UK EARTHQUAKE MONITORING 1997/98

BGS Seismic Monitoring and Information Service

Ninth Annual Report

British Geological Survey
Murchison House
West Mains Road
Edinburgh EH9 3LA
Scotland

Tel: 0131-667-1000
Fax: 0131-667-1877
Internet: http://www.gsrg.nmh.ac.uk/

BRITISH GEOLOGICAL SURVEY

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Global Seismology and Geomagnetism Group

UK Earthquake Monitoring 1997/98

BGS Seismic Monitoring and Information Service

Ninth Annual Report

A B Walker

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Solar-powered earthquake-monitoring station in the north-west Highlands of Scotland (T Bain)

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The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British Technical aid in geology in developing countries as arranged by the Overseas Development Administration.

The British Geological Survey is a component body of the Natural Environment Research Council

Keyworth, Nottingham NG12 5GG
☎ 0115 936 3100
TELEX 378173 BGSKEY G
FAX 0115 936 3200

Murchison House, West Mains Road
Edinburgh EH9 3LA
☎ 0131 667 1000
TELEX 727343 SEISED G
FAX 0131 668 2683

London Information Office at the Natural History Museum, Earth Galleries, Exhibition Road, South Kensington, London SW7 2DE
☎ 0171 589 4090
☎ 0171 938 9056/57
FAX 0171 584 8270

St Just, 30 Pennsylvania Road
Exeter EX4 6BX
☎ 01392 78312
FAX 01392 437505

Geological Survey of Northern Ireland,
20 College Gardens,
Belfast BT9 6BS
☎ 01232 666595
FAX 01232 662835

Maclean Building, Crowmarsh Gifford,
Wallingford,
Oxfordshire OX10 8BB
☎ 01491 838800
TELEX 849365 HYDROL G
FAX 01491 825338

Parent Body
Natural Environment Research Council
Polaris House, North Star Avenue, Swindon
Wiltshire SN2 1EU
☎ 01793 411500
TELEX 444293 ENVRE G
FAX 01793 411501

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UK EARTHQUAKE MONITORING 1997/98

1. Executive Summary

The aims of the Service are to develop and maintain a national database of seismic activity in the UK for use in seismic hazard assessment, and to provide near-immediate responses to the occurrence, or reported occurrence, of significant events. Following a history of seismic monitoring over the past 29 years, the British Geological Survey (BGS) has been charged with the task of operating and further developing a uniform network of seismograph stations throughout the UK in order to acquire standardised data on a long-term basis. The project is supported by a group of organisations under the chairmanship of the Department of the Environment, Transport and the Regions (DETR) with a major financial input from the Natural Environment Research Council (NERC). This Customer Group is listed in Annex A.

In the ninth year of the project (April 1997 to March 1998), two additional strong motion instruments and four large capacity data storage disks have been installed. Some gaps still remain in station coverage; notably in Northern Ireland. Other areas covered by site-specific networks in northern Scotland, Outer Hebrides and the Orkney Islands, are vulnerable to closure owing to their dependency on funds from commissioning bodies.

Some 235 earthquakes were located by the monitoring network in 1997, with 33 of them having magnitudes of 2.0 or greater and 37 reported to be felt by people. The largest felt earthquake in the reporting year (April 1997 to March 1998), with a magnitude of 2.8 ML, occurred near Dartmouth, Devon, on 16 October 1997. It was felt over an area of 1400 km^2 and the maximum intensity in the epicentral region was 4 EMS (European Macroseismic Scale, Annex H). The largest offshore event was in the northern North Sea on 13 May 1997, with a magnitude of 3.4 ML. In addition to earthquakes, BGS frequently receives reports of seismic events, felt and heard, which on investigation prove to be sonic booms, in coalfield areas, where much of the activity is probably induced by mining (eg Newcastle-Under-Lyme) or spurious. During the reporting period, data on two controlled explosions and six sonic events were processed and reported upon following public concern or media attention.

All significant felt events and some others are reported rapidly to the Customer Group through 'seismic alerts' sent by fax and, subsequently, followed up in more detail. The alerts are also available on the Internet. Monthly seismic bulletins were issued 6 weeks in arrears and, following revision, were compiled into an annual bulletin. In all these reporting areas, scheduled targets have been met or surpassed.

The potential of the network's data links and computing capabilities to provide an environmental monitoring capacity has been explored further using additional sensors. These now include radioactivity, ozone, sulphur dioxide and NOx gases. This area of Research and Development has been enhanced through an informal linkage with the Institute of Terrestrial Ecology based at the Bush Estate near Edinburgh.

2. Introduction

The UK earthquake monitoring and information service has developed as a result of the commitment of a group of organisations with an interest in the seismic hazard of the UK and the immediate effects of felt or damaging vibrations on people and structures. The current supporters of the programme, drawn from industry and central and local Government, are referred to as the 'Customer Group' and are listed in Annex A. The project formally started in April 1989 and the published Year 1 report includes details of the history of seismic monitoring by BGS since 1969, as well as the background to the establishment of the project. Earthquake monitoring information is required to refine our understanding of the level of seismic risk in the UK. Although seismic hazard/risk is low by world standards it is by no means negligible, particularly in respect to potentially hazardous installations and sensitive structures. This work helps in assessment of the level of precautionary measures which should be taken to prevent damage and disruption to new buildings, constructions and installations which otherwise could prove hazardous to the population. For nuclear sites, objective information is provided to verify the nature of seismic events or to confirm false alarms, which might result from locally generated instrument triggers. In addition, seismic events cause public concern and there is a need to be able to give objective information as soon as possible after significant events in order to allay any unnecessary worries. Most seismic events occur naturally but some are triggered by human activities such as mining subsidence, and other tremors (eg sonic booms and explosions) are often mistaken for earthquakes.

This Year 9 report to the Customer Group follows the format of the first eight annual reports in reiterating the programme objectives and highlighting some of the significant seismic events in the period April 1997 to March 1998. The catalogue of earthquakes for the whole of 1997 is plotted to reflect the period for which revised data are available and to be consistent with the annual bulletin, which is produced as a separate volume. An updated map of epicentres since 1979 is also included for earthquakes with magnitude ≥2.5 ML; the threshold above which the data set is probably complete. Such events are normally felt by people.

To improve the capacity of the network to deliver on-scale data for the larger earthquakes, and to more effectively calculate their magnitudes, low-gain and strong motion instruments have been added to it. Low-gain instruments employ standard seismometers recording ground velocity but with the electronic amplifier gain reduced by a factor of 50. Strong motion instruments record ground acceleration for the larger felt earthquakes in the range 0.015% g to 0.1% g. Two new strong motion systems have been installed during the year, in North Wales and Leeds, bringing the total to sixteen. Traditionally, strong motion and high sensitivity networks have been treated separately for technical reasons but the digital technology now employed, permits both to be integrated with benefits in cost and reliability. Most importantly, this approach ensures there is a pool of analysts familiar with extracting and processing data despite the infrequency of strong motion earthquakes.

Filling the few remaining gaps in the high sensitivity network, which is intended to have effective station spacing of 70 km, continues to be a project objective although no progress has been possible during the year.

All of the advances made and proposed in the effective background network of the UK can be seen by comparing the present coverage (Fig. 1) with that in 1988 (Fig. 2) although some reliance remains on data contributed from separately funded, site-specific networks. These are vulnerable to closure when the commissioning organisations have completed the work for which they were installed. Strong motion coverage is shown in Figure 6.

3. Programme objectives

3.1 Long-term

The initial overall objectives of the service were:

(i) To provide a database for seismic risk assessment using existing information together with that obtained from a uniform distribution of modern seismograph stations throughout the UK landmass. A mobile network of seismograph stations would be used for specific investigations of seismic events to supplement the background network.

(ii) To provide near-immediate preliminary responses to seismic vibrations reported to have been heard or felt, or of significance to the Customer Group.

These objectives and a strategy to meet them were described more fully in a proposal from BGS dated December 1987. The higher the density of seismograph stations in the network, the more accurate will be the response and the database. In discussion with the Customer Group, a 70 km average spacing of stations (Fig. 5) was agreed as a cost-effective way of achieving the main goals although it was recognised that the determination of some parameters (eg depths of focus and focal mechanisms) could only be approximate.

3.2 Short-term

In 1988, the Customer Group agreed to a reduced initial phase of development of the monitoring network to fit the limited funds likely to become available in the first few years. In this strategy, the following sacrifices were made:

(i) The mobile network could not be specifically supported.

(ii) The 70 km-spacing of stations could not cover the whole country. Advantage would be taken, where possible, of site-specific networks operated for other purposes and of existing recorders with spare channel capacity to add individual stations.

The establishment of a "user-friendly" database and archive of seismicity was to be retained as a high priority element of the project.

3.3 Summary of achievements since 1989

Improvements in network coverage, event detection, delivery of information, databasing and archiving have been made during the course of the project. Highlights are outlined below.

- The installation of seismograph stations to fill in the gaps for the 70 km spacing objective; from 84 stations in 1988 to 141 in 1998. Large areas have been filled in southern England, Irish Sea and northern Scotland.

- The detection capabilities of the network have gradually improved with increasing station coverage and Figures 3 and 4 illustrate the change over the 9-year project period. Almost all magnitude 2.5 earthquakes are felt together with many in the 2.0-2.5 range, and, in 1988, there was poor coverage of such events in many parts of the country.

- In 1988, all stations were recording onto magnetic tapes, which were posted to Edinburgh for analysis. Access to data was generally achieved within two working days of a felt earthquake. Since 1997, all stations have been recorded digitally with data transferred automatically four times a day and on demand at other times when an earthquake occurs. Response time with objective data has been reduced to below one hour, which can generally, be achieved outwith working hours also.

- All UK station positions have been resurveyed using GPS techniques.

- Faster modem links have been installed at all computer recording nodes (23 in total).

- Following upgrading of digital rapid access systems, the potential problem of losing a continuous data record has been addressed by installing large capacity disks to provide a 3-day ring buffer at 13 nodes and a 10-day buffer at the other nine. Developments are in progress to provide a cost-effective, continuous digital archive.

- In order to improve the study of seismicity in the border regions of the North and Irish Seas and the English Channel and SW Approaches, strong data exchange links have been established with European neighbours and with the international agencies, EMSC and ISC (the European Mediterranean Seismological Centre, Paris, and the International Seismological Centre, Newbury). In the North, collaboration with Bergen University has provided direct access, on-line, to digital seismograph stations in western Norway. Elsewhere, BGS has coordinated a 10-nation data exchange network (the Transfrontier Group) from Denmark to Portugal under the EU natural hazards programme.

- A 3-component strong motion network of sixteen stations has been installed from Shetland to Jersey including four stations specifically commissioned by Scottish Nuclear, MOD and the Jersey New Waterworks Company.

- A computer bulletin board has been established which provides access to catalogued seismic events for the previous 12 months, their phase data and details of seismic alerts issued. The Global Seismology Web site provides access to data through the Internet to the past month's catalogue of events.

- Historical material from former UK seismic stations has been brought together and housed in a National Seismological Archive (NSA) at the BGS laboratories in Edinburgh, with a computer-index. A watching brief has been kept on other archives, held elsewhere, with a view to increasing knowledge of the content and preventing their dispersal or destruction. Some of those collections have been transferred to Edinburgh as a result of these interactions.

- The World Seismological Bulletin collection database has been published and is available on the Internet. An UK historical seismological observatories report has been compiled and is also available on the Internet.

- UK earthquake data held on ½" FM magnetic tapes, have been extracted and digitised for events with magnitudes ≥2.0 since 1977. There remains some potential data on the Edinburgh network for the period 1970-1976, recorded on a 1" tape format, which is proving difficult to extract owing to the condition of the tapes and old replay equipment.

- The instrumental digital database is held in a readily accessible format (both for parameter and waveform data) and is updated continuously. Back-up copies are held outside the BGS building in a commercial facility.

- An improved catalogue of historical UK earthquake information has been combined with the modern instrumental data to provide the input for two seismic hazard mapping studies. The assessment for the offshore region was published in 1997 as a Health and Safety Division Offshore Technology Report and the onshore study has been peer reviewed and is now with DTI for publication.

- The potential for using the seismic network for multifunctional environmental monitoring has been proved at three sites near Edinburgh. A number of environmental sensors have been interfaced with the seismic data transmission systems and data files to demonstrate the network's capability to provide baseline information, long term trends, climate change parameters and long-range impact of industrial plumes. An MOU with the Met Office has laid the basis of collaboration and meteorological quality control.

3.4 Uses of the seismic database

In addition to the specific needs of the Customer Group members, the seismic database is used by a variety of organisations both in the UK and worldwide. A summary of the use made of this 30-year catalogue and digital archive of earthquakes, during the past year, is summarised:

3.4.1 University collaboration

Bristol University; Mapping seismic discontinuities

A study at Bristol University, under the leadership of George Helffrich, has been looking at seismic discontinuity mapping using teleseismic data (earthquakes outside the UK).

The earth's major seismic discontinuities in the mantle are at 410 and 660 km depth and are believed to be caused by phase changes in mantle minerals. Seismic waves generated by interaction with discontinuities are weak and usually buried in the noise but the high density of stations in the UK network provides the means to enhance the signal and suppress noise. The Bristol team is using UK and North American data to study the effect that subduction zones have on these seismic discontinuities and to infer their temperature and chemical state at depth. To date, results show that the discontinuities are deflected by the cooler temperatures in subducted slabs a much greater degree than is observed in global studies using long period seismic waves. Temperatures are about 600°C at 350 km depth in the slab, and the thermal halo around the slab is broader than expected from thermal modelling. The work has provided the basis for further research through a NERC studentship.

Brunel University; Glaciotec project

The project, led by Iain Stewart, is a multi-disciplinary investigation of recent crustal movements, postglacial faulting and seismicity associated with the centre of glacio-isostatic uplift. It is an approved part of an International Association of Quaternary Research (INQUA) programme on 'Ice Sheets, Crustal Deformation and Seismicity'. The objectives are to compare and contrast crustal responses to deglaciation in the Fennoscandian, British and North American ice sheet domains, and to assess the influence of glacial deformation on contemporary seismicity patterns and seismic hazard. A reassessment of the extent to which the pattern of glacio-isostatic uplift in Northern Britain is related to the incidence of postglacial faulting and contemporary seismicity is being carried out using the BGS database of seismicity. The project combines field-based geological, geomorphological, sedimentological and palaeoenvironmental expertise with remotely sensed data from satellite and airborne imagery and seismological databases. In particular, current field-based investigations focus on re-appraising the displacement history of suspected postglacial faults and reconstructing recent relative sea-level changes recorded in coastal wetland sites along a transect that extends from the centre of glacio-isostatic uplift to its inferred margin. The aim is to better isolate the contemporary (<150 years) pattern of crustal uplift from sea-level changes, and to compare this with the changing locus and magnitude of glacio-isostatic recovery over preceding millennia. The project will also test whether the distribution of postglacial faults and present-day seismicity is influenced by the limits of the former Loch Lomond Stadial ice-sheet margins. It is hoped that this will feed into improved understanding of seismic hazard in northern Britain by providing a long term (Holocene) perspective on the pattern and magnitude of crustal movements.

Leicester University; UK velocity model

The BGS database is being used by Paul Denton to study velocity discontinuities in the crust, using Receiver Function Analysis techniques. A dataset has been identified at an epicentral distance of between 30 and 100 degrees, to look at the direct P-wave arrival and the P to S-wave conversions that occur at velocity discontinuities within the crust. A process of iteration and inversion will produce a coarse one-dimensional S-wave velocity structure beneath each recording station which, with 141 stations, will build up a UK-wide picture.

Exeter University; Soil gas Geochemistry

Gerard Duddridge and Peter Grainger at the Earth Resources Centre, University of Exeter, have developed techniques in soil gas geochemistry for the detection of faults and fractures using helium (He), radon (Rn) and carbon dioxide (CO_2). It is recognised that Rn activity can be related to seismic activity and as part of a European geochemical seismic zonation project, soil gas measurements have been made in two areas of southwest England for comparison with seismicity data. A fault zone on the southeast side of the Carnmenellis granite in Cornwall was chosen for its historic seismicity and good seismic monitoring network. In Devon, the Sticklepath Fault was selected as a large regional structure with low intensity and infrequent seismic activity. After initial soil gas mapping of each area, a small number of monitoring sites were selected and then sampled every two weeks from 1996 to 1997. The temporal variations of soil gas concentrations were compared to meteorological factors, which could cause them to vary, and also with recorded seismic activity. Anomalously high values of soil gas concentrations could be matched at some sampling points to minor seismic events. Increasing He and anomalous CO_2 values in the north Dartmoor area were noticed as a precursor to the magnitude 1.5 Okehampton event of 26 November 1996. Also, following the magnitude 3.8 Penzance earthquake of 10 November 1996, high Rn was recorded from the Tremough monitoring point near Penryn, Cornwall.

3.4.2 European collaboration

For a number of years through an EU project led by BGS, data exchange with neighbouring countries has been fostered and improved. This has led to more rapid information becoming available on larger transfrontier earthquakes and harmonisation of the catalogues of data used for hazard assessments. Under another EU project for disseminating rapid warnings on earthquakes with magnitudes ≥ 5.0, parts of the UK network have been linked automatically to the European Mediterranean Seismological Centre at Bruyeres-le-Chatel, south of Paris. Separately, French and Norwegian workers have been provided with data on North Sea and English Channel earthquakes to improve attenuation models and constrain focal mechanisms. Major international projects that have drawn upon the UK database include the Global Seismic Hazard Assessment Programme (GSHAP), which is an IDNDR project, and the EC project "Basic European Earthquake Catalogue and Database" (BEECD) under the direction of IRRS-CNR, Milan, Italy.

3.4.3 Hazard studies and database enquiries

The BGS database continues to play an important role in studies of UK seismic hazard. There are two principal applications: safety case preparation for hazardous facilities and more general hazard assessments. As an example of the former, BGS assisted UKAEA in the preparation of the seismic safety case for the Dounreay site during the year, providing analyses of seismicity. More widely, this year saw the publication of the results (in the journal Natural Hazards) of the joint BGS-AEA Technology project on seismic hazard maps for the UK. Work has already commenced on improving these hazard maps by incorporating the latest seismic monitoring results, new ideas into UK tectonics, and new hazard assessment techniques.

Reinsurance

Every year, thousands of earthquakes are recorded and hundreds of research papers are published which expand scientific knowledge about the geological features that produce earthquakes. Most of this information remains inaccessible to those outside the seismological profession. To overcome this problem, the British Geological Survey and Hiscox Syndicates Ltd came together to combine seismological and reinsurance techniques in a computer program that can quickly assess the earthquake risks to a reinsurance portfolio. It is simple to use and can be run on any PC using Windows 3.1 or higher. The user can type in details of a property portfolio within geographic regions known as Cresta accumulation zones in the industry. Optionally, information about the construction type and quality of the buildings to be reinsured can also be entered (if known). Up to twenty layers of reinsurance can then be analysed. The results are returned as the expected loss for each layer, its standard deviation, information on maximum losses and other reinsurance parameters. The probability of different loss levels affecting the whole portfolio can be shown as a graph. The results of each calculation can be stored in the program's own database for later retrieval.

The program has been named the Monica Seismic Risk System as it works on the principle of stochastic modelling, also known as Monte Carlo simulation (MONte (I) CArlo). Using seismic source models that incorporate an analysis of the tectonic and seismological data in each region, the program runs many thousands of simulations of the regional earthquake activity from which it calculates the probability of different amounts of damage and loss. At present, regional data files are available for: Australia SE, Australia W and S, Canada E, Canada W, Chile, Italy, Japan Central, Japan N, Japan S, Mexico, Peru, Philippines, Portugal, Turkey, and New Zealand. More regions will be added in due course. This adaptation of the BGS's seismological expertise has enabled the reinsurance industry to be brought into the sponsoring group for the UK monitoring and information service.

Strong motion records

With the expansion of the strong motion network in the past few years, strong ground accelerations, which would previously have saturated the network, are being recorded from British earthquakes. To-date three strong motion records have been recorded for earthquakes with magnitudes between 2.7 and 3.8 ML at distances of between 17 and 86 km. The values of acceleration measured from these instruments are much less than those expected from the attenuation laws currently used for the UK. Of necessity, these laws have been imported from more highly seismic regions and using earthquakes with larger magnitudes.

Parliamentary questions and advice to the Public Authorities, Industry and media

Some 1,100 enquiries have been answered during the year, with intense interest following felt UK and world earthquakes. A response was provided to the Scottish Office for a parliamentary question concerning offshore explosions.

Data exchange and world reporting

BGS data is exchanged regularly with world agencies to help locate and improve focal mechanism parameters for earthquakes outside the UK and, as a quid pro quo, BGS receives data on UK earthquakes and world events of relevance to the UK, from the many other agencies and institutions.

Test ban treaty verification

Data has been contributed to a programme for calibrating the International network of stations for monitoring the Comprehensive Test Ban Treaty (CTBT). Data from earthquakes and explosions ≥2.5 ML within 1000 km of the UK have been processed and submitted to the international data centre in Washington.

Focal mechanisms

Earthquake focal mechanisms are a basic tool used in the investigation of both local and regional tectonics, providing information on the nature of the brittle crust.

BGS data is used as input to produce earthquake focal mechanisms. In the past, mechanisms could only be obtained for the largest events but as a result of the expansion of the UK network over the years, an increasing number of mechanisms are being obtained. Focal mechanisms have also been obtained for small magnitude events in areas with an optimum azimuthal coverage by dense local networks, for example North Wales and Cornwall.

4. Development of the monitoring network

4.1 Station distribution

The network developed to March 1998, with rapid-access upgrades, is shown in Figure 1 with its detection capability in Figure 3. The scheduled programme for 1997/98 had as its aims:

(i) Further development of the QNX operating system and deployment, for a full trial, alongside an existing SEISLOG unit.

(ii) Installation of additional 4 gigabyte disks to increase the continuous recording capability at all sites where such capacity can be utilised.

(iii) Introduction of two or three new strong motion systems at sub-network digital acquisition centres (priorities being North Wales, Leeds and Moray).

(iv) Continuation of modest enhancements to the multifunctional environmental potential of the network while seeking external support for this initiative.

(v) Maintenance of a watching brief on archives held by other organisations with a view to seeking the transfer to Edinburgh of any considered at risk.

(vi) Publication of archive holdings in an 'updateable' form and inclusion in the Global Seismology web page.

(vii) Completion of the programme of digitising the 1" analogue magnetic tape data.

The QNX system (i) has been running successfully alongside the Lowlands SEISLOG, and another system is due to be installed at Eskdalemuir in 1998. The installation of additional four gigabyte disks (ii) has been fulfilled; at Hartland, Lerwick, Leeds and south east England. The strong motion network (iii) has been enhanced with the installation of two strong motion stations, in North Wales and Leeds; both are recorded onto the rapid-access systems. This brings the total number to sixteen. The multi-functional environmental potential of the network has been enhanced (iv) with the installation of another station, 35 km south of Edinburgh, which is successfully transmitting ozone data and recording temperature and humidity. Contact with archives outside BGS has been maintained (v). The final catalogue of seismological bulletins (vi) has been compiled and a copy is held on the BGS home page. The digitisation of events recorded on the 1" analogue magnetic tapes (vii) is continuing, but is proving difficult, owing to the condition of the tapes and old replay equipment.

4.2 Strong motion network

Obtaining records of strong ground motion for hazard assessments and engineering applications is difficult in areas of low to medium seismicity owing to the infrequency of larger earthquakes. The "importation" of such records from plate margin zones, however, may detract from the realism of analyses conducted in intraplate areas such as the UK. In recognition of the importance of measured strong ground motions, therefore, the project has focused on developing a distribution of 3-component instruments, which would remain on-scale for the larger British earthquakes when the high sensitivity network saturates.

The present distribution of strong motion instruments together with the low-gain instruments, microphones and the environmental station in the Lowlands of Scotland, is shown in Figure 6. Thirteen of the 16 strong motion stations generate open-file data; the other three are operated by, or on behalf of, Scottish Nuclear and MOD.

The impact of this growing network can be seen in Figures 7-10, which show the minimum and maximum magnitudes of earthquakes which can be detected and stay on-scale, as contour maps. Comparisons are drawn between the early phase of development (Figs. 7 and 8) and that prevailing at present (Figs. 9 and 10). Over most of Britain, a magnitude 4.0 earthquake will produce an on-scale trace on at least one strong motion instrument and only rarely will a magnitude 6.0 event cause saturation. The largest known earthquake in the several hundred year historical record, occurred near the Dogger Bank in 1931 with an estimated magnitude of 6.1 ML.

4.3 Related site specific monitoring

With regard to the continuation of site-specific monitoring projects on which the present network depends:

(i) Customer Group membership and support was withdrawn by Nirex on 31 March 1997 following the result of the public inquiry into the development of a rock characterisation laboratory at Sellafield. It is, however, anticipated by BGS that seismic hazard will be an issue for Nirex whatever solution is eventually found for radioactive waste disposal.

(ii) The Jersey New Waterworks Company has continued to support the monitoring network on Jersey.

(iii) The free-field strong motion system for Scottish Nuclear at Torness has continued to operate.

(iv) The 13 stations in northern Scotland and the Orkney Islands, supported by an oil company consortium and HSE, has continued with funding assured until March 1999.

In summary, coverage of the country is almost complete with the aid of these site-specific networks. In the longer-term, however, they represent areas of vulnerability owing to the prospect of the withdrawal of funding.

4.4 Progress with instrumentation

The 24-bit data acquisition system installed in Montserrat in 1996 has continued to perform successfully giving a very wide dynamic range of 140 dB. This removes the distinction between high sensitivity and strong motion systems but the cost of upgrades to 24-bit technology is considerable and resources have not been found to bring the capability into the UK network.

Through the participation in an EU-funded project, coordinated by the European Mediterranean Seismological Centre (EMSC), BGS has developed the capability of providing rapid alerts and data from larger European earthquakes (magnitudes ≥5.0). It depends on coincident event triggers on two (Lownet and Cornwall) out of the UK subnetworks when data is retrieved and event times submitted in less than 1 hour to the EMSC coordination centre at Bruyeres-le-Chatel near Paris. A second strand to the project has resulted in an upgrade of the broad band sensor in Edinburgh and the rapid transmission of data from it, via satellite, to facilitate focal mechanism determinations.

Nine of the networks in the UK have four gigabyte disk storage, (four installed in the past year), allowing up to 10 days of continuous data to be recorded in a ring buffer, together with extra storage for event files which are needed during swarms such as the Blackford series in 1997. These large capacity disks help prevent potential losses as the old analogue Geostore recorders are decommissioned and reliance swings to the event-triggered systems which can miss spurious events, small earthquakes and sonic booms. Twelve networks have one gigabyte disk storage, which provides a three-day window of continuous data.

The new operating system (QNX) has been running successfully alongside the Lowlands SEISLOG and a second system is scheduled for Eskdalemuir. QNX gives a number of advantages: increased processing power, larger memory capacity (from 4 Mb to upwards of 32 Mb), improved communication links using Ethernet cards and ISDN links (digital telephone lines), together with greater portability.

4.5 Environmental monitoring

Environmental monitoring is becoming increasingly important in modern life. Many city centres now have air pollution monitoring equipment but the background levels and wide area effects are often not so well studied due to the high cost of collecting data from a wide-spread network. The costs are especially acute where the data is required on-line, due to the extra expense of telemetry equipment. The existing infrastructure of the UK seismograph monitoring network with its remote stations giving continuous on-line data from the Shetland Islands to Jersey, can potentially provide a cost-effective environmental monitoring network. Users can inspect the data in real-time or transfer it at intervals via modem or the Internet. In principle, any environmental sensor can be interfaced and sampled at, say, once per minute. To this end, three environmental stations (one in collaboration with ITE - Institute of Terrestrial Ecology) have been operating near Edinburgh where air and ground temperature, ozone, radioactivity, UVB, NOx gases and humidity data are being transmitted to a base station. The stations have the capacity to transmit data from 16 environmental sensors simultaneously. Selected potential users of the system, including the Scottish Environmental Protection Agency and the Scottish Water Authorities, have been kept informed of the monitoring capabilities with a view to seeking further support for its development. A Memorandum of Understanding with the Meteorological Office is designed to explore possible avenues of collaboration.

5. Seismic activity in Year 9

5.1 Earthquakes located for 1997

Details of all earthquakes, felt explosions and sonic booms detected by the network have been published in monthly bulletins and, with final revision, are provided in the BGS bulletin for 1997 published and distributed in April 1998 (Walker, 1998). A map of the 235 events located in 1997 is reproduced here as Figure 11 and a catalogue of those with magnitudes of 2.0 or greater is given in Annex B. Fifteen in that magnitude category, together with 22 smaller ones, are known to have been felt. In the period since BGS extended its modern seismic monitoring in the UK (1979 to March 1998), almost all of the earthquakes with magnitudes ≥2.5 ML are believed to have been detected. The distribution of such events for that period (Fig. 12) is, therefore, largely unbiased by the distribution of seismic monitoring stations for the onshore region. Accuracy of individual locations, however, will vary across the country.

5.2 Significant events

Highlights of the seismic activity during the ninth year of the project (April 1997 to March 1998) are given below:

(i) The largest offshore earthquake occurred in the northern North Sea on 13 May. It had a magnitude of 3.4 ML and was located approximately, 270 km ENE of Lerwick, Shetland, in the North Viking Graben region; no felt reports were received. A further five events occurred in the northern North Sea area, with magnitudes ranging between 1.7 and 2.9 ML, and were located using both the BGS and Norwegian networks.

(ii) In North Wales, on 16 May, an earthquake, with a magnitude of 0.1 ML, was located on the Lleyn Peninsula in the same area and at a similar depth as the magnitude 5.4 ML Lleyn earthquake of 19 July 1984, which was felt over an area of 250,000 km^2.

(iii) On 19 May, an earthquake, with a magnitude of 2.7 ML, occurred near the town of Carterton, Oxfordshire. The event was felt throughout the villages of Carterton, Witney, Burford and Bampton. Felt reports described "felt like the foundations were lifted", "the light fitting rattled" and "the whole desk shook and items rattled", indicating a maximum intensity of at least 4 EMS in the epicentral area. This is the largest event in the immediate area since the magnitude 1.9 ML Lechlade earthquake on 15 June 1984, approximately 5 km to the south-west.

(iv) On 22 June, an earthquake, with a magnitude of 2.2 ML, occurred offshore Jersey in the Channel Islands, approximately 2 km west of Grosnez Point (Fig. 13). The event was felt throughout Jersey, where felt reports described "the floor vibrated for 15-20 seconds", "the whole bungalow shook" and "like a plane crashing". A macroseismic survey was carried out and 117 replies were received (111 positive and 6 negative). They indicated a maximum intensity of 4 EMS close to the epicentre. This is the largest event in the area since the magnitude 3.5 ML St. Aubin's Bay earthquake, on 30 April 1990, which was felt throughout Jersey and Guernsey and had a maximum intensity of 5 EMS.

(v) On 8 October, an earthquake, with a magnitude of 2.1 ML, occurred in Ulverston, Cumbria. Felt reports were received from Ulverston, Kirkby-in-Furnace, Broughton Beck and Bouth, and included "like an explosion followed by a rumble" and "a loud bang", indicating an intensity of at least 3 EMS. This is the largest event in the area since the magnitude 3.0 ML, Grange-over-Sands earthquake of 26 June 1993, which was felt over an area of 9000 km^2 and had a maximum intensity of 5 EMS.

(vi) An earthquake, with a magnitude of 2.8 ML, occurred on 16 October approximately 10 km northwest of Dartmouth in Devon. A seismogram of the event recorded on the Cornwall network is shown in Figure 14. Felt reports described "being woken up and the bedside cabinet shaking", "a great shake moved the foundations" and "the house shook from side to side for 1-2 seconds". A macroseismic survey was carried out and 162 replies were received (156 positive and 6 negative). They indicated a maximum intensity of 4 EMS close to the epicentre and a felt area of 1400 km^2. No focal mechanism was obtained for this event owing to the poor station distribution in the epicentral region.

(vii) In the Loch Maree area, of the Scottish Highlands, an earthquake, with a magnitude of 2.5 ML, occurred approximately 10 km southeast of the village of Gairloch on 8 November. Felt reports were received from the village of Gairloch where some residents were awakened from sleep and described the effects like "a large rumble and the house was shaking" and "like distant thunder", indicating an intensity of at least 4 EMS.

(viii) Near Doune, Central Scotland, ten earthquakes were detected with magnitudes ranging between 0.9 and 2.7 ML, six of which were reported felt throughout the Doune area. The two largest events with magnitudes of 2.7 ML, occurred on 6 October and 30 November 1997 and were reported felt throughout the Doune, Callander, Deanston, Thornhill and Dunblane areas of Central Scotland. Felt reports described "we were woken up", "the whole house shook" and "cups fell off the sideboard", indicating an intensity of at least 4 EMS in the epicentral area and in some cases 5 EMS.

(ix) A swarm of 53 earthquakes, seven felt by local residents, were detected in the Blackford area of Tayside, with magnitudes ranging between -0.2 and 2.4 ML. The largest, with a magnitude of 2.4 ML, occurred on 30 July and was felt throughout the Blackford area. The local Police were flooded with calls and felt reports described "the whole building shook", "pictures on the walls moved" and "the cupboard doors flew open", indicating an intensity of at least 4 EMS. This is an area that has experienced a number of events in the past, including the magnitude 3.2 ML Ochil Hills earthquake on 19 February 1979, which had a maximum intensity of 5 EMS.

(x) On 8 December, an earthquake, with a magnitude of 2.3 ML, was located approximately 5 km southeast of the village of Fort Augustus, Scottish Highlands. Felt reports were received from Fort Augustus, which described "we were woken up" and "items in the house were rattling", indicating an intensity of at least 4 EMS.

(xi) Near Caernarvon, Gwynedd, a small earthquake with a magnitude of 1.2 ML, was felt by a resident in the village of Tregarth on 19 December. She described "the house shook" and "heard a rumble", indicating an intensity of 3 EMS, which is surprising as events with such small magnitudes are rarely felt.

(xii) On 8 January 1998, an earthquake, with a magnitude of 1.7 ML, was felt in the Onich area of the Scottish Highlands, approximately 14 km southwest of Fort William. Felt reports were received from the village of Onich, which described "a large rumble like thunder", "the house trembled" and "we thought it was a land slide", indicating an intensity of at least 3 EMS.

(xiii) An earthquake, with a magnitude of 3.1 ML, was located approximately 70 km south of Folkestone, Kent, east Sussex on 27 January 1998. Data was exchanged with the European Transfrontier participants and enquiries were made to the Dover Coastguard and colleagues in France but both confirmed that no felt reports had been received for this event.

(xiv) An earthquake with a magnitude of 2.4 ML was located approximately 15 km south of Penzance, Cornwall, on 8 February 1998. BGS received calls from local newspapers, the Coastguard and many residents, who described "sounded like a train under the house" and "light fittings rattled", indicating an intensity of at least 4 EMS. This event was located 7 km south-east of the 10 November 1996 Penzance earthquake, which had a magnitude of 3.8 ML and was felt with maximum intensities of 5 EMS.

(xv) On 11 February 1998, an earthquake, with a magnitude of 2.3 ML, was felt in the Cwmbran and Newport areas of Gwent. Felt reports described "windows and doors rattled" and "felt like the wall was moving", indicating an intensity of 3 EMS.

(xvi) Near Killin, Central Scotland, two events, with magnitudes of 1.9 and 1.7 ML, occurred on 5 March 1998. They were felt in Killin, Balquhidder and Glendochart where residents reported “loud rumble” and “the bed started to shake”.

(xvii) An earthquake, with a magnitude of 2.7 ML, was located approximately 12 km east of Oban, Strathclyde on 7 March 1998. A seismogram of the event recorded on the Lowlands network is shown in Figure 15. Felt reports were received via Oban Police, the media and many residents, who described "we were woken from sleep", "heard a loud bang or a crack" and "the whole house shook", indicating an intensity of at least 4 EMS. A landslide, some 50 miles to the south of the epicentre, was reported by some newspapers to be caused by the earthquake. This was quickly ruled out as Police reports confirmed that the landslide occurred two hours before the earthquake. This event was located approximately 23 km east of the 29 September 1986 Oban earthquake, which had a magnitude of 4.1 ML and was felt with intensities of 5 EMS.

(xviii) The coalfield areas of central Scotland, Yorkshire, Staffordshire and Nottinghamshire continued to experience earthquake activity of a shallow nature which is believed to be mining induced. Some 65 coalfield events, with magnitudes ranging between 0.7 and 2.1 ML, were detected in the year. Eighteen of these were reported felt by local residents. Eighteen events, with magnitudes ranging between 0.7 and 1.5 ML, were located near Clackmannan in the central region of Scotland; none were reported felt. This is an area, which has experienced many such mining induced events in the past. Following the closure of Monktonhall Colliery near Edinburgh, in March 1997, no further events have been detected.

(xix) Near Newcastle-under-Lyme, Staffordshire, 31 shallow events occurred, with magnitudes ranging between 0.9 and 1.8 ML. Twelve of these events were felt by local residents in the Keele and Whitmore areas of Staffordshire. A seismogram of the largest (1.8 ML), recorded on the Keyworth network, is shown in Figure 16.

(xx) In other coalfield areas, small events were located near Doncaster, South Yorkshire (1.7 ML, 27 April 1997; felt in Doncaster, and 2.1 ML, 17 February 1998; felt Maltby and Braithwell), Nottingham, (0.7 ML, 2 July 1997; felt in Linby), Haltwhistle, Northumberland (0.7 ML, 3 August 1997), Oxton, Nottinghamshire (1.1 ML, 12 August 1997; felt in Oxton), Linby, Nottinghamshire (1.0 ML, 22 August 1997, felt in Linby), Ollerton, Nottinghamshire (1.7 ML, 15 October 1997, 0.8 ML, 21 November 1997 and 0.9 ML, 28 November 1997), Calverton, Nottinghamshire (0.9 ML, 29 October 1997; felt in Calverton), Ashbourne, Derbyshire (0.9 ML, 12 November 1997), Stone, Staffordshire (1.4 ML, 1 December 1997), Mansfield, Nottinghamshire

(0.9 ML, 26 January 1998), Worksop, Nottinghamshire (1.1 ML, 22 March 1998, 1.2 ML, 23 March 1998) and Kingsley, Staffordshire (0.9 ML, 30 March 1998). These events are presumed to be related to present-day coal mining activity.

(xxi) Elsewhere in the country, many seismic events have been reported felt or heard like small earthquakes but, on analysis, have been proved to be sonic booms (Fig. 17). Specific examples are: NE Scotland (23 September 1997), Pembroke (29 October 1997), Edinburgh (30 October 1997), Hartlepool (7 November 1997), North Wales (2 December 1997) and Strathclyde (11 December 1997).

(xxii) Reports have been received of man-made events, which were the focus of media attention. On 9 April 1997, blasting at a quarry near Lerwick, Shetland Islands, was felt by a number of local residents who reported "the whole house shook" and "the cat ran outdoors". Offshore the island of Arran, Scotland, on 2 September 1997, a controlled explosion, part of an exercise from HMS Bidster, was felt by around 40 people in Brodick Castle (Fig. 18).

5.3 Italian earthquakes

Two earthquakes, with magnitudes of 5.6 and 6.0 Ms, on 26 September in Central Italy, resulted in the deaths of 11 people and injury to over 100 more in the Marche and Umbria regions. Extensive damage (Plate 1) was reported throughout the region including damage to the Basilica of Saint Francis at Assisi, some 40 km to the west. These events were felt in many parts of central and northern Italy, from Rome (some 130 km away) to Bologna and Modena, and were also felt in western and central Slovenia and as far as southern Karnten Province, Austria (400 km from the epicentre). Further earthquakes occurred in the area during September and October causing at least 25 further injuries and additional damage to the Basilica of Saint Francis. The series continued spasmodically through to a magnitude 5.4 Mb event on 26 March 1998, which caused some damage but no fatalities. A seismogram of the largest event (6.0 Ms) is shown in Figure 19.

5.4 Global earthquakes

The monitoring network detects large earthquakes elsewhere in the world.

(i) One of the most disastrous earthquakes during 1997, with a magnitude of 7.3 Ms, occurred on 10 May in Northern Iran. It caused the deaths of at least 1,600 people, injured 2,300 more, destroyed or damaged over 16,000 homes and left over 50,000 homeless in the Birjand-Qayen area. Several landslides were reported from the epicentral area and damage was reported from the Herat region of Afghanistan, some 220 km to the north east. A seismogram of the event recorded on the Lowlands network is shown in Figure 20. A smaller earthquake, (4.5 Ms), occurred three days later, 40 km to the south east, killing one person and destroying several houses in Khunik Sar. The most notable event in the region historically, was the magnitude 7.3 Dasht-e-Bayez earthquake of 1968, which resulted in the deaths of between 12,000 and 20,000 people.

(ii) On 21 May, 38 people were killed and more than 1,000 were injured as a result of a magnitude 6.0 Mb earthquake in the intraplate region of Jabalpur, India. (Plate 2). A seismogram of the event recorded on the Hereford network is shown in Figure 21.

(iii) On 4 February 1998, an earthquake, with a magnitude of 6.1 Ms occurred in north east Afghanistan-Tajikistan border region. At least 4,000 people were killed and around 15,000 made homeless. A seismogram of the event recorded on the Cumbria network is shown in Figure 22.

6. The National Seismological Archive (NSA)

6.1 Identification, curation and cataloguing

The World Seismological Bulletin collection database is now available on the GSGG web pages in a searchable form (address: http://www.gsrg.nmh.ac.uk/˜phoh/nsa_database.htm). A reference copy is also held in the NSA for the use of staff and researchers. Cataloguing of seismological reports and publications, seismograms, microfilm, newspaper references and other material is progressing.

A report has been published on historical seismological observatories in the UK, based on NSA material and searches of other archives. A list of these observatories is given in Annex I and their locations are shown on Figure 23. The report is also available electronically on the GSGG web pages (address: http://www.gsrg.nmh.ac.uk/˜phoh/nsa_observatories.htm). This study has confirmed the status of surviving observatory material and has located previously unknown material and observatories (eg. Down House, Kent; Fort William, Scotland; Ben Nevis, Scotland; Beeston, Nottinghamshire, and Selfridges, London).

During the reporting year, all existing seismological material excluding seismographs (two Milne instruments) from Aberdeen University was transferred to the NSA and the seismograms were microfilmed. Seismograms from Coats and Durham observatories were microfilmed, leaving only seismograms and bulletin material from West Bromwich to be completed. The majority of known UK seismological bulletins and seismograms now either reside in the NSA, or have been microfilmed. A summary of the status of observatory records is given below:

Aberdeen: All material from the original Parkhill Observatory, Dyce (1914-1932) is presumed lost (one small photo of a 1924 seismogram is held). Seismograms and seismological bulletins from the Aberdeen Observatory, Kings College, Aberdeen University (1936-1967) have been transferred to the NSA in 1997. Seismogram microfilming has now been carried out and a catalogue produced.

Bidston: Material from the Bidston Observatory, Liverpool (1898-1957) held in the archive consists of seismograms (1938-1956) and station bulletins (1901-1919, 1925-1940). The seismograms have been microfilmed. Other original material is presumed destroyed.

Cambridge: Material from the Crombie Seismological Laboratory, Cambridge held in the NSA, consists of annual reports (1954-1968) and one bulletin (1958).

Coats Observatory, Paisley: Material held from this observatory (1898-1919) consists of seismograms (1900-1919 and 1931-1935) and a seismographic register (1902-1909). The seismograms have now been microfilmed. Other original material is presumed destroyed.

Durham: Material held from the Durham University Seismological Observatory (1930-1975) consists of seismograms (1938-1975) and bulletins (1930-1975). The seismograms have now been microfilmed.

Edinburgh: Material from the Royal Observatory, Edinburgh (1894-1962) consists of selected seismograms (1902-1908) and bulletins (1922-1962). The archive holds a wider range of microfilmed seismograms (1896-1962) than originals, which were destroyed in the late 1960s.

Eskdalemuir: Material from the Eskdalemuir, Scotland Observatory (1908-1925) is varied, and consists of seismograms (1910-1920) and bulletins (1913-1916, 1920-1925). The seismograms have been microfilmed.

Eskdalemuir: WWSSN: The Eskdalemuir Worldwide Standard Seismograph Network seismograms (1964-1995) continue to be stored at Eskdalemuir, with microfilm copies available for inspection in the NSA.

Guildford: Material held from the Seismograph Station at Woodbridge Hill, Guildford consists of bulletins (1910-1915).

Jersey: Material from the Jersey Observatory (1935-1994) consists of seismograms (1936-1985) and bulletins (1946-1965). The seismograms have been microfilmed.

Kew: Material from the Kew Observatory (1898-1969) consists of seismograms (1904-1965) and a range of bulletins (1899-1969), together with a wide range of related material. The seismograms have been microfilmed.

Oxford: Material from the Oxford Observatory (1918-1947) are presumed lost, bar one seismogram held in the NSA.

Rathfarnham: Material from the Rathfarnham Castle Observatory, Dublin (1916-1964), are held by the Dublin Institute for Advanced Science (DIAS). The NSA holds some bulletins (1950-1960).

Shide: Material from the Shide Observatory, Isle of Wight (1895-1917), is presumed destroyed, though the Isle of Wight County Record Office has tracings of a few seismograms. Other material is held in the Carisbrooke Castle Museum.

Stonyhurst: Material from the Stonyhurst College Observatory, Blackburn (1908-1947) is also presumed destroyed, except for some bulletins held in the NSA (1909-1933).

Valentia WWSSN: All records from this station are presumed to be held at Valentia, Ireland.

West Bromwich: The surviving papers and records from West Bromwich Observatory (JJ Shaw) are held at the Lapworth Museum, Birmingham University. Microfilming of seismograms and bulletins is in progress.

6.2 Storage and Inspection facilities

The National Seismological Archive has been visited this year by six scientists, and many data requests have been answered from scientists and researchers worldwide, including a large number by e-mail via the Internet Web pages, which have been updated to provide both information and searchable catalogues.

Following completion of a major renovation of Murchison House, improved facilities, consisting of PC workstations, a larger inspection area and easier access to reference materials, have now been provided in the main archive inspection room.

6.3 Digital records

The programme of digitising old 1" analogue tapes is continuing following the upgrade of computer digitising software but is proving difficult to extract owing to the condition of the tapes and old replay equipment.

7. Dissemination of results

7.1 Near-immediate response

Customer Group members have continued to receive seismic alerts by Fax (Annex C) whenever an event has been reported to be felt or heard by more than two individuals. In the case of series of events in coalfield areas, only the more significant ones are reported in this way. Some 48 alerts have been issued to the Customer Group during the year.

The bulletin board, on a captive process on the central computer in Murchison House, has continued to be maintained on a routine basis for UK and global earthquake information. It contains continually updated seismic alert information together with the most recent 3 months, at least, of provisional data from the routine analysis of the UK network. Throughout the year, an updated catalogue listing of recent earthquakes (1 month) and seismic alerts, giving details of UK and global earthquakes, has been available through an Internet home page (address: http://www.gsrg.nmh.ac.uk/). Questionnaires and updated information on the Jersey and Dartmouth earthquakes were also made available on the home page. Feedback suggests that the GSRG web site is being used extensively for the wide variety of seismological information it offers. In the past year, some 30,000 visits have been logged.

Remote telephone access to all the UK seismic stations is available and six of the principal BGS seismologists can obtain data directly from their homes. Two members of staff are on-call 24 hrs-a-day to improve the response to earthquakes and seismic alerts outside working hours. These advances have resulted in considerable improvements in the immediate response capability for UK and global events including enquiries which prove to be spurious or of non-earthquake phenomena. Most of the UK is now covered in this way for earthquakes with magnitudes of 2.0 ML or greater.

7.2 Medium-term response

Preliminary bulletins of seismic information have continued to be produced and distributed on a routine basis to the Customer Group within 6 weeks of the end of a 1 month reporting period.

7.3 Longer-term

The project aim is to publish the revised annual bulletin of UK seismic activity within 6 months of the end of a calendar year. For 1997, it was issued within 4 months.

8. Programme for 1998/99

During the year, the project team (Annex D) will continue to detect, locate and understand natural seismicity and man-made events in and around the UK and to supply timely information to the Customer Group. The database and archive of UK seismicity and related material will be maintained and extended, with information on holdings disseminated on the Internet. Modest improvements will be made to the station coverage and, as opportunities arise, further strong motion and broad band instruments will be installed. Specific advances anticipated for 1998/99, subject to the continuation of funding at least at the current level and without any unexpected closures of site specific networks, are:

(i) Further installation of the QNX operating system.

(ii) Progress year 2000 compliance of data acquisition and analysis systems.

(iii) Installation of additional 4 gigabyte disks to increase the continuous recording capability at sites where such capacity can be utilised.

(iv) Introduction of two new strong motion systems at sub-network digital acquisition centres, priorities being Moray and northern Scotland.

(v) Pursue opportunities for capturing more strong motion data in collaboration with the nuclear industry.

(vi) Collaborate with universities and AWE to secure further broad band data.

(vii) Maintenance of a watching brief on archives held by other organisations with a view to seeking the transfer to Edinburgh of any considered at risk.

9. Acknowledgements

We particularly wish to thank the Customer Group (listed in Annex A) for their participation, financial support and input of data and equipment to the project. Station operators and landowners throughout the UK have made an important contribution and the technical and scientific staff in BGS (listed in Annex D) have been at the sharp end of the operation. The work is supported by the Natural Environment Research Council and is published with the approval of the Director of the British Geological Survey (NERC).

10. References

Walker, A.B., (editor), 1998. Bulletin of British earthquakes 1997, Brit.Geol.Surv. Tech. Rep. No. WL/98/01.

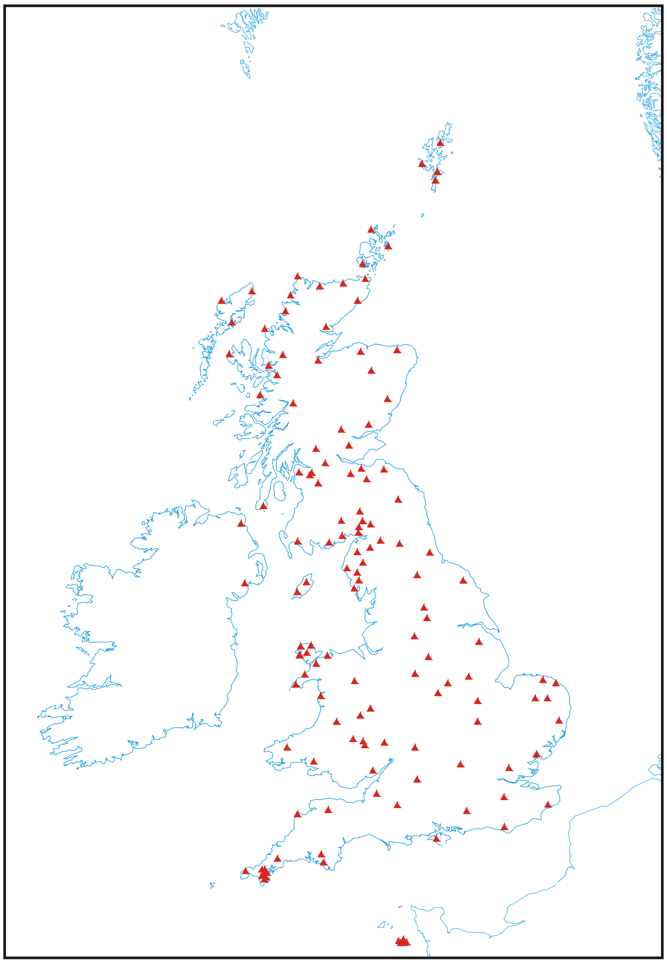

Figure 1. BGS rapid access seismograph network operational in March 1998.

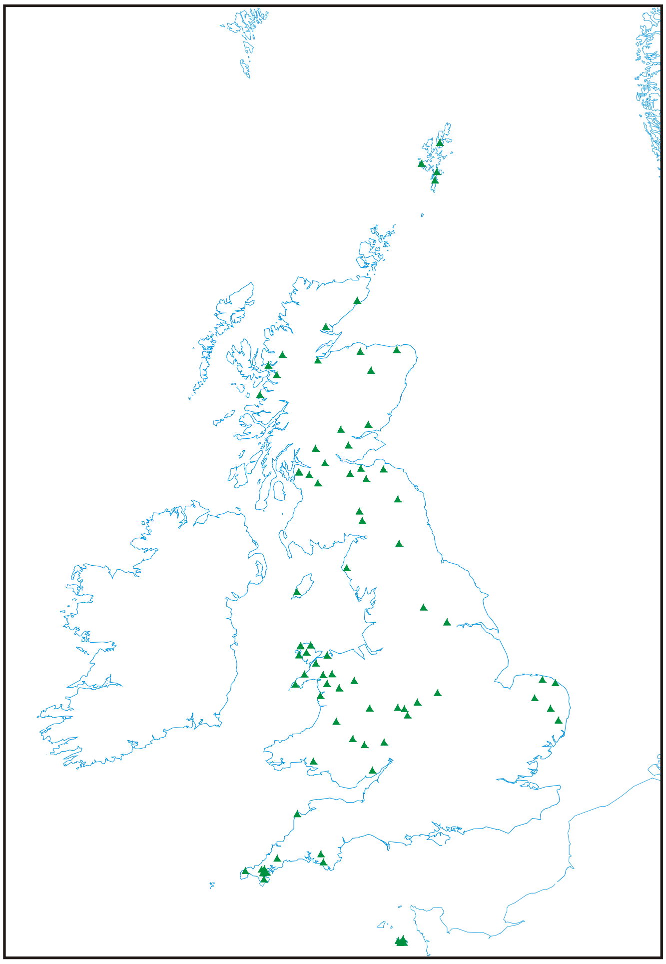

Figure 2. BGS seismograph network in 1988 prior to the commencement of the UK monitoring enhancement project.

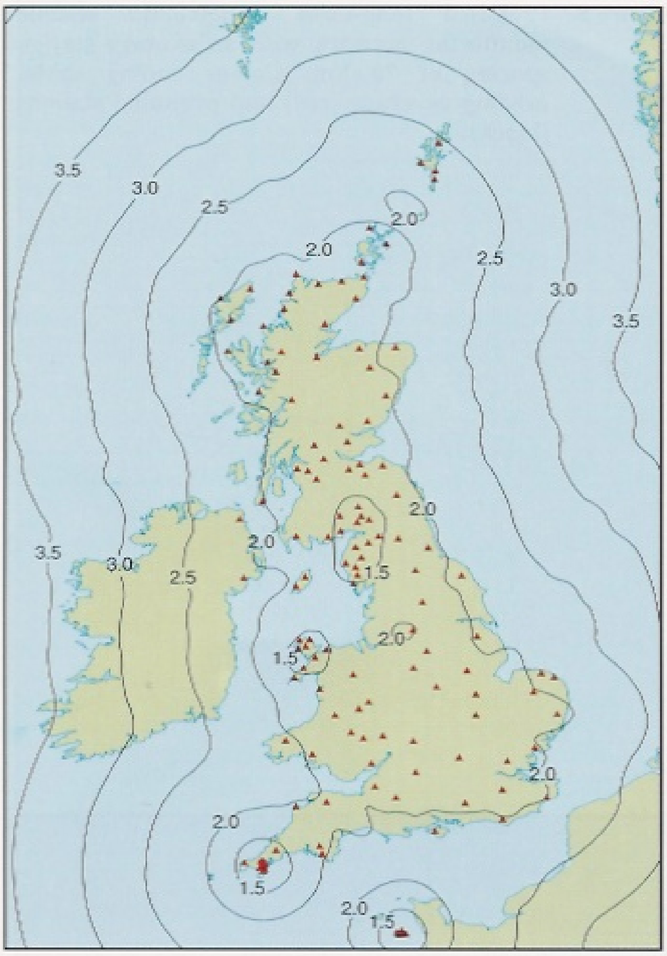

Figure 3. **Detection capability of seismograph network, March 1998. Contour values are Richter local magnitude (ML) for 20 nanometres of noise and S-waves amplitude twice that at the fifth nearest station.**

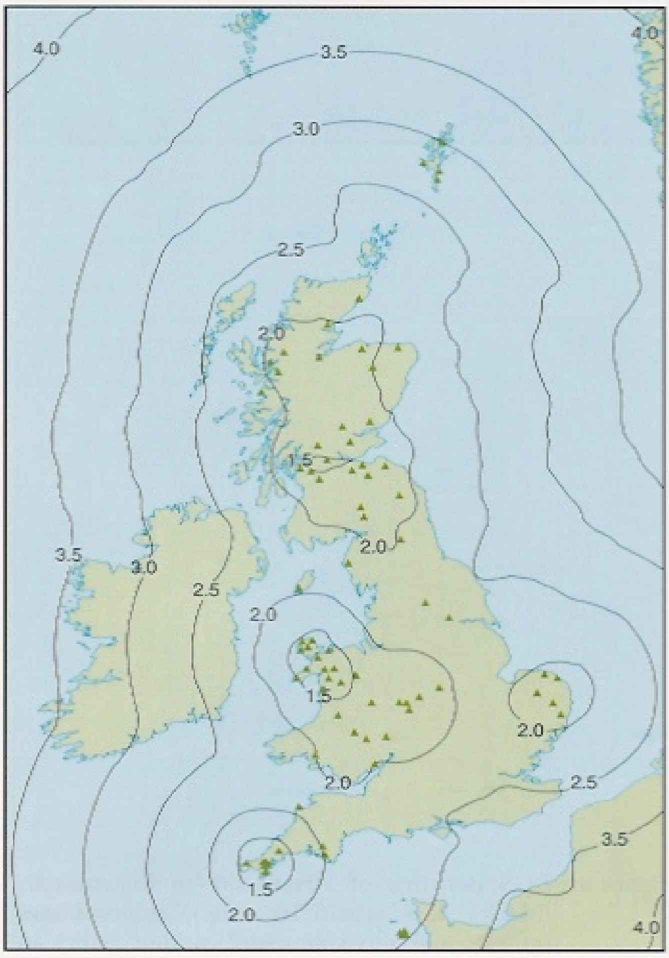

Figure 4. **Detection capability of seismograph network, 1988. Contour values are Richter local magnitude (ML) for 20 nanometres of noise and S-wave amplitude twice that at the fifth nearest station.**

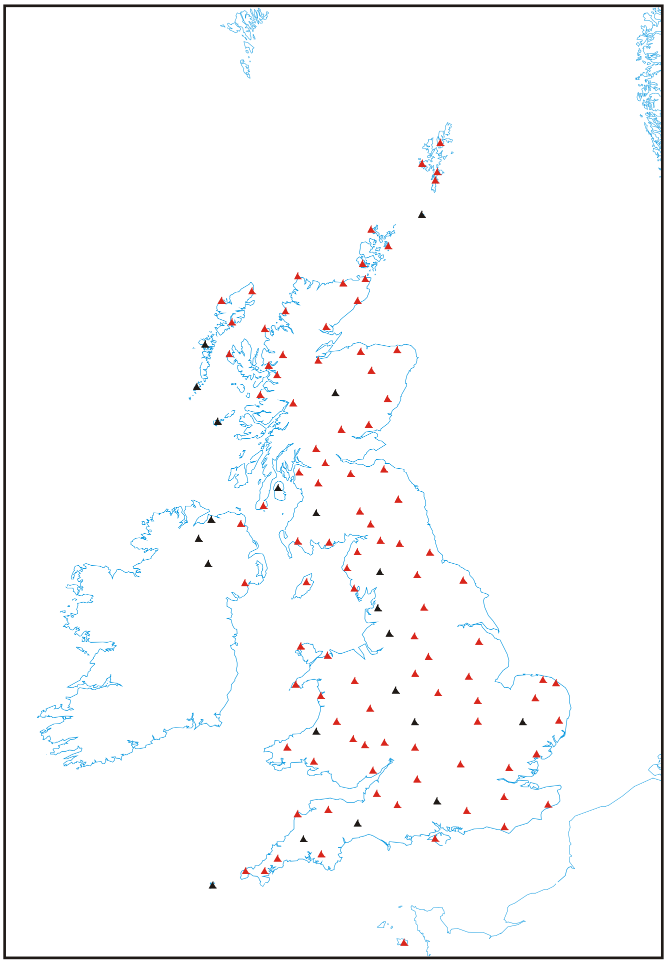

Figure 5. Proposed long-term background seismic monitoring network with an average station spacing of 70 km. Colour coding shows existing coverage (red) and proposed stations (black).

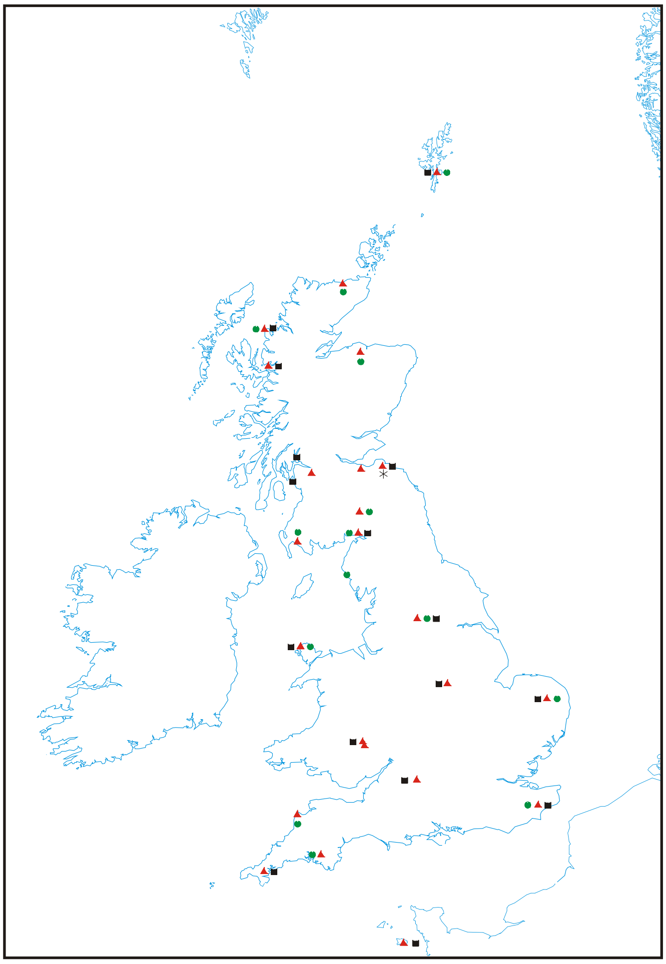

Figure 6. BGS network of strong-motion instruments (black), low sensitivity (red), microphones (green) and environmental station (star) in March 1998.

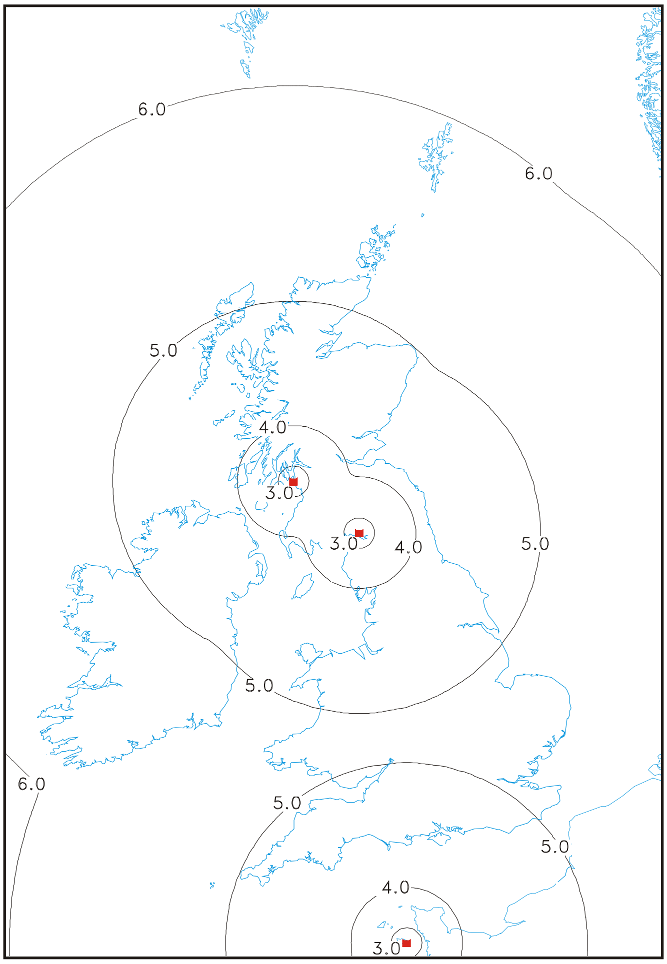

Figure 7. Minimum Richter local magnitude (ML) detectable by the strong motion network operational December 1992.

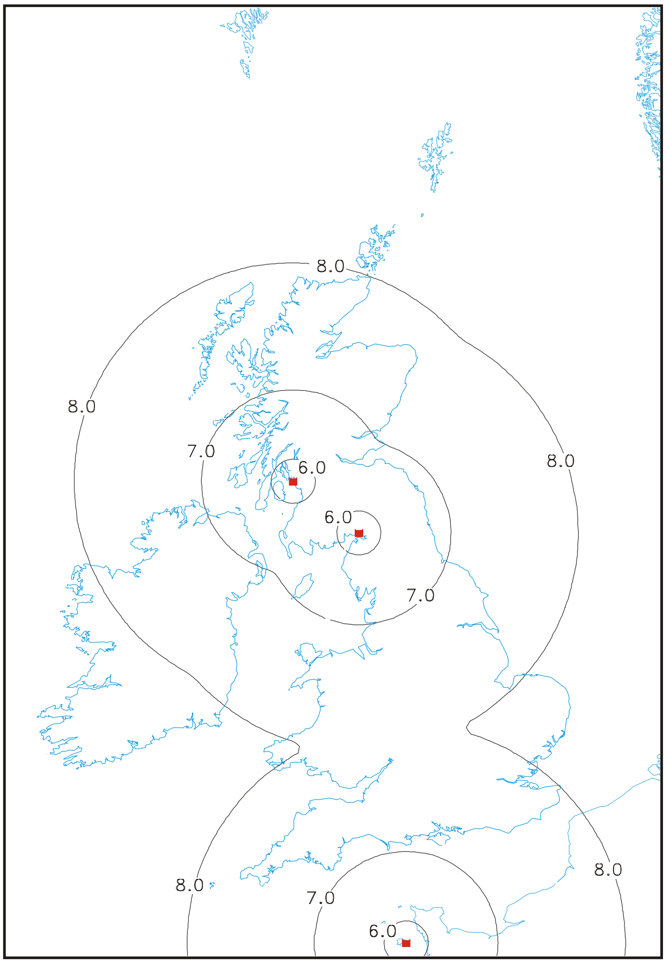

Figure 8. Maximum Richter local magnitude (ML) which will not saturate the strong motion network operational December 1992.

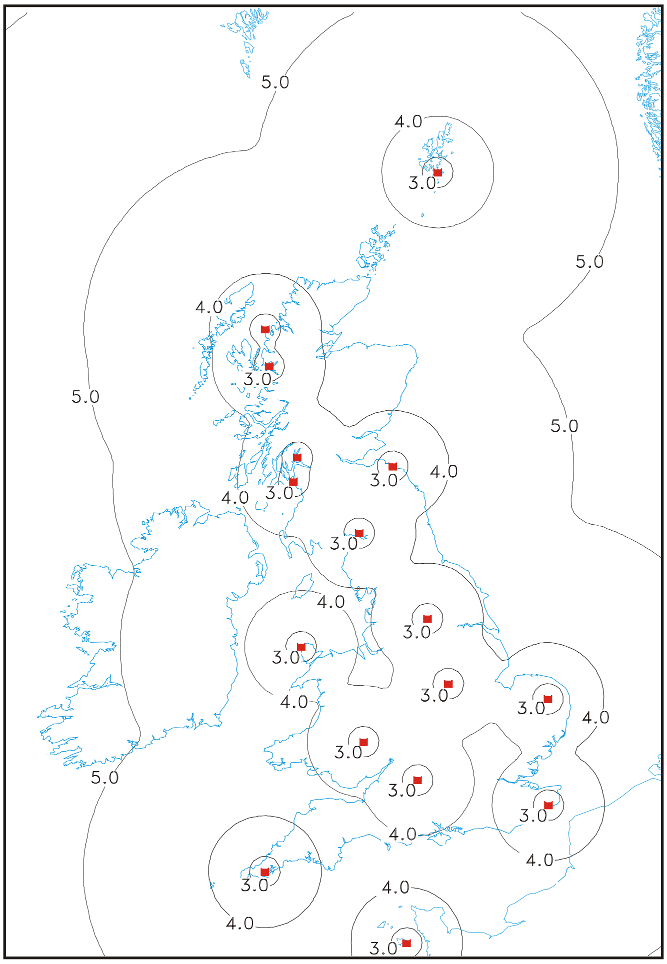

Figure 9. **Minimum Richter local magnitude (ML) detectable by the strong motion network operational March 1998.**

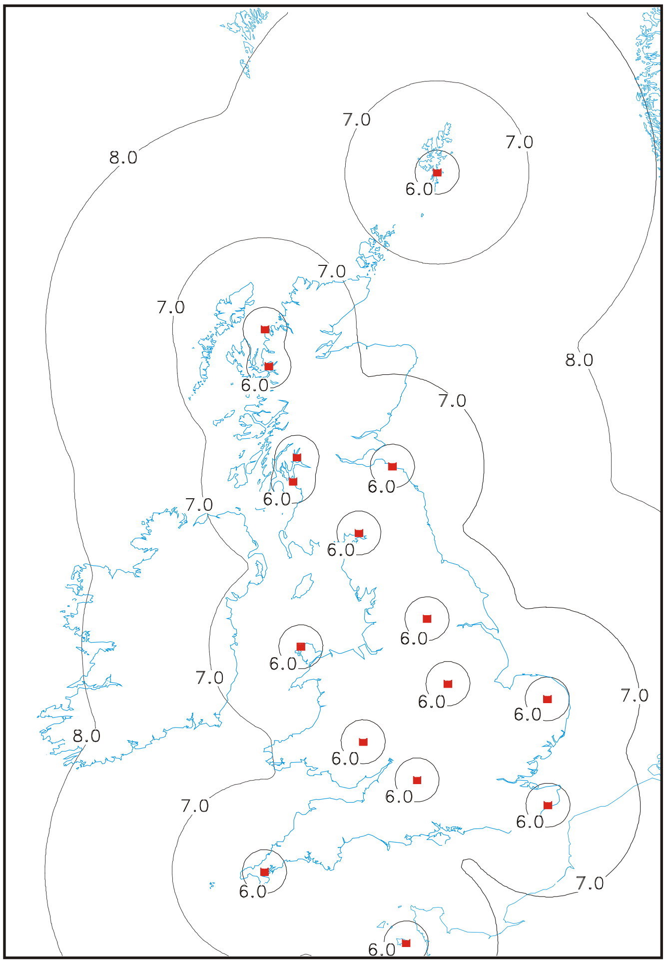

Figure 10. **Maximum Richter local magnitude (ML) which will not saturate the strong motion network operational March 1998.**

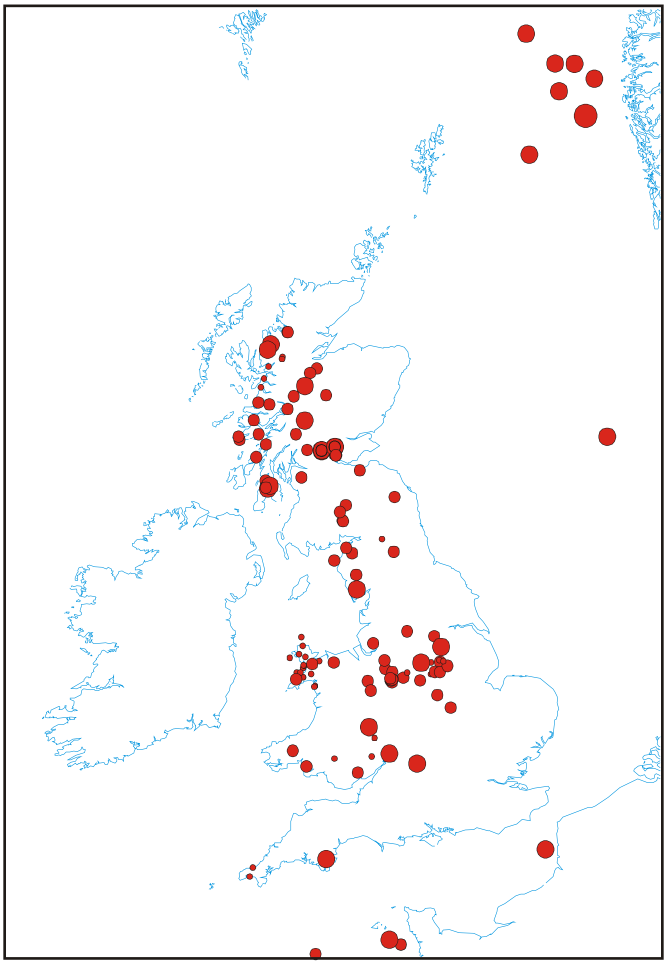

Figure 11. **Epicentres of all UK earthquakes located in 1997.**

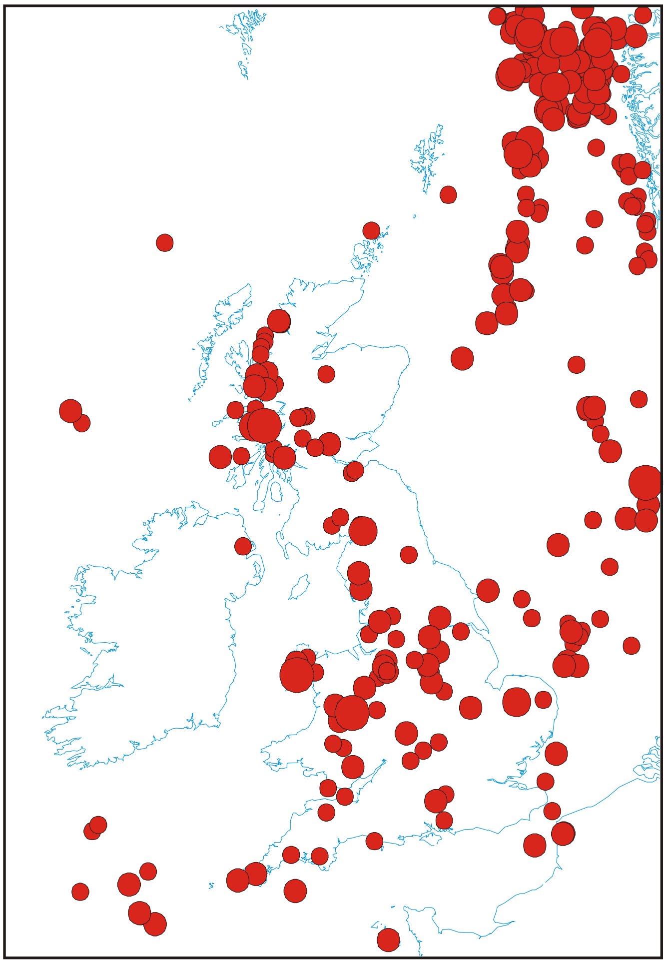

Figure 12. **Epicentres of earthquakes with magnitudes 2.5 ML or greater, for the period 1979 to March 1998.**

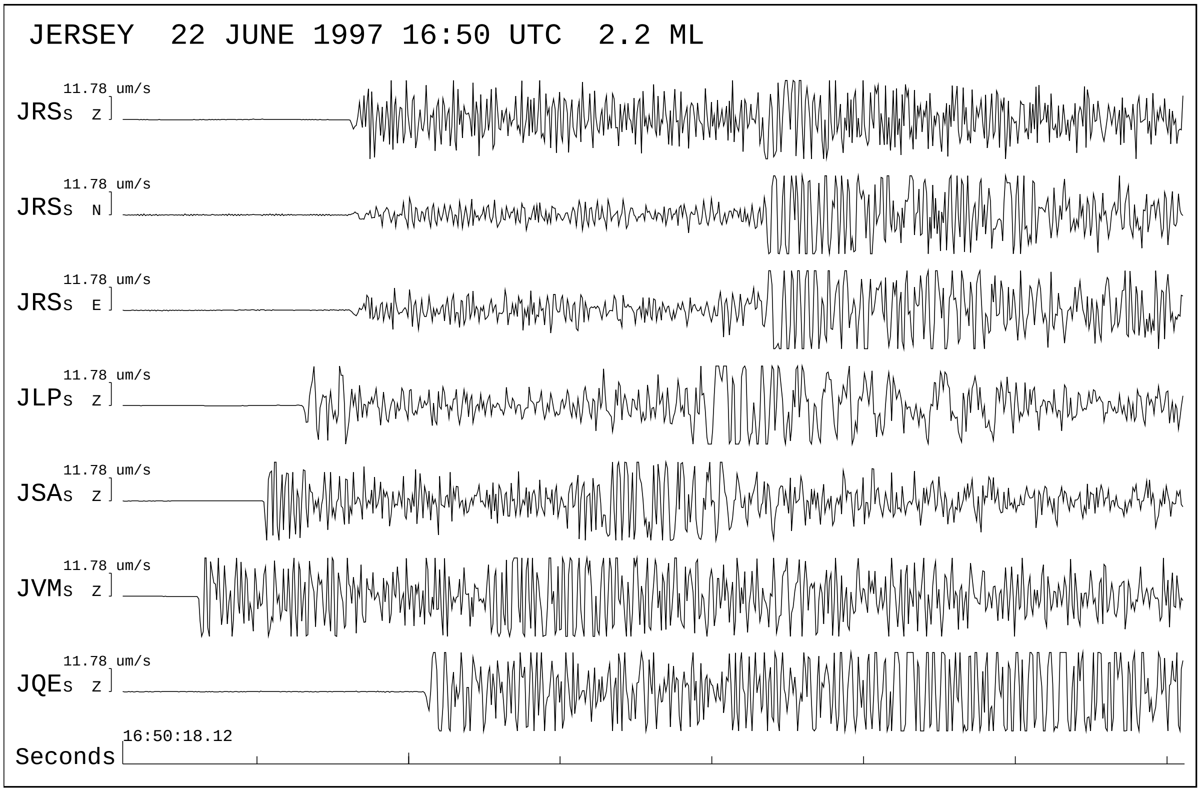

Figure 13. Seismograms recorded on the Jersey network from a magnitude 2.2 ML earthquake felt in Jersey on 22 June 1997 16:50 UTC. Three letter codes refer to stations in Annex E.

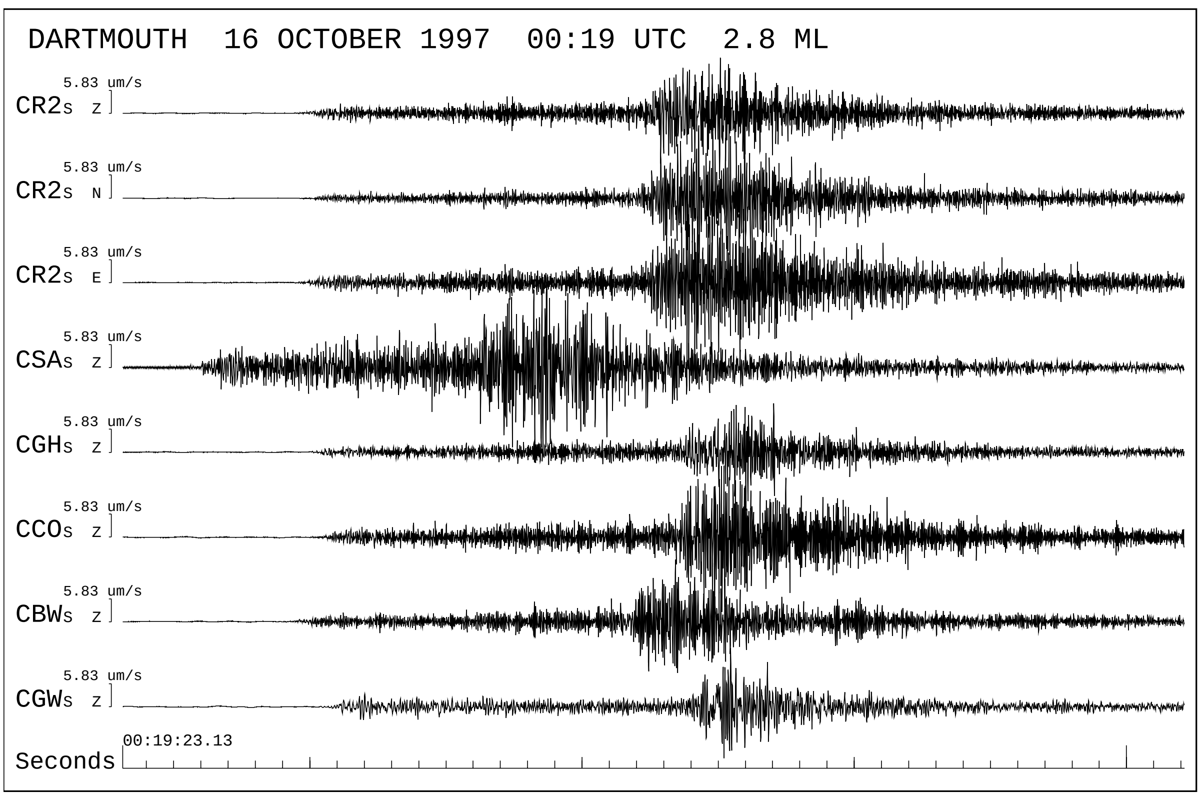

Figure 14. Seismograms recorded on the Cornwall network from a magnitude 2.8 ML earthquake felt in the Dartmouth area on 16 October 1997 00:19 UTC. Three letter codes refer to stations in Annex E.

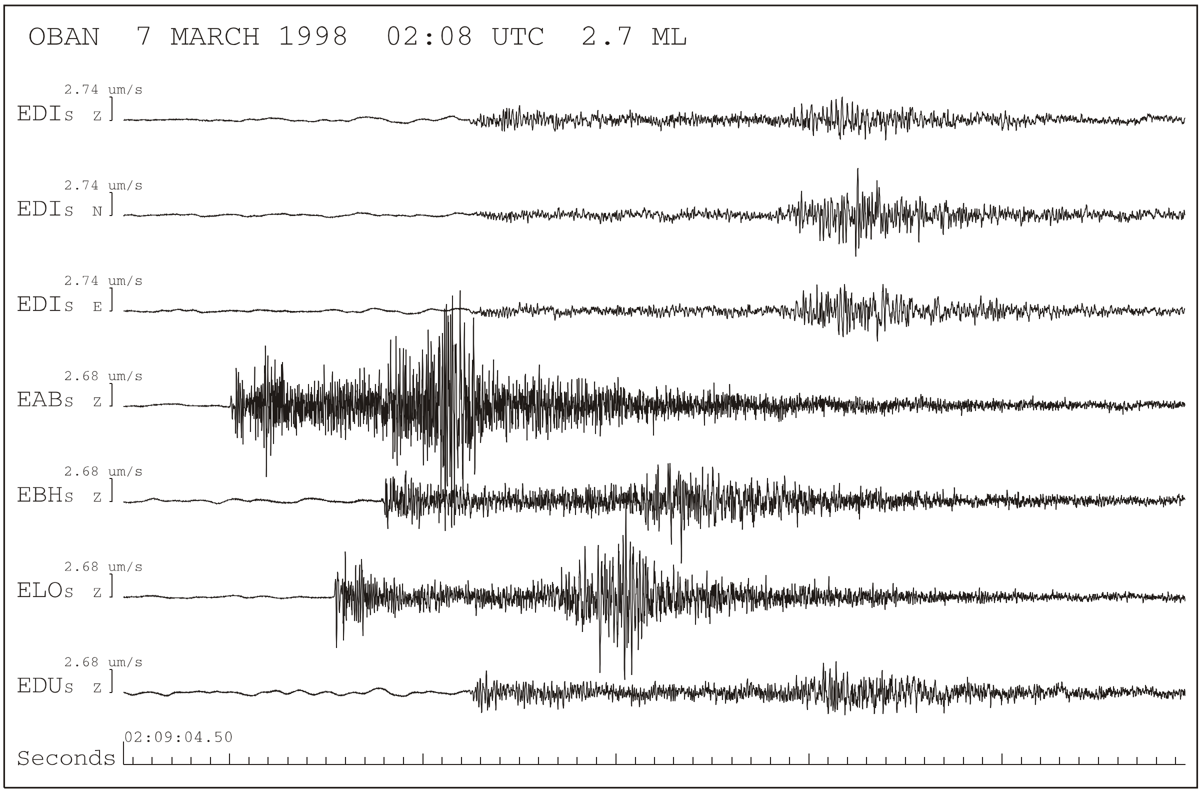

Figure 15. Seismograms recorded on the LOWNET network around Edinburgh from a magnitude 2.7 ML earthquake felt in the Oban area on 7 March 1998 02:08 UTC. Three letter codes refer to stations in Annex E.

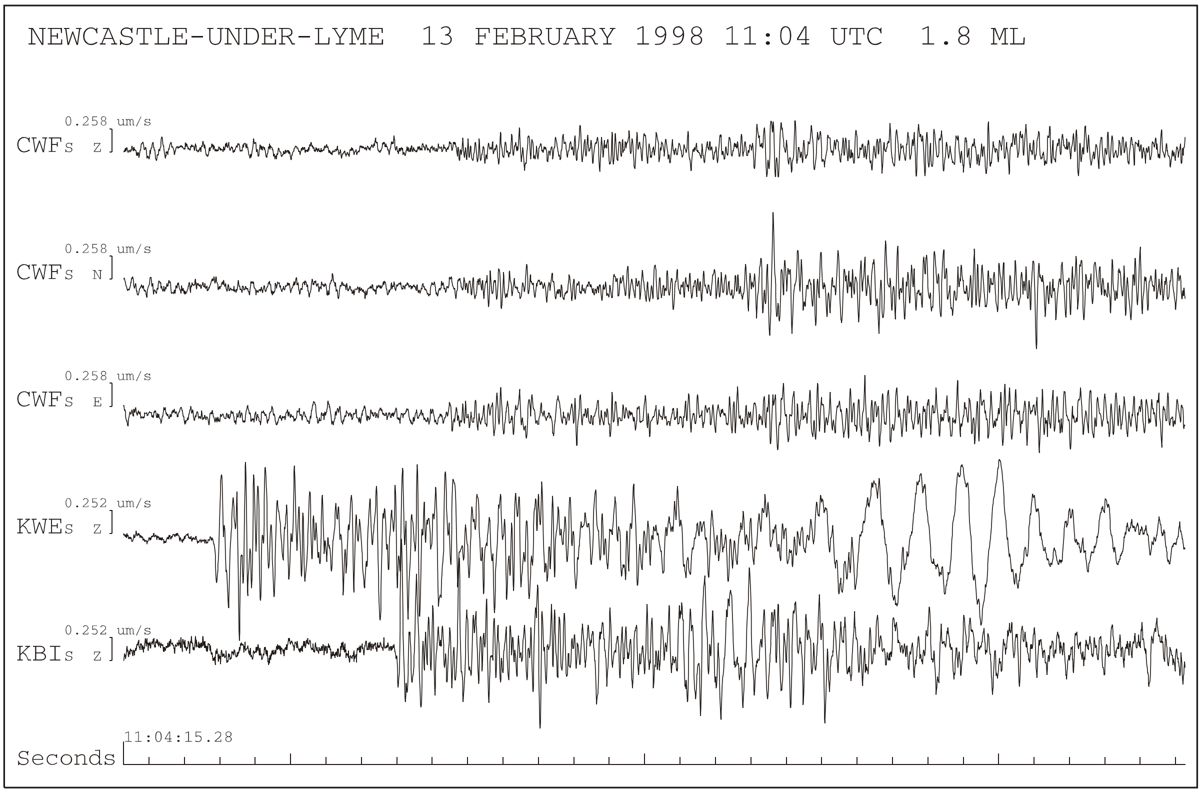

Figure 16. Seismograms recorded on the Keyworth network from a magnitude 1.8 ML coalfield event felt in the Keele area on 13 February 1998 11:04 UTC. Three letter codes refer to stations in Annex E.

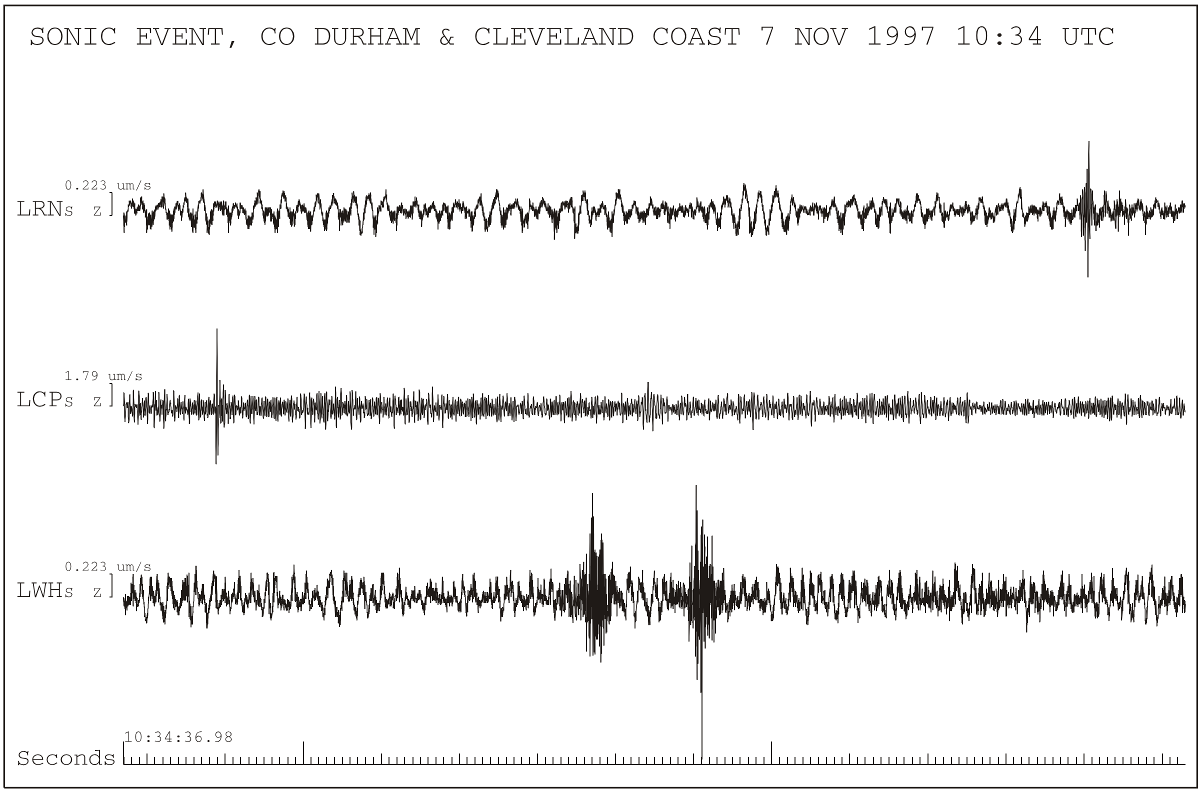

Figure 17. Seismograms recorded on the Leeds network from a sonic event felt in the Hartlepool area on 7 November 1997 10:34 UTC. Three letter codes refer to stations in Annex E.

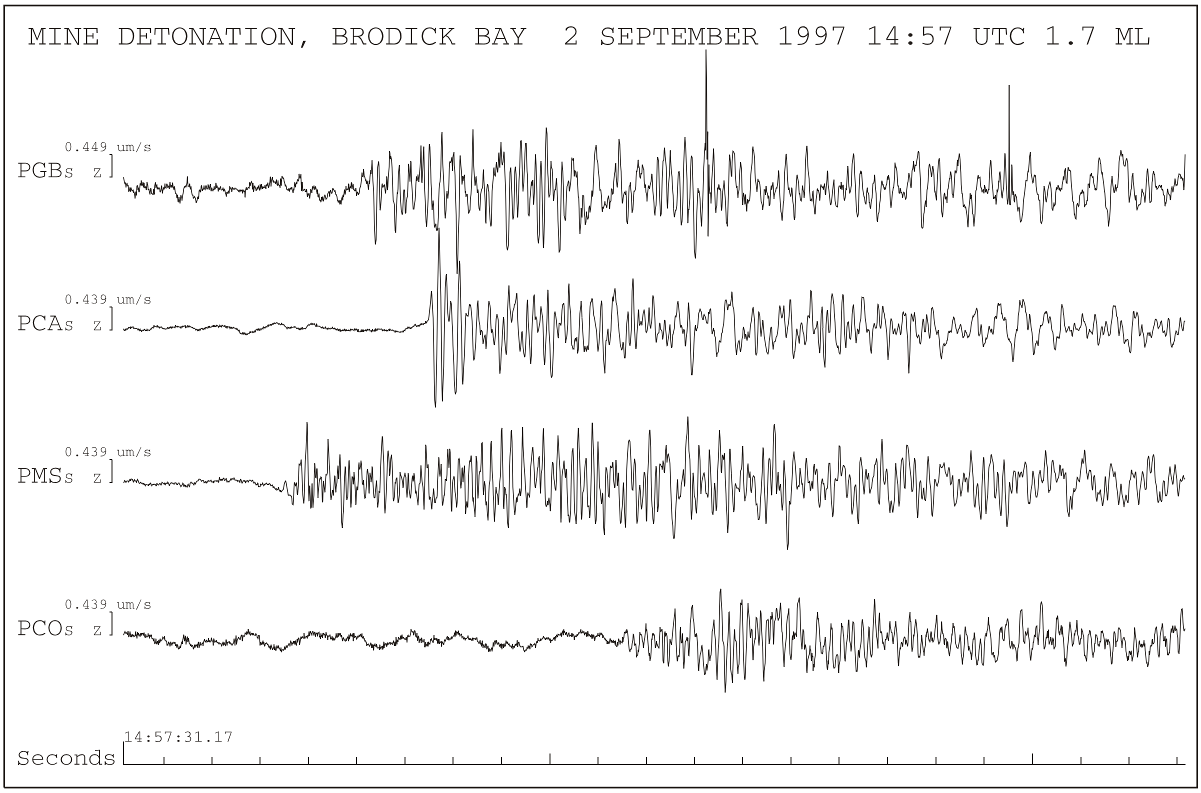

Figure 18. Seismograms recorded on the Paisley network from a magnitude 1.7 ML mine detonation off the Isle of Arran on 2 September 1997 14:57 UTC. Three letter codes refer to stations in Annex E.

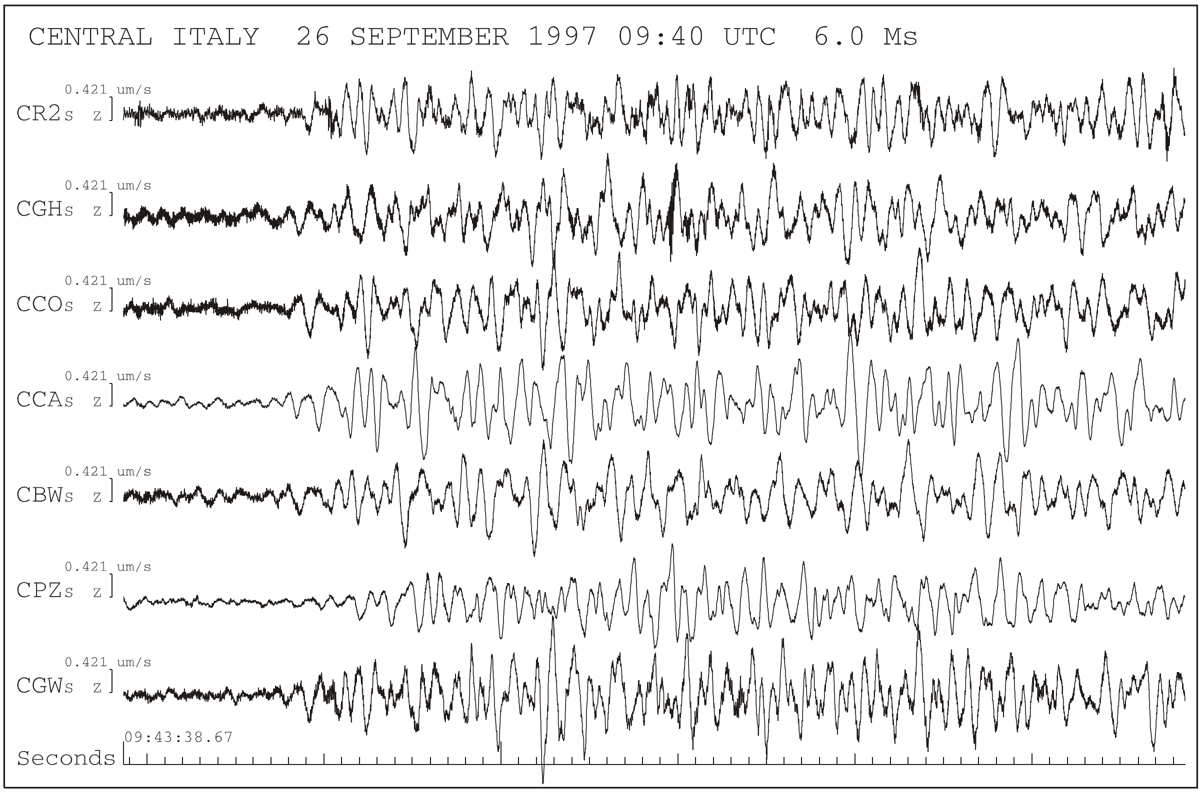

Figure 19. Seismograms recorded on the Cornwall network from a magnitude 6.0 Ms earthquake in Central Italy on 26 September 1997 09:40 UTC. Three letter codes refer to stations in Annex E.

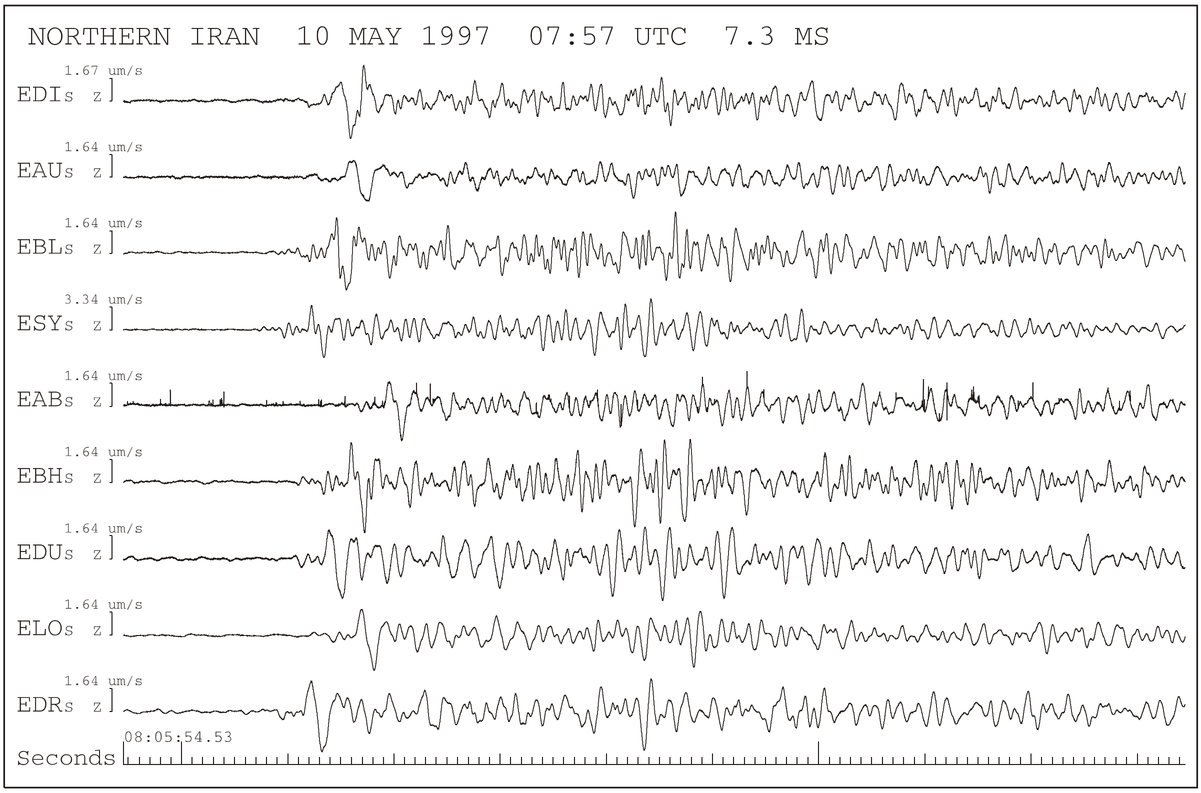

Figure 20. Seismograms recorded on the LOWNET network from a magnitude 7.3 Ms earthquake in Northern Iran on 10 May 1997 07:57 UTC. Three letter codes refer to stations in Annex E.

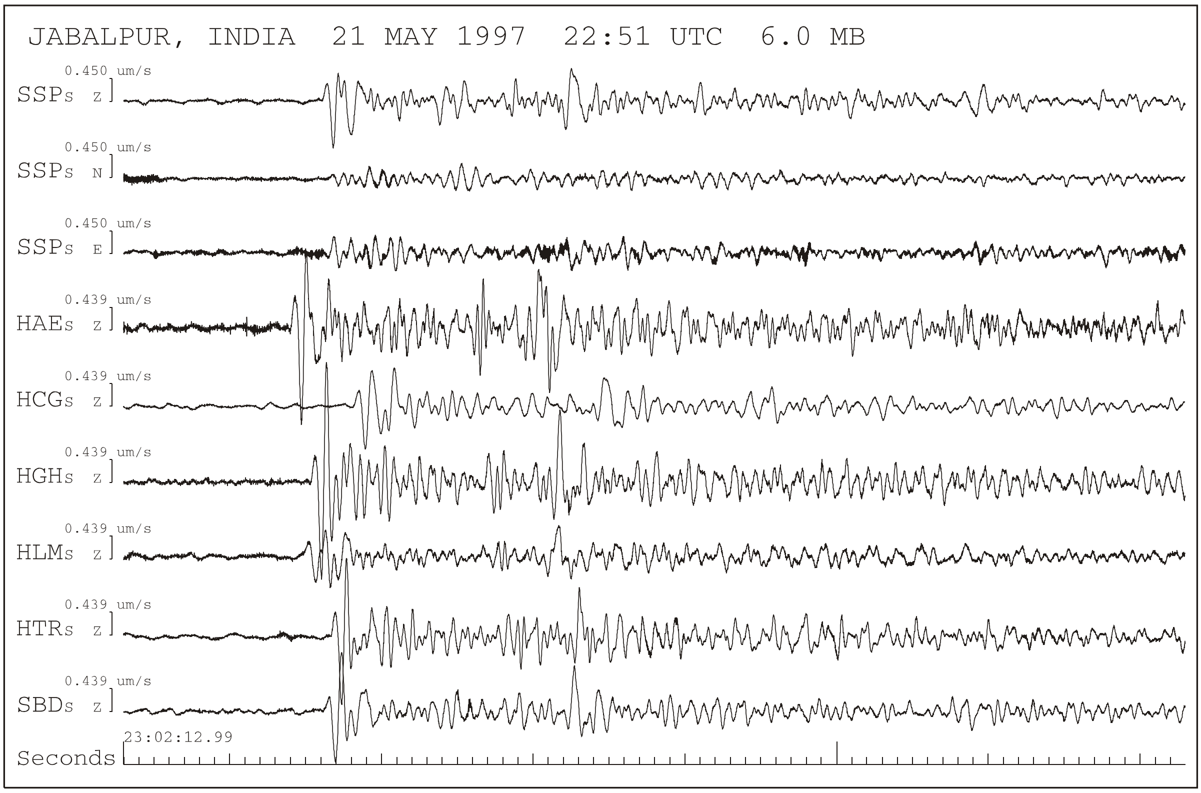

Figure 21. Seismograms recorded on the Hereford network from a magnitude 6.0 MB earthquake in Jabalpur, India on 21 May 1997 22:51 UTC. Three letter codes refer to stations in Annex E.

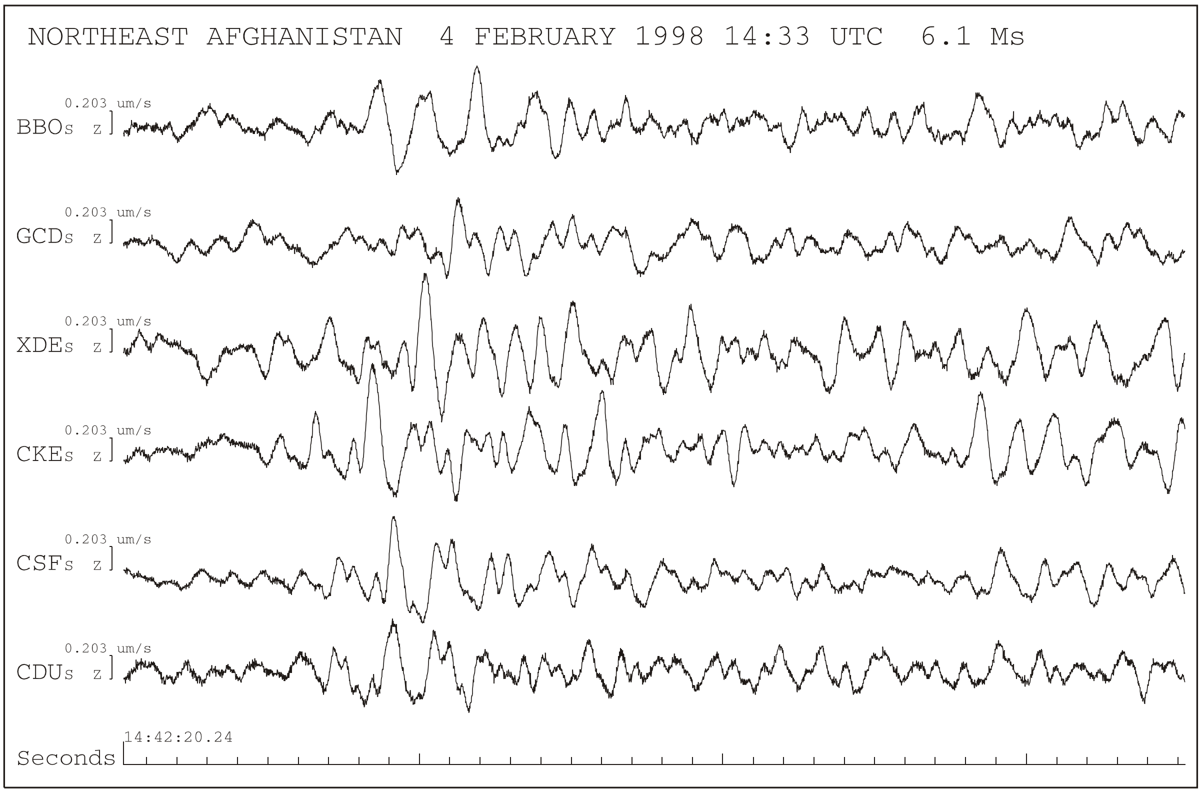

Figure 22. Seismograms recorded on the Cumbria network from a magnitude 6.1 Ms earthquake in Northeast Afghanistan on 4 February 1998 14:33 UTC. Three letter codes refer to stations in Annex E.

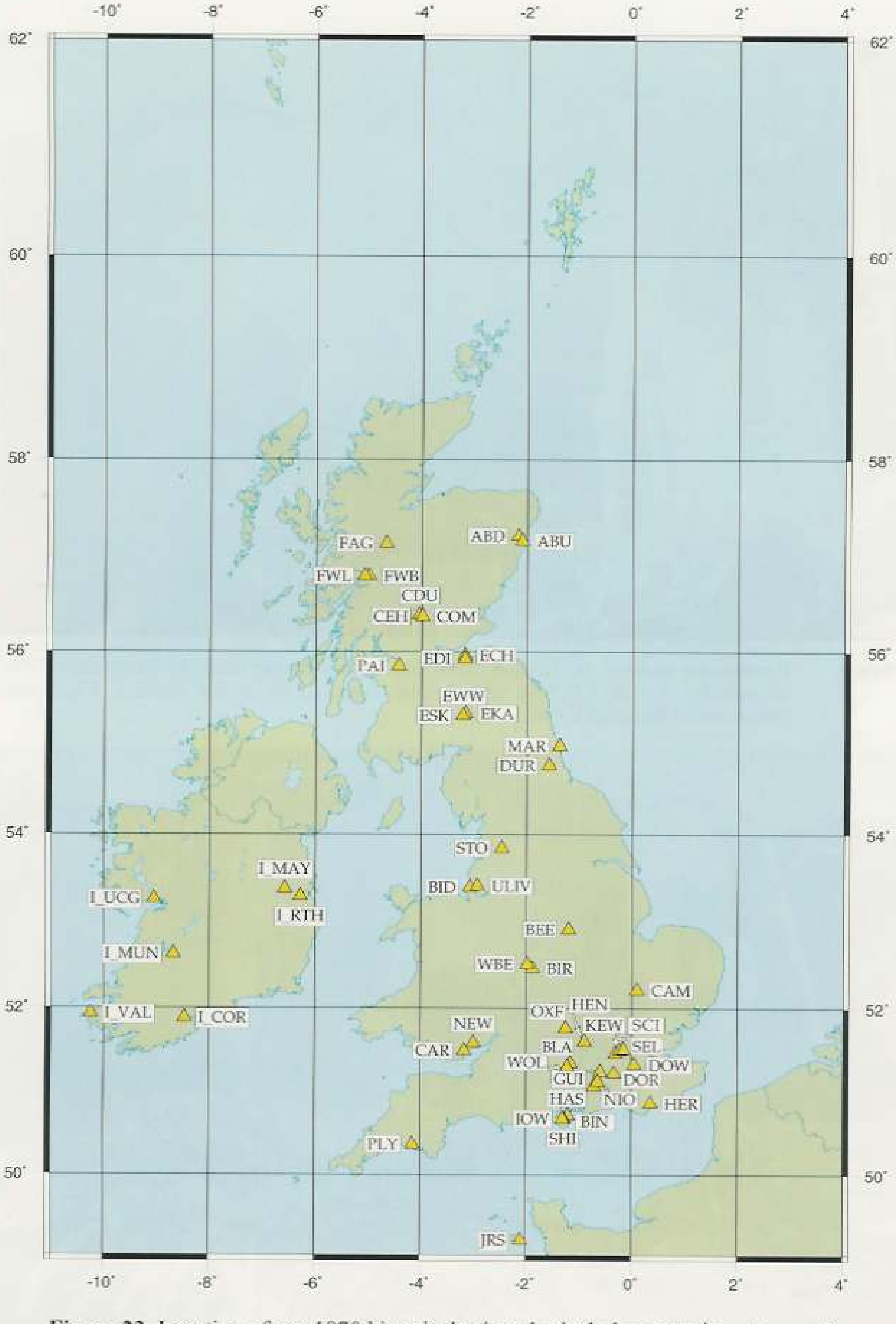

Figure 23. Location of pre-1970 historical seismological observatories. (Annex I)

CONTRIBUTORS TO THE PROJECT

British Nuclear Fuels plc

Department of the Environment, Transport and the Regions

Magnox Electric plc

Natural Environment Research Council

Nuclear Electric plc

Nuclear Installations Inspectorate

Renfrewshire Council

Scottish Hydro-Electric plc

Scottish Nuclear Ltd

University of Exeter

Welsh Office

Western Frontiers Association

Atomic Weapons Establishment (Data only)

Customer Group Members (not contributing in Year Nine)

AEA Technology

British Gas

Health and Safety Executive

International Seismological Centre

Scottish Office

United Kingdom Nirex Limited

EARTHQUAKES WITH MAGNITUDE 2.0 AND ABOVE, RECORDED IN THE UK AND OFFSHORE WATERS:1997

YearMoDy	HrMnSecs	Lat	Lon	kmE	kmN	Dep	Mag	Locality	Int	No	DM	Gap	RMS	ERH	ERZ	SQD	Comments
19970118	090948.3	56.29	3.40	734.0	724.0	9.6	2.9	CENTRAL NORTH SEA		153	43	202	0.31	4.5	4.9	C*D	
19970126	003516.1	61.63	2.71	649.3	1314.3	8.3	2.3	NORTHERN NORTH SEA		221	24	212	0.35	2.6	2.7	C*D	
19970204	221257.1	56.61	-4.57	242.3	749.6	7.4	2.7	RANNOCH MOOR,TAYSIDE	3+	24	49	107	0.12	0.4	2.4	B*C	FELT APPIN...
19970210	230915.5	53.19	-1.53	431.5	366.3	13.4	2.9	CHESTERFIELD,DERBYSHIRE	3+	12	7	101	0.17	0.9	1.6	B*B	FELT CHESTERFIELD...
19970212	032125.8	60.36	1.76	607.4	1170.3	11.8	2.1	NORTHERN NORTH SEA		171	58	145	0.36	2.5	3.6	C*D	
19970312	101549.6	52.28	-2.78	346.7	264.6	13.7	2.1	LEOMINSTER,HER & WOR		9	27	163	0.10	0.6	1.4	A*C	6KM NW OF LEOMINSTER
19970323	055618.8	53.42	-1.04	464.0	391.6	2.7	2.0	BLYTH,NOTTINGHAMSHIRE	3+	8	37	182	0.08	0.9	1.7	A*D	C/F,FELT BLYTH
19970412	100320.5	61.60	3.30	680.8	1313.9	14.1	2.8	NORTHERN NORTH SEA		18	93	207	0.26	1.8	1.6	B*D	
19970501	023624.8	50.49	1.29	633.5	71.1	5.6	2.2	ENGLISH CHANNEL		6	70	303	0.26	6.1	10.7	D*D	65KM SOUTH OF FOLKESTONE
19970513	220711.4	60.85	3.51	699.0	1231.6	15.0	3.4	NORTHERN NORTH SEA		162	53	320	0.17	14.0	19.0	D*D	
19970517	012830.9	63.02	2.13	608.8	1467.0	15.0	3.2	NORWEGIAN SEA		73	23	353	0.09			D*D	
19970517	024737.0	63.16	2.41	621.9	1482.9	15.0	2.8	NORWEGIAN SEA		43	43	357	0.02			A*D	
19970517	214931.8	51.90	-2.29	379.8	222.5	15.4	2.2	GLOUCESTER,GLOUCS		13	23	107	0.10	0.5	1.0	A*B	
19970519	080236.0	51.76	-1.64	424.8	206.8	6.2	2.7	CARTERTON,OXFORDSHIRE	4+	10	27	126	0.16	1.2	2.9	B*C	FELT CARTERTON...
19970622	165016.3	49.25	-2.28	379.8	-71.9	10.9	2.2	JERSEY,CHANNEL ISLANDS	4	6	7	322	0.01	0.2	0.2	A*D	FELT ST PETER...
19970714	114755.8	61.37	3.86	713.0	1290.3	17.6	2.8	NORTHERN NORTH SEA		102	83	341	0.11			D*D	
19970730	083444.0	56.25	-3.75	291.4	707.7	5.1	2.4	BLACKFORD,TAYSIDE	4+	15	15	106	0.04	0.1	0.3	A*C	FELT BLACKFORD...
19970812	081424.8	59.77	6.31	865.9	1127.5	15.0	3.0	NORWEGIAN COAST		74	19	335	0.25			D*D	
19970826	195751.5	56.20	-4.10	269.9	702.4	3.7	2.6	DOUNE,CENTRAL	4+	17	15	76	0.03	0.1	0.2	A*C	FELT DOUNE...
19970831	054737.8	61.23	2.77	655.8	1270.4	15.0	2.9	NORTHERN NORTH SEA		142	22	330	0.20			D*D	
19970916	003907.2	56.25	-3.75	291.5	707.9	4.8	2.1	BLACKFORD,TAYSIDE	3+	15	15	107	0.06	0.2	0.4	A*C	FELT BLACKFORD...
19971006	062141.0	56.20	-4.10	269.8	702.6	4.1	2.7	DOUNE,CENTRAL	4+	15	15	133	0.02	0.1	0.2	A*C	FELT DOUNE...
19971008	093716.0	54.23	-3.12	326.9	482.4	12.1	2.1	ULVERSTON,CUMBRIA	3+	11	12	156	0.07	0.6	0.9	A*C	FELT ULVERSTON...
19971012	192725.8	62.08	1.87	602.2	1361.5	15.0	2.7	NORTHERN NORTH SEA		62	33	353	0.09			D*D	
19971016	001911.7	50.39	-3.73	277.0	56.0	10.4	2.8	DARTMOUTH,DEVON	4	7	13	236	0.05	0.7	0.4	A*D	FELT DARTMOUTH...
19971019	024223.5	57.59	-5.65	182.0	861.6	8.8	2.5	WESTER ROSS,HIGHLAND		11	23	82	0.17	0.9	10.8	C*C	
19971022	112034.8	55.66	-5.41	185.6	646.3	7.7	2.3	KINTYRE,STRATHCLYDE		17	37	134	0.09	0.5	1.5	A*C	
19971108	044701.5	57.67	-5.57	187.2	870.0	9.7	2.5	LOCH MAREE,HIGHLAND	4+	11	25	105	0.07	0.4	2.2	B*C	FELT GAIRLOCH
19971122	034320.2	56.18	-4.10	269.7	701.0	5.1	2.1	DOUNE,CENTRAL	4+	12	15	125	0.03	0.2	0.3	A*C	FELT DOUNE
19971128	212136.1	55.62	-5.46	182.2	641.8	4.3	2.2	KINTYRE,STRATHCLYDE		7	52	325	0.06	8.3	19.2	D*D	
19971130	005924.4	56.20	-4.10	269.6	702.7	4.0	2.7	DOUNE,CENTRAL	4+	14	15	133	0.02	0.1	0.2	A*C	FELT DOUNE...
19971208	235603.4	57.10	-4.60	242.5	804.3	7.0	2.3	FORT AUGUSTUS,HIGHLAND	4+	14	40	84	0.13	0.6	2.5	B*C	FELT FORT AUGUSTUS...

BRITISH GEOLOGICAL SURVEY
MURCHISON HOUSE
WEST MAINS ROAD
EDINBURGH EH9 3LA

TEL: 0131 667 1000
TLX: 727343 SEISED G
FAX: 0131 667 1877 GSRG BGS
INTERNET: http://www.gsrg.nmh.ac.uk/.

TO:	M THOMAS	- DOE	H PAYNE	- WELSH OFFICE
	M WILSON	- SCOT H & H	H GULVANESSIAN	- BRE
	P A MERRIMAN	- BNFL	J P McFARLANE	- SCOTTISH NUCLEAR
	H TUR	- BNFL CAPEN	P W WINTER	- AEA
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	W P ASPINALL	- AA	G DUDDRIDGE	- EXETER UNIVERSITY
	L J OLIVER	- HYDRO ELEC	P McCORMACK	- PAISLEY OBSERVATORY
	P M BRADFORD	- NII, BOOTLE	DIRECTOR	- BGS, KEYWORTH
	J E INKESTER	- NII, BOOTLE	M RAINES	- BGS, KEYWORTH
	R WATSON	- HISCOX	S BRACKELL	- BGS, LONDON INFO OFF
	A HUGHES	- ISC	D W HOLLIDAY	- BGS, KEYWORTH
	D J MALLARD	- CONSULTANT	H J HEASON	- BGS PRESS OFFICE

FROM: Bennett Simpson
DATE: 7 November 1997
TIME: 14:15 UTC
PAGES TO FOLLOW: 1

SEISMIC ALERT: SONIC EVENT HARTLEPOOL AREA 7 NOVEMBER 1997 10:34 UTC

BGS have recieved numerous reports from Hartlepool Nuclear Power Station, a number of Police stations in the area and an environmental health officerof a felt event at 10:35 UTC this morning. A number of people in the visitor centre at the nuclear power station ran outside in alarm. Many residents in the costal towns of County Durham and Cleveland al;so felt this event. Felt reports described "we ran outdoors", "the whole house shook", "felt like there had been an explosion", "doors flew open" and "the windows and doors rattled". Data from the rapid-access networks around Leeds and Eskdalemuir were examined and a signal consistent with a sonic boom was recorded on several seismograph stations at around 10:34 UTC.

RAF Flying Complaints were contacted and they confermed that military aircraft (16F3 Tornado jets) were in operation in the area at the time.

A seismogram of the event, as recorded on the BGS Leeds network is attached.

BRITISH GEOLOGICAL SURVEY
MURCHISON HOUSE
WEST MAINS ROAD
EDINBURGH EH9 3LA

TEL: 0131 667 1000
TLX: 727343 SEISED G
FAX: 0131 667 1877 GSRG BGS
INTERNET: http://www.gsrg.nmh.ac.uk/.

TO:	M THOMAS	- DETR	H PAYNE	- WELSH OFFICE
	M WILSON	- SCOT H & H	H GULVANESSIAN	- BRE
	P A MERRIMAN	- BNFL	J P McFARLANE	- SCOTTISH NUCLEAR
	H TUR	- BNFL CAPEN	P W WINTER	- AEA
	R A BOWDEN	- NIREX	P J BUCKLEY	- HSE
	T C CHIVERS	- NUCLEAR ELEC	V KATHIGAYAN	- HSE OFFSHORE
	C F ALLEN	- MAGNOX ELEC	A W B JACOB	- DIAS
	W P ASPINALL	- AA	G DUDDRIDGE	- EXETER UNIVERSITY
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	R WILLEMANN	- ISC	D W HOLLIDAY	- BGS, KEYWORTH
	D J MALLARD	- CONSULTANT	H J HEASON	- BGS PRESS OFFICE

FROM: Simpson \ Ford
DATE: 7 March 1998
TIME: 12:00 UTC
PAGES TO FOLLOW: 2

SEISMIC ALERT: OBAN, STRATHCLYDE 7 MARCH 1998 02:08 UTC 2.7 ML

BGS have received felt reports, from Oban police, the media and residents in the Oban area of Strathclyde, of a felt event at 02:10 UTC this morning (7 March 1998). Felt reports describe "we were woken from sleep" and "heard a loud bang or a crack". The BGS rapid-access networks detected an event 12km east of Oban at 02:08 UTC. The following preliminary information is available for this earthquake:

DATE	:	7 March 1998
ORIGIN TIME	:	02:08 59.5s UTC
LAT/LONG	:	56.41° North / 5.26° West
GRID REF	:	198.5 kmE / 729.8 kmN
DEPTH	:	9.4 km
MAGNITUDE	:	2.7 ML
INTENSITY	:	4+
LOCALITY	:	12 km east of Oban, Strathclyde

Today's earthquake locates approximately 24 km east of the 29 September 1986 Oban earthquake, which had a magnitude of 4.1 ML and was felt with intensities of 5 EMS.

A seismogram of the earthquake, as recorded on the BGS LO' [illegible] a map of instrumental seismicity within 25 km of the epicentre are attached.

BGS STAFF WITH INPUT TO THE PROJECT

Ms R A R Aitken

Dr D C Booth

Dr C W A Browitt

Mr P S Day

Mrs J Exton

Mr G D Ford

Mr C J Fyfe

Mr D D Galloway

Mr P H O Henni

Dr D J Kerridge

Mr J Laughlin

Mr J H Lovell

Mr P C Marrow

Mr P Millership

Dr R M W Musson

Mr D L Petrie

Mr J D Riddick

Ms M E A Ritchie

Mr B A Simpson

Mr D A Stewart

Mr W A Velzian

Ms A B Walker

Dr P W Wild

GEOGRAPHICAL CO-ORDINATES OF SEISMOGRAPH STATIONS USED BY BGS: MARCH 1998

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (M)	Yrs Open	Comp	Agency
SHETLAND									
LRW	LERWICK	60.1360	-1.1779	445.66	1139.27	100	78-	4R	BGS
LRWS	LERWICK (SM)	60.1397	-1.1831	445.37	1139.69	80	96-	3	BGS
SAN	SANDWICK	60.0176	-1.2386	442.44	1126.05	155	85-	1	BGS
WAL	WALLS	60.2576	-1.6133	421.40	1152.60	170	80-	1	BGS
YEL	YELL	60.5509	-1.0830	450.29	1185.55	200	79-	1	BGS
ORKNEY									
ORE	REAY	58.5480	-3.7622	297.45	963.52	100	95-	4Rm	BGS
OTO	TONGUE	58.4953	-4.3940	260.49	958.79	338	95-	1R	BGS
OHO	HOY	58.8321	-3.2464	328.05	994.48	172	95-	1R	BGS
OWE	WESTRAY	59.3180	-3.0289	341.44	1048.36	87	95-	1R	BGS
OST	STRONSAY	59.0860	-2.5516	368.39	1022.04	15	95-	1R	BGS
OBR	BRABSTER	58.6142	-3.1623	332.47	970.13	89	95-	1R	BGS
MINCH									
RRR	RUBHA REIDH	57.8577	-5.8067	174.19	891.68	61	95-	4Rm	BGS
RSC	SCOURIE	58.3485	-5.1684	214.61	944.33	60	95-	1R	BGS
RRH	RHENIGIDALE	57.9197	-6.6882	122.43	901.86	103	95-	1R	BGS
RFO	FORSNAVAL	58.2133	-7.0052	106.10	935.83	197	95-	1R	BGS
RTO	TOLSTA	58.3778	-6.2092	153.95	950.93	74	95-	1R	BGS
RCR	CAPE WRATH	58.6240	-4.9986	225.90	974.53	100	95-	1R	BGS
REB	EISG-BRACHAIDH	58.1188	-5.2822	206.70	919.10	100	95-	1R	BGS
MORAY									
MCD	COLEBURN DISTIL	57.5827	-3.2541	325.02	855.41	280	81-	4Rm	BGS
MDO	DOCHFOUR	57.4413	-4.3633	258.17	841.43	366	81-	1R	BGS
MFI	FISHRIE	57.6116	-2.2953	382.36	857.97	220	88-	1R	BGS
MLA	LATHERON	58.3050	-3.3640	320.07	935.93	190	81-	1	BGS
MME	MEIKLE CAIRN	57.3150	-2.9650	341.88	825.33	455	81-	1	BGS
MVH	ACHVAICH	57.9232	-4.1816	270.80	894.70	198	84-	1	BGS
KYLE									
KAC	ACHNASHELLACH	57.4999	-5.2982	202.40	850.30	330	83-	1R	BGS
KAR	ARISAIG	56.9175	-5.8302	166.90	787.20	225	83-	1	BGS
KNR	NEVIS RANGE	56.8219	-4.9714	218.68	773.97	1118	91-	1	BGS
KPL	PLOCKTON	57.3391	-5.6527	180.21	833.50	36	86-	4R	BGS
KSB	SHIEL BRIDGE	57.2098	-5.4230	193.30	818.40	70	83-	1R	BGS
KSK	SCOVAL	57.4653	-6.7020	118.10	851.41	250	89-	1R	BGS
LOWNET									
EAB	ABERFOYLE	56.1881	-4.3400	254.80	701.95	250	69-	1R	BGS
EAU	AUCHINOON	55.8454	-3.4474	309.38	662.30	359	69-	1R	BGS
EBH	BLACK HILL	56.2481	-3.5081	306.56	707.19	375	69-	1R	BGS
EBL	BROAD LAW	55.7733	-3.0436	334.54	653.82	365	69-	1R	BGS
EDI	EDINBURGH	55.9233	-3.1861	325.89	670.66	125	69-	4R	BGS
EDR	DRUMTOCHTY	56.9190	-2.5394	367.16	780.97	401	89-	1R	BGS
EDU	DUNDEE	56.5475	-3.0142	337.65	739.95	275	69-	1R	BGS
ELO	LOGIEALMOND	56.4706	-3.7119	294.55	732.24	495	69-	1R	BGS
ESY	STONEYPATH	55.9177	-2.6144	361.60	669.57	328	81-	1R	BGS
EMN	MONKTONHALL	55.9295	-3.0889	331.97	671.24	52	96-	3	BGS
ENH	NEWHAILES	55.9401	-3.0795	332.58	672.42	25	96-	1	BGS
ENC	NEWCRAIG HALL	55.9318	-3.1050	330.97	671.52	45	96-	3	BGS

GEOGRAPHICAL CO-ORDINATES OF SEISMOGRAPH STATIONS USED BY BGS: MARCH 1998

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (M)	Yrs Open	Comp	Agency
PAISLEY									
PCA	CARROT	55.7000	-4.2550	258.30	647.48	305	83-	1	BGS
PCO	CORRIE	55.9880	-4.0970	269.20	679.21	274	83-	1	BGS
PGB	GLENIFFERBRAES	55.8100	-4.4780	244.73	660.58	200	84-	3	BGS
PMS	MUIRSHIEL	55.8461	-4.7441	228.22	664.83	351	83-	1	BGS
POB	OBSERVATORY	55.8458	-4.4299	247.88	664.06	34	92-	1	BGS
ESKDALEMUIR									
ESK	ESKDALEMUIR	55.3167	-3.2050	323.54	603.18	263	65-	4R	BGS
ECK	CAULDKAINE HILL	55.1812	-3.1271	328.24	588.02	337	81-	1R	BGS
XAL	ALLENDALE	54.8617	-2.2147	386.22	551.91	462	83-	1R	BGS
XSO	SOURHOPE	55.4925	-2.2511	384.13	622.11	495	83-	1R	BGS
GALLOWAY & N IRELAND									
GAL	GALLOWAY	54.8664	-4.7114	226.02	555.78	105	89-	4m	BGS
GCL	CUSHENDALL	55.0783	-6.1263	136.66	583.77	278	89-	1R	BGS
GMK	MULL OF KINTYRE	55.3459	-5.5936	172.18	611.65	160	89-	1R	BGS
GMM	MTNS OF MOURNE	54.2377	-5.9498	142.66	489.67	155	89-	1R	BGS
BORDERS									
BBH	BRUNTSHEIL	55.1332	-2.9299	340.72	582.50	207	92-	1	BGS
BNA	NEW ABBEY	54.9659	-3.6244	296.02	564.70	78	92-	1	BGS
BHH	HOWATS HILL	55.0928	-3.2187	322.23	578.28	198	92-	3	BGS
BTA	TALKIN	54.9057	-2.6841	356.14	557.00	276	92-	3	BGS
BDL	DOBCROSS HALL	54.8030	-2.9390	339.65	545.76	132	92-	1	BGS
BWH	WARDLAW	55.1757	-3.6551	294.61	588.08	275	92-	1	BGS
BBO	BOTHEL *	54.7367	-3.2465	319.75	538.70	205	92-	3	BGS
BCM	CHAPELCROSS	55.0151	-3.2212	321.92	569.64	78	92-	m	BGS
BCC	CHAPELCROSS	55.0154	-3.2202	321.98	569.67	68	92-	1	BGS
CUMBRIA									
CKE	KESWICK	54.5878	-3.1062	328.52	521.98	296	92-	1	BGS
CSF	SCAFELL	54.4478	-3.2431	319.40	506.55	548	92-	1	BGS
CDU	DUNNERDALE	54.3363	-3.1950	322.31	494.09	362	92-	1	BGS
CSM	SELLAFIELD	54.4183	-3.4913	303.24	503.58	50	92-	m	BGS
LMI	MILLOM*	54.2206	-3.3070	314.79	481.35	140	89-	3R	BGS
GIM	ISLE OF MAN (N)*	54.2923	-4.4670	239.46	491.34	366	89-	3R	BGS
GCD	CASTLE DOUGLAS*	54.8638	-3.9417	275.39	553.85	189	89-	1R	BGS
XDE	DENT *	54.5058	-3.4897	303.55	513.31	291	83-	1R	BGS
LEEDS									
HPK	HAVERAH PARK	53.9554	-1.6240	424.67	451.12	227	78-	3R	BGS
LCP	CASSOP	54.7368	-1.4741	433.86	538.12	185	91-	1	BGS
LWH	WHINNY NAB	54.3335	-0.6714	486.38	493.94	265	91-	1R	BGS
LRN	RICHMOND	54.4167	-1.7858	413.90	502.40	300	91-	1R	BGS
LMK	MARKET RASEN	53.4569	-0.3266	511.10	396.90	130	91-	1	BGS
LHO	HOLMFIRTH	53.5451	-1.8548	409.62	405.42	460	91-	1	BGS
LDU	LEEDS	53.8025	-1.5553	429.35	434.45	230	83-	2Rm	BGS
NORTH WALES									
WCB	CHURCH BAY	53.3782	-4.5465	230.63	389.87	135	85-	4m	BGS
WFB	FAIRBOURNE	52.6830	-4.0378	262.26	311.47	325	85-	1R	BGS
WIM	ISLE OF MAN (S)	54.1472	-4.6735	225.41	475.70	365	85-	1R	BGS

GEOGRAPHICAL CO-ORDINATES OF SEISMOGRAPH STATIONS USED BY BGS: MARCH 1998

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (M)	Yrs Open	Comp	Agency
NORTH WALES continued									
WLF	LLYNFAES	53.2893	-4.3966	240.27	379.64	65	85-	1	BGS
WME	MYNDD EILIAN	53.3966	-4.3034	246.87	391.36	130	85-	1R	BGS
WPM	PENMAENMAWR	53.2583	-3.9049	272.95	375.20	350	85-	1	BGS
YRC	RHOSCOLYN	53.2506	-4.5741	228.28	375.74	24	84-	1R	BGS
YRE	YR EIFL	52.9810	-4.4254	237.19	345.42	197	84-	1R	BGS
YLL	LLANBERIS	53.1402	-4.1704	254.84	362.57	162	84-	1R	BGS
YRH	RHIW	52.8335	-4.6289	222.93	329.49	300	84-	1R	BGS
KEYWORTH									
CWF	CHARNWOOD FST	52.7382	-1.3071	446.78	315.88	185	75-	3R	BGS
KBI	BIRLEY GRANGE	53.2546	-1.5278	431.50	373.20	270	88-	1	BGS
KEY	KEYWORTH	52.8774	-1.0751	462.24	331.54	75	88-	1	BGS
KSY	SYSTON	52.9642	-0.5873	494.88	341.73	123	88-	1R	BGS
KTG	TILBROOK GRANGE	52.3261	-0.4007	508.98	271.03	78	88-	1	BGS
KUF	UFFORD	52.6175	-0.3895	509.02	303.45	35	88-	1R	BGS
KWE	WEAVER FARM	53.0163	-1.8435	410.50	346.60	320	88-	1R	BGS
EAST ANGLIA									
ABA	BACONSTHORPE	52.8875	1.1471	611.70	336.90	13	82-	1	BGS
AEA	E.ANGLIA UNIV.	52.6208	1.2403	619.30	307.53	45	84-	m	BGS
APA	PACKWAY	52.2999	1.4779	637.10	272.60	35	84-	1	BGS
AWH	WHINBURGH	52.6299	0.9512	599.70	307.70	60	80-	1R	BGS
AWI	WITTON	52.8324	1.4460	632.10	331.70	35	83-	1	BGS
AEU	E.ANGLIA	52.6201	1.2347	618.93	307.44	15	94-	4	BGS
HEREFORD									
SBD	BRYN DU	52.9055	-3.2588	315.35	335.01	497	80-	1	BGS
MCH	MICHAELCHURCH	51.9977	-2.9983	331.47	233.77	233	78-	4	BGS
HAE	ALDERS END	52.0376	-2.5475	362.45	237.88	224	82-	1R	BGS
HCG	CRAIG GOCH	52.3224	-3.6567	287.10	270.70	511	80-	1R	BGS
HGH	GRAY HILL	51.6380	-2.8064	344.20	193.60	210	80-	1R	BGS
HLM	LONG MYND	52.5184	-2.8807	340.25	291.57	429	84-	1	BGS
HTR	TREWERN HILL	52.0790	-3.2697	313.00	243.10	329	82-	1R	BGS
SSP	STONEY POUND	52.4177	-3.1119	324.39	280.59	417	90-	3	BGS
HBL2	BONNYLANDS	52.0508	-3.0384	328.80	239.72	440	91-	1R	BGS
SWINDON									
SWN	SWINDON	51.5130	-1.8005	413.85	179.42	192	93-	4	BGS
SMD	MENDIPS	51.3082	-2.7174	350.00	156.87	300	93-	1	BGS
SSW	STOW-ON-WOLD	51.9667	-1.8499	410.31	229.85	291	93-	1	BGS
SWK	WARMINSTER	51.1483	-2.2471	382.72	138.87	279	93-	1	BGS
SFH	HASELMERE	51.0604	-0.6911	491.71	129.88	260	93-	1	BGS
SIW	ISLE OF WIGHT	50.6711	-1.3747	444.18	85.97	162	93-	1	BGS
SKP	KOPHILL	51.7215	-0.8099	482.20	203.25	215	93-	1	BGS
SOUTH EAST ENGLAND									
TFO	FOLKESTONE	51.1136	1.1406	619.79	139.67	188	89-	4m	BGS
TEB	EASTBOURNE	50.8188	0.1459	551.14	104.40	70	89-	1R	BGS
TSA	SEVENOAKS	51.2427	0.1558	550.46	151.55	170	89-	1	BGS
TBW	BRENTWOOD	51.6549	0.2911	558.47	197.66	82	89-	1R	BGS
TCR	COLCHESTER	51.8349	0.9215	601.26	219.23	40	89-	1R	BGS

GEOGRAPHICAL CO-ORDINATES OF SEISMOGRAPH STATIONS USED BY BGS: MARCH 1998

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (M)	Yrs Open	Comp	Agency
CORNWALL									
CMA	MANACCAN	50.0819	-5.1273	176.30	24.96	50	93-	1	BGS
CCA	CARNMENELLIS	50.1864	-5.2277	169.62	36.87	213	81-	1	BGS
CBW	BUDOCK WATER	50.1482	-5.1144	177.53	32.29	98	81-	1	BGS
CCO	CONSTANTINE	50.1357	-5.1960	171.64	31.14	183	81-	1	BGS
CGH	GOONHILLY	50.0508	-5.1649	173.46	21.61	91	81-	1	BGS
CPZ	PENZANCE	50.1560	-5.5835	144.07	34.66	198	81-	1R	BGS
CR2	ROSEMANOWES2	50.1669	-5.1687	173.74	34.53	152	81-	3	BGS
CRQ	ROSEMANOWES	50.1672	-5.1728	173.45	34.57	165	81-	4R	BGS
CSA	ST AUSTELL	50.3528	-4.8936	194.18	54.39	113	81-	1	BGS
CST	STITHIANS	50.1952	-5.1635	174.24	37.66	139	81-	1	BGS
CGW	GWEEK	50.1003	-5.2224	169.58	27.29	76	93-	1	BGS
DEVON									
DCO	COMBE FARM	50.3200	-3.8724	266.72	48.42	410	82-	1R	BGS
DYA	YADSWORTHY	50.4352	-3.9309	262.89	61.33	280	82-	3R	BGS
HTL	HARTLAND	50.9944	-4.4850	225.64	124.67	91	81-	4Rm	BGS
HSA	SWANSEA	51.7478	-4.1543	251.30	207.70	274	87-	1R	BGS
HPE	PEMBROKE	51.9371	-4.7745	209.30	230.20	355	90-	1R	BGS
HEX	EXMOOR	51.0668	-3.8025	273.72	131.32	278	91-	1R	BGS
JERSEY									
JQE	QUEENS EAST	49.2000	-2.0384			58	91-	1	BGS
JLP	LES PLATONS	49.2428	-2.1039			131	81-	1R	BGS
JRS	MAISON ST LOUIS	49.1924	-2.0917			53	81-	4R	BGS
JSA	ST AUBINS	49.1879	-2.1709			21	81-	1R	BGS
JVM	VALLE D.L.MARE	49.2169	-2.2068			64	81-	1R	BGS

Notes

1. The UK seismograph network is divided into a number of sub-networks, named Cornwall, Devon etc, within which data are transmitted, principally by radio, from each seismometer station to a central recorder where it is registered against a common, accurate time standard.

2. From left to right the column headers stand for Latitude, Longitude, Easting, Northing, Height, Year station opened, number of seismometers at the station (Comp) and the agency operating the station (in this list they are all BGS).

3. Qualifying symbols indicate the following:

   R in Comp column : station details have been registered with international agencies for data exchange.

   m in Comp column : low frequency microphone also deployed.

   * after Name : station removed from original network to be transmitted to a new centre.

   ** after Name : station transmitting to both the Cumbria and Borders network centres.

BGS Seismology reports

WL/97/16	Walker, A.B. UK Earthquake monitoring 1996/97, BGS Seismic Monitoring and Information Service, Eighth Annual Report. June 1997.
WL/97/21	Walker, A.B. Rapid Transfrontier Seismic Data Exchange Network (Transfrontier Group); Final Contract Report. April 1997.
WL/97/27	Lovell, J.H., Ford, G.D, Henni, P.H.O., Baker, C, Stimpson, I.G. and Pettitt, W. Recent Seismicity in the Stoke-on-Trent Area, Staffordshire. May 1997.
WL/97/33	Musson, R.M.W. Chapter 15 (Intensity and intensity scales) of the new Manual of Seismological Observatory practice. August 1997.
WL/97/34	Musson, R.M.W. On the use of Monte Carlo Simulations for Seismic Hazard Assessment. August 1997.
WL/97/37	Musson, R.M.W. A self-pursing file format for earthquake catalogue and data files. September 1997.
WL/97/38	Petrie, D.L., Laughlin, J., Riddick, J. and McDonald J. UK Strong Motion Seismic Network Version 2, status to August 1997. August 1997.
WL/97/44	Ford, G.D., Galloway, D.D., Henni, P.H.O. and Walker, A.B., 1997. The Ambleside earthquakes of 12 September 1988. November 1997.
WL/98/01	Walker, A.B. (ed), Ford, G.D., Galloway, D.D. and Simpson, B.A. Bulletin of British Earthquakes, 1997. March 1998.
WL/98/04	Wild, P.W. and Baptie, B.J. The logistical solution for the automatic determination and dissemination of phase and location parameters for earthquakes in the European-Mediterranean region recorded on BGS's Lownet, Hereford and Cornish monitoring networks. February 1998.

In addition, 8 confidential reports were prepared for commercial customers and bulletins of seismic activity were produced monthly, up to 6 weeks in arrears, for the Customer Group sponsoring the project.

External Publications

Galloway, D.D. and Walker, A.B., 1998. A summary of earthquakes in 1997. The Society for Earthquake and Civil Engineering dynamics (SECED) Newsletter. Vol 12 No 1, February 1998.

Musson, R.M.W. and Winter, P.W., 1997. Seismic hazard maps for the UK. Natural Hazards, Vol 14 pp 141-154.

Musson, R.M.W., 1997. Seismic hazard studies in the UK: Source specification problems of intraplate seismicity. Natural Hazards, Vol 15 pp 105-119.

Musson, R.M.W., 1997. Testing earthquake prediction results statistically. Seismological Research Letters, Vol 68, no 6, pp 944-946.

Redmayne, D.W., Richards, J.A. and Wild, P.W., 1998. Mining-induced earthquakes monitored during the pit closure in the Midlothian coalfield. Quaterly Journal of Engineering Geology, 31, 21-26.

Van Rose, S. and Musson, R.M.W., 1997 Earthquakes - our trembling planet, British Geological Survey, Nottingham. ISBN 0-852722-87-7.

Walker, A.B., 1997. EU Transfrontier Seismic Data Exchange. In IASPEI 1997 (Abstracts), the 29th General Assembly of the International Association of Seismology and Physics of the Earth's Interior, Thessaloniki, Greece August 18-28 1997 pp 237.

Walker, A.B., 1998. Free and rapid seismic data exchange in Europe. Earthwise, Issue 11, February 1998.

Wild, P.W., 1998. Rapid warning of European earthquakes. Earthwise, Issue 11, February 1998.

UK EARTHQUAKE MONITORING 1996/97 BGS SEISMIC MONITORING AND INFORMATION SERVICE: EIGHTH ANNUAL REPORT

A B Walker

The aims of the Service are to develop and maintain a national database of seismic activity in the UK for use in seismic hazard assessment and to provide near-immediate responses to the occurrence, or reported occurrence, of significant events. Following a history of seismic monitoring at a number of localities over the past 28 years, the British Geological Survey (BGS) has been charged with the task of developing a uniform network of seismograph stations throughout the country in order to acquire more standardised data in the future. The project is supported by a group of organisations under the chairmanship of the Department of the Environment (DOE) with a major financial input from the Natural Environment Research Council (NERC). This Customer Group is listed in Annex A.

In the eighth year of the project (April 1996 to March 1997), the upgrading of the UK network to the new digital standard, has been completed. One low sensitivity and three strong motion instruments have been installed. There are, however, some remaining gaps in station coverage; notably in Northern Ireland. Other areas, covered by site-specific networks in Cumbria, northern Scotland, Outer Hebrides and the Orkney Islands are vulnerable to closure owing to their dependency on funds from commissioning bodies.

Some 204 earthquakes have been located by the monitoring network in 1996, with 27 of them having magnitudes of 2.0 or greater, of which nine are known to have been felt. The largest felt earthquake in the reporting year (April 1996 to March 1997), with a magnitude of 3.8 ML, occurred 12 km offshore, Penzance, Cornwall, on 10 November 1996. The earthquake was felt over an area of 14,000 km^2 and the maximum intensity in the epicentral region was 5 EMS (European Macroseismic Scale, Annex H). The two largest offshore events were in the northern North Sea, with magnitudes of 3.9 ML. In addition to earthquakes, BGS receives frequent reports of seismic events, felt and heard, which on investigation prove to be sonic booms, spurious, or in coalfield areas, where much of the activity is probably induced by mining (eg Musselburgh, near Edinburgh). During the reporting period, data on four controlled explosions and five sonic events have been processed and reported upon following public concern or media attention.

All significant felt events and some others are reported rapidly to the Customer Group through 'seismic alerts' sent by fax and are then followed up in more detail. Monthly seismic bulletins are issued 6 weeks in arrears and, following revision, are compiled into an annual bulletin. In all these reporting areas, scheduled targets have been met or surpassed.

The completion of a joint EU project with neighbouring countries (10 member states led by BGS) to promote rapid data exchange across borders has led to a significant advance in the free flow of information. This 'Transfrontier Group' has adopted an e-mail based protocol for data exchange which operates in an automatic way, thereby avoiding time consuming person-to-person interactions and the problems of earthquakes which occur outwith working hours.

The potential of the network's data links and computing capabilities to provide an environmental monitoring capacity has been explored further using additional sensors. They now include radioactivity, ozone, sulphur dioxide and NOx gases. Proposal have been submitted to SEPA and the EU to help expand this environmental capability.

RAPID TRANSFRONTIER SEISMIC DATA EXCHANGE NETWORK (TRANSFRONTIER GROUP); FINAL CONTRACT REPORT

A B Walker

It has become widely recognised in recent years that areas of low to medium seismicity contain a definite risk for industrialised countries which engage in 'high consequence' activities (eg nuclear power and reprocessing, offshore and onshore hydrocarbon exploitation, chemical works and large engineered structures such as dams, bridges and tunnels). Understanding the earthquake hazard and identifying the causative faults in such areas is difficult because of the infrequency of the larger earthquakes and the relatively short period of instrumental monitoring. Recognising that 10 of the northern and western Member States of the European Union fall into the category outlined above, the Commission contracted research under the Second Framework Agreement for these States to improve, enhance and harmonise their capabilities in this area. Emphasis was to be placed on tackling the problems of free and rapid data exchange, particularly in transfrontier areas, in order to underpin downstream research and hazard assessments with accurate information.

The need for improved integration of data and methodologies has been stimulated by the larger damaging earthquakes of the region; Liege, Belgium, 1983 (60 MECUs damage), Roermond, Netherlands, 1992 (more than 100 MECUs) and, more recently, Annecy, France, 1995 (45 MECUs). These events had modest magnitudes ranging from 5.0 to 5.8 on the Richter scale and are by no means the largest possible for the region. In order to assess the probability of occurrence of larger events so that engineers, planners and governments can take account of the risks, details of smaller earthquakes, their distributions, relationships with geological faults and the way energy attenuates with distance must be known. Elsewhere in the world, intraplate earthquakes have proved to be highly destructive: a 32 km surface rupture in Australia from three earthquakes with magnitudes between 6.3 and 6.7 (1988); 10,000 people killed in an unprepared area of Peninsular India from a magnitude 6.3 earthquake in 1993.

Objective data on earthquakes which are felt is important to diffuse, rapidly, the alarm which is generated in populous areas. Most magnitude 2.5 and some smaller earthquakes fall into this category.

As a major step in researching these intraplate earthquakes, the project has brought together agencies in the 10 Member States to exchange and combine earthquake information in increasingly standard formats so that their positions, magnitudes, stress condition and relation to causative faults have been determined more accurately. The common feature of "national" earthquake epicentres being duplicated on each side of a border for the same earthquake, has been eliminated. With that, has gone one problem in the quantification of seismic hazard.

Modest additions to the combined 450 seismic monitoring stations have been made during the project. Most notable, has been the installation of a modern network throughout Portugal. The greater achievement has been the more rapid transmission of information from outstations to national centres in near real-time and the establishment, there, of hardware and software to make it readily available to other participants. A standard form of data exchange protocol has been adopted and implemented (the Auto Data Request Manager: AutoDRM) which is based on e-mail technology using the Internet. As such, it has worldwide application and is already used by international agencies such as the European-Mediterranean Seismological Centre (EMSC) and the nuclear test discrimination group, GSE.

Throughout the establishment of these new systems, participants have exchanged data with increasing efficiency to yield a combined catalogue of some 3,500 earthquakes with magnitudes greater than 2.0, over the 28-month project period In addition, earlier files have been cleaned of duplicates back to 1990 to produce a harmonised catalogue for publication of a seismicity map against a topographic backdrop. The publication, itself, would result from the next phase of the project.

In order to trigger the **rapid** exchange of data for wider public dissemination of objective information following a significant earthquake, the general definition of significance has been agreed as:

An earthquake which is felt by people regardless of its magnitude or which, if not felt, has a magnitude of 3.0 ML or greater.

In practice, there are some caveats for the higher and lower seismicity areas where the smallest events have lower or greater significance, respectively.

Many individual earthquakes, felt widely, have been researched in detail using data freely available from across borders. The largest of these had a magnitude of 5.6, occurred near the French-Spanish border in the Pyrenees and caused damage and rock slides. A more modest, magnitude 4.5, earthquake which caused minor damage in Belgium, was felt across borders in France and the Netherlands.

Focal mechanism studies have been conducted on many of these earthquakes, across a wide range of magnitudes, to investigate local stress conditions and faulting styles. They are of fundamental relevance to the state of the European crust and the geological processes within it and to the application of knowledge in the accurate quantification of seismic hazard as a threat to the population and the European economy.

The groundwork has been laid, both in the exchange procedures and trust established, and in the harmonisation of data catalogues, for further advances in improved hazard assessments. Particular targets to achieve that goal include standardised magnitude determinations, regional (rather than national) energy attenuation laws, fault correlations, depth variations, crustal structure variations and a wider spread of focal mechanisms and epicentre patterns.

RECENT SEISMICITY IN THE STOKE-ON-TRENT AREA, STAFFORDSHIRE.

J H Lovell, G D Ford, P H O Henni, C Baker, I Stimpson, and W Pettitt

North Staffordshire has a long history of seismicity characterised, at least in the last 20 years, by outbursts of natural and mining-induced earthquakes which have caused considerable local public interest. This activity has been monitored twice in the past by local seismograph networks installed by BGS and the University of Keele, and the pattern of activity described.

The most recent period of activity started in February 1995 with a series of felt (magnitudes up to 2.5 ML) and smaller events centred in two areas around Newcastle-under-Lyme and Stoke-on-Trent. Analysis of these two swarms and comparison with previous activity suggests that they consist of both mining-induced and possible tectonic events. Installation of a local network and refinement of the crustal velocity model would allow more accurate locations and the determination of fault-plane solutions. It would also permit more definitive statements to be made about the origins of this seismicity.

CHAPTER 15 (INTENSITY AND INTENSITY SCALES) OF THE NEW MANUAL OF SEISMOLOGICAL OBSERVATORY PRACTICE

R M W Musson

The original Manual of Seismological Practice (MSOP) was produced at a time in which macroseismic studies were to some extent in decline, as the improvements in instrumental monitoring convinced some seismologists that the study of intensity was no longer important. Since then, the increased importance of seismic hazard studies, seismic risk studies, and studies of historical seismicity, has meant that there has been a considerable revival of interest in macroseismics, and a corresponding high level of technical advance. Of particular note is the release of the European Macroseismic Scale, which represents a significant advance over previous intensity scales in clarity and consistency.

Consequently, although it might seem surprising at first thought, the chapter on Intensity and Intensity Scales in the MSOP is as much in need of complete revision to reflect modern practice as are the chapters on instrumental techniques. The chapter has therefore been rewritten entirely. The draft has been exposed on the World Wide Web for comment from interested parties, especially members of the European Seismological Commission Working Group on Macroseismology, and the comments received have been incorporated into the draft. The text, presented here, thus represents a consensus of international opinion on modern macroseismic practice.

ON THE USE OF MONTE CARLO SIMULATION FOR SEISMIC HAZARD ASSESSMENT

R M W Musson

The use of Monte Carlo techniques in seismic hazard analysis is best known as a means of treating uncertainty in Probabilistic Seismic Hazard Assessment (PSHA) calculations. Different input parameters for the PSHA calculations are selected using Monte Carlo techniques rather than a logic tree. However, Monte Carlo techniques can also be used in a more direct manner: they can be used to generate large numbers of synthetic earthquake catalogues from which the probability of different levels of ground motion can be derived. This method is not new, but seems to be under-utilised. While it may lack the precision of conventional PHSA methods for low probability calculations, it has a number of advantages. The technique is very flexible. It is very easy to modify the form of the seismicity model used, for example, to introduce non-Poissonian behaviour, without extensive reprogramming. Uncertainty in input parameters can also be modelled very flexibly - for example, by the use of a standard deviation rather than by the discrete branches of a logic tree. In addition (and this advantage is perhaps not as trivial as it may sound) the simplicity of the method means that its principles can be grasped by the layman, which is useful when results have to be explained to people outside the seismological/engineering communities, such as planners and politicians.

A SELF-PARSING FILE FORMAT FOR EARTHQUAKE CATALOGUE AND DATA FILES

R M W Musson

In modern seismology it is a fairly common need to process files of earthquake epicentres by computer in order to perform some task, which might be as simple as merely plotting them on a map, or might be some more complex statistical analysis connected with seismic hazard or earthquake prediction research. The software used for such analyses is usually highly specialised; it cannot be purchased from commercial sources, and must be written specially for the task in hand, usually by the seismologist himself or a colleague. This paper presents a way in which any file of epicentral data that meets a few basic standards can be configured, with the addition of a single header line, such that it can be read by any processing program designed to take advantage of this method. The programmer can therefore write analysis programs that will read many different files in different formats without the need to change either the file format or the formatting codes in the program.

UK STRONG MOTION SEISMIC NETWORK VERSION 2

D L Petrie, J Laughlin, J Riddick and J Macdonald

This document has been produced to assist staff set up, configure and calibrate the INTEGRA three component Strong Motion instruments currently used by the Global Seismology and Geomagnetism Group (GSGG) of the British Geological Survey (BGS). The details contained in this report supersede those given by Miller and Turbitt (1994) and it is intended that as the network is developed and extended regular updates will be produced in order that all instrumentation is standardised throughout the network.

Currently in August 1997, the network consists of 15 sites at which are deployed various configurations and models of INTEGRA three component seismometers interfaced to calibration logic, data loggers and retrieval systems (SEISLOG), (Utheim and Hasvkov, 1996). There are several variations of seismometer interface, calibration boards and interfaces between the data collection and retrieval systems. This document is intended to detail each of these different configurations and is a first step in standardising the wiring, calibration and servicing procedures of the UK Strong Motion network.

THE AMBLESIDE EARTHQUAKES OF 12 SEPTEMBER 1988

G D Ford, D D Galloway, P H O Henni and A B Walker

On 12 September 1988, three earthquakes, with magnitudes of 3.0, 2.8 and 1.8 ML, occurred within five minutes of each other near the town of Ambleside in Cumbria. They were originally catalogued by Turbitt et al (1990) using phase readings from the BGS seismograph network operational at that time, and were revised in 1995 by Ford et al (1995). Additional data from the AWE (Atomic Weapons Establishment) stations at Middlesmoor, North Yorkshire, and Eskdalemuir in southern Scotland, were also used in the location. No reliable focal mechanism could be obtained due to the poor distribution of stations around the event and the saturation of records on nearby stations preventing the use of SV/P amplitude ratios. The felt area of the largest of the three earthquakes was 2,900 km^2 (Isoseismal 3) and the maximum intensity was 5 EMS (European Macroseismic Scale) which was observed at Ambleside, Coniston, Hawkshead and Windermere. Slight damage (small cracks in plaster) was reported at Ambleside and Hawkshead.

BULLETIN OF BRITISH EARTHQUAKES 1997

A B Walker (editor)

There have been 235 earthquakes located by the monitoring network during the year, with 33 of them having magnitudes 2.0 ML or greater. Of these, 15 are known to have been felt, together with a further 22 smaller ones, bringing the total to 37 felt earthquakes in 1997.

The largest onshore earthquake occurred on 10 February, with a magnitude of 2.9 ML; it was located approximately 6 km southwest of Chesterfield in Derbyshire. Felt effects were experienced throughout Chesterfield, Ashgate, South Wingfield and Matlock, where residents typically reported "the house trembled" and "the whole bed shook". A fault plane solution of the event shows reverse faulting with a component of strike-slip motion on planes striking EW and dipping south or planes striking NE and dipping to the NW. This is the first event that has been felt in the area, since the magnitude 1.8 ML Chesterfield earthquake, on 3 February 1987, which was felt with intensities of at least 3 EMS in the epicentral area.

The largest offshore earthquake occurred in the northern North Sea on 13 May. It had a magnitude of 3.4 ML and was located approximately 270 km ENE of Lerwick, Shetland, in the North Viking Graben region of the North Sea; no felt reports were received. A further six events occurred in the northern North Sea area during the year, with magnitudes ranging between 2.1 and 2.9 ML, and were located using both the BGS and Norwegian networks.

On 4 February, an earthquake, with a magnitude of 2.7 ML, occurred in the Rannoch Moor area of Tayside. It was felt in Appin, Bridge of Orchy and on Rannoch Moor with intensities of at least 3 EMS. Felt reports described "a rumble like thunder", "the whole house shook and I was frightened" and "heard a loud bang". This event locates in the same general area as the magnitude 2.5 ML, Glen Lyon earthquake on 9 January 1990, which was felt with intensities of at least 4 EMS.

On 19 May, an earthquake, with a magnitude of 2.7 ML, occurred near the town of Carterton, Oxfordshire. The event was felt throughout the villages of Carterton, Witney, Burford and Bampton. Felt reports described "felt like the foundations were lifted", "the light fitting rattled" and "the whole desk shook and items rattled" indicating a maximum intensity of at least 4 EMS in the epicentral area. This is the largest event in the immediate area, since the magnitude 1.9 ML Lechlade earthquake on 15 June 1984, approximately 5 km to the southwest.

On 22 June, an earthquake, with a magnitude of 2.2 ML, occurred offshore Jersey in the Channel Islands, approximately 2 km west of Grosnez Point. The event was felt throughout Jersey, where felt reports described "the floor vibrated for 15-20 seconds", "the whole bungalow shook" and "like a plane crashing". A macroseismic survey was carried out and 117 replies were received (111 positive and 6 negative). They indicated a maximum intensity of 4 EMS close to the epicentre. This is the largest event in the area since the magnitude 3.5 ML St. Aubin's Bay earthquake, on 30 April 1990, which was felt throughout Jersey and Guernsey and had a maximum intensity of 5 EMS.

On 8 October, an earthquake, with a magnitude of 2.1 ML, occurred in Ulverston, Cumbria. Felt reports were received from Ulverston, Kirkby-in-Furnace, Broughton Beck and Bouth, and included "like an explosion followed by a rumble" and "a loud bang", indicating an intensity of 3 EMS. This is the largest event in the area since the magnitude 3.0 ML, Grange-over-Sands earthquake of 26 June 1993, which was felt over an area of 9000 km^2 and had a maximum intensity of 5 EMS.

An earthquake, with a magnitude of 2.8 ML, occurred on 16 October approximately 10 km northwest of Dartmouth in Devon . Felt reports described "being woken up and the bedside cabinet shaking", "a great shake moved the foundations" and "the house shook from side to side for 1-2 seconds". A macroseismic survey was carried out and 162 replies were received (156 positive and 6 negative). They indicated a maximum intensity of 4 EMS close to the epicentre and a felt area of 1400 km^2. No focal mechanism was obtained for this event owing to the poor station distribution in the epicentral region.

In the Loch Maree area, of the Scottish Highlands, an earthquake, with a magnitude of 2.5 ML, occurred approximately 10 km southeast of the village of Gairloch on 8 November. Felt reports were received from the village of Gairloch where some residents were awakened from sleep and described the effects like "a large rumble and the house was shaking" and "like distant thunder".

Near Doune, Central Scotland, ten earthquakes were detected during 1997, with magnitudes ranging between 0.9 and 2.7 ML. The two largest events with magnitudes of 2.7 ML, occurred on 6 October and 30 November and were reported felt throughout the Doune, Callander, Thornhill and Dunblane areas of Central Scotland. Felt reports described "we were woken up", "the whole house shook" and "cups fell off the sideboard", indicating an intensity of at least 4 EMS in the epicentral area and in some cases 5 EMS. A further four events were reported felt throughout the Doune area, with magnitudes ranging between 1.7 and 2.6 ML.

A swarm of forty-nine earthquakes, five felt by local residents, were detected in the Blackford area of Tayside during 1997 with magnitudes ranging between -0.2 and 2.4 ML. The largest, with a magnitude of 2.4 ML, occurred on 30 July and was felt throughout the Blackford area. The local Police were flooded with calls and felt reports described "the whole building shook", "pictures on the walls moved" and "the cupboard doors flew open" indicating an intensity of at least 4 EMS. This is an area that has experienced a number of events in the past, including the magnitude 3.2 ML Ochil Hills earthquake, on 19 February 1979, and had a maximum intensity of 5 EMS.

On 8 December, an earthquake, with a magnitude of 2.3 ML, was located approximately 5 km southeast of the village of Fort Augustus, Scottish Highlands. Felt reports were received from Fort Augustus, which described "we were woken up" and "items in the house were rattling" indicating an intensity of at least 4 EMS.

Near Caernarvon, Gwynedd, a small earthquake with a magnitude of 1.2 ML, was felt by a resident in the village of Tregarth, on 19 December. She described "the house shook" and "heard a rumble" indicating an intensity of 3 EMS, which is surprising as events with such small magnitudes are rarely felt.

In North Wales, two events with magnitudes of -0.2 and 0.1 ML were located on the Lleyn Peninsula, in the same area and at similar depths as the magnitude 5.4 ML Lleyn earthquake of 19 July 1984, which was felt over an area of 250,000 km^2.

The coalfield areas of central Scotland, Yorkshire, Staffordshire and Nottinghamshire continued to experience earthquake activity of a shallow nature which is believed to be mining induced. Some 61 coalfield events, with magnitudes ranging between -0.6 and 2.0 ML, were detected in the year. Seventeen of these were reported felt by local residents.

The area east of Edinburgh continued to be active during the first three months of the year, a series of 17 events occurred in the Musselburgh/Newcraighall area, and represent a continuation of the activity which started in October 1996 (Walker, 1997). The largest of these events in 1997, with magnitudes of 1.7 ML, occurred on 9 and 11 January and were felt in the Musselburgh area with intensities of at least 4 EMS. Four events in this series were felt by local residents who described "the whole house shook and rumbled" and "there was a loud bang". The pattern (most events occurring in the working week) and location of the activity was a consequence of mining at Monktonhall colliery. The two most likely causes of these events are: the undermining and subsidence of old workings with void and pillar collapses and shearing in strained rock layers; or the bridging, and subsequent breaking during subsidence, of a strong rock layer between the mine and the surface (in this case, 900 metres above). Following the closure of Monktonhall Colliery in March 1997, no further events have been detected.

Near Newcastle-under-Lyme, Staffordshire, thirteen shallow events occurred, with magnitudes ranging between 0.9 and 1.8 ML. Six of these events were felt by local residents in the Keele and Whitmore areas of Staffordshire.

Seventeen events, with magnitudes ranging between 0.7 and 1.5 ML, were located near Clackmannan in the central region of Scotland; none were reported felt. This is an area which has experienced many such mining induced events in the past.

THE LOGISTICAL SOLUTION FOR THE AUTOMATIC DETERMINATION AND DISSEMINATION OF PHASE AND LOCATION PARAMETERS FOR EARTHQUAKES IN THE EUROPEAN-MEDITERRANEAN REGION RECORDED ON BGS'S LOWNET, HEREFORD AND CORNISH MONITORING NETWORKS.

P W Wild and B J Baptie

BGS are members, along with seven other European seismological institutes, of a two year EC funded project (May 1996 to May 1998) called the Rapid Transfer Project. This project has several remits, all directed towards the goal of speeding up the notification of European earthquake parameters and source mechanisms.

One of the tasks that BGS had to perform within the project, was to set up the ability for phase data from three of BGS's networks to be transferred to the European-Mediterranean Seismological Centre's (EMSC) headquarters in Paris, automatically following a large earthquake (>4.5) in the European-Mediterranean region. This task is simple in its concept, but has been very complicated in its solution as it relies on automating the passing of data through a number of independent computer systems and programs. This report describes the logistical solution for this task.

SUMMARY OF EARTHQUAKES IN 1997

D D Galloway and A B Walker

The year 1997 was not exceptional in terms of worldwide earthquakes. There were no 'great' earthquakes (magnitude over 8.0), six 'major' earthquakes (magnitudes between 7.0 and 7.9) and 74 'strong' earthquakes (magnitudes between 6.0 and 6.9). These numbers are less than the long-term averages for these magnitude ranges, which are 1, 18 and 120, respectively. The number of people killed by earthquakes during 1997 was 2,919 against a long-term average of 8,700 (Table 1). This was mainly due to the larger 'major'earthquakes occurring in remote, sparsely populated areas (Fig. 1).

The most disastrous earthquake during the year, with a magnitude of 7.3 Ms, occurred on 10 May in Northern Iran. It caused the deaths of at least 1,572 people, injured 2,300 more, destroyed or damaged over 16,000 homes and left over 50,000 homeless in the Birjand-Qayen area. Several landslides were reported from this same area. Damage was also reported from the Herat area of Afghanistan. Another earthquake, with a magnitude of 4.5 Ms, occurred three days later, 40 km to the south east, killing one person and destroying several houses in Khunik Sar. The most notable event, historically, was the magnitude 7.3 Dasht-e-Bayez earthquake of 1968, which resulted in the deaths of 12-20,000 people.

The year started off with a destructive earthquake, which caused extensive damage, on 9 January. It had a magnitude of 5.8 Ms and destroyed or damaged over 410 homes and buildings in the Dzhergetal area, Kyrgyzstan; no casualties were reported. Two days later, on 11 January, a magnitude 6.9 Ms earthquake killed one person and caused extensive damage in the Arteaga region of Michoacan, Mexico. It was felt throughout Michoacan and in Mexico City.

Several fatal and damaging earthquakes occurred in Southern Xinjiang, China, during the year. The first, on 21 January, with a magnitude of 5.8 Ms, killed 12 people, injured 40 more, destroyed and damaged some 31,000 homes, left several thousand homeless and killed some 4,000 livestock in the Jiashi Area. The others occurred on 1, 5, 6 March and 11 April, with magnitudes of 5.5, 5.9, 5.8 and 6.1 Ms, respectively. A further 11 people were killed, 118 more were injured, thousands of buildings were destroyed leaving over 100,000 homeless and losses of over 11,000 livestock as a result of these earthquakes.

On 22 January, in the Antakya region of Turkey, a magnitude 5.4 Mb earthquake injured 5 people and damaged 10 houses in the epicentral area.

A 'strong' earthquake, with a magnitude of 6.8 Ms, occurred in the Turkmenistan-Iran border region on 4 February. It killed 88 people, injured 2,000 more and either destroyed or damaged over 16,000 homes in the Bojnurd-Shirvan area resulting in damage estimates of over $30 million.

On 27 February, the second 'major' earthquake during the year, with a magnitude of 7.3 Ms, occurred in Pakistan. Sixty people were killed, hundreds more injured, hundreds of cattle were killed and over 500 houses were destroyed, leaving thousands homeless in the Harnai-Sibi and Quetta areas. It was felt throughout much of central Baluchistan.

The next day, on 28 February, a magnitude 6.1 Ms earthquake occurred on the Armenia-Azerbaijan-Iran border and killed 965 people, and over 160,000 livestock in the Ardabil area of northwest Iran. It injured 2,600 and left some 12,000 homes damaged or destroyed and over 36,000 people homeless. Severe damage was caused to roads, electrical power lines, communications and water distribution systems in the epicentral area.

On 26 March, an earthquake, with a magnitude of 5.9 Ms, occurred in Kyushu, Japan. Twenty-two people were injured, many houses were damaged and railway services were interrupted in the Kagoshima Prefecture. Airports were temporarily closed at Kagoshima, Kumamoto and Tsuruda as a result of the earthquake.

In the Hindu Kush region (near the Afghanistan, Pakistan and Tajikistan border), on 13 May, an earthquake with a magnitude of 6.1 Mb killed one person and injured 11 more in the Malakand-Peshwar area, Pakistan. This earthquake was felt strongly throughout northeast Afghanistan, northern Pakistan and Tajikistan and was also felt some 1000 km away in Delhi, India.

On 21 May, 38 people were killed and more than 1,000 were injured as a result of a magnitude 6.0 Mb earthquake in the intraplate region of Jabalpur, southern India.

On 9 July, near the coast of Venezuela, an earthquake with a magnitude of 6.8 Ms caused extensive damage and disrupted power, telephone and water services throughout the Cariaco-Cumana area and on the Isla de Margarita and the Isla Coche. At least 81 people were killed and over 500 were injured. This earthquake was felt throughout northeast Venezuela, as far west as Maracaibo and on Trinidad and Tobago.

On 21 July, an earthquake, with a magnitude of 5.0 Mb, killed 15 people and caused injury to 46 others at the Avgold's Hartebeesfontein mine near Stilfontein in the Republic of South Africa.

In southern Iran, some 850 km southwest of the devastating earthquake of 10 May, an earthquake, with a magnitude of 5.0 Mb, injured 67 people and damaged several buildings in the Firuzabad area on 24 August.

Two earthquakes, with magnitudes of 5.6 and 6.0 Ms, on 26 September in Central Italy, resulted in the deaths of 11 people and injury to over 100 more in the Marche and Umbria regions. Extensive damage was reported throughout the region including damage to the Basilica of Saint Francis at Assisi, some 40 km to the west. These events were felt in many parts of central and northern Italy from Rome (some 130 km away) to Bologna and Modena and were also felt in western and central Slovenia and as far as southern Karnten Province, Austria (400 km from the epicentre). Further earthquakes occurred in the area during September and October causing at least 25 further injuries and additional damage to the Basilica of Saint Francis.

In Indonesia, on 28 September, 17 people were killed and over 300 injured in the Parepare area of Sulawesi during a magnitude 5.6 Ms earthquake in the region.

On 15 October, an earthquake, with a magnitude of 6.8 Ms, killed 8 people, caused injury to 300 more and either destroyed or damaged over 22,000 houses in Central Chile. Numerous power and telephone outages and several landslides and rockslides were also reported from the epicentral area. The earthquake was felt throughout Chile, as far south as Buenos Aires, Argentina (some 1300 km away), and also in parts of Bolivia and Peru, some 1800 km to the north of the epicentre.

On 21 November, an earthquake, with a magnitude of 5.9 Ms, occurred near the India/Bangladesh border. It killed 23 people, injured 200 more and caused severe damage to several buildings, including the collapse of a five storey building, in Chittagong, Bangladesh. Houses were also damaged and old trees were uprooted at Alikadam, Bandarban, Lama and Nakhyaungcharipara.

Most of the severely damaging earthquakes during 1997 were in the 'major' or 'strong' categories. There were, however, some notable exceptions. One of these was the magnitude 4.9 Mb Pakistan earthquake, on 19 March. This relatively small magnitude event caused the deaths of 15 people, injured several others and damaged numerous houses in the Bajaur region. Another exception was the magnitude 4.8 Ms earthquake, which occurred on 12 January in the Berat area of Albania. One person was slightly injured and minor damage was reported at Ura Vajgurope and at Berat, where over 70 houses were destroyed.

The UK summary of earthquakes is covered in the summary for the 1997 bulletin of British earthquakes above.

SEISMIC HAZARD MAPS FOR THE UK

R M W Musson and P W Winter

Past studies of seismic hazard in the UK that have used modern probabilistic methods of hazard assessment have been site-specific studies, mostly in connection with nuclear installations. There has been a need for general-purpose maps of seismic hazard to show relative variation of exposure within the UK and to give some guidance on absolute values. Such maps have now been produced, incorporating, for the first time, the wealth of new information on historical earthquakes in Britain that has been gathered over the last fifteen years. The hazard calculations were undertaken using new computer code based on the USGS program SEISRISK III, but incorporating a "logic tree" approach to model variation in the input parameters (eg focal depth) or uncertainty in the formulation of the model (eg attenuation parameters). An innovative approach was taken to the formulation of seismic source zones, in which two overlapping models were employed. The first of these uses relatively broad source zones based loosely on an interpretation of seismicity and tectonics, while the second uses numerous small zones that reflect the locations of past significant earthquakes. This double approach (using the logic tree methodology) has the merit of both considering the general trend of earthquake activity as well as focusing in on known danger spots. The results show that the areas of highest hazard are western Scotland, northwestern England and Wales, where the intensity with 90% probability of non-exceedance in 50 years is 6 EMS.

SEISMIC HAZARD STUDIES IN THE UK: SOURCE SPECIFICATION PROBLEMS OF INTRAPLATE SEISMICITY

R M W Musson

Although the UK is in an area of only low to moderate seismicity, the seismic hazard is sufficient to pose a threat to sensitive structures such as chemical plants and nuclear facilities. In quantifying the level of hazard by conventional probabilistic methodology, however, some problems arise in attempting to interpret earthquake data in terms of geological structure and faults. In the UK, not only is it impossible to identify any demonstrably active faults but also it is extremely difficult to discern any relationship between the pattern of seismicity and local or regional geological structure.

This study discusses the use of two zonation approaches which complement each other in such a way that the general character and trend of seismicity is preserved. In one approach, the zonation is informed by the structural geology, where possible; geological zonation is avoided if it produces sources with heterogeneous seismicity. In the other approach, the record of past earthquakes is divided up into very small zones around individual epicentres or groups of epicentres, the size of each zone usually being proportional to the uncertainty in the epicentral determination of the appropriate event. This zonation preserves an observed tendency of some British earthquakes to repeat themselves. It is suggested that, in intraplate areas such as the UK, it is often inappropriate to attempt to model individual fault sources. No faults in the UK are provably active. Because an earthquake of moderate size can occur on a very short fault segment, it is impractical to restrict fault modelling to major features. Even the two largest UK faults, suspected to be active, pose problems in attributing historical seismicity to them as distinct features.

TESTING EARTHQUAKE PREDICTION RESULTS STATISTICALLY

R M W Musson

The work of a professional seismologist is not all science; often a significant amount of public relations comes into it as well. One aspect of this is the requirement, increasingly common, to comment on earthquake predictions that have achieved a high public profile. These often originate outside the scientific community, from a variety of possible motives, and their public profile can be in inverse proportion to their value. This paper describes a method for statistically evaluating a series of earthquake predictions, first proposed by Stark, which overcomes many of the technical problems that make other methods disputatious and unsatisfactory. Two examples of the method are given for typical cases of controversial earthquake predictions.

MINING-INDUCED EARTHQUAKES MONITORED DURING THE PIT CLOSURE IN THE MIDLOTHIAN COALFIELD

D W Redmayne, J A Richards and P W Wild

The British Geological Survey installed a seismometer network to monitor earthquakes around Rosslyn Chapel in the Midlothian Coalfield from November 1987 until January 1990. Accurate locations were obtained for 247 events and a close spatial and temporal association with concurrent coal mining, with a rapid decay of earthquake activity following pit closure, was demonstrated, indicating a mining-induced cause. Residual stress from past mining appears to have been an important factor in generating seismicity and observations indicate that limiting the width of the workings or rate of extraction may significantly reduce or eliminate mining-induced earthquake activity, an extremely desirable prospect which warrants further investigation. A frequency-magnitude analysis indicates a relatively high abundance of small events in this coalfield area. The maximum magnitude of a mining-induced earthquake likely to have been experienced during the life of the coalfield (maximum credible magnitude) was 3.0 ML, although an extreme event (maximum possible magnitude) as large as 3.4 ML was remotely possible. Significant seismic amplification was observed at Rosslyn Chapel, which is founded on sand and gravel, compared with a nearby bedrock site. As a consequence, relatively small magnitude events caused high, and occasionally damaging, seismic intensities at the chapel. This is likely to be an important effect at similar sites elsewhere.

EARTHQUAKES - OUR TREMBLING PLANET

S Van Rose and R M W Musson

This 72 page book, with numerous coloured illustrations including original artwork, is an update and expansion on the Natural History Museum's 1983 booklet on earthquakes. The intended audience is made up of schools and interested non-technical readers. The book provides an overview of most aspects of seismology for the general reader, including the causes of earthquakes, celebrated historical earthquakes, how earthquakes are studied, earthquakes induced by human activity, earthquake prediction, protecting against earthquakes, and so on.

EU TRANSFRONTIER SEISMIC DATA EXCHANGE

A B Walker

It has become widely recognised in recent years that areas of low to medium seismicity contain a definite risk for industrialised countries which engage in 'high consequence' activities (eg nuclear power, hydrocarbon exploitation, chemical works and large engineered structures such as bridges and tunnels). Understanding the earthquake hazard and identifying the causative faults in such areas is difficult because of the infrequency of the larger earthquakes and the relatively short period of instrumental monitoring. Ordinary dwellings and industries can be at risk from earthquakes in the magnitude range of 5 to 5.5, when they occur close to vulnerable cities. For example, the 1992 Roermond earthquake in the Netherlands, with a magnitude of 5.8 ML caused damage in the epicentral region and losses estimated in excess of 100 MECUs. Ten EU Member States in the low to medium seismicity region, Ireland, United Kingdom, the Netherlands, Denmark, Belgium, Luxembourg, France, Germany, Portugal and Spain are collaborating to establish and maintain a network of seismological institutions with the capability of exchanging raw data within, at most, one working day of the occurrence of a significant earthquake. The extension of networks and harmonisation of methods have been features of the project with the differing levels of available resources leading to cross-institution technology transfers. The introduction of a standard automated data exchange system (AutoDRM) has put the project on a convergent path with the European data centres EMSC and ORFEUS and with GSETT. Success in this endeavour will benefit social, scientific and engineering communities. This project is supported by the European Commission DG XII for Science, Research and Development under the Environment programme 1991-1994: Climatology and Natural Hazards. A seismicity map of the region has been compiled for the period of 1990 to 1996 with a magnitude threshold of 2.5 ML.

FREE AND RAPID SEISMIC DATA EXCHANGE IN EUROPE

A B Walker

In recent years it has become widely recognised that areas of low to medium seismicity contain a definite risk for industrialised countries which engage in 'high consequence' activities (eg nuclear power and reprocessing, offshore and onshore hydrocarbon exploitation, chemical works and large engineered structures such as dams, bridges and tunnels). Understanding the earthquake hazard and identifying the causative faults in such areas is difficult because of the infrequency of the larger earthquakes and the relatively short period of instrumental monitoring. Recognising that 10 of the northern and western Member States of the European Union fall into the category outlined above, a project was set up to improve, enhance and harmonise their capabilities in this area. Emphasis was placed on tackling the problems of free and rapid data exchange, particularly in transfrontier areas, in order to underpin downstream research and hazard assessments with accurate information.

Awareness of the finite risk of intraplate earthquakes has been raised by some dramatic examples. In 1988 in northern Australia, three earthquakes with magnitudes between 6.3 and 6.7 caused a 32 km surface rupture in a 12 hour period. In 1993, a magnitude 6.3 earthquake in the "stable shield" area of Peninsular India caused the deaths of 10,000 people. There had been no known previous history of such events in these regions. Closer to home, in 1580, an earthquake centred between Dover and Calais was felt strongly throughout Belgium, Luxembourg, the Netherlands, most of England, northern France and NW Germany. Damage to buildings occurred in London, where falling masonry killed two people, and in 'the Low Countries' an unspecified number of deaths was also reported. Elsewhere within the EU, the need for improved integration of data and methodologies has been stimulated by the larger damaging earthquakes of the region; Liege, Belgium, 1983 (60 MECUs damage), Roermond, Netherlands, 1992 (more than 100 MECUs) and, more recently, near Annecy, in France, where the population was alarmed by high intensities of shaking (7 to 8 EMS) and where losses were estimated at 45 MECUs. These events had modest magnitudes ranging from 5.0 to 5.8 on the Richter scale and are by no means the largest possible for the region. In order to assess the probability of occurrence of larger events so that engineers, planners and governments can take account of the risks, details of smaller earthquakes, their distributions, relationships with geological faults and the way energy attenuates with distance must be known.

The project has created a free exchange of data such that border earthquakes are no longer catalogued as separate events by neighbouring countries. More accurate and objective information is rapidly available to non-scientific authorities (eg governments, local officials, engineers, planners, police, media and the public) and a harmonised catalogue and map of earthquakes in the Transfrontier area has been compiled. The growing database is providing a platform for seismicity and seismo-tectonic studies, earthquake mechanisms and seismic hazard assessments.

RAPID WARNING OF EUROPEAN EARTHQUAKES

P W Wild

Earthquake activity in Europe is widespread. It includes the well-publicised destructive events of Greece and Italy and of all other Mediterranean countries which are in the collision zone between the Eurasian and African plates. But the north-western nations do not escape and Britain experiences some 200-300 earthquakes each year, of which about 30 are felt by people. Larger, damaging events occur from time-to-time in these less seismic areas. For this whole region, the European Mediterranean Seismological Centre (EMSC) co-ordinates rapid acquisition and dissemination of information on earthquakes with magnitudes greater than 5.5 from its headquarters near Paris. It is supported, as an international agency, by 40 member institutes and other data providers, together with the Council of Europe. BGS currently holds its presidency.

BGS has been participating in a two year project co-ordinated by the EMSC and jointly funded by the European Commission and the seven European project members to extend EMSC capabilities. The goal of the project is to extend data communications and acquisition to allow the rapid release of accurate information for any earthquake of magnitude greater than 5.0 occurring in the European-Mediterranean region. This information is issued by the EMSC in a two-step procedure, with the location, depth, time and magnitude of the earthquake generally available within 1 hour, followed later by detailed information on the earthquake's source mechanism.

These aims have been met by increasing the distribution of standard "short-period" seismometer stations that can automatically send data to the EMSC (shown in red in the Figure), and increasing data availability from seismometer stations that are capable of measuring over a broad frequency band. These "broad-band" stations are able to provide information that can give a better understanding of the geological processes that give rise to the earthquakes.

BGS has contributed towards this project in two ways. Firstly, earthquake parameters from data acquired by seismometer stations in Central Scotland, Mid-Wales and Cornwall are automatically computed and sent to the EMSC by E-mail, without any operator intervention, within 15 minutes of the earthquake being detected. This information is then joined by the EMSC with data from other countries to provide accurate locations and magnitudes of each earthquake. Those with a magnitude greater than 5.0 are then reported by fax, telex and E-mail. Secondly, a new broad-band seismometer has been installed in Edinburgh, with its data available on-line to the EMSC, for inclusion in calculations of the earthquake's source mechanism.

The advances made during this EC project will be utilised more widely within the 140-station seismic monitoring network operated by BGS in the UK. There is a prospect of further automation throughout the network to increase the flow of cross-border information which contributes to the better understanding of earthquakes and seismic hazard in Britain and neighbouring countries.

SYNOPSIS OF EMS-92 INTENSITY SCALE

1 - **Not felt**
Not felt, even under the most favourable circumstances.

2 - **Scarcely felt**
Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.

3 - **Weak**
The vibration is weak and is felt indoors by a few people. People at rest feel a swaying or light trembling.

4 - **Largely observed**
The earthquake is felt indoors by many people, outdoors by very few. A few people are awakened. The level of vibration is not frightening. Windows, doors and dishes rattle. Hanging objects swing.

5 - **Strong**
The earthquake is felt indoors by most, outdoors by few. Many sleeping people awake. A few run outdoors. Buildings tremble throughout. Hanging objects swing considerably. China and glasses clatter together. The vibration is strong. Top heavy objects topple over. Doors and windows swing open or shut.

6 - **Slightly damaging**
Felt by most indoors and by many outdoors. Many people in buildings are frightened and run outdoors. Small objects fall. Slight damage to many ordinary buildings eg; fine cracks in plaster and small pieces of plaster fall.

7 - **Damaging**
Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many ordinary buildings suffer moderate damage: small cracks in walls; partial collapse of chimneys.

8 - **Heavily damaging**
Furniture may be overturned. Many ordinary buildings suffer damage: chimneys fall; large cracks appear in walls and a few buildings may partially collapse.

9 - **Destructive**
Monuments and columns fall or are twisted. Many ordinary buildings partially collapse and a few collapse completely.

10 - **Very destructive**
Many ordinary buildings collapse.

11 - **Devastating**
Most ordinary buildings collapse.

12 - **Completely devastating**
Practically all structures above and below ground are heavily damaged or destroyed.

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A complete description of the EMS-92 scale is given in: Grunthal, G., (Ed) 1993. European Macroseismic scale 1992 (up-dated MSK-scale). Cahiers du Centre European de Geodynamique et de Seismologie. Vol 7.

Natural
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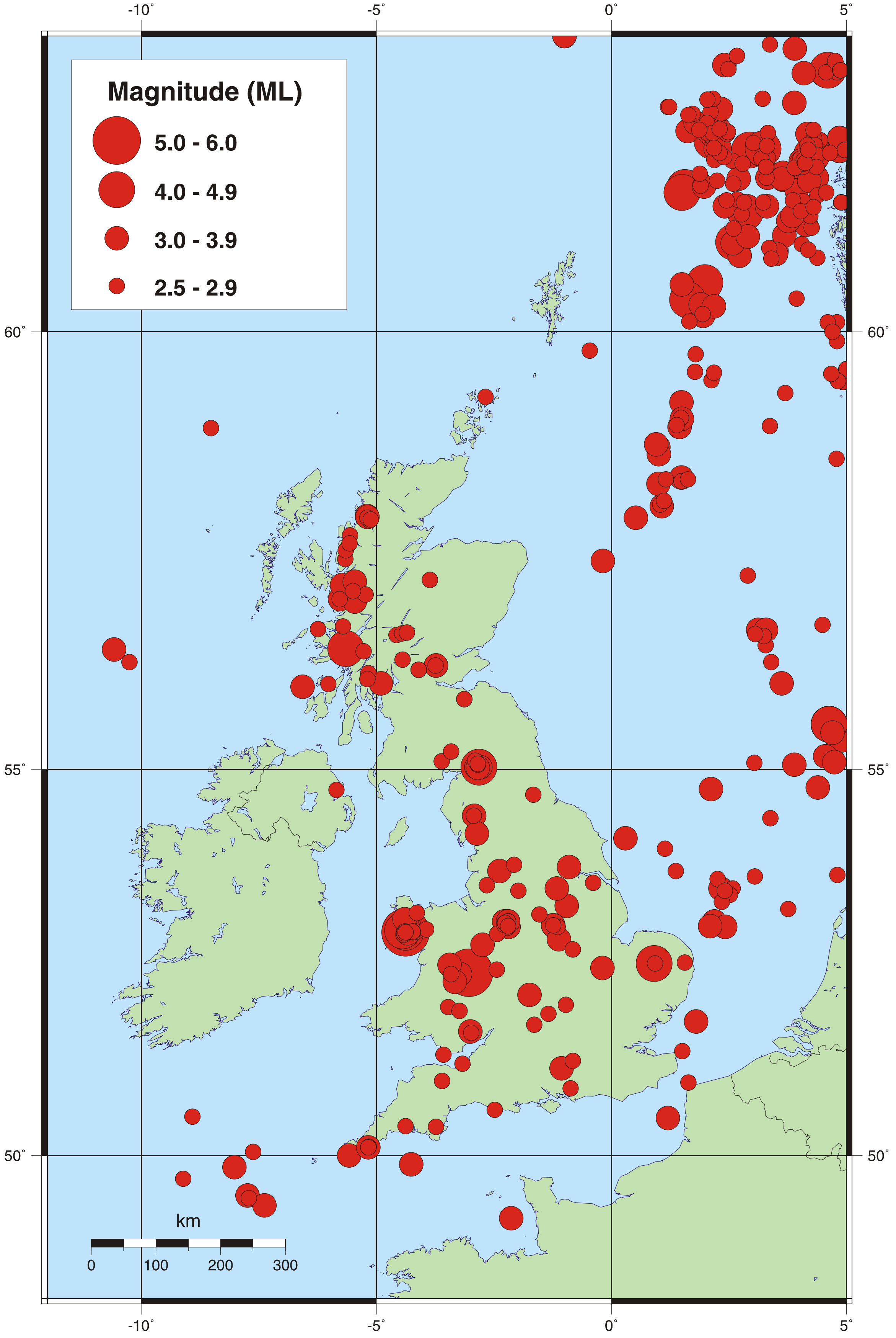

Epicentres of earthquakes with magnitudes 2.5 ML or greater, for the period 1979 to March 1998