UK EARTHQUAKE MONITORING 1992/93

BGS Seismic Monitoring and Information Service

Fourth Annual Report

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BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WL/93/08

Global Seismology Series

UK Earthquake Monitoring 1992/93

BGS Seismic Monitoring and Information Service

Fourth Annual Report

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April 1993

UK Seismic Monitoring and Information Service Year Four Report to Customer Group: April 1993

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

Bibliographic reference
Browitt, C W A & Walker, A B., 1993. BGS Seismic Monitoring and Information Service Fourth Annual Report.
British Geological Survey Technical Report WL/93/08

Edinburgh British Geological Survey 1993

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UK EARTHQUAKE MONITORING 1992/93

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 at a number of localities over the past 24 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. This Customer Group is listed in Annex A.

In the fourth year of the project (April 1992 to March 1993), there has been no extension in coverage of the background seismic monitoring network although progress has been made with site access negotiations for the central southern England area. The rapid response capability, however, has been significantly improved with 5 sub-networks added to the 4 previously upgraded to the new digital standard.

When central southern England is completed, there will remain some gaps in coverage, notably NW Scotland. Other areas are, at present, only covered by site-specific networks in SW England, N Wales, and Cumbria, which may be vulnerable to closure.

Some 300 earthquakes have been located by the monitoring network in the past year, with 49 of them having magnitudes of 2.0 or greater. The largest on land had a magnitude of 3.5 and was strongly felt in the region around Caernarvon Bay in the early evening of 29 July 1992. Offshore, the largest earthquake had a magnitude of 4.7 and located 230 km NE of Shetland in the North Sea. Smaller earthquakes have been felt in several areas of the country including Strathcarron, Loch Leven, central Scotland and southern Wales and a large, magnitude 5.9 earthquake in the Netherlands was felt throughout SE England and slightly in Halifax and Liverpool.

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 the mining. On 8 August 1992, strongly felt vibrations said to have cracked windows and a balcony in London were traced to a rock concert by Madness in Finsbury Park.

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 bulletins are now issued 6 weeks in arrears with provisional details of all earthquakes located, and, after revision, they are compiled into an annual bulletin.

As part of the programme to establish a national database and archive of British earthquakes, improved accommodation has been found for the textual material and tape archives in Edinburgh, two external collections have been inspected and significant progress has been made with digitising and duplicating seismic events recorded on analogue magnetic tapes since 1970.

2. Introduction

The UK earthquake monitoring and information service has developed from 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 project 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 monitoring by BGS since 1969 and an outline of the background to the establishment of the project.

This Year 4 report to the Customer Group follows the format of the first three annual reports in reiterating the programme objectives and highlighting some of the significant seismic events in the period April 1992 to March 1993. The catalogue of earthquakes for the whole of 1992 is plotted to reflect the period for which revised data is available and to be consistent with the annual bulletin produced as a separate volume. No new seismic monitoring stations have been installed during the year towards the specific objective of establishing a uniform distribution with an average spacing of 70 km. However, site access has been negotiated for a number of new stations in central southern England with installation only held up whilst final agreement is obtained for the base station. Meanwhile, upgrades have been made to the remotely-accessible digital standard in Cumbria, Borders, Keyworth, Jersey and Kyle in addition to the ones previously installed in Cornwall, Hereford, North Wales and around Edinburgh. These have substantially improved the identification and rapid location of seismic events and Figure 6 shows their present combined detection capability.

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 site-specific networks which are vulnerable to closure by the bodies which have commissioned them.

3. Programme objectives

3.1 Long-term

The overall objectives of the service are:

(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 3) was agreed as a cost-effective way of achieving the main goals although it was recognised that some parameters (eg depths of focus and focal mechanisms) would not be well-determined.

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 3 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. Priority for new networks would be in the south east of England and around the north Irish Sea. Later, the Department of Environment purchased equipment for central southern England and this modified coverage by the background network is shown in Figure 4.

(iii) Upgrading of the analogue stations to digital recording and direct access to remote networks (from Edinburgh) using computer or telephone links would be reduced to an opportunistic, phased level as resources became available.

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

4. Development of the monitoring network

4.1 Station distribution

The network developed by December 1992 is shown in Figure 1 with its detection capability in Figure 5. The scheduled programme for 1992/93 had as its aims:

(i) Installation of a new seismograph network in central southern England to fill the most evident gap in the present coverage. This was to have remote access from Edinburgh.

(ii) Upgrading to digital, remote access standard, existing networks in the UK.

(iii) Installation of a borehole system to reduce background noise in the Keyworth network and, possibly, another in SE England.

(iv) Checking the geographic locations of most of the existing seismograph stations using new satellite-based positioning systems.

(v) Installation of 2 or 3 of the triggered strong motion recorders.

The installation of the new network in central southern England (i) has not yet been completed. Land access and negotiations have, however, been conducted at several sites and the installation awaits only the conclusion of an agreement with the preferred base station recording site at the Science Museum, Wroughton airfield. The network should be completed within 2-3 months of receiving that agreement. The programme of extending the remote access capability of the network (ii) has exceeded expectations, with a total of 76 of the 120 stations in the UK now being in that category, and provides considerably improved rapid access (Fig 6). In 1992/93, networks in western Scotland, around Keyworth and in Jersey have been upgraded and new BNFL-funded site-specific enhancements around Chapelcross and Sellafield also deliver 'rapid-access' data to Edinburgh which BNFL has released to the project. The proposed upgrade in SE England, however, has not yet been conducted. The introduction of borehole systems (iii) has not been accomplished but firm plans have been made for 2 such installations to take place in the near future on the Keyworth network. These will test the cost-effectiveness of the strategy to improve signal-to-noise ratios in areas of poor site geology. The programme of checking station locations using GPS (iv) has commenced with 11 sites completed. The proposed development of the strong motion network (v) has suffered set-backs owing to difficulties in modifying equipment for the purpose but, under contracts with the Jersey New Waterworks Company, BNFL and the MOD, new strong motion systems have been installed in Jersey, Chapelcross and Faslane. The prospect of another system at Torness, for Scottish Nuclear, has also increased. With regard to the continuation of site-specific monitoring projects on which the present network depends:

(i) Nuclear Electric have permitted the North Wales instrumentation to be left in place during the year, following its withdrawal of maintenance funds on 31 March 1992. This proved to be particularly valuable in monitoring the largest land-based earthquake of the year (3.5 ML) at Caernarvon on 29 July 1992. The network's long-term continuation, however, will depend on Nuclear Electric's future position and the additional funding for its operation.

(ii) The DTI/ETSU-sponsored monitoring in SW England for the HDR Geothermal project has continued with the contract due to run to March 1994. There is some prospect of that continuing at a reduced level for a further year.

(iii) BNFL have contracted for an intensive microseismic monitoring study in Cumbria and have extended the Chapelcross study to February 1994. These are being conducted through a local enhancement of the UK background network with more detailed interpretation of the results. All seismicity data is being made available to the UK monitoring programme on an open-file basis.

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

4.2 Progress with instrumentation

Further software improvements have been made to the SEISLOG rapid access, digital recording system; in particular, to permit searches to be made on the continuous ring buffer of information, which is the source of raw data presented to the event-triggering software. Recognised events are then stored on a separate file for automatic or manual transmission to the analysis computer in BGS Edinburgh whilst ring buffer data is progressively overwritten. The new capability permits interrogation of the data for reported felt events or those detected elsewhere which, owing to small signals at greater distances, have not been identified and saved by the triggering software. It provides, therefore, the benefits of a continuously recording system such as the Geostore analogue recorders but with rapid access and digital quality, provided intervention to the ring buffer is made in time. In order to extend that potential, larger (400 megabyte) disks have replaced the 40 Mb disks on earlier systems at 7 of the 9 sites equipped with SEISLOG. This gives a 24-hour window of continuous data together with extra storage for event files which would be needed during significant aftershock sequences such as that experienced following the Lleyn earthquake in 1984.

5. Seismic activity in Year 4

5.1 Earthquakes located for 1992

Details of all earthquakes and felt explosions and sonic booms detected by the network have been published in monthly bulletins and, with final revision, will be provided in the BGS bulletin for 1992 scheduled for publication in July 1993. A map of the 296 events located in 1992 is reproduced here as Figure 7 and a catalogue of those with magnitudes of 2.0 or greater is given in Annex B. Seven in that magnitude category are known to have been felt.

5.2 Significant events

Highlights of the seismic activity during the fourth year of the project (April 1992 to March 1993) are given below:

(i) In Wicklow, Eire, a magnitude 1.4 ML earthquake occurred on 28 April 1992 and was felt by local residents. Even small magnitude events such as this are rare in Ireland in contrast to Great Britain where they are common.

(ii) In Hereford, 6 km NW of Ross-on-Wye, a magnitude 2.2 ML earthquake occurred on 8 July 1992. Although events of this magnitude are often felt, no reports were received on this occasion; possibly because of its depth, some 18 km.

(iii) In Strathcarron, 20 km NE of Kyle of Lochalsh, a magnitude 2.8 ML earthquake occurred on 26 July 1992 (Fig 8). It was felt with intensities of at least 3 MSK (the meaning of 3+ in Annex B) and locates in an area where a number of earthquakes have occurred in the past 20 years; the largest in 1974 with magnitude 4.4 ML, some 20-30 km to the south east of this event.

(iv) In Caernarvon Bay, North Wales, the largest earthquake in the reporting period (excluding North Sea events) occurred on the 29 July 1992 with a magnitude of 3.5 ML (Fig 9). A macroseismic survey throughout the region showed that it was felt around Caernarvon with a maximum intensity of 5 MSK (just below the damaging level) and that the potential felt area was 10,000 km^2. It locates some 20 km NE of the magnitude 5.4 ML Lleyn earthquake (19 July 1984) at a shallower depth (11 km compared with 20 km). The focal mechanism shows reverse faulting with a small component of strike-slip and movement on a near-vertical plane striking NS or on a near-horizontal plane striking NE-SW. The mechanism agrees with the NW-SE maximum compressive stress direction generally observed for Britain.

(v) On the island of Jura, western isles of Scotland, a magnitude 2.7 ML earthquake was detected on 27 August 1992. Although this is a size which would normally be felt, it located in a remote part of western Jura and no felt reports were received. A number of events have been located in this general area over the past decade; the largest on 9 April 1985 with magnitude 2.4 ML.

(vi) In Balquhidder, 30 km NW of Stirling, an earthquake with magnitude 2.2 ML occurred on 30 December 1992. It was not felt, but located in the same general area as the felt event of 4 August 1991, magnitude 2.8 ML.

(vii) In North Wales, aftershocks have continued from the Lleyn Peninsula, magnitude 5.4 ML earthquake of July 1984. The largest in the year had a magnitude of 1.8 ML and no felt reports of it have been received.

(viii) In the North Sea, the largest offshore earthquake in the reporting period (with magnitude 4.7 ML) occurred on the 8 November 1992 in the north Viking Graben approximately 230 km NE of Shetland in the North Sea. A single felt report was received from the Mϕre region of western Norway but there were no other reports from North Sea platforms nor other land areas probably owing to the poor weather conditions at the time of the event. It is one of 15 events which have been located in the Viking/Central Graben area over the past year.

(ix) Two small aftershocks of the felt Johnstonebridge event of 27 February 1992 (magnitude 2.7 ML) occurred on 5 April and 3 May 1992. They were not felt due to their small size (0.1 and 0.2 ML).

(x) In south Wales, 1 km W of Bargoed a coalmining event with a magnitude of 2.2 ML was felt by local residents in Bargoed and some 3 km away in the village of Nelson. The felt reports ranged from overturning of perfume, sauce and milk bottles to cracked windows. This high intensity (5 MSK) can be attributed to the shallow depth of occurrence, 1.6 km.

(xi) Near Tiverton on the Devon/Somerset border on 23 September 1992, a magnitude 2.7 ML event represents the first natural seismicity to be detected in the area since instrumental monitoring started in 1981. Its fault plane solution shows reverse faulting with a component of strike-slip on planes striking NS or planes striking EW and is consistent with a NW-SE maximum compressive stress direction.

(xii) An event 9 km NW of Whitehaven occurred on 8 November 1992 with magnitude 2.0 ML. Its epicentre is close to the magnitude 5.0 ML event on 11 August 1786 (magnitude based on felt effects reported at the time).

(xiii) A small swarm of events 10 km south of the island of Arran, Scotland, with magnitudes ranging from 0.9 to 1.7 ML, occurred on 6 and 7 of January 1993. Two other events have been located in this area in the past three years and this event is some 30 km SW of the felt Brodick Bay earthquake of 1975, magnitude 2.5 ML.

(xiv) Some 20 coalfield events, with magnitudes ranging from 0.3 to 1.7 ML, were located in the Clackmannan area of Fife in Scotland; four of which were felt by local residents (Fig 10).

(xv) In other coalfield areas, small earthquakes were located at Pilsley, Derbyshire (1.6 ML, 10 April 1992), Rawtenstall, Lancashire (1.3 ML, 17 April 1992), Cromford, Derbyshire (1.3 ML, 27 April 1992), Cannoch, Shropshire (1.0 ML, 2 May 1992), Gamston, Nottinghamshire (2.0 ML, 19 May 1992), Llandrillo, Clwyd (1.4 ML, 16 June 1992), Aughton, Yorkshire (2.0 ML, 25 September 1992), Maltby, Yorkshire (1.8 ML, 20 November 1992) and Edwinstowe, South Wales (1.1 ML, 5 February 1993). These events are presumed to be related to present-day coalmining activity.

(xvi) Some 52 earthquakes have been located in the Constantine area of Cornwall during the year; the largest with a magnitude of 1.0 ML. This upsurge of activity following the felt events in 1986 and 1981 (largest magnitude 3.5 ML), suggest cyclical behaviour with a 5-6 year period.

(xvii) A number of reports have been received concerning local quarry blasts and underwater explosions. Specific examples are: a WWII German mine detonation off Bournemouth on 25 June 1992, magnitude 2.4 ML, and a similar one off Flamborough Head on 24 November 1992; near Beith in the Strathclyde region of Scotland, on 21 December 1992, where the blast from a local quarry was felt by residents in Beith some 3 km away. Another example includes a navy weapons shot trial near Portsmouth, on 18 January 1993, which caused concern among local residents who thought they had experienced an earthquake.

(xviii) Elsewhere in the country, many 'seismic' events have been reported to be felt or heard like small earthquakes but, on analysis, have been proved to be sonic booms. Specific examples are Scarborough (8 April 1992), Sunderland (27 May 1992), Hartlepool (28 May 1992), Milton Keynes (3 June 1992), Ponteland (10 June 1992), Orkney Islands (04 November 1992), Peterborough (12, 17, 19 and 24 November 1992), Newark-on-Trent (23 November 1992), Penzance, Cornwall (01 December 1992, Fig 11), Montrose (1 February 1993), Scarborough (5 February 1993), Dounreay (2, 11, 12 February 1993), Humberside (22 February 1993) and Anglesey (26 February 1993).

5.3 Rock concert event

BGS received several reports from residents of an earthquake in the Finsbury park area of NE London on 8 and 9 August 1992 at 20:30 UTC and 20:00 UTC, respectively. They were felt in Green Lane, Rowley Gardens and Anwell Court and reports included "cracked balcony" and "cracked windows". The local police evacuated 3 tower blocks and the Fire Department checked for damage before allowing re-entry. The times both corresponded to a Madness pop concert in Finsbury Park and it was concluded that this was the cause of the disturbances. No significant earthquakes were detected at these times on the national monitoring network although the nearest station was some 30 km away.

In Brussels during the 1980s, there were similar effects during the U2 concerts on two occasions; the first on 27 October 1984 and the second on 8 July 1987. Seismologists at the Royal Observatory obtained a seismic record and provided the following information about those comparable events:

(i) Vibrations were felt up to 500m away.

(ii) At 5 km a seismograph recorded a 10μm monotonic signal at a frequency of 2 Hz lasting about 4 minutes.

(iii) These vibrations were repeated at intervals of around 10 minutes.

(iv) The cause was attributed to infrasound (sub-audible vibration) generators which are used, together with the music and light, to provide the overall effect. Such low frequency waves will propagate effectively and are in the frequency band typical of local earthquakes.

5.4 Roermond earthquake

In the early hours of 13 April 1992 (at 01:20 UTC) a magnitude 5.9 ML earthquake occurred in the Netherlands near the town of Roermond close to both the German and Belgian borders. A seismogram of the event is shown in Figure 12. It was felt over 300 km away in SE England and BGS staff received enquiries from people affected in that area as well as from expatriots closer to the epicentre and from the Media in general. The rapid access seismograph networks operating through western Britain, at the time, enabled BGS staff to locate the event within a couple of hours and with a precision such that subsequent use of local data only moved the epicentre by 7km. A network of national seismological centres, established in recent years through an EC initiative, ensured that all relevant data was freely exchanged between the participants before breakfast-time.

In a detailed follow-up, all neighbouring countries have contributed to a macroseismic survey of the damage and felt effects. In the UK, BGS published its standard earthquake questionnaire in local SE England newspapers and in one national. A total of 158 replies were received (excluding those from people who felt the earthquake on the continent) of which 66 were positive responses, from 35 different towns, villages or suburbs. The maximum intensity was 4 MSK at one place only

(Folkestone, Kent). The intensity was generally 3 MSK in Kent and on the coast of Essex, which corresponds to the radius of perceptibility to be expected from an event of this size. The most distant places at which the earthquake was felt slightly were Halifax and Liverpool.

A comprehensive workshop was held on the earthquake in January 1993, the proceedings from which are expected to be published this year. A considerable amount of property damage was suffered in the epicentral region with estimates of losses in excess of 100 MECU. There were also a number of ground failures in the region including cracking, sand boils and landslides (Plate 1).

The earthquake occurred on the western margin of the Lower Rhine embayment in the Roer Valley graben of south eastern Netherlands which had a close geological relationship with the basins in the North Sea during Mesozoic times. More recently, its development is thought to be independent from the North Sea, being more closely associated with the Rhine graben.

The lessons learned from the Roermond earthquake in terms of damage potential, attenuation of seismic waves, ground effects and geological correlations are highly relevant to the United Kingdom. Such earthquakes are likely to occur within the country, the most recent of this magnitude being on the Dogger bank in 1931 which caused damage to property down the east coast of England despite its location 90 km offshore.

5.5 Global earthquakes

The monitoring network detects large earthquakes elsewhere in the world. Those which dominated the News included:

(i) Southern California on 28 June 1992 with magnitude 7.4 MS. This earthquake was felt over large areas of California, Arizona and Nevada. Damage occurred in the epicentral area and over 200 people were reported injured.

(ii) Nicaragua on 2 September 1992 with magnitude 7.2 MS. At least 105 people were killed, 63 reported missing and 16,000 made homeless. Most of the casualties and damage were caused by a tsunami affecting the west coasts of Nicaragua and Costa Rica.

(iii) Cairo on 12 October 1992 (Fig 13) with magnitude 5.7 MB. At least 540 people were killed, more than 6,500 injured and around 8,300 buildings were damaged or destroyed. It was felt throughout Egypt from Alexandria to Aswan and in Israel from Elat to Jerusalem and Tel Aviv. Initial estimates of damage indicate costs of around 30 million US dollars. This earthquake was probably smaller than that which occurred on the Dogger Bank in 1931, 90 km off the east coast of England.

(iv) Flores, Indonesia, on 12 December 1992, 7.5 MS. At least 2,200 people were killed or missing in the Flores region, over 500 were injured and 40,000 left homeless. Most of the buildings at Maumere on the island of Flores were destroyed by the earthquake and severe damage and landslides occurred at many locations on the island. The earthquake was felt throughout the Sunda Islands, on Sumba and Timor and in southern parts of Sulawesi.

6. Archives

6.1 Identification and cataloguing

The programme to catalogue all existing textual material held by BGS is largely complete although the final steps, including the issue of a report, have been disrupted owing to the resignation of a member of staff. Curation of some of the more fragile collections has also been held up.

There has been no change in the status of collections held by BGS and detailed in the Year 3 report to the Customer Group. Two external archives have been inspected during the year:

DTI library: The archive entitled "Scandinavian earthquake archive" which was produced by Principia Mechanica (PML) in the early 1980s has been examined at the DTI library in Palace Street, London. It covers earthquakes in Norway, Sweden, Denmark, and the North Sea and was compiled and used in the production of a PML North Sea seismicity report to Department of Energy, published in 1986 as part of the Department's Offshore Technology Series. The bulk of the archive comprises secondary source material.

Strasbourg EMSC: At the request of the European-Mediterranean Seismological Centre in Strasbourg, R Musson has examined its European-wide archives which are held there. A report has been prepared on the inspection together with recommendations for future storage and curation requirements.

6.2 Storage and Inspection facilities

New and improved accommodation in Murchison House (BGS Edinburgh) has been assigned for the textual collections including an inspection area and offices for staff. The most recent (2-3 years) of analogue magnetic tapes are also held within Murchison House and the remainder (since 1970) are in external storage. By mid-1993, they will be moved to a new, more secure, external store which will be manned.

6.3 Digital records

With the progressive upgrading of the UK monitoring network, seismic records are increasingly being acquired directly in digital form. Where data is extracted from the analogue tapes, it is now being routinely digitised before analysis and interpretation. For the older records (since 1970), which are held on deteriorating analogue magnetic tapes, a programme of digitising has been in progress for over one year. It is proving to be a greater task than first envisaged and progress to-date is summarised below:

1970-mid 1975: Data is largely on old-style 1" tapes gathered on the Lowlands network (LOWNET) around Edinburgh. These tapes are difficult to handle and no attempt has yet been made under this project although individual events have been recovered for specific earthquake revisions conducted for Nuclear Electric and BNFL.

1975-1992: All events recorded on the Lowlands network have been digitised for this period.

1975-1992: Events recorded on other networks have been digitised except for the period 1980-1984.

1980-1991: For events with magntitudes above 2.5 the digitising is complete except where there have been difficulties with poor tapes and timing signals.

The completion of the digitising project is likely to take another year and there may be residual problems with some events on early, deteriorated tapes and on a batch which proved to suffer from faults in the manufacturing process.

A duplicate copy of all digitised records is being held on optical disk outside Murchison House.

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 one or two individuals. In the case of series of events in coalfield areas, only the more significant ones are reported in this way. Some 50 alerts have been issued to the Customer Group during the year.

The bulletin board, on a captive process on the VAX computer in Murchison House, has continued to be maintained on a routine basis for British 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.

Networks in the Scottish Lowlands, North Wales, Hereford, Cornwall, Keyworth, Borders, Cumbria, Kyle and Jersey can now be remotely accessed from Edinburgh and, in particular, from the homes of the principal seismologists. They have further improved the immediate response capability for UK seismic events (Fig 1) so that almost all of the UK can now be covered in this way for earthquakes with magnitudes of 2.5 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 normally within 6 weeks of the end of a 1 month reporting period. This represents an improvement of about 2 weeks over previous years and is considered to be the optimum for the present technology and resources available.

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. Owing to problems with computing and staff resources, this has not yet been achieved but in 1992 revised proof copies were ready in June. Delays in printing, however, resulted in a release date of December 1992. In 1993, a way of reducing such delays will be sought.

8. Programme for 1993/94

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. Further progress will be made in the provision of a 'user-friendly' database and archive of UK seismicity and in extending the background, 70 km-spacing, seismograph coverage of the country. Specific advances anticipated for 1993/94 are:

(i) Completion of the new seismograph network in central southern England to fill the most evident gap in the present coverage. This will have remote access from Edinburgh.

(ii) Upgrading to digital, remote access standard, most of the existing networks in the UK.

(iii) Installation of a borehole system to reduce background noise in the Keyworth network and, possibly, in SE England.

(iv) Completing the check on geographic locations of the existing seismograph stations using new satellite-based positioning systems.

(v) Installation of additional triggered strong motion recorders as opportunities arise.

(vi) Completion of the digitising of the final few percent of seismic events collected on analogue magnetic tape over the past 20 years except, possibly, those for which there are technical problems with the tapes.

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

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).

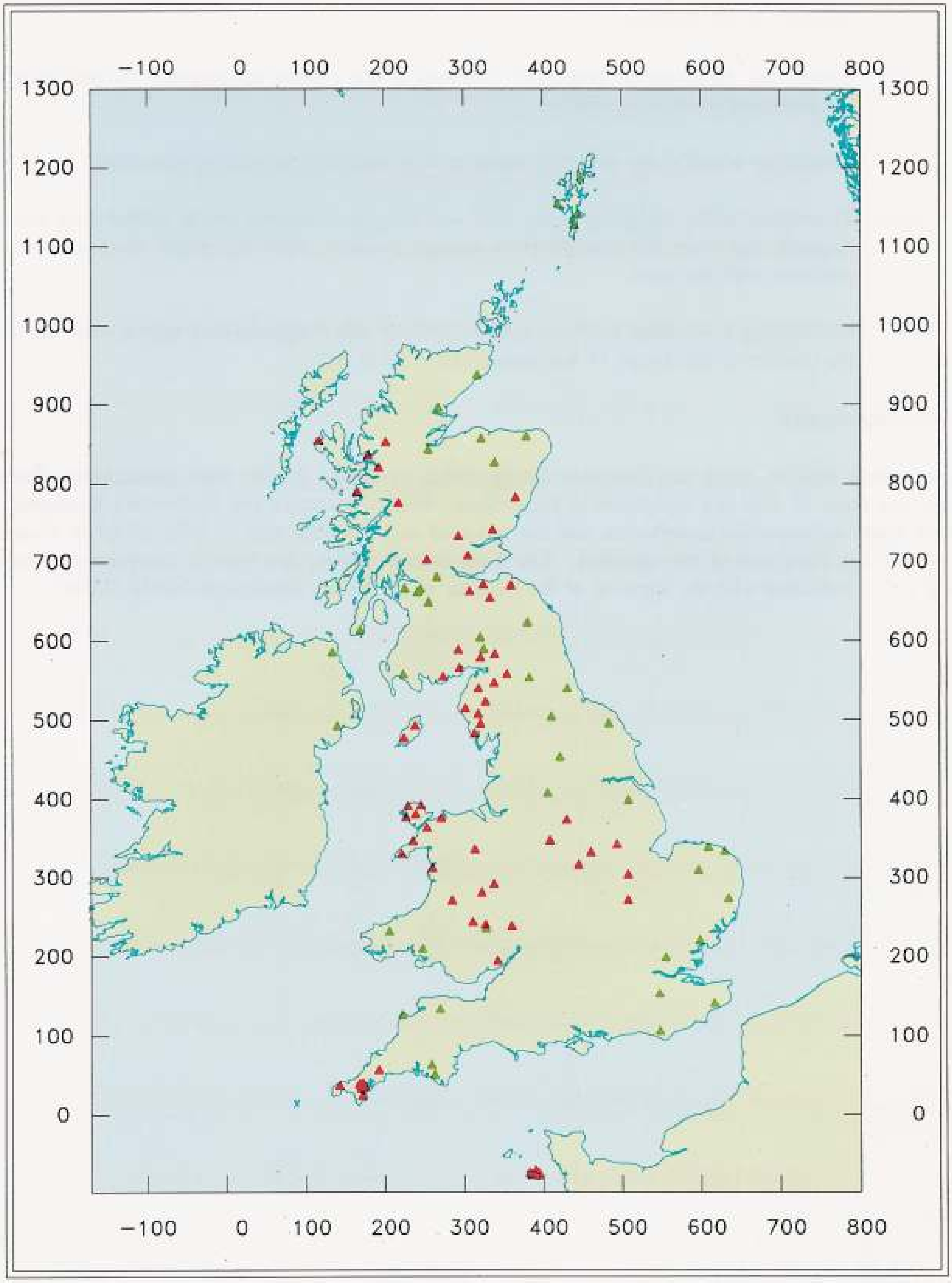


Figure 1. The BGS seismograph network operational in December 1992. Colour coding shows the standard stations (green) and those upgraded to rapid access by March 1993 (red).

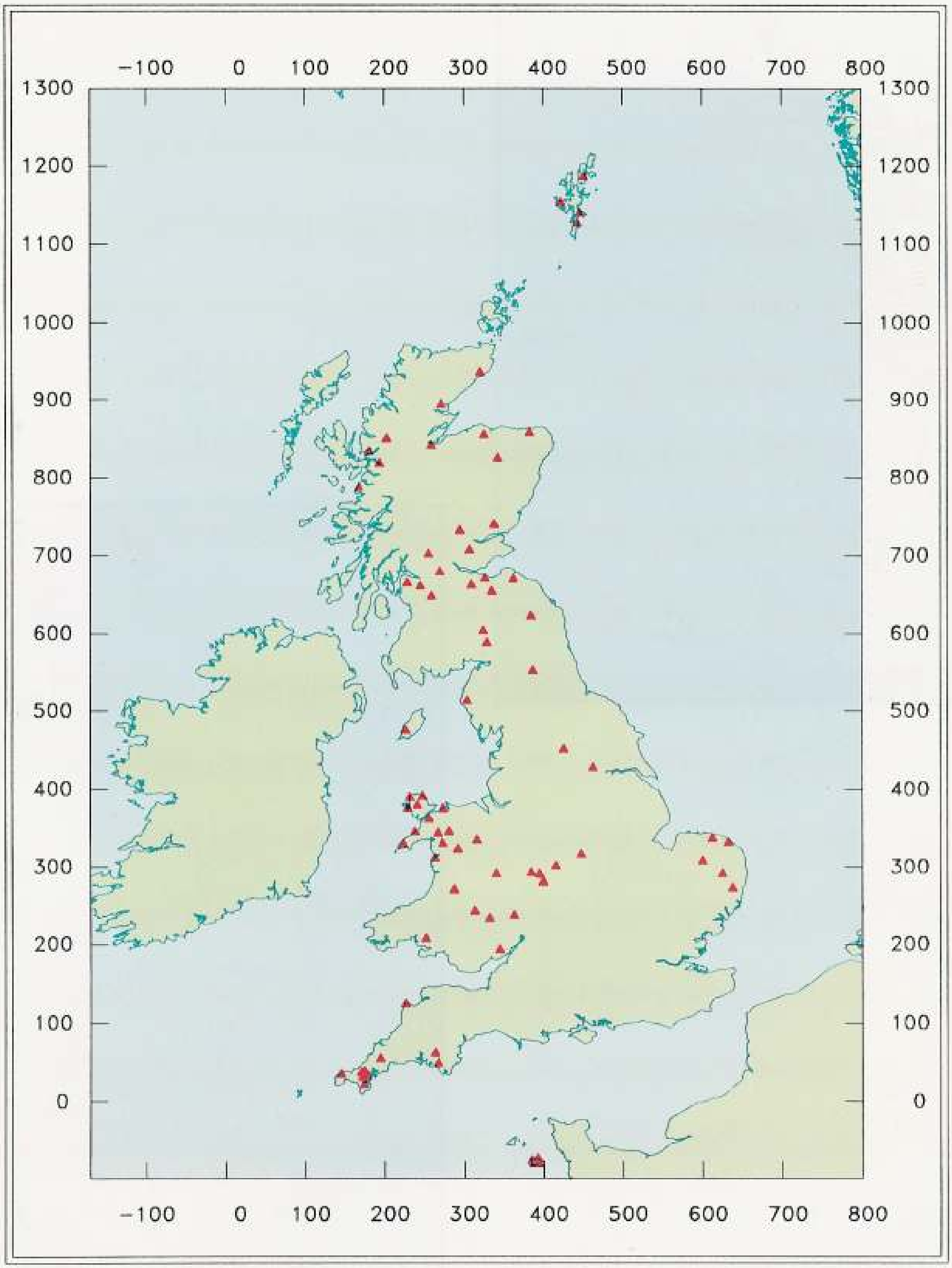
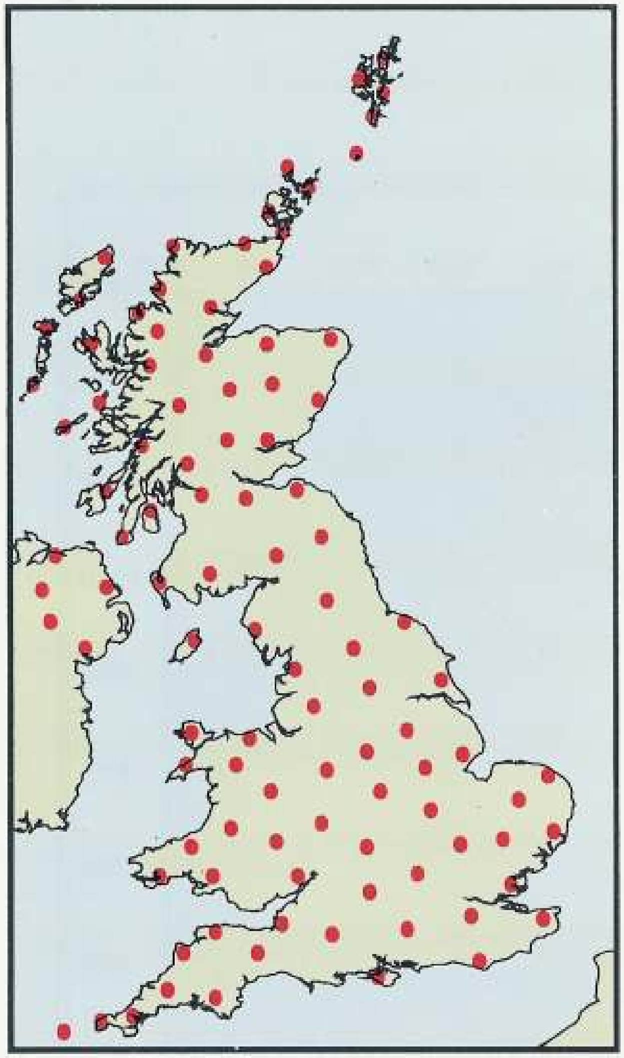


Figure 2. The BGS seismograph network in 1988 prior to the commencement of the UK monitoring enhancement project.



◄ Figure 3.

Proposed long-term UK background seismic monitoring network with an average station spacing of 70 km.

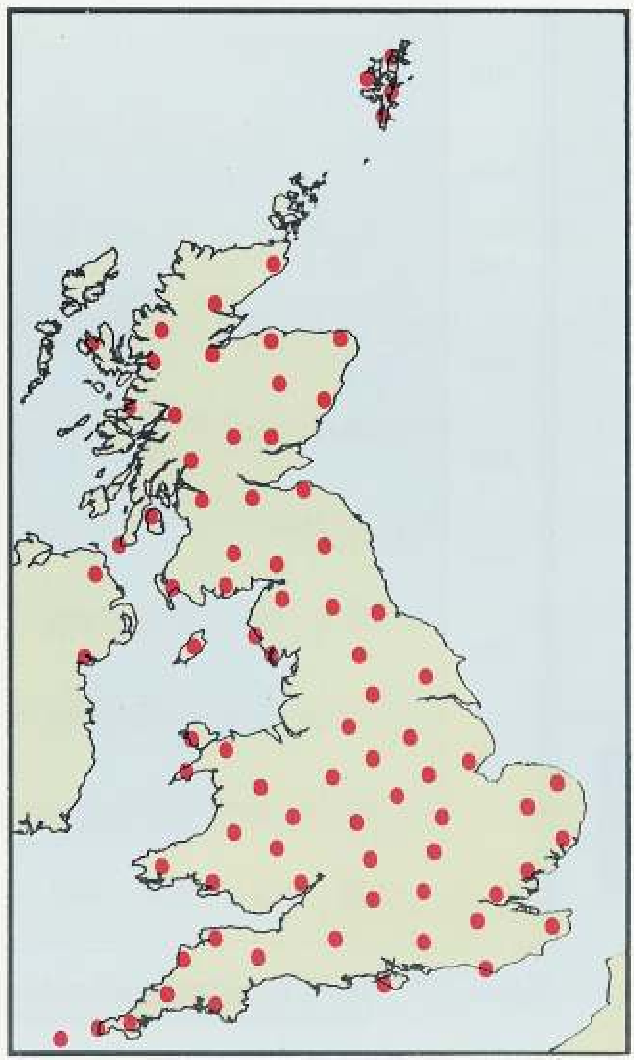


Figure 4. ►

Proposed UK seismograph network coverage for 1993 at background station spacing after discounting site-specific dense networks.

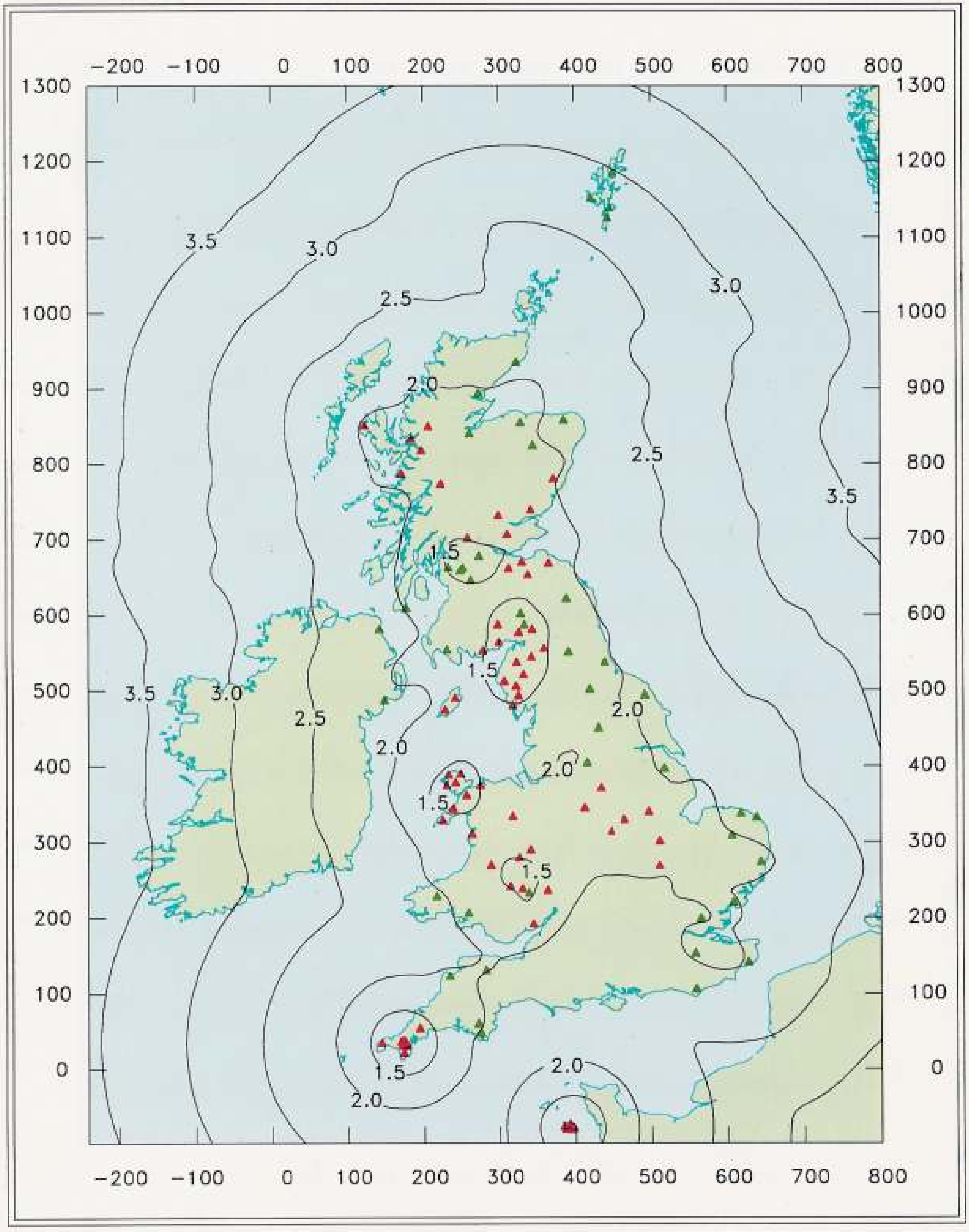


Figure 5. Earthquake identification capability. Contour values are Richter local magnitude (ML) for 20 nanometres of noise and S-wave amplitudes twice that at the fifth nearest station.

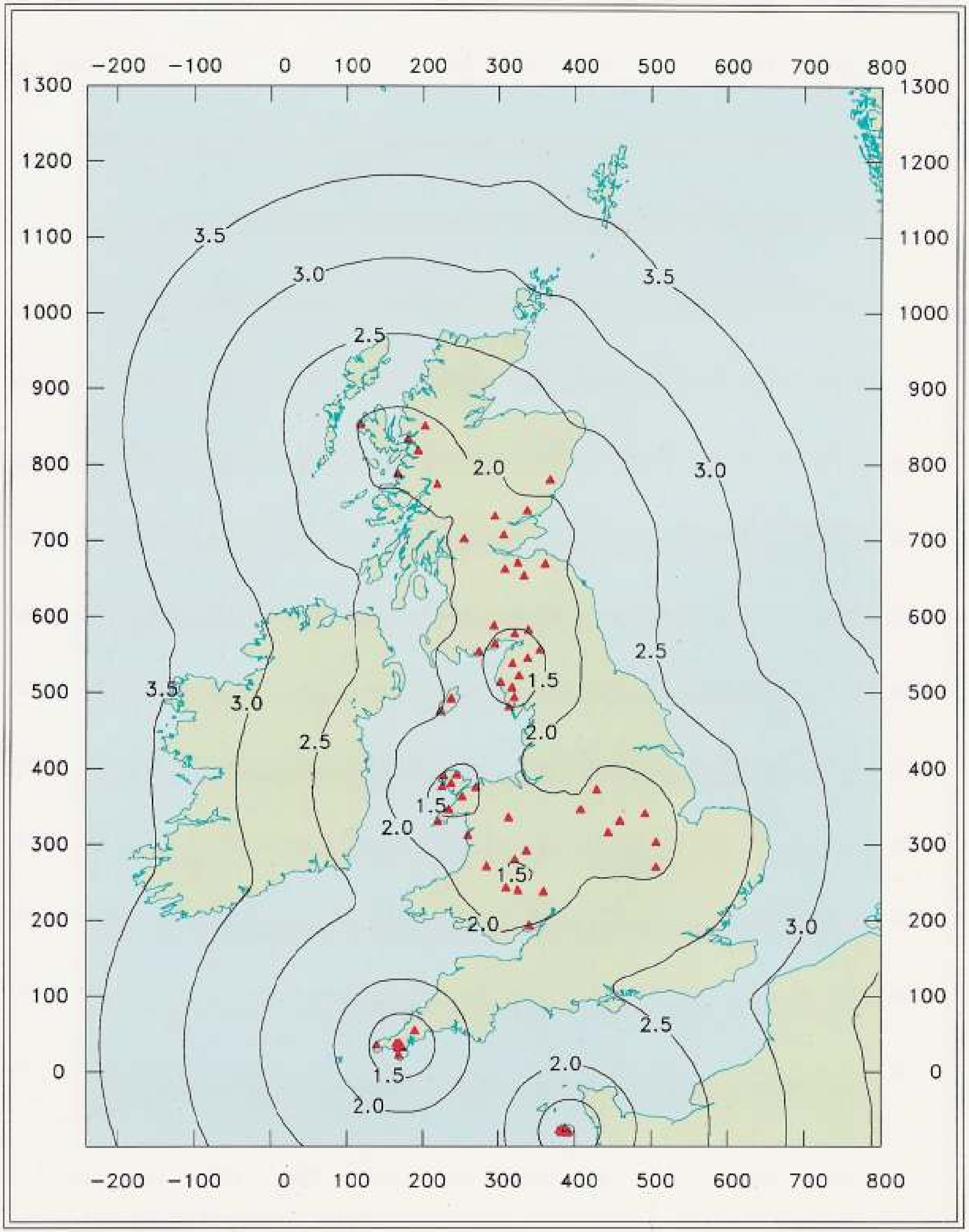


Figure 6. Detection capability of the rapid access networks. Contours show the magnitude (ML) of an earthquake which would be detected by 5 stations in the presence of 20 nanometres of background noise at 10 Hz.

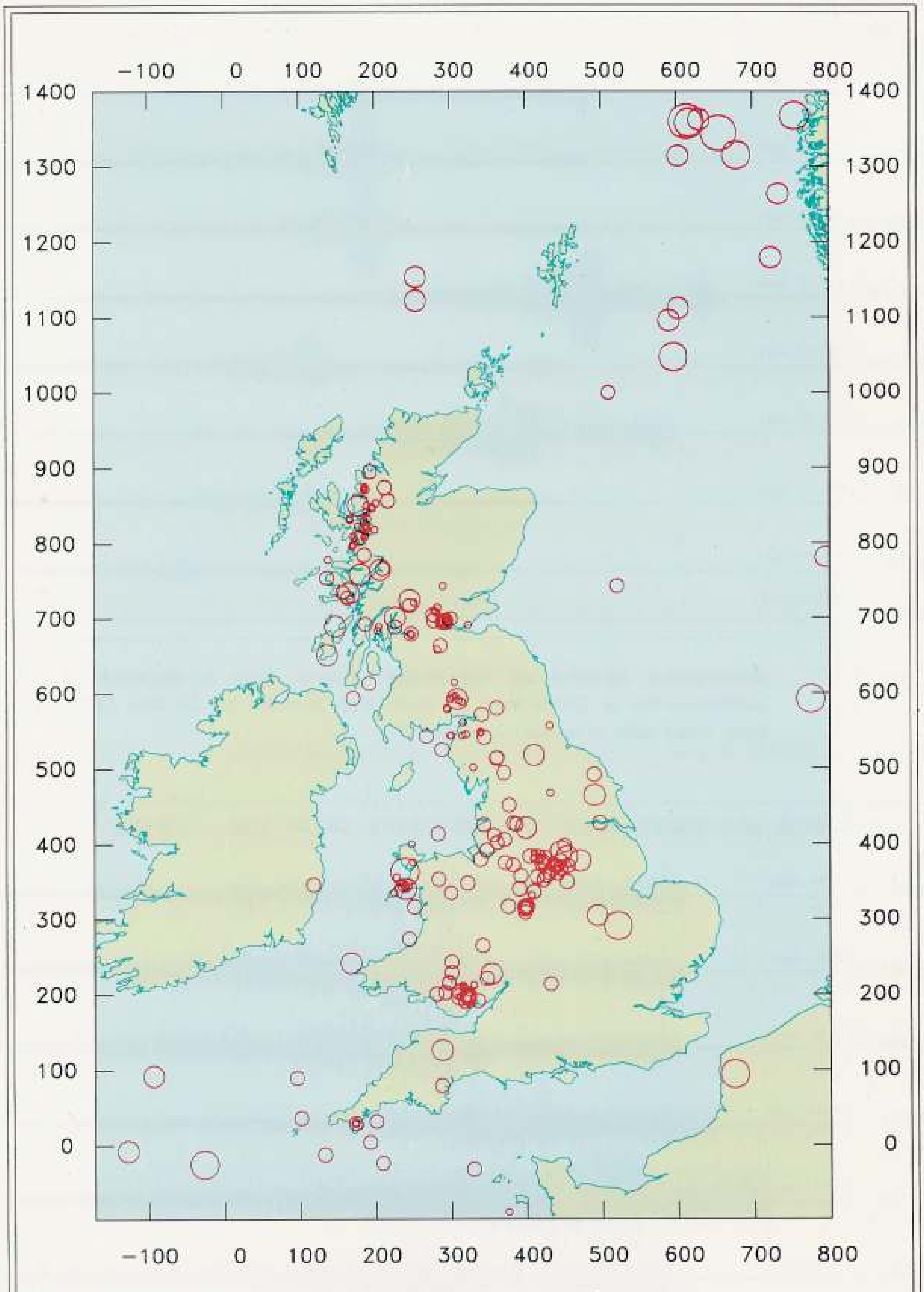


Figure 7. Epicentres of all UK earthquakes located in 1992

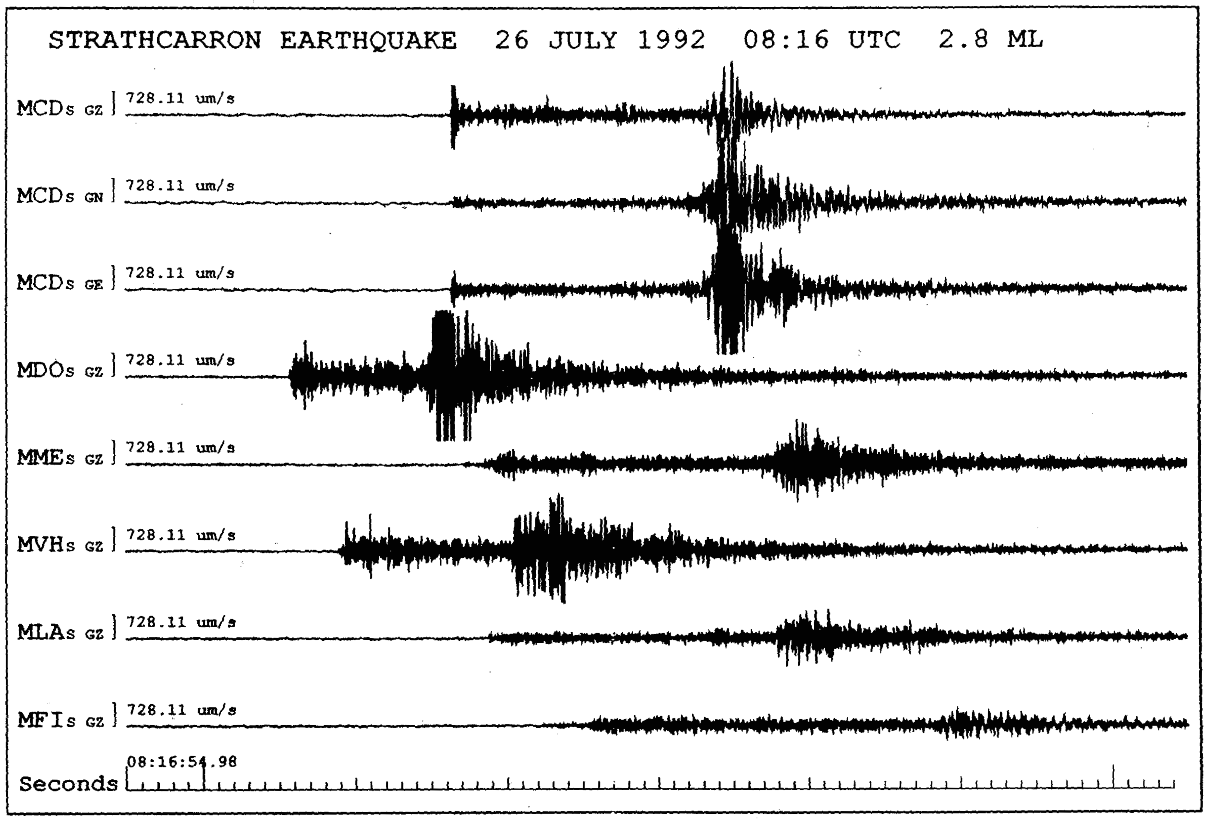


Figure 8. Seismograms recorded on the Moray network from a magnitude 2.8 ML earthquake felt at Strathcarron in north west Scotland on 26 July 1992. Three letter codes refer to stations in Annex E.

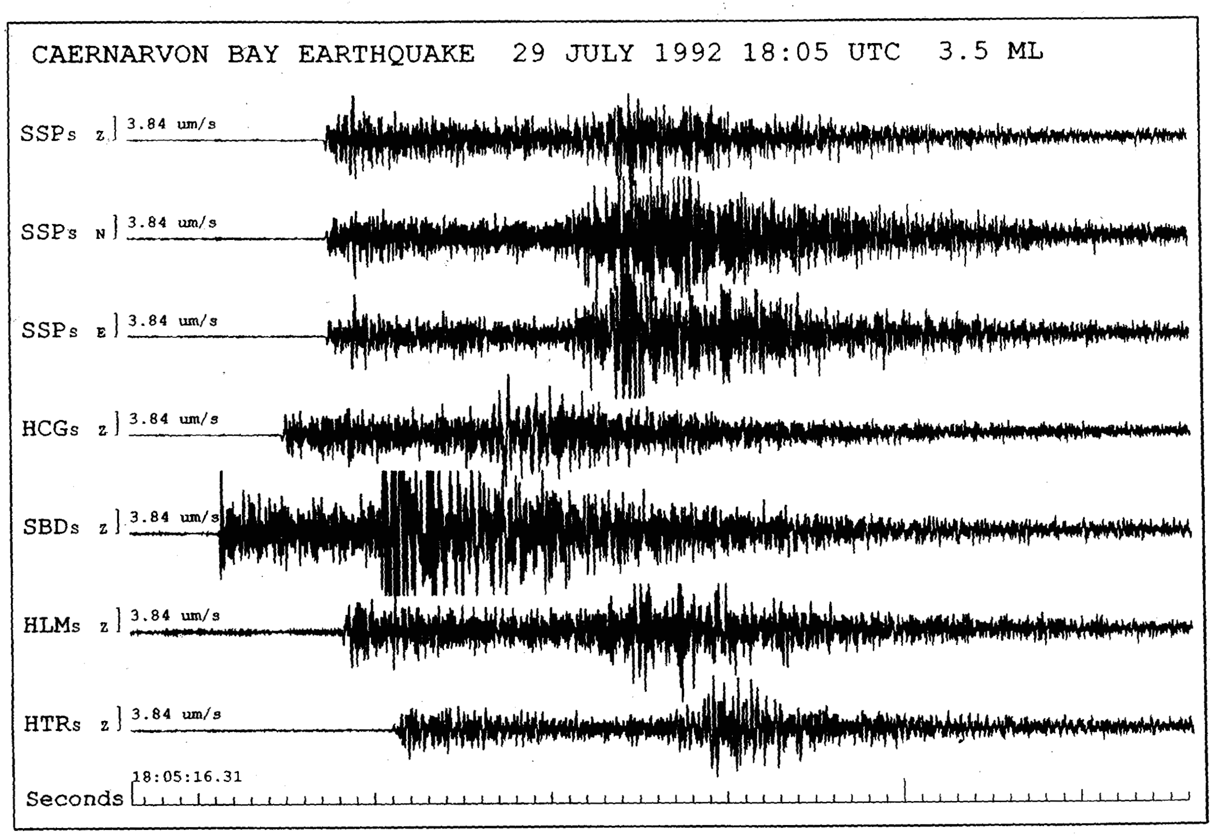


Figure 9. Seismograms recorded on the Hereford network from a magnitude 3.5 ML earthquake felt in the Caernarvon Bay region on 29 July 1992. Three letter codes refer to stations in Annex E.

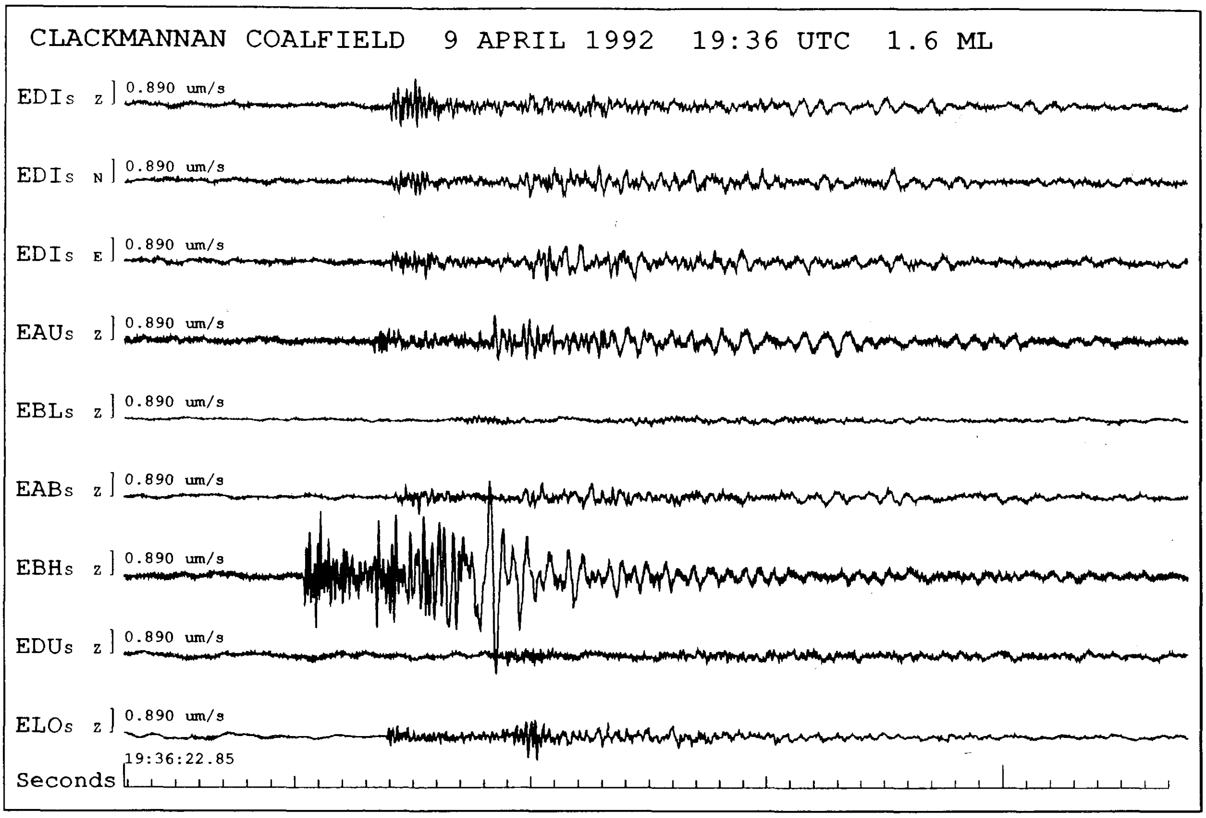


Figure 10. Seismograms recorded on the Lowlands network around Edinburgh from a magnitude 1.6 ML coalfield event near Clackmannan, Central Region, on 9 April 1992. Three letter codes refer to stations in Annex E.

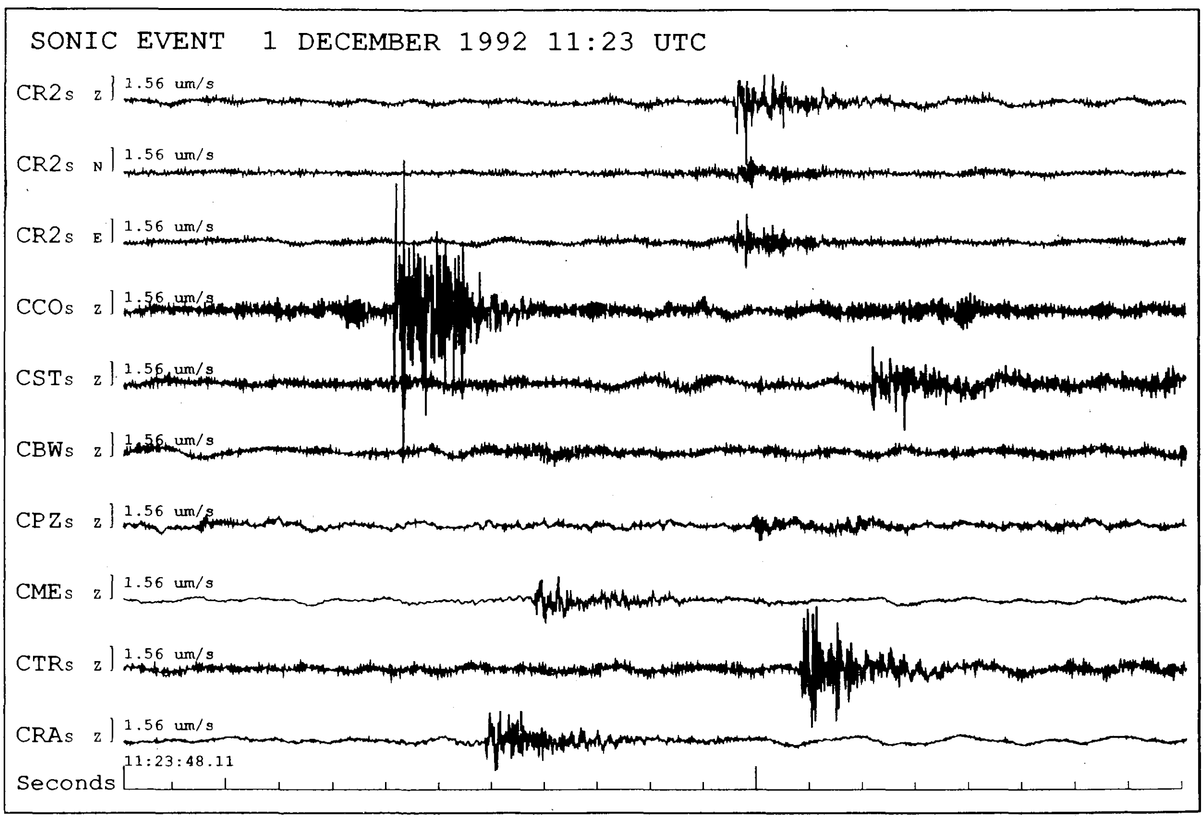


Figure 11. Seismograms recorded on the Cornwall network from a felt sonic event on 1 December 1992. Three letter codes refer to stations in Annex E.

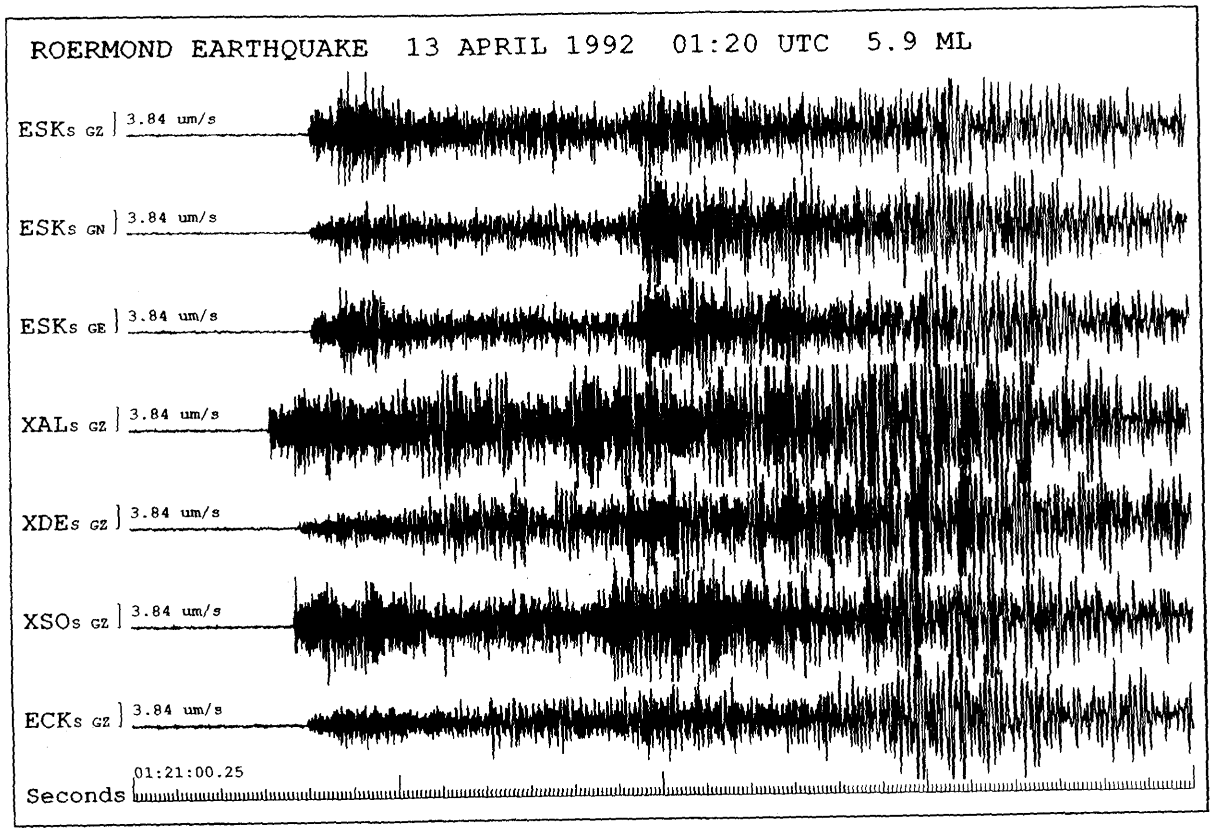


Figure 12. Seismograms recorded on the Eskdalemuir network from the magnitude 5.9 ML earthquake in Roermond on 13 April 1992. Three letter codes refer to stations in Annex E.

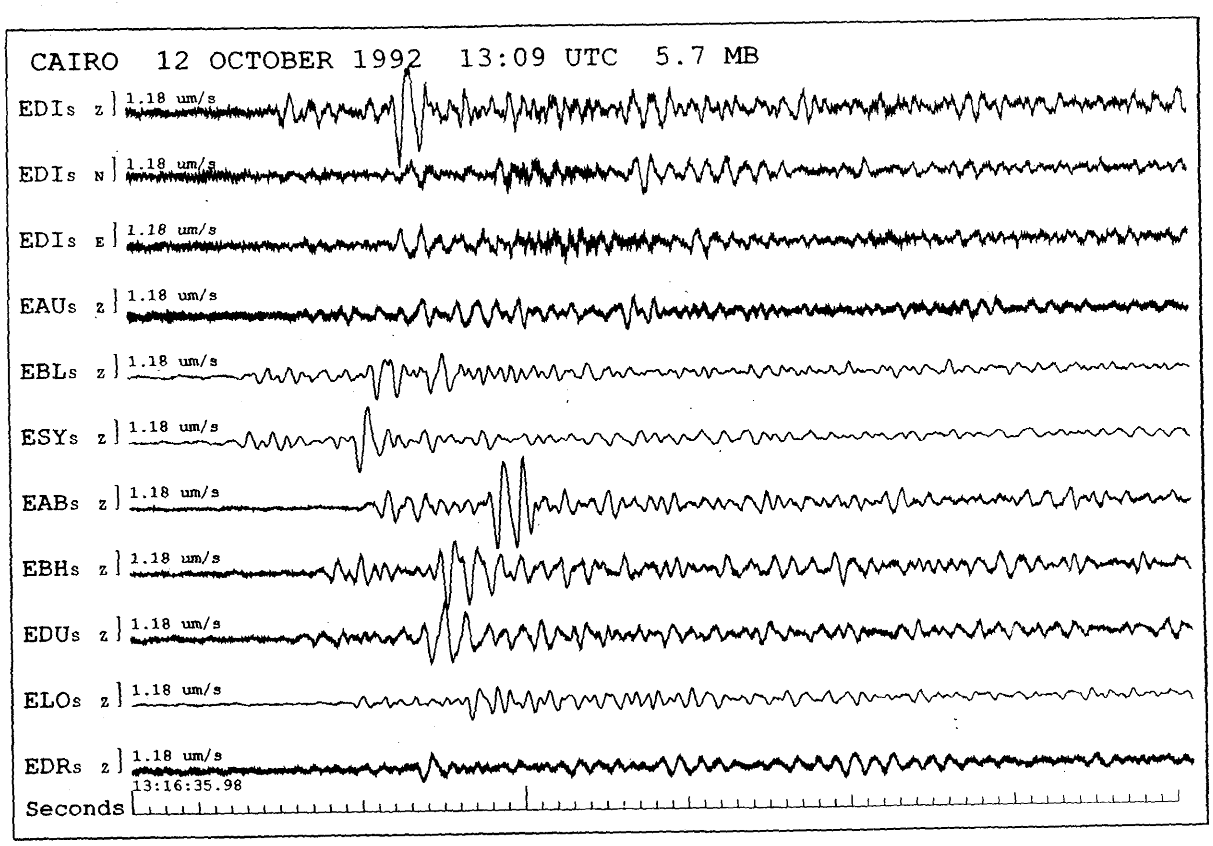


Figure 13. Seismograms recorded on the Lowlands network around Edinburgh from the magnitude 5.7 MB earthquake in Cairo on 12 October 1992. Three letter codes refer to stations in Annex E.

Plate 1. Damage in the epicentral region of the 13 April 1992, magnitude 5.9 ML Roermond earthquake, Netherlands. Top: church bells at Herkenbosch open to the sky following the removal of the damaged spire. Bottom: landslip in Miocene sands near Brunssum.

CONTRIBUTORS TO THE PROJECT

Department of the Environment
British Nuclear Fuels plc
Department of Economic Development (N Ireland)
Nuclear Installations Inspectorate
Scottish Hydro-Electric plc
Scottish Nuclear Ltd
Renfrew District Council
Welsh Office
Natural Environment Research Council

Ministry of Defence	Data
Department of Trade and Industry	Data
Nirex	Data

Customer Group Members (not contributing in Year Four)

British Gas
Health and Safety Executive
British Coal
International Seismological Centre
Nuclear Electric plc
AEA Technology
Scottish Office Environment Department

EARTHQUAKES WITH MAGNITUDES ≥ 2.0 RECORDED IN THE UK AND OFFSHORE WATERS: 1992

YearMoDy	HrMnSecs	Lat	Lon	kmE	kmN	Dep	Mag	Locality	Int	No	DM	Gap	RMS	ERH	ERZ	SQD	Comments
19920102	213948.7	59.69	1.42	592.5	1094.0	15.0	2.4	NORTHERN NORTH SEA		61	53	217	0.07	4.8	5.0	C*D	
19920105	054028.2	60.35	3.94	727.3	1177.2	3.5	2.6	NORTHERN NORTH SEA		7	91	209	0.37	10.4	3.9	D*D	
19920110	215902.3	61.60	3.32	682.1	1313.3	12.9	3.4	NORTHERN NORTH SEA		20	98	231	0.40	2.9	2.3	C*D	
19920127	024349.7	50.66	1.88	674.1	91.9	7.3	3.0	BOULOGNE, FRANCE		26	72	116	0.26	1.0	4.1	B*D	
19920127	221605.6	61.64	1.88	605.7	1312.5	0.6	2.6	NORTHERN NORTH SEA		12	167	238	0.93	5.5	5.8	D*D	
19920217	012233.1	52.49	-0.21	521.7	289.2	11.4	3.4	PETERBOROUGH, CAM'SHR	5	21	19	116	0.17	0.6	0.9	B*B	FELT PETERBOROUGH...
19920227	025024.9	55.21	-3.41	310.5	591.7	5.9	2.7	JOHNSTONEBRIDGE,D&G	3+	43	16	54	0.26	0.4	3.1	B*C	FELT NEWTON...
19920228	005027.4	53.33	-1.18	454.7	381.4	11.6	2.0	NR WORKSOP, NOTTS		14	25	98	0.15	0.6	4.2	B*C	
19920302	163427.5	54.54	-1.82	411.6	516.2	15.4	2.3	BARNARD CASTLE,CO DURH		40	14	62	0.29	0.6	1.0	B*A	
19920408	154939.0	52.93	-4.36	241.3	339.4	15.7	2.0	NE PWLLHELI,GWYNEDD		17	7	95	0.08	0.3	0.8	A*B	
19920410	152637.6	62.06	2.48	634.0	1360.8	15.0	2.6	NORTHERN NORTH SEA		14	131	236	0.30	4.3	4.5	C*D	
19920413	012002.8	51.17	5.95	955.4	171.5	13.5	5.9	ROERMOND, NETHERLANDS		42	34	72	0.41	1.2	1.7	C*C	
19920423	131044.8	52.02	-5.38	168.2	241.3	5.0	2.1	ST GEORGE'S CHANNEL		20	43	154	0.23	0.8	1.9	B*C	
19920515	171324.4	56.67	-5.55	182.6	758.3	1.0	2.0	KINGAIRLOCH,STRATHCLYD		7	104	339	0.13	15.4	12.2	D*D	
19920518	052837.6	57.08	6.39	907.9	829.6	10.0	3.4	NORTHERN NORTH SEA		32	539	281	0.46	9.6	12.3	D*D	
19920519	021253.9	53.28	-0.92	471.7	376.2	0.5	2.0	GAMSTON,NOTTINGHAM'IRE		32	40	84	0.49	0.9	1.4	C*C	COALFIELD TYPE
19920522	084019.0	61.09	4.26	737.1	1261.8	19.3	2.9	NORTHERN NORTH SEA		18	27	126	0.19	0.8	1.0	B*B	
19920605	114848.5	59.83	1.66	605.3	1110.1	7.3	2.0	NORTHERN NORTH SEA		14	162	169	0.34	1.9	3.2	C*D	
19920611	050914.8	50.53	-8.91	-89.6	93.4	10.9	2.9	CELTIC SEA		22	241	278	0.31	7.0	8.3	D*D	SOUTH OF IRELAND
19920616	032621.1	55.68	-6.15	139.0	650.7	3.7	2.1	ISLAY, STRATHCLYDE		14	51	245	0.33	3.3	7.8	C*D	
19920628	122331.4	62.00	4.85	758.4	1365.6	15.0	3.2	NORWEIGIAN COAST		22	27	260	0.68	4.4	2.5	D*D	
19920629	030511.8	49.84	-8.02	-33.0	11.2	1.7	3.2	SW SCILLY ISLES		9	178	355	0.07	8.1	1.2	D*D	
19920708	085958.8	51.93	-2.67	354.0	226.5	18.4	2.2	ROSS-ON-WYE,HER & WOR		38	14	132	0.20	0.5	0.7	B*B	
19920726	081652.7	57.49	-5.66	180.6	849.8	15.1	2.8	STRATHCARRON,HIGHLAND	3+	19	16	227	0.24	1.7	1.0	B*D	FELT STRATHCARRON...
19920729	180514.1	53.13	-4.39	239.9	362.0	11.0	3.5	CAERNARVON BAY, WALES	5	22	15	72	0.06	0.2	0.4	A*B	FELT CAERNARVON,BANGOR...
19920806	073242.0	59.88	6.03	849.0	1137.4	6.4	3.7	NORWEGIAN COAST		19	33	128	0.43	2.2	2.9	C*C	
19920806	185010.7	59.95	-4.55	257.6	1121.3	15.0	2.1	NW OF ORKNEY ISLANDS		5	185	343	0.16			D*D	UNCERTAIN LOCATION
19920817	005335.3	51.68	-3.26	313.2	198.8	1.6	2.2	BARGOED,MID GLAMORGAN	2+	33	24	49	0.19	0.4	1.0	B*C	
19920827	155200.3	56.03	-6.02	149.7	689.1	11.1	2.7	JURA,STRATHCLYDE		36	81	247	0.25	1.0	0.9	B*D	OFFSHORE LOCATION
19920828	183751.3	60.07	6.16	853.2	1159.4	1.0	2.9	NORWEGIAN COAST		4	404	353	0.08			A*D	
19920831	182553.6	55.06	3.89	776.2	590.2	19.1	3.7	CENTRAL NORTH SEA		29	296	213	0.38	2.0	3.2	C*D	
19920902	192701.2	54.05	-0.61	491.2	463.0	10.1	2.1	SLEDMERE,YORKS		19	31	172	0.40	1.6	3.5	C*C	
19920913	063841.1	52.62	-0.61	494.2	303.1	3.5	2.2	KETTON,LEICS		10	15	154	0.18	2.3	5.0	C*C	
19920917	001634.3	56.73	4.49	796.4	779.0	5.0	2.9	NORTH SEA		11	441	336	0.25			D*D	
19920923	104757.9	51.01	-3.60	287.9	125.2	10.4	2.7	TIVERTON,DEVON		40	15	85	0.35	0.8	1.4	C*B	10KM NW TIVERTON.
19920925	052609.4	53.39	-1.30	446.4	388.2	0.2	2.0	AUGHTON,YORKS		8	21	293	0.27	4.9	3.2	C*D	COALFIELD TYPE
19920926	003545.8	60.24	-4.57	257.7	1153.0	11.5	2.2	WEST OF SHETLAND		7	187	276	1.05	18.2	18.7	D*D	
19921017	021939.0	62.04	2.15	617.1	1358.5	18.4	4.1	NORTHERN NORTH SEA		46	177	248	0.73	6.8	7.7	D*D	
19921025	094206.7	56.73	-5.12	209.1	764.3	6.4	2.2	LOCH LEVEN,HIGHLAND	2+	45	14	129	0.32	0.6	1.1	C*C	FELT AT ONICH
19921025	221625.7	65.22	0.76	529.0	1708.0	20.0	3.9	NORTH NORWEGIAN SEA		11	445	299	0.26			D*D	
19921030	051044.9	56.17	-4.76	228.9	700.4	6.4	2.2	ARROCHAR,STRATHCLYDE		21	26	143	0.15	0.4	1.0	B*C	
19921030	173414.1	49.61	-9.29	-126.4	-7.0	13.3	2.6	SW SCILLY ISLES,CORN		13	273	355	0.30		14.9	D*D	220 KM SW SCILLY ISLES.
19921104	042002.0	62.03	2.21	620.2	1356.9	13.7	3.2	NORTHERN NORTH SEA		21	174	247	0.36	4.7	5.4	C*D	
19921108	173952.3	54.60	-3.70	289.9	523.9	8.9	2.0	WHITEHAVEN,CUMBRIA		47	17	59	0.22	0.4	0.7	B*B	OFFSHORE LOCATION
19921108	191234.6	61.88	2.94	659.4	1342.8	31.4	4.7	NORTHERN NORTH SEA	2+	25	116	197	0.32	1.9		C*D	FELT MORE REGION, NORWAY
19921123	053015.2	56.43	-5.76	167.9	732.8	8.2	2.1	MULL,STRATHCLYDE		23	54	167	0.32	1.1	2.4	C*D	
19921127	201849.4	53.68	-1.99	400.4	420.2	9.4	2.0	RIPPONDEN,W YORKSHIRE		12	17	140	0.25	3.2	6.2	C*C	
19921226	052309.4	59.25	1.48	598.4	1045.5	11.7	3.9	NORTHERN NORTH SEA		48	159	116	0.59	1.5	2.7	D*D	
19921230	154924.9	56.38	-4.46	248.1	723.3	2.2	2.2	BALQUHIDDER,CENTRAL		32	22	109	0.29	0.7	1.0	B*C	

FAX

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H TUR	BNFL	P FORD	UKAEA
C WILSON	DED	M J ALLEN	BRITISH COAL
P MACDONALD	ETSU	P J BUCKLEY	H&S EXEC
D J MALLARD	NUCLEAR ELEC	A W B JACOB	DIAS
C F ALLEN	NUCLEAR ELEC	H PAYNE	WELSH OFFICE
W P ASPINALL	AA	DIRECTOR	BGS
C BEAK	HYDROBOARD	M RAINES	BGS, KEYWORTH
R J STUBBS	NII, LONDON	A WHITTAKER	BGS, KEYWORTH
C PATCHETT	NII, BOOTLE	B TAYLOR	BGS, INFO SERVICES
J E INKESTER	NII, BOOTLE	S BRACKELL	BGS, LONDON INFO OFFICE
A ACTON	BRITISH GAS	B STEPHENSON	BGS, MARKETING
C BUMPUS	NIREX	J BALDWIN	NERC, PR
G HERBERT	SCOT H & H		

FROM: C W BROWITT/A B WALKER
DATE: 30 JULY 1992
TIME: 15.15
PAGES TO FOLLOW: ONE

SEISMIC ALERT: EARTHQUAKE NEAR CAERNARFON, NORTH WALES, 29 JULY 1992 18:05 UTC FOLLOW-UP

Further to our tax of 2200 BST on 29 July the following updates our location parameters and general information using data from the UK and Ireland:

Date:	29 July 1992
Origin Time:	18.05 14.15s UTC
Grid Reference:	239.7 KME 361.9 KMN
Depth:	9.5 km
Magnitude:	3.4 ML
Solution Quality:	Good (B*B)
Locality:	8 km W of Caernarfon, close to Llanddwyn Island lighthouse

There are few details of felt effects so far but strong shaking (intensity 4) has been reported from Bangor some 21 km to the NE of the epicentre with other reports from Llanfaelog (W Anglesey), 12 km to the NW, and from Caernarfon and Snowdonia to the East. A macroseismic survey has been initiated.

This event had almost 1000 times less energy than that of the magnitude 5.4 Lleyn earthquake of 19 July 1984, centred some 18 km to the south, and was smaller than 3 of its many aftershocks. It compares with the Peterborough earthquake of 17 February this year (ML = 3.4) which was felt up to 50 km away. The most recent felt British earthquake prior to 29 July occurred near Strathcarron/Applecross W Scotland on 26 July with a magnitude of 2.6 ML and a felt radius of about 13 km.

The history of earthquakes in the Caernarfon region is known back to 1773 when an earthquake of similar magntitude occurred. Since then, of the many earthquakes felt in the area, those in 1852 and 1903 (magnitude 5.3 and 4.9, respectively) were the most significant after the 1984 Lleyn event. It is not possible to say whether the earlier two were associated with the Lleyn or this new Caernarfon epicentre, or some other. Their epicentres are estimated to be S/SW of Caernarfon but the uncertainties could encompass both of the more recent centres.

FAX

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G HERBERT	SCOT H & H		

FROM: C W BROWITT/A B WALKER
DATE: 10 AUGUST 1992
TIME: 11.35
PAGES TO FOLLOW: ONE

SEISMIC ALERT: EVENT NE LONDON 8 AUGUST 1992 20:30 UTC

We have had several reports of an earthquake in NE London at 20:30 UTC on 8 August. It was felt in Green Lane, Rowley Gardens and Anwell Court (N4) and reports included "cracked balcony" and "cracked windows". The local police reported that residents evacuated 3 tower blocks and the Fire Department checked for damage before they re-entered. Further, second-hand information indicated that similar felt effects have been experienced at ≈ 20:00 UTC on 9 August 1992.

The BGS rapid access network in Hereford did not detect anything at the above times indicating a magnitude less than 2.0 ML if the cause was the earthquake. However, both of these times coincide with a Madness pop concert in the nearby Finsbury Park area of London.

ROCK CONCERT AND EARTHQUAKES

In Brussels during the 1980s, there were similar effects during U2 concerts on 2 occasions; the first on 27 October 1984 and the second on 8 July 1987. The following information has been provided by our colleagues at the Royal Observatory in Brussels:

(i) Vibrations were felt by people up to 500m away.

(ii) At 5 km, a seismograph recorded a $10\mu m$ monotonic signal at a frequency of 2 Hz lasting about 4 minutes.

(iii) These vibrations were repeated at intervals of around 10 minutes.

(iv) The cause was attributed to infrasound (sub-audible vibration) generators which are used, together with the music and light, to provide the overall effect. Such low frequency waves will propagate effectively and are in the frequency band typical of local earthquakes.

We conclude that the vibrations in NE London were more likely to have been caused by the Madness pop concert rather than by a small earthquake.

ANNEX C

BGS STAFF WITH INPUT TO THE PROJECT

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
Mr N S Hunt
Mr J Laughlin
Mr P C Marrow
Mr A Miller
Mr S N Morgan
Mrs A I Muir
Dr R M W Musson
Mr D L Petrie
Mr M G Raines
Mr D W Redmayne
Mrs J A Richards
Ms M E A Ritchie
Mr B A Simpson
Mr D A Stewart
Mr T Turbitt
Mr W A Velzian
Ms A B Walker
Mr R J Wallace
Mrs F Wright
Mr R M Young

GEOGRAPHICAL CO-ORDINATES OF SEISMOGRAPH STATIONS: MARCH 1993 ANNEX E

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
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
MORAY									
MCD	COLEBURN DISTIL	57.5827	-3.2541	325.02	855.41	280	81-	4Rm	BGS
MDO	DOCHFOUR	57.4412	-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	58.305	-3.364	320.1	935.9	190	81-	1	BGS
MME	MEIKLE CAIRN	57.315	-2.965	341.9	825.3	455	81-	1	BGS
MVH	ACHVAICH	57.9232	-4.1816	270.79	894.70	198	84-	1	BGS
KYLE									
KAC	ACHNASHELLACH	57.4999	-5.2982	202.40	850.29	330	83-	1R	BGS
KAR	ARISAIG	56.9175	-5.8302	166.90	787.20	225	83-	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	818.39	70	83-	1R	BGS
KSK	SCOVAL	57.4653	-6.7020	118.09	851.40	250	89-	1R	BGS
KNR	NEVIS RANGE	56.8219	-4.9714	218.68	773.97	1118	91-	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	56.9184	-2.5404	367.18	780.96	388	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
PAISLEY									
PCA	CARROT	55.700	-4.255	258.3	647.5	305	83-	1	BGS
PCO	CORRIE	55.988	-4.097	269.2	679.2	274	83-	1	BGS
PGB	GLENIFFERBRAES	55.810	-4.478	244.5	660.5	200	84-	3	BGS
PMS	MUIRSHIEL	55.846	-4.744	228.2	664.8	351	83-	1	BGS
POB	OBSERVATORY	55.637	-4.417	247.9	640.8	34	92-	1	BGS
ESKDALEMUIR									
ESK	ESKDALEMUIR	55.3167	-3.2050	323.54	603.18	263	65-	4Rm	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

GEOGRAPHICAL CO-ORDINATES OF SEISMOGRAPH STATIONS: MARCH 1993 **ANNEX E**

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (m)	Yrs Open	Comp	Agency
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 MIC	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	N ISLE OF MAN *	54.2923	-4.4670	239.458	491.345	366	89-	3R	BGS
GCD	CASTLE DOUGLAS*	54.8638	-3.9417	275.395	553.845	189	89-	1R	BGS
XDE	DENT *	54.5058	-3.4897	303.55	513.31	291	83-	1R	BGS
BBO	BOTHEL **	54.7367	-3.2465	319.752	538.699	205	92-	3	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
BCM	CHAPELCROSS MIC	55.0151	-3.2212	321.92	569.64	78	92-	m	BGS
BCC	CHAPELCROSS	55.0154	-3.2202	321.99	569.67	68	92-	1	BGS
GALLOWAY AND N IRELAND									
GAL	GALLOWAY	54.8664	-4.7114	226.02	555.78	105	89-	4m	BGS
GCL	CUSHENDALL	55.076	-6.130	136.4	583.7	275	89-	1R	BGS
GMK	MULL OF KINTYRE	55.3459	-5.5936	172.18	611.65	160	89-	1R	BGS
GMM	MTNS OF MOURNE	54.239	-5.951	142.6	489.8	140	89-	1R	BGS
LEEDS									
HPK	HAVERAH PARK	53.9554	-1.6240	424.67	451.12	227	78-	3R	BGS
LDU	LEEDS UNIV	53.8025	-1.5553	429.35	434.45	230	83-	m	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	HOLMEFIRTH	53.5451	-1.8548	409.62	405.42	460	91-	1	BGS
NORTH WALES									
WCB	CHURCH BAY	53.3782	-4.5465	230.63	389.86	135	85-	4m	BGS
WFB	FAIRBOURNE	52.6830	-4.0378	262.27	311.47	325	85-	1R	BGS
WIM	ISLE OF MAN	54.1472	-4.6735	225.41	475.70	365	85-	1R	BGS
WLF	LLYNFAES	53.2893	-4.3966	240.27	379.64	65	85-	1	BGS
WME	MYNDD EILIAN	53.3966	-4.3034	246.86	391.37	130	85-	1R	BGS
WPM	PENMAENMAWR	53.2583	-3.9049	272.94	375.20	350	85-	1R	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

GEOGRAPHICAL CO-ORDINATES OF SEISMOGRAPH STATIONS: MARCH 1993

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (m)	Yrs Open	Comp	Agency
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									
AWH	WHINBURGH	52.6299	0.9512	599.70	307.70	60	80-	1R	BGS
ABA	BACONSTHORPE	52.8875	1.1471	611.70	336.90	13	82-	1	BGS
AWI	WITTON	52.8324	1.4460	632.09	331.69	35	83-	1	BGS
APA	PACKWAY	52.2999	1.4779	637.10	272.60	35	84-	1	BGS
AEA	E ANGLIA UNIV	52.6208	1.2403	619.30	307.50	45	84-	m	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	193.64	210	80-	1R	BGS
HLM	LONG MYND	52.5169	-2.8878	339.76	291.41	259	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
SOUTH EAST ENGLAND									
TFO	FOLKSTONE	51.1136	1.1406	619.79	139.67	188	89-	4	BGS
TEB	EASTBORNE	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
CORNWALL									
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	31.15	183	81-	1	BGS
CGH	GOONHILLY	50.0508	-5.1649	173.47	21.61	91	81-	1	BGS
CME	MENERDUE FARM	50.1760	-5.1903	172.24	35.61	178	82-	3R	BGS
CPZ	PENZANCE	50.1560	-5.5835	144.07	34.66	198	81-	1R	BGS
CR2	ROSEMANOWES 2	50.1669	-5.1687	173.74	34.53	152	81-	3	BGS
CRA	RAME	50.1648	-5.1921	172.06	34.36	198	82-	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
CTR	TROLVIS QUARRY	50.1665	-5.1624	174.18	34.47	191	82-	3	BGS
CGW	GWEEK	50.1003	-5.2224	169.585	27.288	76	93-	1	BGS

GEOGRAPHICAL CO-ORDINATES OF SEISMOGRAPH STATIONS: MARCH 1993

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (m)	Yrs Open	Comp	Agency
DEVON									
HTL	HARTLAND	50.9944	-4.4850	225.64	124.67	91	81-	4Rm	BGS
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
HSA	SWANSEA	51.7478	-4.1543	251.30	207.70	274	87-	1R	BGS
HPE	PEMBROKE	51.9371	-4.7745	209.27	230.18	355	90-	1R	BGS
HEX	EXMOOR	51.0668	-3.8025	273.72	131.32	278	91-	1R	BGS
JERSEY									
JLP	LES PLATONS	49.2428	-2.1039			131	81-	1R	BGS
JSA	ST AUBINS	49.1879	-2.1709			21	81-	1R	BGS
JRS	MAISON ST LOUIS	49.1924	-2.0917			53	81-	4R	BGS
JVM	VAL DE LA MARE	49.2169	-2.2068			64	81-	1R	BGS
JQE	QUEENS EAST	49.200	-2.038			56	91-	1	BGS
JQW	QUEENS WEST	49.196	-2.057			73	91-	1	BGS
JQS	QUEENS SOUTH	49.180	-2.063			62	91-	1	BGS

Notes

1. The UK seismograph network is divided into a number of subnetworks, named Cornwall, Devon etc, within which data is 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/92/11 Browitt, C.W.A. and Turbitt, T. BGS Seismic Monitoring and Information Service, Third Annual Report.

WL/92/19 Walker, A.B. HDR Seismic Monitoring: Annual Report 1991-1992.

WL/92/29 Turbitt, T. (Ed.), Ford, G.D., Galloway, D.D., Marrow, P.C., Musson, R.M.W., Redmayne, D.W., Richards, J.A., Ritchie, M.E.A., Simpson, B.A., Walker, A.B. and Wright F. Bulletin of British Earthquakes 1991.

WL/92/31 Musson, R.M.W. A report on the seismological archives at Strasbourg.

WL/92/33 Musson, R.M.W. and Henni, P. Felt effects in the UK of the 1992 Roermond earthquake.

WL/92/36 Marrow, P.C. UK earthquake magnitudes: A comparison of methods and published results.

WL/92/53 Marrow, P.C. Average earthquake recurrence statistics for the UK area and the Poisson assumption.

WL/92/54 Richards, J.A. and Miller, A. Borehole seismometers: an experimental appraisal.

WL/93/05 Walker, A.B., Ford, G.D. and Musson, R.W.M. The Caernarvon Bay earthquake 29th July 1992 (3.5 ML).

In addition, 14 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

Browitt, C.W.A., 1992. Impact of Earthquakes on the Community. In: *Avoiding Disasters,* ICE Hazards Forum (extended abstract of invited lecture).

Gutdeutsch, R., Grunthal, G. and Musson, R.M.W., (eds), 1992. Historical earthquakes in Central Europe vol 1, *Abhandlungen der Geologischen Budesanstalt Band 48, Vienna.*

Musson, R.M.W., 1992. Routine macroseismic monitoring in the UK, In: Cecic, I., (ed), *Proc. 2nd AB Workshop on Macroseismic Methods, Poljce, Yugoslavia, 15-18 Oct 1990,* Seismological Survey of Slovenia, Ljubljana.

Musson, R.M.W., 1992. Single diagnostic analysis of earthquake effects, In: Cecic, I., (ed), *Proc. 2nd AB Workshop on Macroseismic Methods, Poljce, Yugoslavia, 15-18 Oct 1990,* Seismological Survey of Slovenia, Ljubljana.

Musson, R.M.W., 1992. Guide to the use of the MSK-92 intensity scale, In: Grunthal, G., (ed) MSK-92 Macroseismic intensity scale, *Cahiers du Centre Européen de Géodynamique et de Séismologie no 6, Luxembourg.*

Musson, R.M.W., 1992. Examples of intensity assignment, In: Grunthal, G., (ed) MSK-92 Macroseismic intensity scale, *Cahiers du Centre Européen de Géodynamique et de Séismologie no 6, Luxembourg.*

Musson, R.M.W., 1992. Sudden destruction: the effects of earthquakes on human affairs, *Geographical Magazine,* **64:9**, 45-48.

BGS SEISMIC MONITORING AND INFORMATION SERVICE: THIRD ANNUAL REPORT

C W A Browitt and T Turbitt

The UK earthquake monitoring and information service project has developed from the commitment of a group of organisations, the 'Customer Group', with an interest in the seismic hazard of the UK. The project formally started in April 1989 and the published Year 1 report includes details of the history of monitoring by BGS since 1969 and an outline of the background to the establishment of the project.

This Year 3 report to the Customer Group follows the previous format in reiterating the programme objectives and highlighting some of the significant seismic events in the period April 1991 to March 1992. The catalogue of earthquakes for the whole of 1991 is plotted to reflect the period for which the bulletin of revised data is produced. Progress towards the overall need to establish a uniform distribution of seismic monitoring stations with an average spacing of 70 km is reviewed. With insufficient funds available to move to this situation in the short term, reliance is placed on some of the site-specific networks commissioned by some members of the Customer Group who have made the data collected in this way openly available. Low cost ways of adding individual monitoring stations to the network have been pursued and, on an opportunistic basis, upgrades to more modern digital systems are being implemented.

The effect of these upgrades is to make immediately available, data outside the Edinburgh region with a consequent improvement in response time for felt earthquakes in many parts of England and Wales.

SW ENGLAND SEISMIC MONITORING FOR THE HDR GEOTHERMAL PROGRAMME IN CORNWALL: APRIL 1991 TO MARCH 1992

A B Walker

The potential for earthquakes to be triggered by fluid injected into boreholes has been recognised for 25 years and natural earthquakes in Cornwall have been reported for over 250 years. As a result, the Geothermal Steering Committee advising the Hot Dry Rock (HDR) project recommended that background seismic monitoring be undertaken around the HDR experimental site at Rosemanowes. A network of seismographs was established for this purpose by the British Geological Survey (BGS) in late 1980 and has been operated continuously through March 1992. The primary aim of the network has been to provide an independent, continuous assessment of all vibrational transients in order to discriminate between those caused by the Hot Dry Rock experiments and those of natural origin or from other man-made sources. In this respect, the work provides an insurance against claims that extraneous seismic activity is related to those experiments.

Throughout April 1991 to March 1992, 10 natural earthquakes have been located with magnitudes between -1.0 and 2.2 ML; the largest in the Bristol Channel on the 30 November 1991. Of the six located within 10 km of the HDR site, three occurred near Constantine on 21 February 1992 with magnitudes 0.8, 0.7 and -0.2 ML and form part of the continuing series of instrumentally located events in that area since 1981. Two others occurred near Helford on the Lizard Peninsula at depths of 1.7 and 1.5 km and mark the first natural seismicity to occur at such shallow depths throughout the eleven years of continuous monitoring. The other event (-1.0 ML) occurred 2 km NE of Rosemanowes quarry at a depth of 3.8 km. Although this small event represents the lower limit of the network's detection capabilities, it locates in the same area as two previous events in December 1990.

Over the eleven-year monitoring period, some 450 natural seismic events have been located by the Cornwall network. It has proved to be an area of moderate seismicity within the UK, with six natural earthquakes felt. Five of those in the Constantine series and the other near Liskeard, with magnitudes ranging from 1.9 to 3.5 ML.

BULLETIN OF BRITISH EARTHQUAKES 1991

T Turbitt (Editor)

The largest earthquakes of the year, onshore, occurred at Newtown, Powys, on 16 June (magnitude 2.8 ML), and at Balquhidder, Central Scotland, on 4 August (2.8 ML). Both were felt in the immediate area with intensity 3 MSK. Offshore, the largest earthquake occurred in the northern North Sea on 25 April with a magnitude of 4.2 ML. The epicentre was near the Alwyn oil fields but no felt reports were received.

On 14 December a magnitude 3.6 ML earthquake was felt in the area around Boulogne in France. It is of significance to UK seismic hazard due to its position only 30 km from the south coast of England.

Sixty five small events were detected in the coalfield areas of Fife; two were reported felt. In the coalfields of Derbyshire, Yorkshire, Nottinghamshire and Staffordshire over 100 events were detected, 13 of which were felt. A small event (0.8 ML) near Camborne in Cornwall at the site of an active tin-mine, was felt on 20 March.

Earthquakes were also felt near Ardentinny, Strathclyde (16 June, 2.0 ML); Gelligaer, Mid Glamorgan (9 January, 1.2 ML) and Stirling, Central Scotland (31 October, 1.1 ML).

A magnitude 2.2 ML earthquake at Loch Nevis, Highland on 27 September, was followed by 15 small aftershocks. Small swarms of activity occurred at Crianlarich, Central Scotland; Gleneagles, Tayside; Milngavie, Strathclyde and Dumfries, Dumfries and Galloway. Eight aftershocks of the 1984 Lleyn Peninsula earthquake were detected.

A REPORT ON THE SEISMOLOGICAL ARCHIVES AT STRASBOURG

R M W Musson

Strasbourg has one of the oldest seismological observatories in Europe, dating back to the end of the 19th century. It is still the most important centre for seismology in France, being the home of both the Institut de Physique du Globe (IPG) and the Centre Séismologique Euro-Méditerranéen (CSEM). The IPG is at foremost a national institute; the CSEM an international one.

At the request of the CSEM, the author visited Strasbourg on 22-24 June 1992 to examine the archives held by CSEM. This report describes the current situation of the seismological archives and makes recommendations for future practice.

FELT EFFECTS IN THE UK OF THE 13 APRIL 1992 ROERMOND EARTHQUAKE

R M W Musson and P Henni

Immediately after the 13 April 1992 earthquake an appeal for information in the form of a questionnaire was published in local newspapers in the SE of England, and in one national newspaper. A total of 158 replies were received (excluding those from people who felt the earthquake on the continent) of which 66 were positive responses, from 35 different towns, villages or suburbs.

The maximum intensity was 4 MSK at once place only (Folkestone, Kent). The intensity was generally 3 MSK in Kent and on the coast of Essex, which corresponds to the radius of perceptibility to be expected from an event this size. The most distant places at which the earthquake was felt slightly were Halifax and Liverpool.

UK EARTHQUAKE MAGNITUDES: A COMPARISON OF METHODS AND PUBLISHED RESULTS

P C Marrow

Methods and results of magnitude assessments of earthquakes in the UK area published by six different agencies are compared with those catalogued by BGS. Relationships are derived between scales by double error regression on earthquake magnitudes published by both BGS and another agency.

BGS ML determinations are shown to be in good agreement with those of other sources such as NORSAR but are systematically less than those reported by LDG (France) throughout the range of common observations.

Current and past practice of magnitude calculation within BGS (and the former IGS) are described. Examples of the development of regionally valid local magnitude scales are discussed and recommendations made for possible future measurement practice in the UK region. Earthquake magnitude revisions performed by BGS in recent years are listed.

AVERAGE EARTHQUAKE RECURRENCE STATISTICS FOR THE UK AREA AND THE POISSON ASSUMPTION

P C Marrow

The seismicity of the United Kingdom region is low in world terms. However, there is increasing need to know about hazards to structures with very long design lives and also about hazards with very low annual probabilities of exceedence for "high consequence" activities such as nuclear power generation, petrochemical production/refining, waste disposal and reservoir construction. This need has led to greatly enhanced seismic monitoring of the UK area, and consequently, to greatly improved knowledge of the rate of occurrence of earthquakes of different magnitudes and their locations. These statistics, together with recent extensive archival research into earthquakes in the historical period, permit full site-specific probabilistic seismic hazard analysis (PSHA) for individual engineering projects. Part of such analyses may require the definition of the relative number of small and large earthquakes - the "b" value for a region.

The regional "b" value is computed for the UK area (1.05 $\pm$0.06 and consistent with the globally observed average value of 1.0) and average return periods for earthquakes in the range 3.0 - 6.5ML are tabulated.

Most PSHA assume the earthquake process is Poissonian. This is a major assumption that implies that earthquakes are independent in time (memoryless) and that it is stationary ("a" and "b" in the Gutenberg-Richter relationship do not change with time). This model is shown to be a valid approximation for the UK area as a whole.

BOREHOLE SEISMOMETERS: AN EXPERIMENTAL APPRAISAL

J A Richards and A Miller

Three seismometers were utilised to install and test a new borehole seismometer, the LA100 (Integra Systems). This has a very similar output to BGS's standard seismometer, the Willmore Mk III (Sensonics), but without its limitations of size and manoeuvrability. The principal objectives of these trials were firstly, to assess the comparability of output of the two types of seismometer and secondly, to investigate the effectiveness of borehole instrumentation in improving signal-to-noise ratios in areas where surface site noise and/or thick sedimentary cover are encountered.

A Willmore Mk III and a LA100 seismometer were operated in parallel on the surface at one site, and showed good correlation of output for a number of seismic sources over the frequency range examined (0 to 30 Hz). Uphole-downhole arrays were installed in each borehole to compare responses at the surface with those at depth. At a noisy site with 26 m of superficial cover, the level of background noise was significantly reduced in the 100 metre deep borehole. Signal levels for some events were also reduced at depth because of the amplification effect at the surface, but the overall signal-to-noise ratio was generally significantly better on the downhole seismometer. Even at a relatively quiet, rural site, with 5 m of superficial deposits, the improvement in signal-to-noise ratio was evident on the downhole seismometer (at a depth of 15 m) under certain noisier conditions such as during windy weather.

The results of these trials, therefore, suggest that the LA100 seismometer would give comparable output to the Willmore Mk III over the desired frequency range, and that downhole installation of seismometers is effective in improving signal-to-noise ratios in areas with superficial cover, particularly where there are local sources of background noise.

THE CAERNARVON BAY EARTHQUAKE 29 JULY 1992 (3.5 ML)

A B Walker, G D Ford and R M W Musson

On 29 July 1992 at 18:05 UTC an earthquake with a magnitude of 3.5 ML was located in Caernarvon Bay. It was felt over approximately 10,000 sq km and had a maximum intensity of 5 MSK which was observed in only two locations.

An interpretation of the focal mechanism of the event shows reverse faulting with a small component of strike-slip with movement either on a plane striking NS and dipping 53° E or a plane striking NE-SW and dipping 25° NW. The mechanism is consistent with a NW-SE compressive stress direction determined for other localities in Britain and NW Europe.

IMPACT OF EARTHQUAKES ON THE COMMUNITY

C W A Browitt

In the past 20 years, losses from all natural disasters have been estimated at 3 million deaths, hundreds of billions of dollars and the disruption of the lives of 15% of the World's population. Earthquakes are the greatest contributor, accounting for over half of the deaths this century, and the scale of individual events can be awesome. The Tangshan earthquake of 1976 killed up to 650,000 people. The estimated cost of the next great earthquake in Tokyo is $200 billion and in San Francisco is $50 billion despite their disaster mitigation programmes. In recent years, 90% of deaths from natural disasters have occurred in developing countries where vulnerability is increasing. World population has quadrupled this century and urbanisation has increased from 14% in 1900 to 45% at the present time with much of this expansion in vulnerable coastal areas. As a result, there has been a significant increase in disasters and losses owing to greater exposure to the hazards.

In less earthquake prone areas, large intraplate earthquakes can occur in regions with no previous history (eg Tennant Creek, Australia, 1988). Small earthquakes can cause damage and deaths; such as in Liege, Belgium in 1983 (Mb=5.0, $60 million) and in Newcastle, Australia in 1989 (Mb=5.4, $1.1 billion, 11 deaths). In the UK in 1580, 2 lives were lost in London from an earthquake centred in the straits of Dover.

There is a need for accurate data on site vulnerability (earthquake occurrence and response of site geology) from which engineers can, economically, design and construct new buildings and retrofit old ones to be earthquake resistant. At present, we are in the International Decade for Natural Disaster Reduction which includes, as one of its aims, the application of such a formula to the problems of the Developing World.

HISTORICAL EARTHQUAKES IN CENTRAL EUROPE

R Gutdeutsch, G Grunthal and R M W Musson

This is the first of a series of monographs on historical earthquakes in Europe published by the University of Vienna. This volume contains 3 contributions on historical earthquake methodology, the history of theories about earthquakes prior to 1750, and the German earthquake of 1872.

ROUTINE MACROSEISMIC MONITORING IN THE UK

R M W Musson

Macroseismic surveys are normally done in the UK by the BGS for all earthquakes with onshore epicentres and magnitudes greater than 3.5 ML, and for offshore events with a significant felt area. The questionnaire used, the means of distributing it, and the techniques for analysing the resulting data, are described and discussed.

SINGLE DIAGNOSTIC ANALYSIS OF EARTHQUAKE EFFECTS

R M W Musson

Single diagnostic analysis (SDA) is a technique designed to provide a new way of examining macroseismic data, in which individual occurrences of specific earthquake effects are plotted, rather than being aggregated in an intensity assignment. The advantage of this is that it removes the subjective element present in intensity assignments. There are two approaches to this technique - one is to plot any occurrence of the effect being examined; this is particularly appropriate for use with historical data where there is no statistical control. The other is to examine the percentage of observers at any place who reported observing the effect. In this study the second technique is applied to an analysis of the effects of the 19 July 1984 Lleyn Peninsula earthquake in north Wales.

GUIDE TO THE USE OF THE MSK-92 INTENSITY SCALE

R M W Musson

This is a set of guidelines for the use of the European Macroseismic Scale (updated MSK-92 intensity scale) setting out the general way in which the scale should be used and interpreted, the restrictions on its use, the intentions of its authors, and how to apply it in particular cases.

EXAMPLES OF INTENSITY ASSIGNMENT

R M W Musson

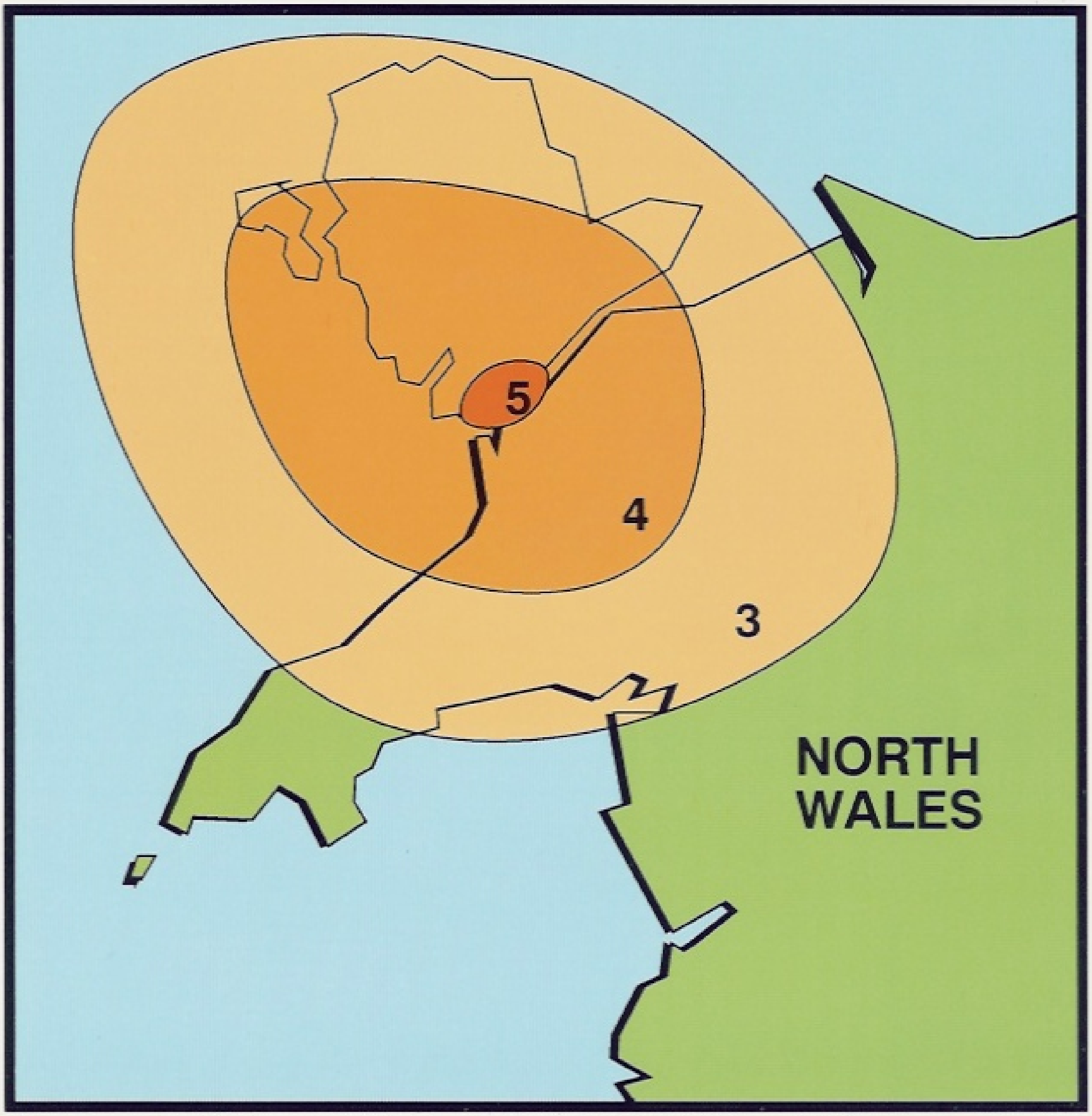
This annexe to the European Macroseismic Scale (updated MSK-92 intensity scale) gives two worked examples of the scale in use, one using historical data (for Comrie, 7 September 1801 earthquake) and one using questionnaire data (for western Carlisle, 26 December 1979 earthquake).

SUDDEN DESTRUCTION: THE EFFECTS OF EARTHQUAKES ON HUMAN AFFAIRS

R M W Musson

The fascination of earthquakes is discussed, and the idea that it is not earthquakes themselves that kill but buildings, with the casualties often affected by such factors as time of day. The economic repercussions are considered, as are some of the ways of minimising damage.

Natural Environment Research Council



Caernarvon Bay Earthquake 29th July 1992, 18:05 UTC (3.5 ML) - MSK Intensities