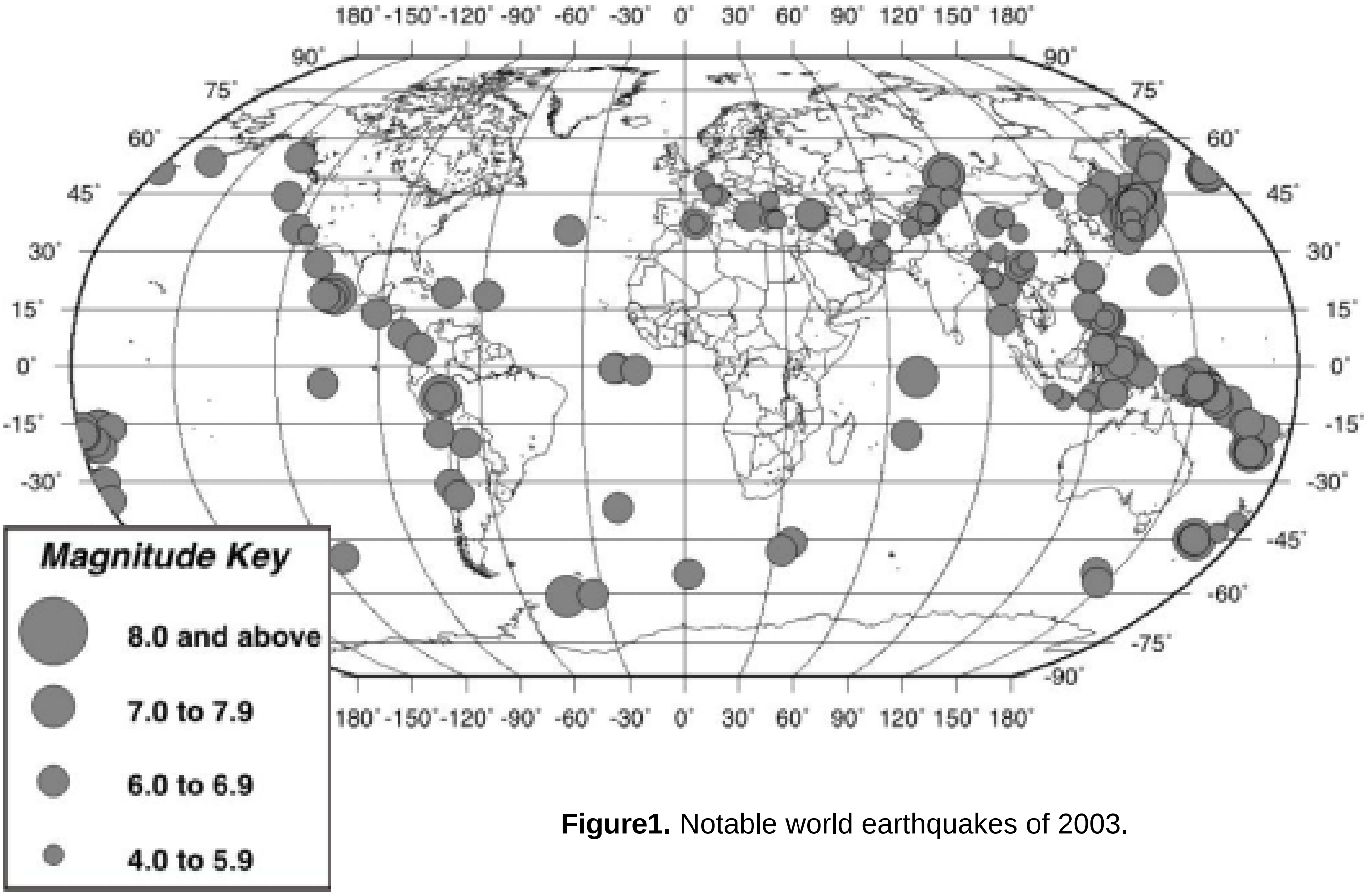


Figure1. Notable world earthquakes of 2003.

DATE	LAT	LON	MAGNITUDE	LOCATION	DEATHS
21 January	13.63 N	90.77 W	6.5 Mw	Guatemala (Coast of)	1
22 January	18.77 N	104.10 W	7.6 Mw	Offshore Colima, Mexico	29
27 January	39.50 N	39.88 E	6.1 Mw	Turkey	1
24 February	39.61 N	77.23 E	6.4 Mw	Southern Xinjiang, China	263
25 February	39.48 N	77.39 E	5.4 Mw	Southern Xinjiang, China	5
25 March	8.29 S	120.74 E	6.5 Mw	Flores, Indonesia	4
29 March	35.98 N	70.59 E	5.9 Mw	Hindu Kush, Afghanistan	1
01 May	39.01 N	40.46 E	6.4 Mw	Eastern Turkey	177
04 May	39.43 N	77.22 E	5.8 Mw	Southern Xinjiang, China	1
21 May	36.96 N	3.63 E	6.8 Mw	Northern Algeria	2,266
26 May	2.35 N	128.86 E	7.0 Mw	Halmahera, Indonesia	1
27 May	36.94 N	3.58 E	5.8 Mw	Northern Algeria	9
24 June	32.93 N	49.48 E	4.6 Mb	Western Iran	1
10 July	28.36 N	54.17 E	5.7 Mw	Southern Iran	1
21 July	25.98 N	101.29 E	6.0 Mw	Yunnan, China	16
26 July	22.85 N	92.31 E	5.6 Mw	India/Bangladesh Border	2
16 August	43.77 N	119.64 E	5.4 Mw	Eastern Mongolia	4
22 September	19.78 N	70.67 W	6.5 Mw	Dominican Republic	3
27 September	50.04 N	87.81 E	7.3 Mw	SW Siberia, Russia	3
16 October	25.95 N	101.25 E	5.6 Mw	Yunnan, China	3
25 October	38.40 N	100.95 E	5.8 Mw	Gansu, China	9
13 November	34.71 N	103.83 E	5.1 Mb	Gansu, China	1
14 November	27.37 N	103.97 E	5.0 Mb	Yunnan, China	4
18 November	12.03 N	125.42 E	6.5 Mw	Samar, Philippines	1
01 December	42.91 N	50.52 E	6.0 Mw	Xinjiang, China	11
22 December	35.71 N	121.10 W	6.5 Mw	Central California	2
25 December	8.41 N	82.82 W	6.5 Mw	Panama/Costa Rica Border	2
26 December	29.00 N	58.33 E	6.6 Mw	Southeast Iran	43,200
					46,021

Table 1. Earthquakes causing deaths in 2003.

The one 'great' earthquake of the year, with a magnitude of 8.3 Mw, occurred on 25 September 2003, in Japan's northernmost prefecture of Hokkaido. This was followed by several aftershocks of which the largest had a magnitude of 7.4 Mw and which occurred just over an hour after the mainshock. Over 755 people were injured and extensive damage, landslides and power outages occurred in southeastern Hokkaido as a result of these earthquakes. Damage is estimated at around $US 90 million. The location and mechanism of this event implies that it occurred as a result of thrust faulting on the plate interface between the overriding North American plate and the subducting Pacific plate. Earthquakes of this size (8 and above) have occurred in this region before, most notably the magnitude 8.1 event on 4 March, 1952, which killed 31 people, injured 72 others and caused extensive damage in the region.

Without doubt, the magnitude 6.6 Mw southeastern Iran earthquake was the most disastrous during 2003, accounting for over 93% of the fatalities. The epicentre was approximately 10 km to the southwest of Bam, which borders the Dasht-e-Lut desert, in the Kerman Province, Iran. It occurred on the morning of 26 December and left the city of Bam and it's surrounding communities in complete devastation. Some 43,200 people were killed, over 30,000 more were injured and around 75,000 were left homeless. It destroyed approximately 85-90% of the buildings in the region, including homes, schools and health facilities and caused widespread infrastructural damage. Over 45,000 buildings in Bam and surrounding villages were destroyed or damaged including 131 schools, several hospitals and over 100 health centres and clinics. Several of the drill wells, which supply water to the region, were also damaged leaving people largely dependent on water tankers and bottled water. Surface faulting on the Bam Fault between Bam and Baravat, numerous sinkholes and several landslides were also observed. An important cultural loss to the region was also evident with the destruction of the ancient citadel of Arg-e-Bam, which was located on the historic Silk Road and thought to be the largest mud brick structural complex in the world and over 2,000 years old. The earthquake occurred as the result of stresses generated by the motion of the Arabian plate northward against the Eurasion plate at a rate of approximately 3 cm/year.

On 21 January, an earthquake, with a magnitude of 6.5 Mw, occurred off the coast of Guatemala and killed 1 person, injured several others and disrupted services in Escuinta and Guatemala City. It was felt strongly throughout Guatemala and was also felt in Honduras and southern Mexico.

In Mexico, on 22 January, a magnitude 7.6 Mw earthquake killed 29 people, injured 1,073 more and destroyed or damaged over 40,000 homes affecting over 177,000 people. The epicentre was approximately 50 km offshore Colima near to the juncture of 3 tectonic plates: the North American Plate to the northeast, the Rivera Plate to the northwest and the Cocos Plate to the south. The majority of the deaths and damage occurred in the Colima and Villa de Alvarez areas. Landslides, power and telephone outages, gas leaks and damage to roads were also reported from in and around the epicentral region. A local tsunami was also observed at Manzanillo, with wave heights of about 1 metre, and a sieche was observed on Lake Pontchartrain. Additional damage was reported in the region from a magnitude 6.2 Mw aftershock, which occurred about 17 hours later.

On 27 January, a magnitude 6.1 Mw earthquake occurred in Turkey. The earthquake caused the death of 1 person in Saglamtas and injured several more in the Pulumur area.

Three fatal and damaging earthquakes occurred in Southern Xinjiang, China during 2003. The largest, on 24 February, with a magnitude of 6.4 Mw, killed 263 people, injured 4,000 others, destroyed over 8,500 buildings and homes and damaged more than 9,000 others leaving around 110,000 homeless. Among the buildings destroyed were hundreds of schools and mosques and some 50 health facilities. The worst affected area was in the county of Bachu, where almost all water and power supplies were also totally destroyed. Another two earthquakes occurred in the same region on 25 February and 4 May, with magnitudes of 5.4 and 5.8 Mw, respectively. A further 6 people were killed, hundreds more were injured and further damage occurred in the epicentral region as a result of these earthquakes.

On Flores, Indonesia, on 25 March, a magnitude 6.5 Mw earthquake killed 4 people, injured 20 others and damaged several buildings and a pier in the Reo area of the island.

In the Hindu Kush region (near the Afghanistan, Pakistan and Tajikistan border), on 29 March, an earthquake with a magnitude of 5.9 Mw killed one person and injured 2 more in the Bajaur, Peshawar area, Pakistan. This earthquake was felt strongly throughout Chitral, Islamabad and Peshawar, Pakistan, in Kabul and other parts of Afghanistan and was also felt in Dushanbe, Tajikistan.

On 1 May, in the Bingol Province of southeastern Turkey, a magnitude 6.4 Mw earthquake killed 177 people, injured 520 others, completely destroyed 82 houses and damaged some 2,575 others. Almost half of the fatalities occurred when a primary boarding school collapsed, killing 85 children and a teacher. The earthquake also resulted in the death of some 2,000 livestock. Most of the casualties and damage occurred in Bingol and in surrounding towns and villages such as Celtiksuyu and Sancak.

A damaging earthquake, in northern Algeria, on 21 May, with a magnitude of 6.8 Mw, resulted in the deaths of some 2,266 people. Over 10,000 others were injured and approximately 150,000 were made homeless. Over 210 buildings, some 1,029 individual houses, almost 700 classrooms and around 45% of the health facilities in the Algiers, Boumerdes, Reghoa and Thenia areas were also destroyed. A tsunami, which was generated, with wave heights of 2 metres, caused damage to boats off the coast of the Balearic Islands and was also recorded on the coast of Alicante, Castellon and Murcia, Spain. Damage from the earthquake has been estimated at US$100 million. The earthquake occurred in the boundary region between the Eurasian plate and the African plate. Six days later, on 27 May, a magnitude 5.8 Mw earthquake occurred in the same region and killed a further 9 people, injured 200 others and destroyed several buildings which had been previously weakened by the 21 May event.

In Indonesia, on 26 May, one person was killed, 7 more were injured and many were made homeless as 20 houses were destroyed and 28 others were damaged at Berebere, Morotai Island during a magnitude 7.0 Mw earthquake.

On 24 June, in western Iran, an earthquake, with a relatively small magnitude of 4.6 Mb, killed one person and 85 heads of livestock in the Aligudarz area. The livestock were killed as a result of a landslide in the region.

In southern Iran, on 10 July, an earthquake, with a magnitude of 5.7 Mw, killed one person and injured 25 others in the Gajjiadad area. At least 3,500 homes were damaged and utility services were severely disrupted in the area.

Three fatal and damaging earthquakes occurred in Yunnan, China during the year. The first, on 21 July, with a magnitude of 6.0 Mw, killed 16 people, injured 584 others, destroyed 24,000 housing units and damaged over a million others affecting the lives of over 1.25 million people in 15 counties. Most of the deaths and injuries occurred in Dayao County. The second occurred 3 months later, on 16 October, and had a magnitude of 5.6 Mw. Three people were killed, 32 others were injured and some 12,000 homes were destroyed or damaged in the Dayao County region. A month later, on 14 November, another fatal earthquake, with a magnitude of 5.0Mb, occurred in the same general area. It killed 4 people, caused injury to 65 others, destroyed 600 houses, damaged thousands more and caused several power outages in Ludian and Zhaotong Counties.

On 26 July, a magnitude 5.6 Mw earthquake, in the India-Bangladesh border region, killed 2 people, injured 25 others and destroyed or damaged over 500 buildings at Rangamati, Bangladesh. Landslides and subsidence was reported from the region around Chittagong, Cox's Bazar and Rangamati.

An earthquake, with a magnitude of 5.4 Mw, occurred in the Inner Mongolia Autonomous Region on 16 August. Considered the worst earthquake to hit the region in over 700 years, it caused the deaths of 4 people, injured 1,054 others and left over 115,000 homeless. More than 7,900 houses were demolished and approximately 83,000 others were seriously damaged. The majority of the casualties and damage occurred in the areas surrounding Bairin Zuoqi and Ar Horqin Qi, under the administration of Chifeng City. Damage and economic losses from this earthquake has been estimated at around US$1.68 million.

On 22 September, 3 people were killed and more than 15 others were injured as a result of a magnitude 6.5 Mw earthquake in the Dominican Republic. One person was killed in Puerto Plato and 2 others died, as a result of heart attacks, in San Francisco de Macoris. Many buildings were either completely destroyed or badly damaged in Puerto Plato, San Francisco de Macoris and Santiago and landslides occurred along several highways in the epicentral region.

Along the Russia / Xinjiang border region, in southwest Siberia, a magnitude 7.3 Mw earthquake on 27 September, killed 3 people and injured 5 others. Over 300 houses were destroyed and 1,942 buildings were damaged leaving over 1,800 people homeless in the Kosh Agach and Ust Ulagan areas. Damage also occurred in Ongudai and Shebalino. Ground subsidence was reported in the Chaganuzun area that created a flood of the Chuya River. This is the largest earthquake in this region since a magnitude 7.7 event on December 20, 1761.

Two earthquakes minutes apart occurred in Gansu, China on 25 October. The first occurred at 12:41

UTC and the second occurred 6 minutes later, at 12:47 UTC, and both events had magnitudes of 5.8 Mw. At least 9 people were killed, 43 were injured, 10,000 houses were destroyed and 45,000 were damaged as a result of these earthquakes. Damage to 2 reservoirs, a temple and a Buddha statue was also reported as well as the deaths of some 16,000 heads of livestock. The majority of the casualties and damage occurred in Minle and Shandan Counties. Damage from these earthquakes is estimated at $US 40 million. The following month, on 13 November, a magnitude 5.1 Mb earthquake struck Gansu, China. The region most affected from this event was the Jone, Lintian, and Minxian areas, where one person was killed, 30 others were injured and many buildings and roads were damaged.

On 18 November, a magnitude 6.5 Mw earthquake occurred on Samar in the Philippines. It killed one person, injured 21 others, collapsed a school and damaged several concrete structures in the Can Avid area and caused power outages throughout the island. A landslide also occurred in the epicentral area, which blocked the main highway near Taft.

An earthquake, on 1 December, caused several fatalities in Zhaosu County, Xinjiang. The epicentre was in the Kazakhstan / Xinjiang border region and the magnitude was 6.0 Mw. At least 11 people were killed, 47 were injured, 769 houses were destroyed and many more were damaged as a result of the earthquake.

A 'strong' earthquake, with a magnitude of 6.5 Mw, struck the Central Coast of California on 22 December. It killed 2 people, injured 40 others and collapsed around 40 buildings in the Paso Robles and Templeton areas. Further buildings were damaged and small fires occurred at Atascadero, Morro Bay and Cambria. Damage also occurred to a road bridge and to several highways in the Oceano area, mainly as the result of landslides. The airport at Oceano was also closed as cracks appeared in the runway. Damage as a result of the earthquake has been estimated at $US 300 million.

An earthquake, with an epicentre on the border between Panama and Costa Rica, occurred on 25 December. Damage was reported from Panama, where 200 homes and a hospital were severely damaged and Costa Rica, where several homes were completely destroyed and 2 hospitals were evacuated after they became damaged. Over 75 people were injured and 2 were killed as a result of this magnitude 6.5 Mw earthquake.

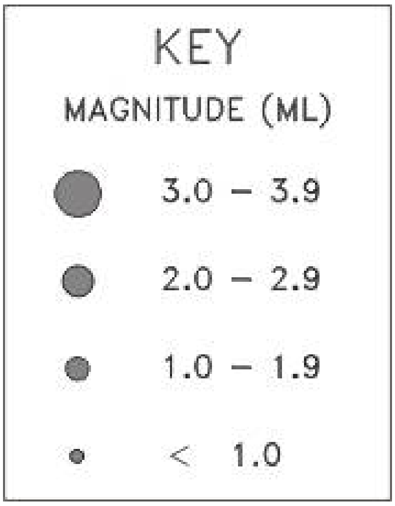
UK EARTHQUAKES

The British Geological Survey detected and located some 146 earthquakes in the British Isles and surrounding continental shelf areas during the year (Figure 2), with 32 of them having magnitudes of 2.0 ML or greater. Of these, 10 are known to have been felt, together with a further 14 smaller ones, bringing the total to 24 felt earthquakes in 2003.

The largest onshore earthquake, with a magnitude of 3.2 ML, occurred near Aberfoyle on 20 June at a depth of 5.2 km. The BGS received reports, via the Police and residents of the Aberfoyle area such as "the whole house shook" and "there was a rumble like thunder". This event was followed by two aftershocks on the same day with magnitudes of 2.8 and 2.5 ML. Reports were also received for both of these events with intensities of 3 EMS. There were a total of 11 earthquakes detected in the Aberfoyle earthquake sequence during 2003, with locations approximately 3.5 km southwest of the village of Aberfoyle. A total of 8 of the events were reported by local residents. Visual inspection of the seismograms recorded from the earthquakes in the sequence indicated a high degree of similarity between the individual events. It was found that the earthquakes were confined to an area of about 1000m long and 200m wide striking in SW-NE direction. The location area falls into the Highland Boundary Fault Zone (HBFZ), which presents a major tectonic boundary extending across the entire width of Central Scotland in NE-SW direction. Due to the similarities in the waveform signals, a joint focal mechanism based on first motion polarities was determined through a grid-search for the events in the sequence. Polarity readings from 13 stations were used. The first nodal plane strikes in WSW-ENE direction and dips to the NW with both left-lateral and normal movement. The second nodal plane strikes in NNW-SSE direction, dips eastward with both right-lateral and normal movement. The alignment of the epicentre locations in SW-NE direction suggests that the first nodal plane was the actual fault plane. This fault plane follows the strike direction of the HBFZ. However, the P axis points SSW, in disagreement with the regional stress pattern possibly indicating local variation from the regional stress pattern.

The largest offshore earthquake occurred in the Northern North Sea on 15 December, with a magnitude of 3.9 ML. It was located approximately 265 km east of Lerwick in the Shetland Islands. A further 14 events occurred in the North Sea and surrounding waters during the year, with magnitudes ranging between 0.3 and 3.0 ML. The earthquake with a magnitude of 0.3 ML was detected

Figure 2. Epicentres of all UK earthquakes located in 2003 (from the Bulletin of British Earthquakes 2003).



approximately 30 km east of Yell, Shetland Islands on 30 June. On 23 July, an earthquake with a magnitude of 1.2 ML was located approximately 25 km west of Sumburgh Head in the West Fair Isle Basin.

An earthquake with a magnitude of 1.4 ML occurred in the Manchester area on 5 January. The BGS received one report for this event from a resident of Manchester, who described, "felt a slight shudder" indicating an intensity of 2-3 EMS. This earthquake locates in the same general area as the series of events that occurred throughout late 2002.

On 12 January, an earthquake with a magnitude of 2.4 ML, occurred near Blackford, Tayside. Reports such as "there was the usual heavy sudden bang followed immediately by the shaking of the bedroom walls and the shuddering of the floor" and "there was a rumble like a heavy lorry passing", indicate an intensity of at least 3 EMS. A further eight earthquakes were detected in the Blackford area during 2003, with magnitudes ranging from 0.7 to 2.2 ML. Three of these events were reported by local residents. This is an area that has continued to be active in recent years: 49 events occurred in 1997, of which five were felt by local residents; 10 events occurred in 1998, of which 2 were felt by local residents; 3 events occurred in 1999; 4 events occurred in 2000, of which 3 were felt; 3 events occurred in 2001, of which all were felt; 4 events occurred in 2002, of which one was felt. These are all in the same general area as the magnitude 3.2 ML Ochil Hills earthquake in 1979, which had a maximum intensity of 5 EMS.

An earthquake with a magnitude of 1.5 ML occurred on 22 February, near Inveraray, Strathclyde. Reports received from Furnace and Cairndow such as, "a loud bang", "a 300 year old house shaking" and "a trolley rattling", indicate an intensity of 3 EMS.

A magnitude 2.1 ML earthquake occurred on 3 March, with a location on the Isle of Mull, Strathclyde region. The BGS received one report for this event from the Isle of Mull, describing, "I heard a loud roar and things rattled on the walls", indicating an intensity of 3 EMS. A further event occurred on the Isle of Mull on 17 February with a magnitude of 1.9 ML.

Six events occurred during 2003, in the Newcastle-Under-Lyme region of Staffordshire, with magnitudes ranging from 1.4 to 2.3 ML. No reports were received for any of these events.

A magnitude 3.1 ML earthquake occurred on 19 August, near Doncaster, South Yorkshire. The BGS received reports, via residents of Retford, Nottinghamshire. The reports described, "the whole house shook", "the sensation woke me from sleep" and "all the radiators and windows rattled", indicating an intensity of 4 EMS. This event is the largest in the area since the magnitude 3.2 ML East Retford earthquake on 22 March 1984, which had an intensity of 3 EMS.

An earthquake with a magnitude of 2.1 ML occurred near Loch Fannich, Highland on 11 November. The BGS received a single report for this earthquake from a resident of Achanalt which described, " I heard a loud deep explosion and the house shook" indicating an intensity of 2-3 EMS.

Three events occurred in the Caernarvon Bay area of Gwynedd, on 18 April, 2 June and 23 August, with magnitudes of 0.4, 0.9 and 0.6 ML, respectively.

Near Pontypool, Gwent, three events occurred throughout the year, with magnitudes of 1.1, 1.6 and 1.5 ML, respectively.

The coalfield areas of Yorkshire, Nottinghamshire and Mid Glamorgan continued to experience shallow earthquake activity that is believed to be mining induced. Some, 16 coalfield events, with magnitudes ranging between 0.9 and 1.8 ML, were detected during the year. Local residents reported six of these events. Of these 16 events, 10 events were located in the Maltby area of South Yorkshire, with magnitudes ranging between 1.0 and 1.5 ML.

David D Galloway and Bennett A Simpson are both members of the Earthquake Seismology and Geomagnetism Group of the British Geological Survey.

The 'Bulletin of British Earthquakes 2003' edited by B A Simpson and D D Galloway will be available in May 2004. Copies of this and previous years' bulletins can be obtained from the Earthquake, Seismology and Geomagnetism Group secretary and from BGS bookshops. For further details contact: D D Galloway, Earthquake Seismology and Geomagnetism Group, British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH9 3LA, Scotland, UK.

But is it Reliable ?
Assessing Seismic Hazard Assessments

David Mallard reports on the SECED Evening Meeting

Following an introduction from the Chairman, **Ziggy Lubkowski**, this well-attended meeting was opened by **David Mallard** with a warning. Whilst it is becoming increasingly important for us to be able to judge the adequacy of probabilistic seismic hazard assessments [PSHAs], this is far from straightforward and not a task to be undertaken lightly.

In any attempt to quantify hazard estimates, inevitable shortfalls in knowledge introduce uncertainties which can only be countered by making use of expert judgement. Like all other probabilities, therefore, the results of PSHAs depend, often in large measure, on accumulations of subjective judgements. An indication of the void that these judgements need to bridge in any given instance is given by a comparison between the effective time-scales required of the hazard estimate and those of the actual 'experience' data for the location in question.

Mallard pointed out that the ubiquitous presence of uncertainty, and the consequential need to employ expert judgement, explains why apparently anomalous situations can arise when successive PSHAs are carried out for the same location. In a seismotectonic environment like the UK, where significant advances in understanding are likely to be few and far between, the advantages available to a new study by such extra information as does exist could quite possibly be undermined by the exercise of questionable judgement(s). Such situations demonstrate the desirability of being able to judge systematically how adequate any hazard estimate is likely to be. Given the absence (blatant errors apart) of definitive "rights" or "wrongs", however, he suggested that all one can do is to either: (a) compare the hazard estimate itself with the evidence from other, independent, sources of information, or (b) review (and, where possible, test) the legitimacy of the individual expert judgements which have influenced that estimate.

The three principal speakers then made their presentations, starting with **Julian Bommer** who began by making the point that, although PSHA studies cannot strictly be validated, they can, at least, be shown to be "not invalid", through rigorous peer review and the assurance that no fundamental errors are made.

In this last context, he reported that fundamental errors in setting up logic-trees and in the execution of PHSA are not at all uncommon: as a specific example, he cited instances where software packages such as EQRISK and SEISRISK, both of which effectively model earthquakes as point sources (and hence simulate epicentral or hypocentral distance), had been used in conjunction with ground-motion prediction equations based on distances measured relative to the fault rupture. Since fault rupture distances are consistently equal to or smaller than epicentral distances, especially for larger earthquakes, this practice will lead to appreciable underestimation of the hazard.

Dr Bommer considered that a reliable seismic hazard assessment must include reference to the most up-to-date information regarding the seismicity, tectonics and strong-motion characteristics of the region under study. It should also identify AND capture the uncertainties associated with the inputs to the hazard calculations. In his view, most of the uncertainty associated with seismic hazard assessment is epistemic, meaning that it arises because of lack of knowledge. The quantification of epistemic uncertainty requires expert judgement, and the greater confidence that the client wishes to have that the uncertainty has been properly captured, the greater the number of experts whose judgement needs to be elicited.

Drawing on his recent personal involvement, Dr Bommer concluded with a brief explanation of the SSHAC guidelines under which appropriate differing levels of expert involvement and opinion elicitation procedures are employed, depending on the sensitivity of the project under consideration. (For further details, see SECED Newsletter, vol. 17, no. 4, February 2004, pp.7-11).

The next presentation was made by **Roger Musson**. Considering the potential impact of seismic hazard studies on design costs, he argued that it is not unreasonable to raise the issue of validation of the results of such studies. Often seismic source models are highly opaque. A complex decision-making process results ultimately in a hazard curve, but what comes in between can often be obscure. The standard "checking" procedure involves a peer review team, who consider the subjective opinions (or expert judgements) of the original analysts and interpret them in the light of their own subjective opinions. The problem is, that it is possible to take decisions in seismic hazard analysis which seem reasonable in isolation, but which can have overall implications that are undesirable. If these decisions are evaluated purely in terms of the processes by which they were arrived at, and not in terms of their impact on the model, any such undesirable effects will not show. Also, conventional sensitivity analyses address only those decisions involving parameter values which have a direct impact on the results.

What is needed in addition are procedures by which objective tests can be made of the realism of the seismic model as a complete description of regional seismicity, allowing for uncertainty (the presumption in deriving seismic hazard results is that the seismicity during the lifetime of the structure will accord with the model). For the results to be considered valid, therefore, the description must be physically realistic. As a first test of this realism, Dr Musson suggested that the predictions of the model can be compared against historical experience. He warned, however, that historical experience is but a short sample (typically, about 300 years for the UK) of long-term processes, and one might need a few thousand years of data to see the full "seismic cycle". For this reason, a model fixed too closely to the historical record would be unlikely to reflect the full uncertainty. Nevertheless, whatever the "true" long-term seismicity parameters may be, it is certainly the case that those parameters are somehow manifest in the historical earthquake record. If, therefore, it is found that the historical earthquake record is inconsistent with the selected set of model parameters values, then those values cannot be realistic and should not be used.

Dr Musson commended this form of testing as a check for uncovering apparently defensible decisions that, in practice, lead to models which are actually incompatible with historical experience. He suggested that such decisions are not so uncommon as one might suppose and that, therefore, tests of this type should be made regularly on high-consequence projects. Whilst questions relating to attenuation, for example, remain unanswered, it should become routine practice to bridge the gap between the input parameter values and the final hazard curve by examining the implications of those values in terms of actual earthquake distributions. Whilst 300 years of observed data might be a statistical fluke compared to long term seismicity rates, it is far more probable that they are not and a model which is not compatible with the historical record is unlikely to provide a reliable prediction of earthquake hazard for the next 50 years.

Finally, **Willy Aspinall** discussed the challenge of reacting most appropriately to situations where alternative seismic hazard assessments are available, quoting some of the ideas that had been developed in a recent rationalisation of three successive hazard maps for the offshore UK Continental Shelf. In this particular case, with no tabulated results, significant effort (involving manual digitisation and the use of a numerical 2-D bi-cubic spline representation) was required to bring the different plotted contours to a common basis that would allow direct comparisons to be made. It was then possible to consider the merits of the individual reports and the procedures that each had used to calculate their hazard estimates, concentrating on the 10^{-4} p.a. probability of exceedance figures and largely, but not exclusively, on the *pga* hazard. For evaluating the reports, those generic decisions which would have had most effect of the hazard results were rated against "best" practice and marked accordingly.

The selected checks on the soundness of the individual assessments tested seven separate aspects of what had been done. One of these, relating to the seismological model parameterisation, explored five particular decisions that would have had a significant effect on the results, namely: the maximum and minimum magnitudes allowed for; the way the activity rate(s) had been calculated; and the b-value(s) and focal depth distribution(s) used. For convenience, the overall marking scheme allowed a maximum possible aggregate score of 100 and the resulting attributions were used as an indication of how the individual reports measured up against the procedures employed in comprehensive seismic hazard assessments for the UK nuclear industry which was the standard that the client wished to see invoked.

The aggregate scores given to each of the reports allowed weights to be assigned to their results in various combinations wherever they provided overlapping coverage so as to produce numerically-synthesised 'hybrid' *pga* hazard contour maps, for 10^{-2} p.a. and 10^{-4} p.a. exceedances, which took account of all the alternative interpretations that were available, along with some of the associated uncertainties, by relating them together in a rational Bayesian manner. Two final checks were made:

(i) a "sanity check" comparing the contours on the hybrid offshore maps with the results from a number of site-specific SHAs for coastal sites, and

(ii) a comparison with minimal hazard levels, corresponding to the "no earthquake" condition, computed using just the magnitude completeness thresholds appropriate to the local earthquake records.

Using a hazard map produced using this last rationale and the hybrid hazard map which combined the results from the three existing SHAs, a final map was created on which the hazard levels were everywhere the higher of the two.

In conclusion, Dr Aspinall suggested that it would be both desirable and possible to extend this methodology in order to reflect <u>all</u> the uncertainties present in a set of existing assessments (i.e. both epistemic and aleatory), when defining rationalised hazard levels and confidence envelopes.

Discussion

When the meeting was thrown open for general discussion, the first contribution was from Peter Ford who described the position adopted by regulators and, in particular, the legitimacy which, given their legal responsibilities, they have to seek in situations where expert judgement is so important. For a case to be acceptable, they need to be confident that it would be considered defensible by the widest possible spectrum of informed opinion.

Nick Ambraseys wondered how an "expert" should be defined, how experts should be selected, and how one should select those who assess the assessors. He also drew attention to some specific variations he has encountered in empirical databases which contribute to the uncertainties that are of concern.

Bryan Skipp was concerned that various terms, such as "validate", "epistemic", etc., had been used in the presentations which appeared not to have been defined, or used, with any great precision. Roger Musson agreed that it was not possible strictly to "validate" hazard models but, reflecting the view expressed by all of the speakers, suggested that it was both possible and important to carry out tests aimed at exposing those components of models which were NOT valid.

Ziggy Lubkowski asked how one should most appropriately react to situations where the uncertainty is such that it is necessary to invoke alternative source models. David Mallard suggested that, as well as the primary results in which all such alternatives appear as suitable weighted options in the logic-tree, the site-specific hazard exposure resulting from each of the individual source models should be presented. Roger Musson made the point that his approach for testing zonations would be of considerable assistance in such situations.

In the context of frailties that might be encountered in reviewing assessments, David Mallard considered that, in addition to those that had already been mentioned by the speakers, lapses in internal consistency are always sources of concern. It is important that, wherever possible, assessments are data-driven and chopping and changing between magnitude scales, for example, was a sure way of introducing additional uncertainty.

The rest of the discussion was largely concerned with the procedures by which expert opinion should be harnessed and utilised. Julian Bommer commended the SSHAC approach, noting especially the importance of using experts with a breadth of experience, and he and Roger Musson described some of their recent experience of working within that framework. David Mallard felt that one of the priorities in setting up a properly multi-disciplinary team is to have redundancy in expert coverage, i.e. the group should not rely on a single expert in any one topic. Willy Aspinall reported that work on the volcano eruptions at Montserrat had made use of a scheme which differed from that of SSHAC in that the opinions offered by the various experts were assigned different weights according to their experience. John Donald pointed out that, so far as regulators are concerned, the seismic hazard assessment is only part of the story, the main consideration being the consequence of failure. On this basis, he thought that it would be unlikely, for the foreseeable future, that a project in the UK would require an SSHAC Level 4 assessment. Whilst Julian Bommer accepted that this was likely to be the case, he argued that, since there is only a small number of groups in the UK that are involved in this field, it could be useful to consider workshops or some other forum at which the experts could address the problem of seismic hazard in the UK collectively, rather than always having to compete for work.

Japan-Europe Seismic Risk Workshop

Bristol University 5-6 July 2004

The fifth in a series of biennual seismic risk workshops will take place at Bristol University on 5 and 6 July 2004. Presentations will be made on recent research by invited Japanese, European and UK researchers.

Members of SECED are welcome to attend this event. Please contact David Muir Wood (d.muir-wood@bristol.ac.uk) or Janet Offer (janet.offer@bristol.ac.uk 0117-9289760) for more details and for information on registration.

Practical Seismic Design

Principles and Application to Eurocode 8

16-17 September 2004 at Imperial College London

This two day course is organised by the Department of Civil and Environmental Engineering at Imperial College, in collaboration with SECED. The course takes the form of a series of lectures from leading UK and international experts from both the university and consulting sectors. The course aims to be design oriented, and will include the presentation of some case studies.

The first day will cover the basic elements of practical seismic design and covers the choice of earthquake actions, the seismic behaviour of soils, and the design & analysis of reinforced concrete and steel building structures to resist earthquake effects. The second day will provide an introduction to Eurocode 8, concentrating on Parts 1 and 5 of the code, with emphasis on the aspects covered on the first day.

The full fee (VAT exempt) for this two day course is £475 if booked before 16 August 2004 and £550 after 16 August 2004. Discounts are available for academic and SECED members.

For queries regarding registration matters contact Bang Nong (T: +44 (0)20 7594 6882; E: cpd@imperial.ac.uk). For queries regarding the technical content contact Dr Ahmed Elghazouli at Imperial College (E: a.elghazouli@imperial.ac.uk).

General Assembly of the ESC

Potsdam, Germany - September 12 - 17, 2004

The 2004 General Assembly of the European Seismological Commission (ESC) will provide the opportunity to meet scientists from different countries to discuss and exchange ideas about the state of the art in seismology and physics of the Earth's interior.

The scientific programme of the Assembly will be focused on the standard Subcommission Open Symposia and several special symposia, workshops and meetings. It will concentrate on the research conducted within the following Subcommission topics:

SC-A	Seismicity of the European-Mediterranean Area
SC-B	Data Acquisition, Theory and Interpretation
SC-C	Earthquake Source Physics
SC-D	Crust and Upper Mantle Structure
SC-E	Earthquake Prediction Research
SC-F	Engineering Seismology
SC-G	Rapid Intervention Field Investigation Teams

The following special sessions are tentatively proposed:

SS-1	Earthquake sources, hazard and risk in the Southern Mediterranean: North Africa and Near East
SS-2	INSAR and GPS technology applications in monitoring crustal deformation
SS-3	Education and outreach: promoting seismology, earthquake engineering and seismic risk in schools, museums, and universities.

Keynote Lectures will be:

KL1	History of the research institutions on the Potsdam Telegraph Hill, Peter Bormann
KL2	The role of modern volcano seismology in volcano monitoring, modelling and forecasting, Jürgen Neuberg
KL3	Estimating earthquake design loads in Europe: Issues and challenges for seismology, Julian Bommer
KL4	Global Urban Earthquake Risk and the European Seismological Commission, Brian Tucker

The deadline for payment of registration fee without surcharge is August 16th 2004. Fees for participants are 300 Euros. Concessions are available for students and accompanying persons.

For further information visit the Assembly website: http://www.gfz-potsdam.de/pb2/ESC2004/

Touring Lecture : Earthquake Engineering Design of Foundations

From Research to Practice

The British Geotechnical Association's touring lecture with Dr Alain Pecker will take place in November 2004. A brief synopsis follows:

Once earthquake risk and site effects have been evaluated the designer needs to proceed with the proportioning of the foundation. To date there is little in the way of code based recommendations to cover this. Eurocode 8 is an exception and contains an extensive section on the design of foundations to resist earthquake loading. This has been developed using the results of a number of special investigations, both laboratory and theoretical. The lecture will address the background to the provisions in the Eurocode, will cover shallow foundations and deep foundations, and review differences between low level response for which the soil can be expected to remain elastic and other situations where nonlinear behaviour of the soil adjacent to the foundation occurs. The lecture will illustrate the new trends in earthquake resistant design of foundations with the possibility of introducing concepts, familiar to structural engineers, like displacement based design and capacity design philosophy.

NOTABLE EARTHQUAKES NOVEMBER 2003 - JANUARY 2004

Reported by British Geological Survey

YEAR	DAY	MON	TIME UTC	LAT	LON	DEP KM	MAG	LOCATION
2003	13	NOV	02:35	43.71N	103.83E	10	5.1	GANSU, CHINA

At least one person killed and 30 people were injured.

2003 14 NOV 18:49 27.37N 103.97E 33 5 CHINA
At least 4 people were killed, 65 people were injured, 600 houses were destroyed and 98,000 buildings were damaged.

2003 17 NOV 06:43 51.15N 178.65E 33 7.8 RAT ISLANDS,ALEUTIAN ISLANDS

2003 18 NOV 17:14 12.03N 125.42E 35 6.5 SAMAR, PHILIPPINES
One person was killed and approximately 21 people were injured.

2003 26 NOV 13:38 27.28N 103.75E 33 4.7 CHINA
Four people were injured and thousands of buildings were damaged or destroyed in Ludian.

2003 1 DEC 01:38 42.91N 80.52E 10 6 KAZAKHSTAN-XINJIANG BORDER
At least 11 people were killed and 47 people were injured.

2003 11 DEC 16:28 31.95N 49.21E 33 5 WESTERN IRAN
At least 5 people were injured.

2003 22 DEC 19:15 35.71N 121.10W 8 6.5 CENTRAL CALIFORNIA
Two people were killed and approximately 40 buildings collapsed or were severely damaged at Paso Robles. At least 40 people were injured in the Paso Robles-Templeton area. Buildings were damaged and fires occurred at Atascadero, Cambria and Morro Bay. Damage is estimated at 300 million US dollars.

2003 25 DEC 07:11 8.43N 82.85W 33 6.5 PANAMA-COSTA RICA BORDER
At least 2 people were killed, 75 people were injured and many buildings were damaged or destroyed.

2003 26 DEC 01:56 28.99N 58.33E 10 6.6 SOUTHEASTERN IRAN
At least 41,000 people were killed and 30,000 people were injured. Eighty-five percent of buildings were damaged or destroyed in the Bam area. A detailed report on this earthquake can be obtained from: www.iiees.ac.ir/English/Bam_report_english.html.

2004 1 JAN 20:59 8.32S 115.80E 33 5.8 BALI REGION, INDONESIA
At least one person was killed, 22 people were injured and approximately 2,000 buildings were damaged on Lombok. At least 7 people were injured and 4,000 buildings were damaged on Bali.

2004 10 JAN 18:38 36.86N 3.47E 10 4.5 NORTHERN ALGERIA
Approximately 300 people were injured.

2004 29 JAN 10:56 51.09N 2.98W 7 2.7 BRIDGWATER, SOMERSET
Felt with intensities of 3 EMS.

2004 29 JAN 10:56 51.09N 2.98W 7 3.1 BRIDGWATER, SOMERSET
Felt with intensities of 3 EMS.

2004 29 JAN 20:23 51.09N 2.98W 7 3.1 BRIDGWATER, SOMERSET
Felt with intensities of 4 EMS.

2004 29 JAN 20:23 51.09N 2.98W 7 3 BRIDGWATER, SOMERSET
Felt with intensities of 4 EMS.

Issued by: Bennett Simpson, British Geological Survey, February 2004.
Non-British earthquake information is supplied by: The United States Geological Survey

SECED Elections

SECED are pleased to announce that the following were re-elected to the SECED Committee:

- Paul Greening
- David Mallard
- Chris Browitt

Forthcoming Events

16/17 September 2004
Practical Seismic Design
Imperial College/SECED Short Course
Imperial College, London

29 September2004
Dynamic Performance of High Specification Foundations (To be confirmed)
ICE 6.00pm

27 October 2004
Structural Impact
ICE 6.00pm

SECED Newsletter

The SECED Newsletter is published quarterly. Contributions are welcome and manuscripts should be sent on a PC compatible disk or directly by Email. Copy typed on one side of the paper only is also acceptable.

Diagrams should be sharply defined and prepared in a form suitable for direct reproduction. Photographs should be high quality (black and white prints are preferred). Diagrams and photographs are only returned to the authors on request. Diagrams and pictures may also be sent by Email (GIF format is preferred).

Articles should be sent to:

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Editor SECED Newsletter,
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SECED

SECED, The Society for Earthquake and Civil Engineering Dynamics, is the UK national section of the International and European Associations for Earthquake Engineering and is an affiliated society of the Institution of Civil Engineers.

It is also sponsored by the Institution of Mechanical Engineers, the Institution of Structural Engineers, and the Geological Society. The Society is also closely associated with the UK Earthquake Engineering Field Investigation Team. The objective of the Society is to promote co-operation in the advancement of knowledge in the fields of earthquake engineering and civil engineering dynamics including blast, impact and other vibration problems.

For further information about SECED contact:
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SECED Website

Visit the SECED website which can be found at http://www.seced.org.uk for additional information and links to items that will be of interest to SECED members.
Email: webmaster@seced.org.uk