UK EARTHQUAKE MONITORING 1990/91

BGS Seismic Monitoring and Information Service

Second Annual Report

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BRITISH GEOLOGICAL SURVEY

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UK Earthquake Monitoring 1990/91

BGS Seismic Monitoring and Information Service

Second Annual Report

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Solar-powered earthquake-monitoring station in the North-west Highlands of Scotland

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CONTENTS

UK EARTHQUAKE MONITORING 1990/91

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 22 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 with the major financial input from the Natural Environment Research Council. This Customer Group is listed in Annex A.

In the second year of the project (April 1990 to March 1991), one additional seismograph station has been added to the network (in Pembrokeshire) and two other sites have been selected for future installations. The most notable outstanding gap, in central southern England, has been identified as the highest priority for a new sub-network when funding permits. The development of a digital dial-up recording system and its use in upgrading one seismograph network in Cornwall and one in Scotland has significantly extended the BGS capability in rapidly responding to reports of seismic events.

A temporary network of seismograph stations placed around the epicentre of the magnitude 5.1 Bishop's Castle earthquake of 2 April 1990, was maintained for 7 months. It showed that the event was unusual in producing only 7 small aftershocks but this number was sufficient to more accurately determine the depth of occurrence (14-15 km) and the strike of the fault plane (N-S). Elsewhere in the country, earthquakes have been felt in many localities with the strongest intensities experienced on Jersey in April 1990 and at Shrewsbury in July 1990.

In addition to earthquakes, BGS receives reports every week 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. 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 issued 2 months in arrears with provisional details of all earthquakes located, and, after revision, they are compiled into an annual bulletin.

Problems which surrounded the establishment of the national database and archive of British earthquakes have been overcome and progress has been made in cataloguing and indexing the BGS holding of historical material. A watching brief has been maintained on other archives in an effort to avoid losses when local interest wanes. Agreement has been reached with the States of Jersey Meteorological Office to transfer, to BGS Edinburgh, its collection of seismograms which date back to the late 1930s.

2. Introduction

The UK earthquake monitoring and information service project has developed from the commitment of a group of organisations with an interest in the seismic hazard of the UK. 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 2 report to the Customer Group follows the format of the first annual report in reiterating the programme objectives and highlighting some of the significant seismic events in the period April 1990 to March 1991. The catalogue of earthquakes for the whole of 1990 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 increase in response time for felt earthquakes in many parts of England and Wales (Fig 1). All of the advances made and proposed in the network geometry can be seen by comparing the present station coverage (Fig 5) with that before the start of the project (Fig 2).

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 sources to supplement the background network.

(ii) To provide near-immediate preliminary responses to seismic vibrations reported to have been heard or felt, or judged to be 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 would not be specifically supported.

(ii) The 70 km-spacing of stations would 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. 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 1990 is shown in Figure 5 with its detection capability in Figure 6. The programme for 1990/91 called for:

(i) Installation of new seismograph stations to record at existing centres in W Scotland, SW Wales, E Devon and the W Midlands.

(ii) Upgrading the Cornwall network to digital recording and dial-up access from Edinburgh, and planning a second upgrade to take place in 1991.

On item (i), progress has not been as fast as anticipated. The addition of a station to the existing network in western Scotland (Fig 2) has proved difficult owing to the high relief of the topography limiting the options for line-of-sight UHF radio transmission. A suitable site has now been identified but implementation is held up owing to problems in obtaining access permission. A station was installed in SW Wales on 6 September 1990 transmitting across the Severn estuary into the recorder at Hartland in Devon. Whilst the station in eastern Devon (also scheduled to record at Hartland) has not been installed, a suitable site was selected and negotiations for access started. In the West Midlands, however, there has been no effective progress owing, principally, to a lack of confidence in the security of sites used on a temporary basis in the past.

On item (ii), progress has been as planned. The pilot digital, dial-up recording system was installed for test and development purposes in Edinburgh in June 1990 and an identical system established on the Cornwall network in September. The 'teething' problems of these new systems took some months to overcome but the result is that immediate access is now available to data from the Edinburgh (LOWNET) and Cornwall networks from any location in the UK (or elsewhere). The capability for immediate response has been significantly enhanced as a consequence (Fig 1). Plans have been made, and preparatory work conducted, to upgrade the Hereford network which covers much of central and southern Wales.

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

(i) Nuclear Electric have sustained monitoring in North Wales throughout the year and are likely to continue for a second year although at a less intensive level.

(ii) The Department of Energy-sponsored monitoring of the HDR geothermal research work in Cornwall has continued and is likely to be renewed in some form following the reduction of the HDR programme in October 1991.

(iii) Nuclear Electric are unlikely to renew the contract for monitoring around the Heysham power station.

A strong-motion, event-triggered recorder with seismic sensors has been installed at Hunterston power station for Scottish Nuclear.

4.2 Progress with instrumentation

The development and proving of the digital system, SEISLOG, which is a joint project between BGS and Bergen University has progressed to the stage that data is being routinely collected in Edinburgh and Cornwall. Following the initial installation of these systems, further developments were incorporated to improve reliability and immunity from short-term power breaks. This process of improvement will continue.

Borehole sensors to reduce background noise levels, particularly for stations on the less suitable geology of eastern England, have continued to be developed and tested. Trials at Heysham in a 100m borehole and near Edinburgh in a 15m borehole have brought the system to a point where deployment in the UK network is viable.

The first of a new generation of strong motion seismic data acquisition systems was developed for the Hunterston power station installation and a robust, customised variant of it has been designed under Quality Assurance procedures for the Ministry of Defence. These could potentially form the basis of a strong motion recording system more widely distributed in the UK.

5. Seismic activity in Year 2

5.1 Earthquakes located for 1990

Details of all earthquakes and sonic booms detected by the network are provided in the BGS bulletin for 1990 which is scheduled for publication in August 1991. A map of the 422 events located is reproduced here as Figure 7 and a catalogue of those with magnitudes of 2.0 or greater is listed in Annex B.

5.2 Significant events

Highlights of the seismic activity during the second year of the project (April 1990 to March 1991) are given below.

(i) In Shropshire, near the Welsh border, the damaging, magnitude 5.1 Bishop's Castle earthquake on 2 April 1990 proved to be the largest in the UK during this second year of the project. It has been discussed in some detail in the previous project report and full details are given in the BGS report by M Ritchie et al (July, 1990) and the external publication, Ritchie et al (1990). The 11 station seismograph network which was installed immediately after the event, recorded 7 aftershocks before its withdrawal in November. Despite their small number, these events provided critical evidence on the depth of the causative fault (14-15 km) and, together with the strike-slip mechanism determined from the mainshock, have shown that the fault lies in a N-S direction. They also confirm that it was a high stress-drop event in contrast to the magnitude 5.4 earthquake on the Lleyn Peninsula in 1984.

(ii) In North Wales, the aftershock activity from the Lleyn earthquake continued throughout the year with 10 small events being located. The largest of these, on 20 April 1990, had a Richter magnitude of 2.0 ML. It was not reported to be felt although, surprisingly, smaller aftershocks than this have been felt in the area in the past despite their focal depths of over 20 km.

(iii) In Jersey, on 30 April 1990, a magnitude 3.5 ML earthquake was felt strongly throughout the island and, to a lesser extent, on Guernsey some 45 km to the north-west. In many places, it had a sufficiently high intensity of shaking (V on the MSK scale) to awaken people and dislodge unstable objects. It was not reported to be felt on the French coast about 50 km to the east. The mainshock and 16 aftershocks (Fig 8) were located 8 km south of St Aubins bay in a cluster between 7 and 9 km deep. Full details are given in the BGS report by A Walker (December 1990). Jersey has a documented history of felt earthquakes over the past 200 years with the last phase of strongly felt events being in the 1920s and 1930s.

(vi) In Glen Torridon, a magnitude 2.4 ML earthquake was felt at intensity III MSK at Kinlochewe on 8 June 1990.

(v) In Shrewsbury, on 10 July 1990, a magnitude 2.2 ML earthquake, centred 4 km to the south-west of the town centre, was felt strongly (IV MSK) and also in the surrounding villages (Fig 9). Despite its small magnitude and limited felt area, it attracted considerable media attention owing to heightened interest in the region following the Bishop's Castle earthquake 3 months earlier. The proximity of the temporary network of seismographs established around Bishop's Castle provided sufficient data for a detailed study of the Shrewsbury event. It had a depth of approximately 9 km and the focal mechanism shows that the fault movement was predominantly normal on a plane striking either N-S or NW-SE. There is insufficient information to resolve which of the two is the fault plane. Full results are available in the BGS report by M Ritchie and R Musson (October, 1990).

(vi) In Comrie, Tayside, a small earthquake with magnitude 1.4 ML was felt locally on 18 July 1990 at intensity II MSK. There have been occasional events over the past decade in this region which was famous for the frequency of its earthquakes in the 1790s, 1830s and 1840s. In 1875, following a small number of felt events, Victorian naturalists built an observatory with crude earthquake detection instruments in an unsuccessful attempt to learn more about the phenomena. Called 'Earthquake House', the observatory has been restored and opened to the public by the Perth and Kinross District Council with some help from BGS.

(vii) In the North Sea, the largest earthquake, in Year 2, with a magnitude of 4.4 ML, occurred approximately 60 km north-east of the Magnus oil field on 10 November 1990. Further south, on 21 March 1991, a magnitude 3.3 ML event occurred in the Witch Ground graben. Neither of them were reported to be felt on oil platforms, although in 1988 an earthquake similar in size to the latter was felt strongly throughout the Ekofisk field.

(viii) In Carrickfergus, Northern Ireland, a strong seismic signal was recorded on 19 October 1990 throughout the recently installed North Irish Sea network of seismograph stations (Fig 10). It proved to be from the collapse of the abandoned Tennant salt mine in the suburbs of the town. With hindsight, earlier, much smaller events were found to have been felt locally and detected on the nearest seismograph. The collapse caused a depression 200 metres in diameter and 7 metres deep. Fortunately, the potential for such an event had been recognised by A Griffith (BGS, N Ireland) many years before and housing development had been kept off the land.

(ix) In many places, seismic events with the characteristics of coalmining-induced earthquakes have occurred although in the absence of local, site-specific monitoring this interpretation cannot be confirmed. In the Mansfield, Notts., region such events have caused public concern and have resulted in many enquiries; particularly in 1991. The South Wales coalfields have been active (eg near Edwardsville) and there have been series of events felt at Leigh, (Greater Manchester), in the Clackmannan coalfield and near Wakefield, among other localities.

(x) Throughout the country, many 'seismic' events have been reported to be felt and heard like small earthquakes but, on analysis, have proved to be sonic booms. Examples come from Orkney, Isle of Man, Anglesey, Cornwall, Colchester, Norfolk, Hull, Cleveland and Lothian.

5.3 Global earthquakes

Data exchange on British, European and Global earthquakes has continued under reciprocal arrangements with individual institutions and with the International Seismological Centre, Newbury (ISC), the National Earthquake Information Centre, Denver (NEIC) and the European and Mediterranean Seismological Commission, Strasbourg (CSEM).

Earthquakes which dominated the News included:

(i) Romania on 30 May 1990 with magnitude 6.7 Mb. This was one of a series of deep (90 km) earthquakes which have affected Romania over the years (in 1940, 1977, 1986). In this case, only 13 people were killed and 700 injured but the great interest of the News media in the politics of the country at that time led to considerable parallel interest in this event. Because of the time of the event (10.40 GMT), seismologists in the United States were not available to the US media which resulted in BGS staff contributing to US TV and radio breakfast-time bulletins.

(ii) NW Iran on 20 June 1990 with magnitude 7.7 MS (Fig 11). It caused 50,000 deaths, 100,000 injuries and 400,000 homeless and it appears to have had a direct precedent in 1780 when a similar number of people were killed in the same area. Five months later in 1990, a magnitude 6.8 MS earthquake struck a remote area in southern Iran with considerable damage to villages but only light casualties.

(iii) Philippines on 16 July 1990 with magnitude 7.8 MS. This earthquake killed 1600 people which is not a high toll for earthquakes of this size. However, owing to the destruction of bridges and damage to roads caused by the landslides which were triggered, the event had a very serious effect on the economy. The farms in the north of Luzon were cut off from their source of supplies and the markets in the south from the farm produce. As a result, some people who barely felt the shaking from the event suffered severely from the secondary economic consequences.

A small earthquake in Sicily on 13 December 1990 with a magnitude of 5.4 Mb is of relevance to the UK because such earthquakes can occur here. It killed 15 people, injured 200, made 800 homeless and caused a surface fault rupture 10 km long. A study conducted by British engineers shortly after the event concluded that the pattern of damage, which was representative of a maximum intensity of VII MSK, appeared to be strongly influenced by local topographic effects. As a consequence, they questioned the common practice of using smoothed, broad scale, isoseismal mapping for events of this size as the procedure does not realistically represent local damage patterns. Despite considerable damage in some areas, it was found that there was no damage to industrial facilities and that earlier strengthening of older buildings had proved to be effective.

Worldwide, there appears to be no significant change in the rate of seismic activity with time but this is not appreciated by the News media and the general public. Two factors appear to contribute to this perception: the increasing capability of modern communications to bring immediate news, particularly of human problems, from all parts of the World and a real increase in the exposure of mankind to earthquake hazards. We are more vulnerable and, therefore, more at risk from a constant hazard (frequency of occurrence) because the population is increasing and cities are often sited or expanded in coastal or estuarine areas on unsuitable foundations with high densities of buildings and people. We are, in effect, throwing ourselves in front of the (earthquake wave) train.

6. Archives

6.1 Identification and cataloguing

Problems of cramped conditions for working on the bulletin, seismogram and other textual archives have been satisfactorily resolved. A member of staff has been recruited into a vacancy left by a previous resignation and some professional training has been received by the incumbent. As a result, progress has been made with cataloguing the BGS holdings with the aim of completing a first-level computer-based index by the end of 1991. Suitable hardware and software has been installed to facilitate this operation.

The Year 1 report listed information on catalogues held externally to BGS and the following upgrades that information:

Jersey: A set of smoked paper seismograms written on the Mainka instrument which was installed in the Maison St Louis Observatory, Jersey, in 1936, has been examined on-site. The records appear to be in good condition and to span a large part of the past 50 years. Agreement has been reached with the States of Jersey Meteorological Office to transfer the records to BGS for cataloguing and safekeeping.

Aberdeen: The seismograms and other papers from Aberdeen which ceased recording in 1966 are currently kept in good conditions by Aberdeen University Department of Physics, who wish to retain them. It is informally agreed that BGS will take over responsibility if the University can no longer accommodate the records.

Bidston: The seismograms are held by BGS but are in poor condition as a result of neglect. Possible conservation solutions are being actively pursued.

Durham: This observatory is still functional and the records are maintained by Durham University Department of Earth Sciences.

Eskdalemuir: Records from ESK are stored by the Meteorological Office at Eskdalemuir under BGS curation.

Kew: All Kew material is held by BGS.

Oxford: All the Oxford seismograms bar one appear to have been destroyed some time after 1947. The one survivor is held by BGS.

Paisley: The records are still kept by Paisley Observatory with which BGS maintains links.

Shide: This observatory closed in 1913 and the records are presumed destroyed, though the Isle of Wight County Record Office has tracings of a few.

Stonyhurst: After extensive enquiries as far afield as the Vatican, it now appears more likely that the Stonyhurst seismograms were destroyed some time after 1947.

West Bromwich: No clue has been found to the fate of these records. They are presumed destroyed.

6.2 Storage and inspection facilities

The anticipated integrated storage and inspection facility, within Murchison House, for all types of seismological data, has not materialised as planned. The textual archives, however, are now well-catered for although the analogue tape archive, covering the past 22 years of monitoring, continues to be housed off-site in conditions which are unsatisfactory on some counts. In particular, it is inappropriate to provide local inspection facilities on-site. Within a wider review of storage for similar Earth Science records, BGS is likely to identify a solution within one year.

In order to facilitate the storage and protection of digital seismograms, an optical disk system has been installed with copying facilities for making back-ups. All of the more significant UK earthquake seismograms are now routinely digitised and stored in this way and many past events of particular significance have been added to the digital dataset.

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 with small ones reported separately to British Coal. Similarly, small ones near nuclear power stations are reported to Nuclear Electric because of its special interests. In all cases, copies are supplied to Dr B R Marker, DOE. Some 47 alerts have been issued to the whole 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.

The upgrading of the Lowlands network to a digital standard and, particularly, the similar upgrade to the Cornwall network has improved the quality of the data available. The immediate response capability for southern Britain has been considerably improved although there are still significant gaps even for magnitude 3.0 and greater events in the worst noise conditions (Fig 1). The plan to upgrade the Hereford network, in 1991, which covers the south-east and central Wales area, will bring all of mainland Britain into the net for rapid response to earthquakes of this magnitude. It should be noted, however, that at this stage, there will be no redundancy to cover breakdowns and staff will only be available to use the data on a 'best endeavours' basis outwith normal working hours.

7.2 Medium-term response

The response time for producing preliminary bulletins of events has been reduced from 3 months to 2 months beyond the end of a one month recording period. This level of reporting has been sustained since May 1990 and it is considered to be the optimum with 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 of staff resources, this has not yet been achieved; the 1989 bulletin was published in February 1991. The schedule for the 1990 bulletin is, however, more optimistic and proof copies should be available in July 1991.

8. Programme for 1991/92

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 1991/92 are:

(i) Installation of new seismograph stations in E Devon, Yorkshire and W Scotland.

(ii) Planning the proposed network of up to 6 stations in central southern England, with some prospect of installation within the year, if resources permit.

(iii) Upgrading the Hereford network to the digital, remote access standard and adding an extra station from the Bishop's Castle-Shrewsbury area.

(iv) Installing a small number of triggered strong motion recorders using instrumentation transferred from the NERC Geophysical Equipment Pool.

(v) Providing a first-level index of BGS holdings of textual archive material.

(vi) Transferring to Murchison House, the historical seismograms from Jersey which approximately cover the period 1940 to 1980.

(vii) Publishing a map of UK seismicity for the period 1980-1989.

(viii) 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 through 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).

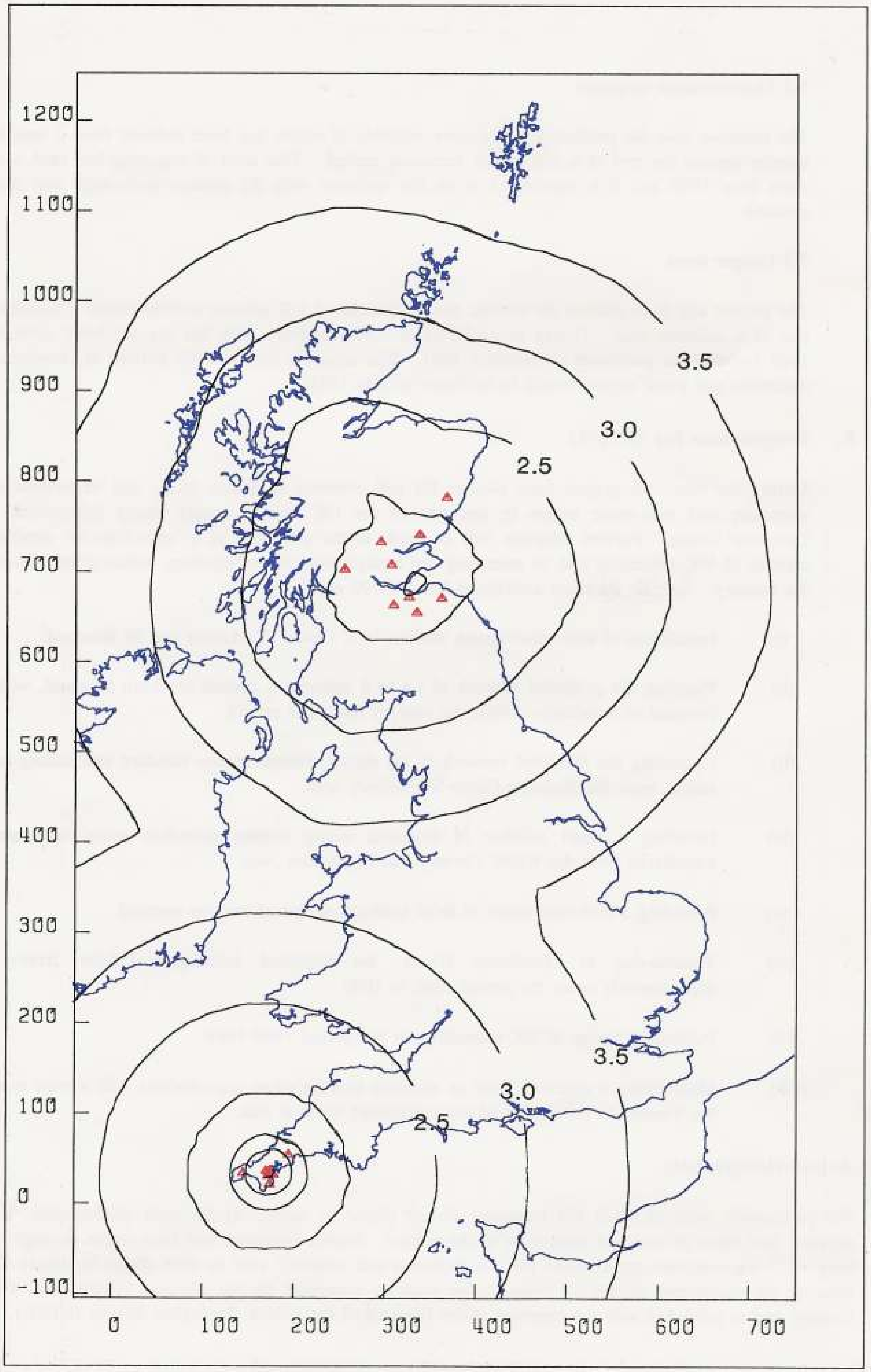

Figure 1. Detection capability of the Lowlands and Cornwall seismograph networks to which rapid access is available. Contours show the magnitude of an earthquake which would be detected by 5 stations in the presence of background noise of 20 nanometres at 10 Hz.

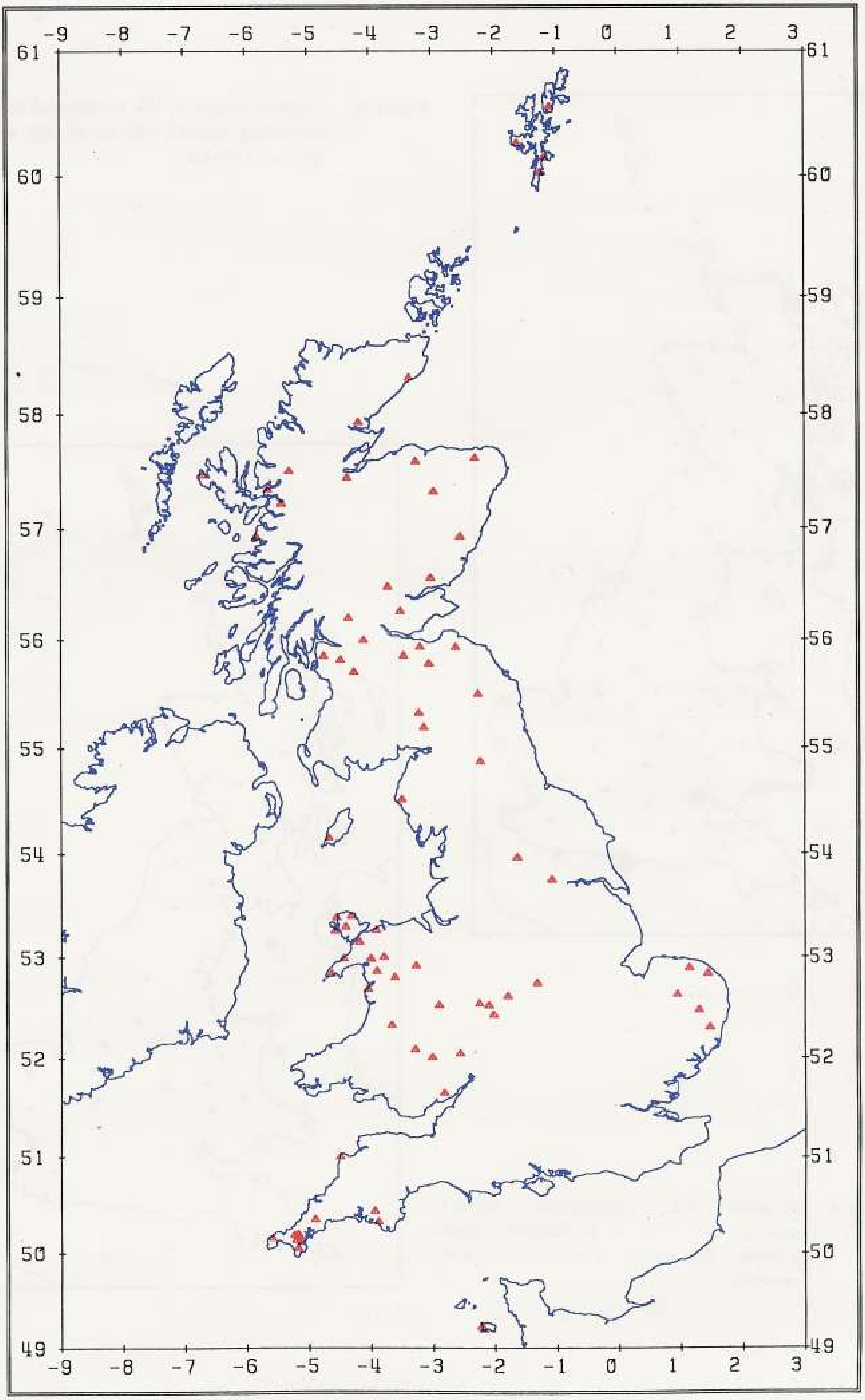

Figure 2. BGS seismograph network in 1988 prior to the commencement of the UK monitoring enhancement project.

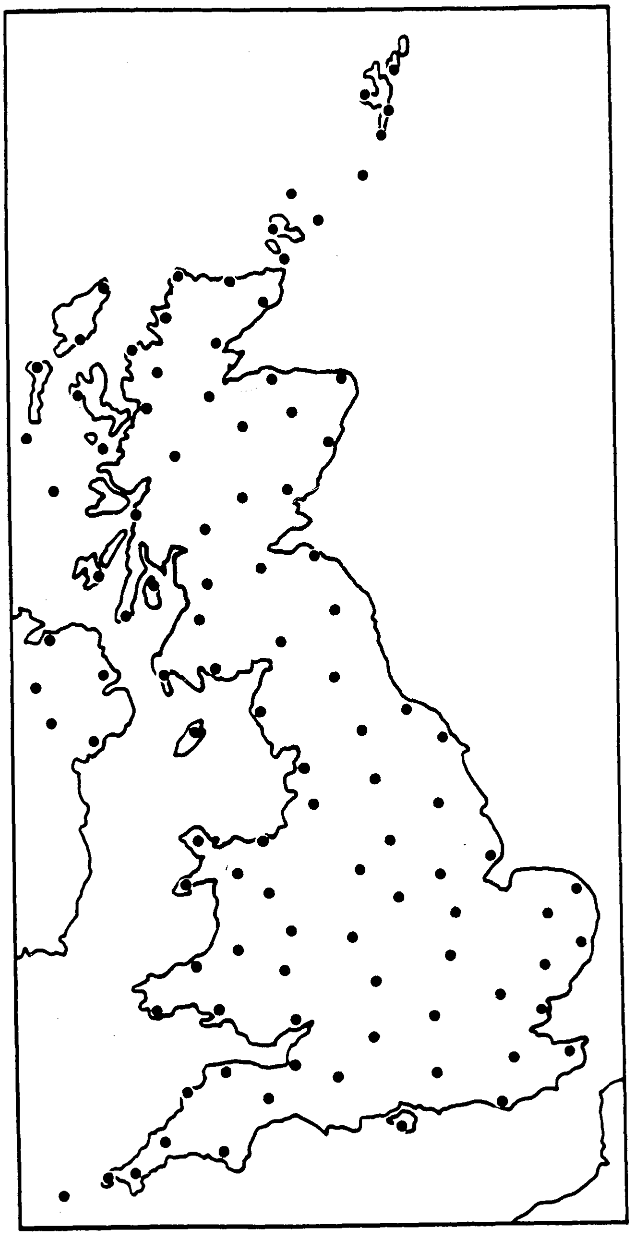

Figure 3. Proposed long-term UK background seismic monitoring network with an average station spacing of 70 km.

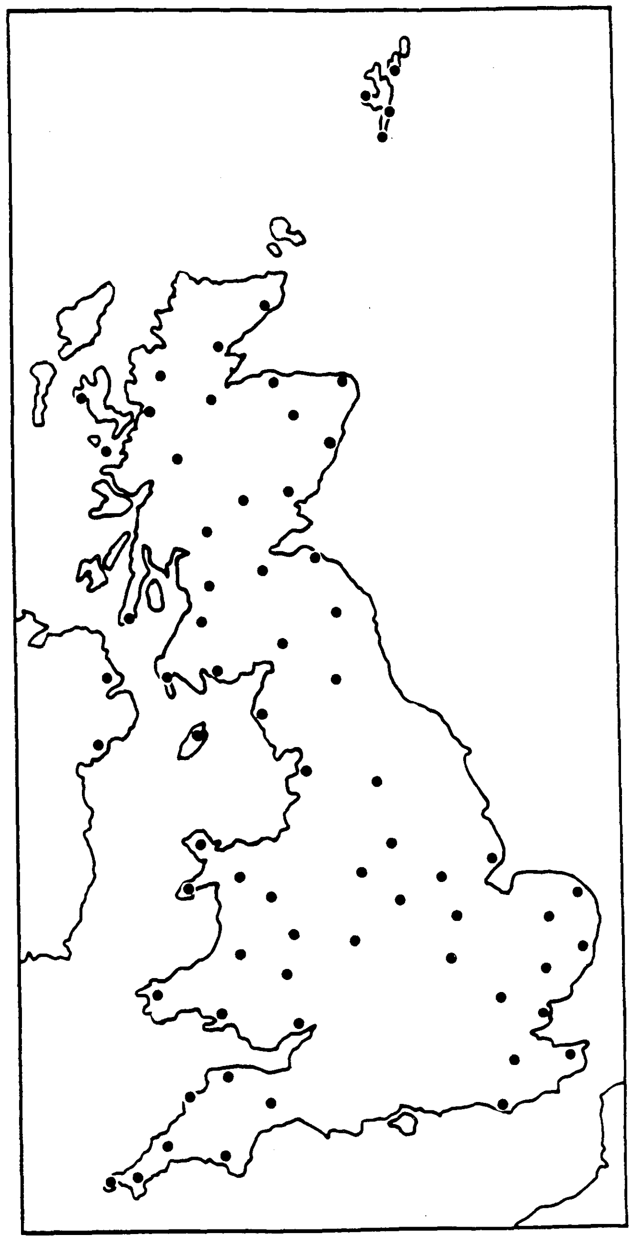

Figure 4. Proposed UK seismograph network coverage for 1991 at background station spacing discounting site-specific dense networks.

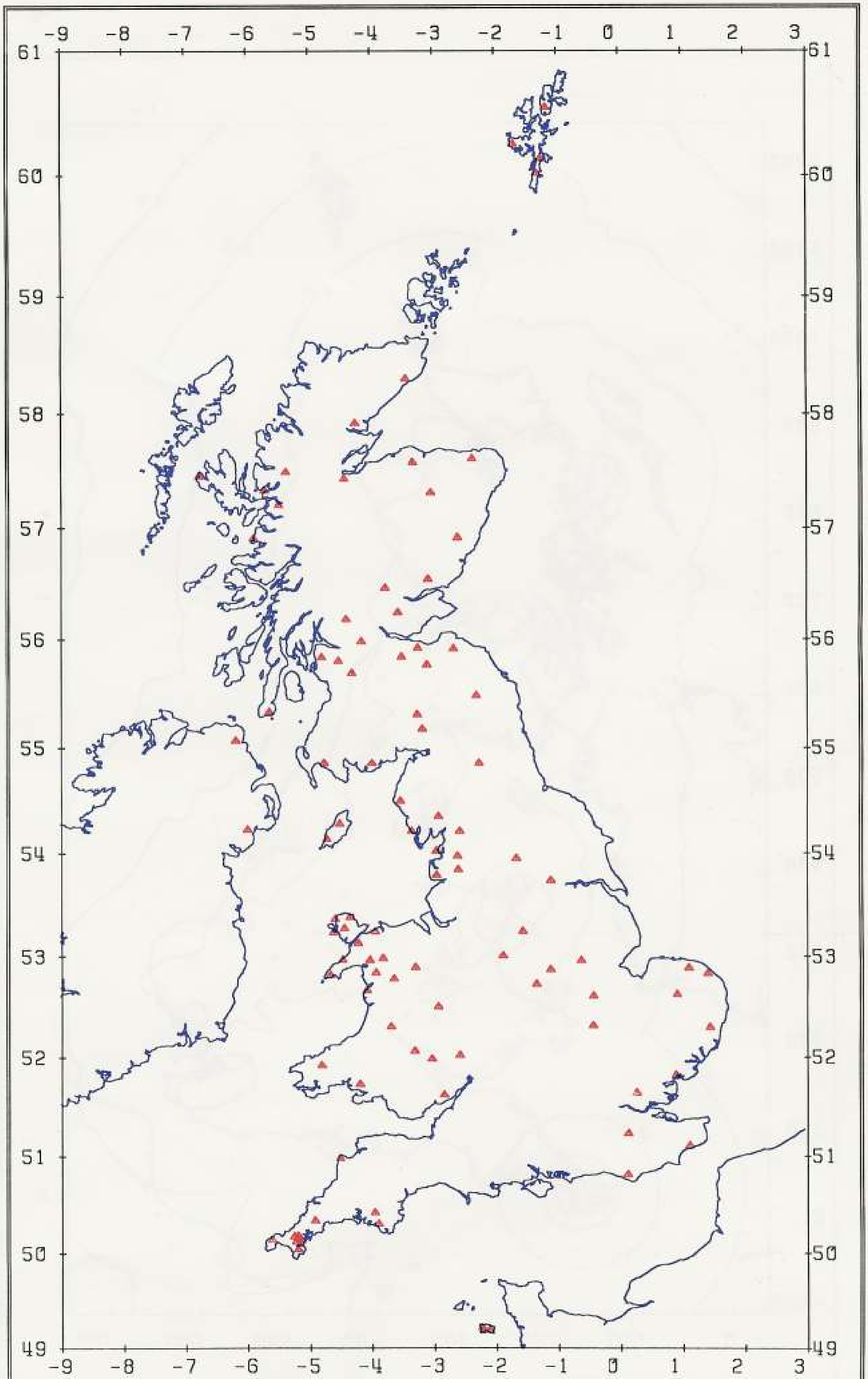

Figure 5. BGS seismograph network operational in December 1990.

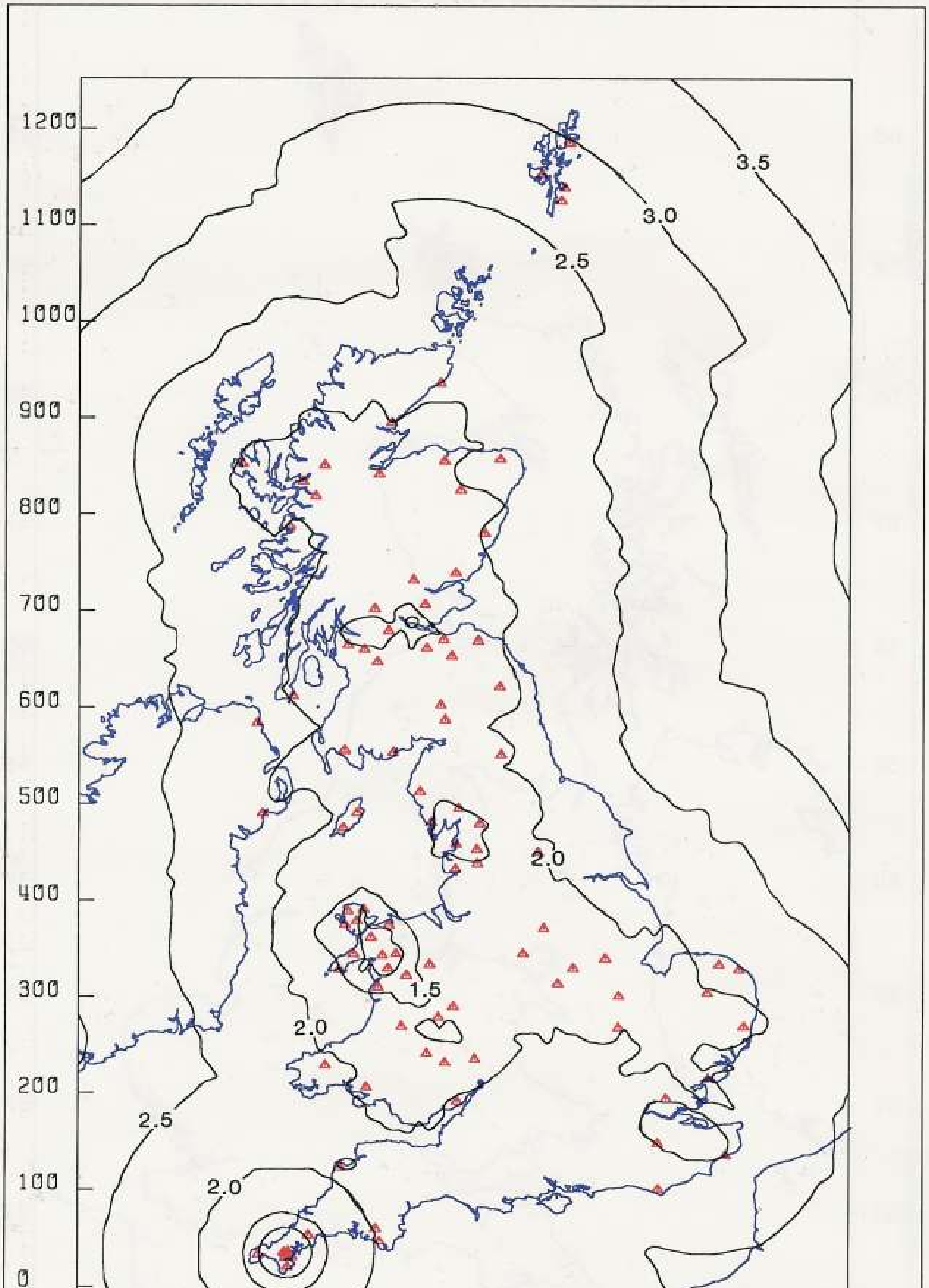

Figure 6. Earthquake identification capability. Contour values are Richter local magnitude (ML) for 20 nanometres of noise and S-wave amplitudes twice that at the fifth nearest

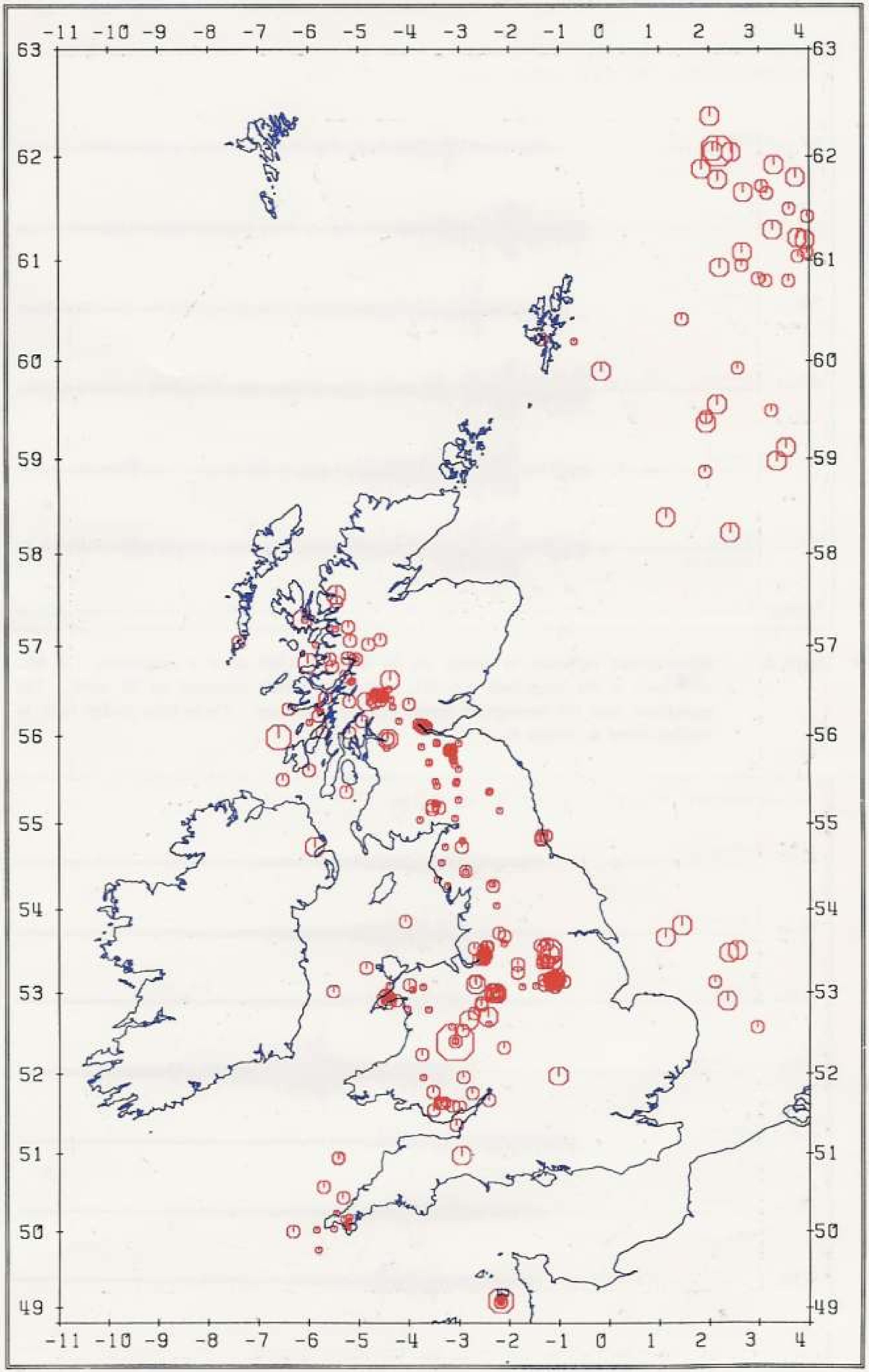

Figure 7. Epicentres of all UK earthquakes located in 1990.

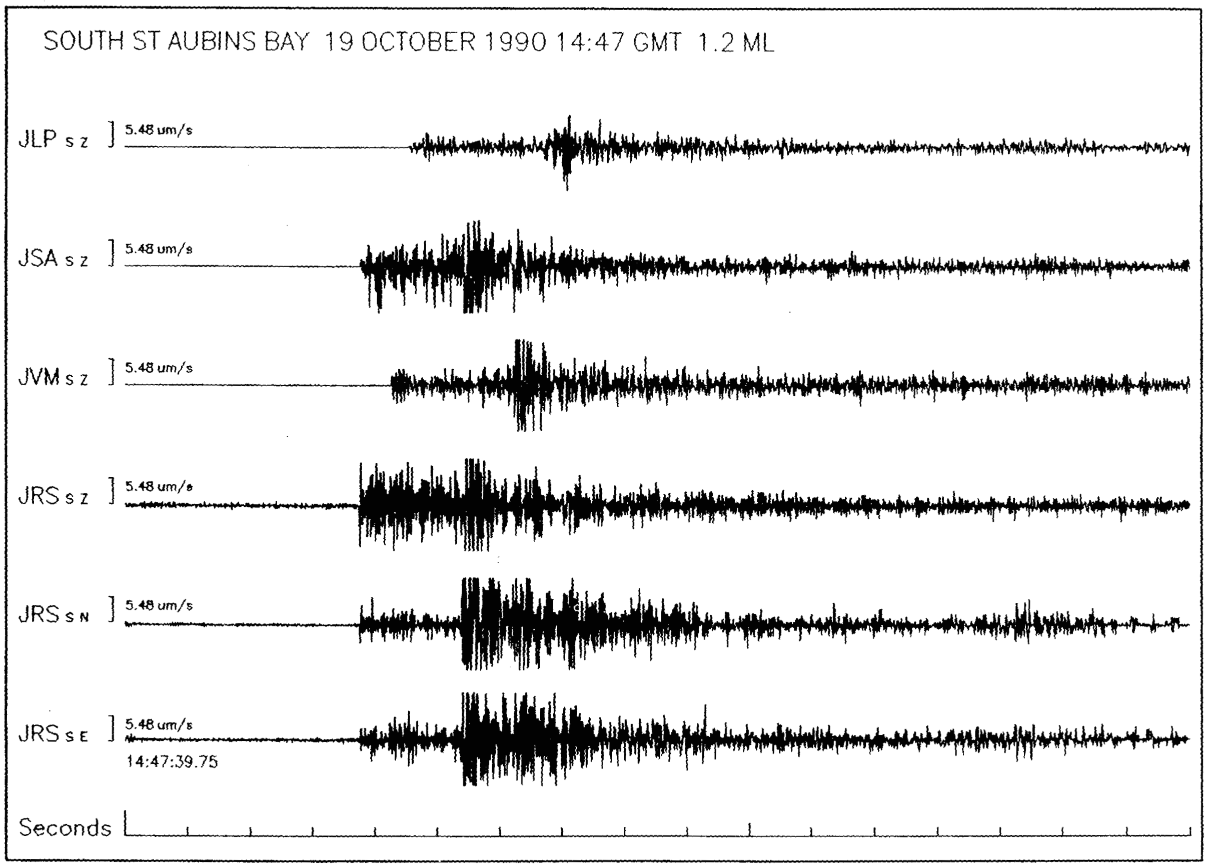

Figure 8. Seismograms recorded in Jersey on 19 October 1990 from a magnitude 1.2 ML aftershock of the magnitude 3.5 ML earthquake which occurred on 30 April. The mainshock was felt throughout Jersey and on Guernsey. Three-letter codes refer to stations listed in Annex E.

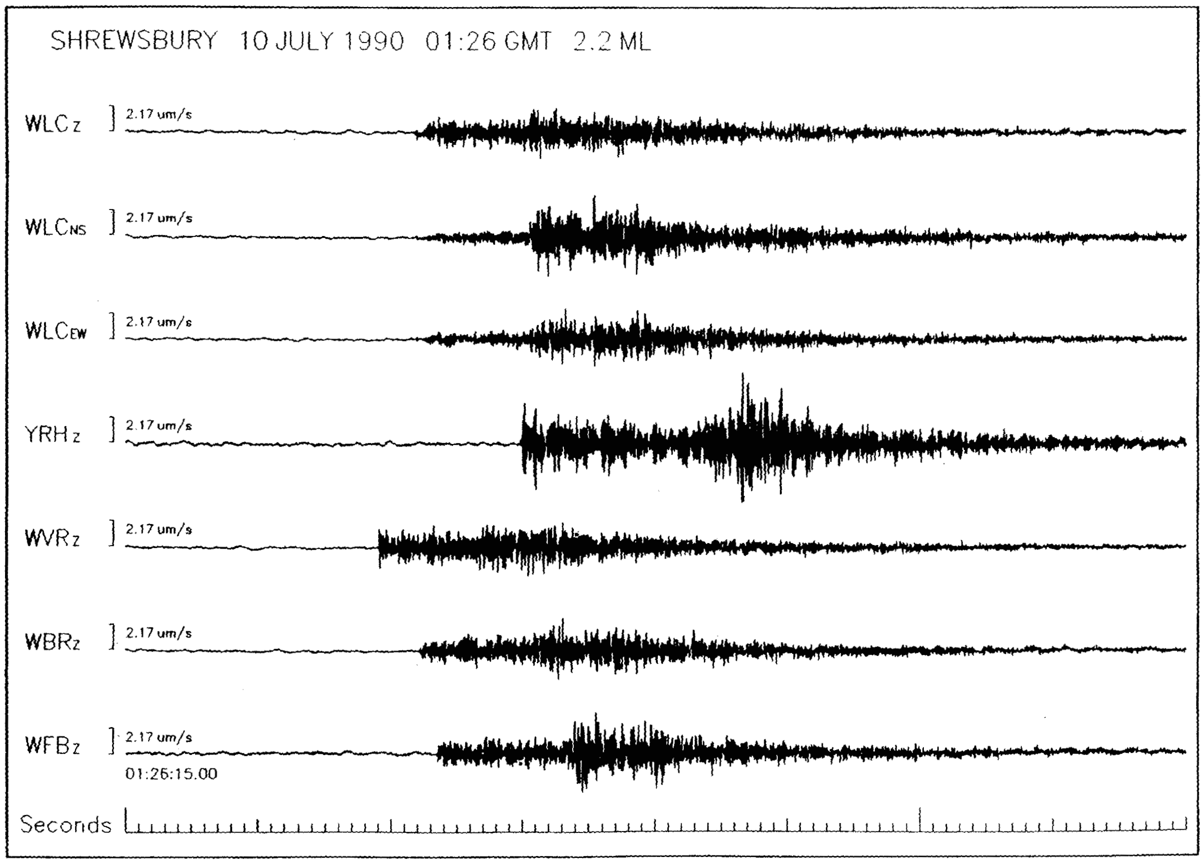

Figure 9. Seismograms recorded on the temporary Bishop's Castle network from a magnitude 2.2 ML earthquake felt in the Shrewsbury area on 10 July 1990.

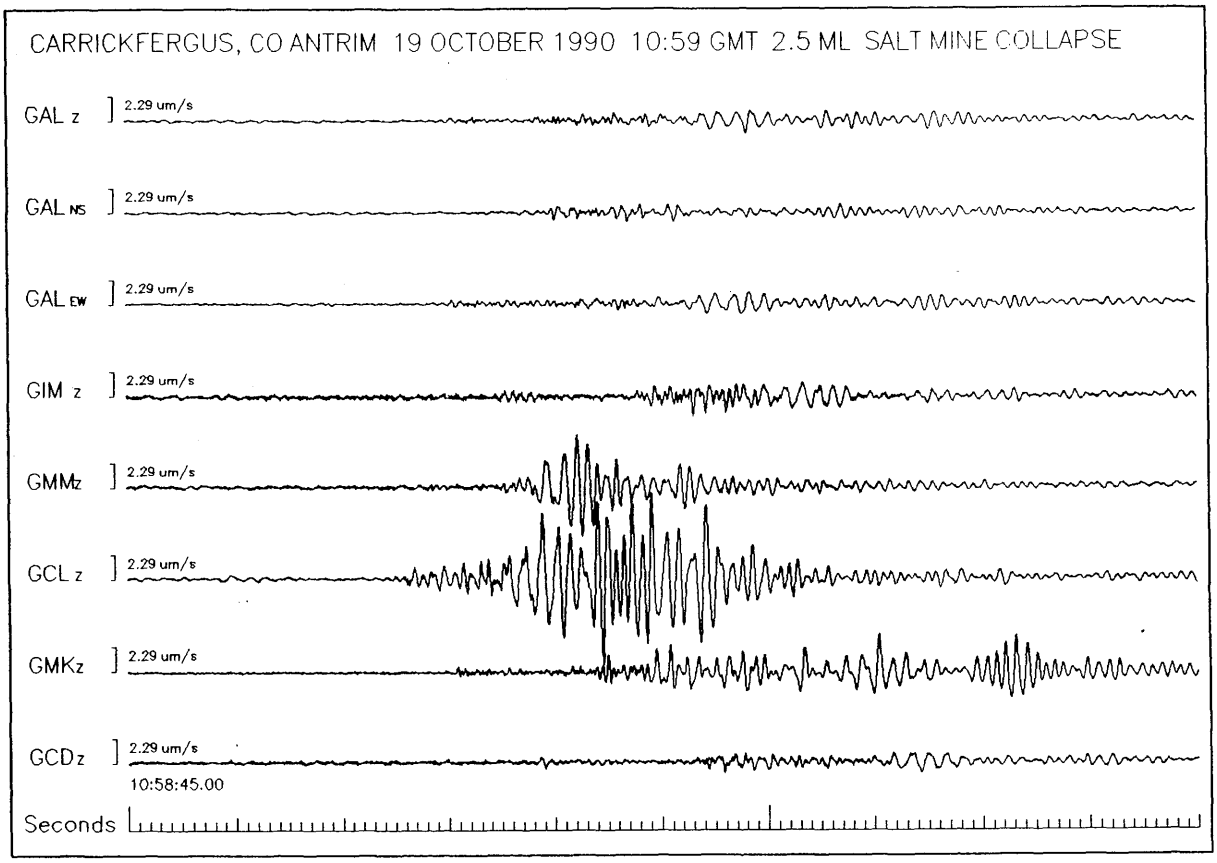

Figure 10. Seismograms recorder around the north Irish Sea from the collapse of an abandoned salt mine near Carrickfergus in N Ireland. It had a magnitude equivalent to 2.5 on the Richter scale. Three-letter codes refer to stations listed in Annex E.

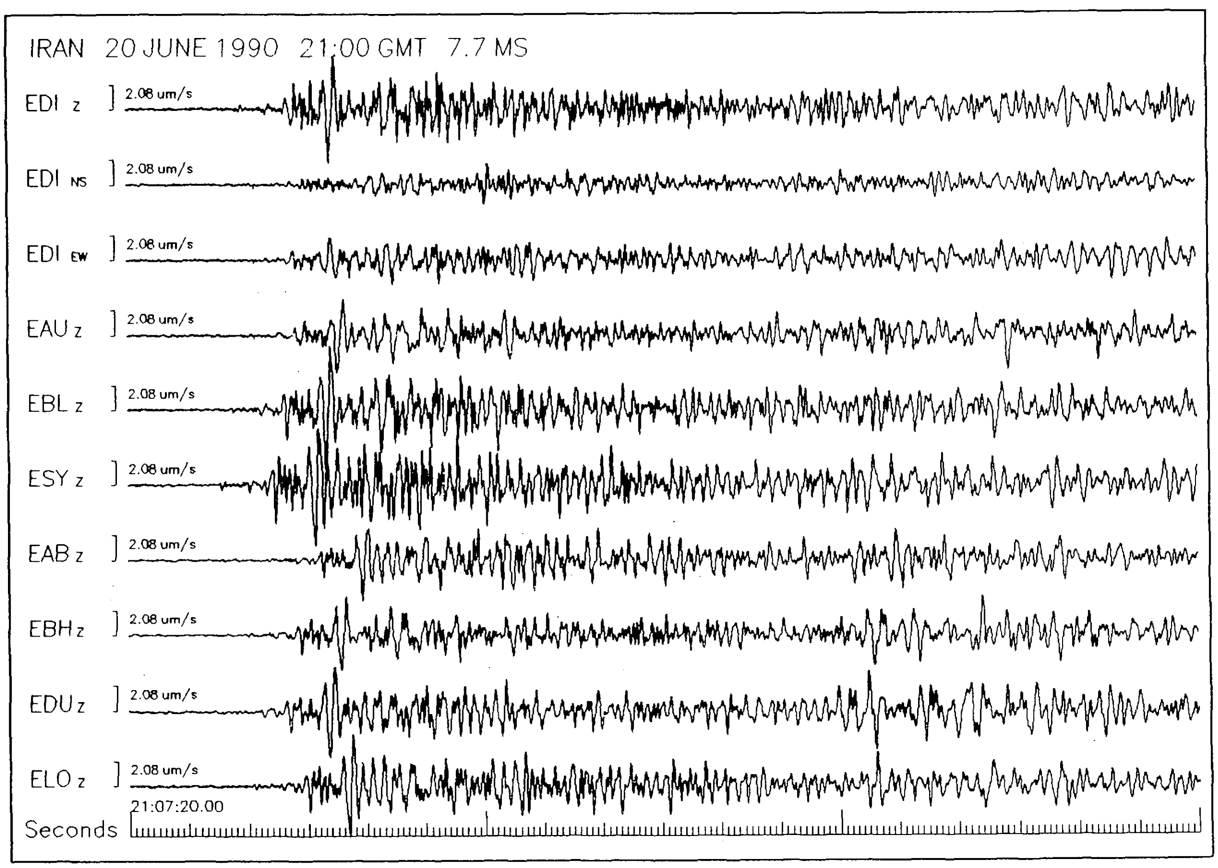

Figure 11. Seismograms recorded around Edinburgh from the magnitude 7.7 MS earthquake in NW Iran on 20 June 1990. Three-letter codes refer to stations listed in Annex E.

CONTRIBUTORS TO THE PROJECT

Department of the Environment
British Nuclear Fuels plc
AEA Technology
Department of Economic Development (N Ireland)
Department of the Environment (N Ireland)
Nuclear Installations Inspectorate
Scottish Hydroelectric plc
British Coal
Renfrew District Council
Natural Environment Research Council

Nuclear Electric plc	Data
Scottish Nuclear plc	Data
Ministry of Defence	Data
Department of Energy	Equipment

Customer Group Members (not contributing in Year Two)

British Gas
Nirex
Health and Safety Executive
Department of Trade and Industry
Scottish Development Department
Welsh Office
International Seismological Centre

EARTHQUAKES WITH MAGNITUDES ≥ 2.0 RECORDED IN THE UK AND OFFSHORE WATERS: 1990

EVENTS ≥2.0 ONSHORE UK

Date	HrMnSecs	Lat	Lon	KmE	KmN	Dep	Mag	Locality	Int	No	M	Gap	RMS	ERH	ERZ	Q	SQD	Comments...
060190	231515.1	55.98	-4.39	250.9	678.3	5.4	2.2	MILNGAVIE,STRATHCLYDE	4+	21	18	130	0.09	0.2	0.6	B	A*C	FELT STRATHBLANE,BEARSDEN & MILNGAVIE
090190	192059.1	56.64	-4.35	255.8	752.3	7.6	2.5	GLEN LYON,TAYSIDE	4+	28	44	119	0.28	0.8	2.1	C	B*C	FELT LOCH RANNOCH & GLEN LYON
260190	134230.8	56.00	-6.57	115.3	687.8	9.2	3.0	COLONSAY,STRATHCLYDE	4+	18	112	278	0.21	2.0	3.1	C	B*D	FELT ON COLONSAY (4 MSK) & IONA (2 MSK)
260190	200956.9	52.00	-0.98	470.2	233.6	16.3	2.1	BUCKINGHAM,BUCKS		10	54	205	0.19	1.2	2.2	C	B*D	
080290	015325.2	53.52	-1.16	455.8	402.5	17.9	3.0	DONCASTER,S YORKSHIRE	4	17	26	135	0.27	1.7	1.7	B	B*B	FELT SHEFFIELD,ROTHERHAM,THORNE,BARNSLEY
080290	052352.3	53.03	-2.26	382.3	348.2	1.5	2.0	STOKE-ON-TRENT,STAFFS	2+	17	68	167	0.27	1.4	1.4	C	B*D	FELT STOKE-ON-TRENT AREA
120290	093329.4	53.49	-1.15	456.2	399.8	12.7	2.4	DONCASTER,S YORKSHIRE		17	28	136	0.13	0.6	1.0	B	A*C	AFTERSHOCK
260290	130938.7	53.02	-2.21	385.7	346.8	4.5	2.4	STOKE-ON-TRENT,STAFFS	3+	25	25	75	0.25	0.6	1.5	C	B*C	FELT STOKE-ON-TRENT AREA
040390	001847.0	53.02	-2.22	385.5	347.5	4.2	2.8	STOKE-ON-TRENT,STAFFS	5	14	25	153	0.09	0.5	1.1	B	A*C	FELT THROUGHOUT NORTH STAFFORDSHIRE
040390	070919.4	53.02	-2.22	385.5	347.2	3.2	2.3	STOKE-ON-TRENT,STAFFS	3+	21	25	74	0.23	0.6	2.1	C	B*C	FELT STOKE-ON-TRENT AREA
140390	024106.2	51.01	-2.91	335.9	124.4	7.6	2.1	SOMERTON,SOMERSET		7	96	224	0.09			D	C*D	
020490	134634.2	52.43	-3.03	329.7	282.4	14.3	5.1	BISHOP'S CASTLE,SHROPS	6	18	14	63	0.12	0.5	0.6	A	A*A	FELT THROUGHOUT ENGLAND & WALES
040490	023914.1	53.13	-2.62	358.6	359.0	9.9	2.0	ALPRAHAM,CHESHIRE		18	50	80	0.13	0.4	0.6	B	A*C	
200490	002227.0	52.95	-4.40	238.6	342.4	24.8	2.0	LLEYN,GWYNEDD		21	3	105	0.09	0.3	0.8	B	A*B	AFTERSHOCK
300490	233557.3	49.13	-2.13	390.5	-86.0	8.1	3.5	ST AUBINS BAY,JERSEY	5	4	8	310	0.02	0.0	0.0	C	A*D	S OF ST AUBINS BAY, FELT THROUGHOUT JERSEY
160590	083240.7	52.74	-2.37	375.2	316.5	14.3	2.1	TELFORD,SHROPSHIRE		18	43	118	0.27	1.0	1.2	C	B*C	
230590	171255.3	57.30	-6.09	153.8	830.9	8.5	2.1	SKYE,HIGHLAND		11	27	314	0.18	2.1	2.7	C	B*D	
310590	183758.9	56.83	-5.99	156.8	778.2	4.6	2.2	ARDNAMURCHAN,HIGHLAND		11	120	270	0.12	2.4	4.0	C	B*D	OFFSHORE LOCATION
080690	005315.6	57.57	-5.42	195.7	858.8	10.8	2.4	GLEN TORRIDON,HIGHLAND	3+	20	11	155	0.38	1.4	2.7	C	C*C	FELT AT KINLOCHEWE
100790	012615.9	52.70	-2.76	348.6	311.6	8.4	2.1	SHREWSBURY,SHROPSHIRE	4+	26	15	70	0.26	0.7	1.5	B	B*B	FELT SHREWSBURY,TELFORD,CLUN,CLUNBERRY...
050990	061029.8	56.40	-4.81	226.7	726.8	2.7	2.0	TYNDRUM,CENTRAL		26	38	136	0.27	0.9	2.5	C	B*C	
191090	105906.2	54.75	-5.85	152.5	546.3	0.0	2.5	CARRICKFERGUS,ANTRIM	2+	13	41	147	0.30	1.1	1.5	C	B*C	SALT MINE SUBSIDENCE,FELT CARRICKFERGUS AREA

2.2ML INT. 4.

EVENTS ≥2.0 NORTH SEA REGION

Date	HrMnSecs	Lat	Lon	KmE	KmN	Dep	Mag	Locality	Int	No	DM	Gap	RMS	ERH	ERZ	Q	SQD	Comments...
070190	013142.0	61.20	3.93			7.6	2.3	NORTHERN NORTH SEA		13	48	290	0.29	2.6	1.9	D	C*D	
290190	114946.9	61.80	3.74			1.0	2.1	NORTHERN NORTH SEA		9	99	314	0.56	9.3	5.5	D	D*D	
050290	054958.6	61.66	2.70			0.4	2.3	NORTHERN NORTH SEA		5	129	334	0.10	5.5	2.3	D	D*D	
160290	191903.7	62.04	2.46			20.0	2.9	NORTHERN NORTH SEA		11	164	322	0.37	51.1	68.4	D	D*D	
120390	222612.4	53.52	2.58	703.5	12.4	1.4	2.8	SOUTHERN NORTH SEA		11	108	289	0.26	4.6	2.7	D	C*D	
240390	161158.5	53.49	2.41	692.5	408.3	0.5	2.7	SOUTHERN NORTH SEA		10	97	284	0.18	4.4	4.0	D	C*D	
040490	125318.2	61.88	1.87			22.2	2.4	NORTHERN NORTH SEA		13	179	242	0.25	6.9	8.0	D	D*D	
150490	120541.4	52.91	2.38	694.4	343.7	0.0	2.4	SOUTHERN NORTH SEA		10	64	310	0.26	5.5	4.7	D	D*D	
020590	131932.9	59.37	1.96			1.0	2.0	NORTHERN NORTH SEA		4	188	342	0.09	0.0	0.0	C	A*D	
030590	113007.5	60.93	2.23			2.2	2.0	NORTHERN NORTH SEA		10	138	278	0.41	4.1	2.9	D	C*D	
190790	140257.9	53.82	1.48	628.7	441.9	4.5	2.3	SOUTHERN NORTH SEA		5	110	345	0.04	3.0	3.4	D	C*D	
070890	160134.3	62.05	2.10			15.0	2.1	NORTHERN NORTH SEA		6	179	323	0.26	58.8	77.2	D	D*D	
090890	033238.1	61.22	3.78			11.3	2.0	NORTHERN NORTH SEA		4	56	344	0.17	0.0	0.0	C	B*D	
190890	103121.9	58.98	3.37			1.0	2.5	NORTHERN NORTH SEA		5	110	302	0.11	8.8	1.4	D	D*D	
190890	121924.1	59.12	3.55			0.5	2.4	NORTHERN NORTH SEA		5	97	293	0.10	5.5	3.2	D	D*D	
190890	142641.6	58.23	2.44			0.2	2.4	CENTRAL NORTH SEA		10	196	174	0.40	4.9	6.4	D	C*D	
300890	040549.9	59.56	2.18			19.6	2.7	NORTHERN NORTH SEA		29	178	110	0.73	2.4	4.9	D	D*D	
061090	055954.3	62.38	2.04			1.0	2.6	NORTHERN NORTH SEA		3	180	357	0.91	0.0	0.0	D	D*D	
071090	085751.3	61.92	3.31			0.2	2.6	NORTHERN NORTH SEA		10	98	324	1.55	17.8	9.8	D	D*D	
221090	021127.1	61.30	3.28			16.1	2.2	NORTHERN NORTH SEA		8	84	318	0.35	6.2	3.1	D	D*D	
311090	183256.3	61.78	2.19			1.0	2.6	NORTHERN NORTH SEA		9	159	331	0.28	39.2	46.8	D	D*D	
101190	064407.4	62.05	2.19			10.0	4.4	NORTHERN NORTH SEA		25	234	248	0.41	3.6	4.0	D	C*D	
191190	060951.5	58.39	1.16			7.6	2.9	CENTRAL NORTH SEA		24	324	168	0.27	3.5	1.8	D	C*D	
221190	234823.4	59.90	-0.13			6.5	2.4	SHETLAND ISLANDS		18	63	177	0.23	2.6	5.0	D	C*D	EAST OF SHETLAND ISLANDS
271290	031648.8	53.68	1.15	608.4	424.9	1.8	2.4	SOUTHERN NORTH SEA		12	88	249	0.71	5.1	3.1	D	D*D	

ANNEX B

F A X

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

TEL: 031 667 1000
TLX: 727343 SEISED G
FAX: 031 667 1877 GSRG BGS

TO:				
B R MARKER	- DOE		N J FULFORD	- BRITISH GAS
J COLLOFF	- BNFL		T JONES	- NIREX
A LORD	- BNFL		T A F WILLIS	- SSEB
C WILSON	- DED		P J FORD	- UKAEA
D J MALLARD	- CEGB		T M JOWITT	- BRITISH COAL
W P ASPINALL	- AA		F K GROSZMANN	- H&S EXEC
C BEAK	- HYDROBOARD		F D KANE	- DOE(NI)
R J STUBBS	- NII			
C PATCHETT	- NII		DIRECTOR	- BGS
			R T HAWORTH	- BGS, KEYWORTH
			M RAINES	- BGS, KEYWORTH
			B TAYLOR	- BGS, INFO SERVICES

FROM: C W A BROWITT

DATE: 1 MAY 1990

TIME: 15.15 BST +

PAGES TO FOLLOWS:

SEISMIC ALERT: JERSEY 30 APRIL 1990

AN EARTHQUAKE ON JERSEY IN THE EARLY HOURS OF THIS MORNING (23.35 GMT ON 30 APRIL 1990).

PROVISIONAL DETAILS ARE:

DATE:	30 APRIL 1990
TIME:	23.35 : 47.4 SEC GMT
LAT/LON:	49.14N -2.2W
MAGNITUDE:	4.0 MD (DURATION)
INTENSITY:	IV-V MSK

THE EVENT WAS ALSO FELT (AT LOWER INTENSITY) ON GUERNSEY.

AN AFTERSHOCK WITH MAGNITUDE 1.7 MD WAS DETECTED AT 23.44 WITH A PROVISIONAL EPICENTRE 5 KM TO THE EAST OF THE MAINSHOCK. IMPROVED SOLUTIONS SHOULD BE AVAILABLE TOMORROW ON RECEIPT OF DIGITAL DATA FROM JERSEY.

LDG REPORTED TO CSEM A LOCATION OF 49 DEG, 6 MIN NORTH, 2 DEG 5 MIN WEST AND MAGNITUDES OF 4.1 MD, 4.2 ML.

JERSEY HAS A KNOWN HISTORY OF ACTIVITY FOR THE PAST 300 YEARS WITH THE MOST SIGNIFICANT EVENTS THIS CENTURY OCCURRING ON 30 JULY 1927 (5.5 ML), 17 FEB 1927 (5.4 ML) AND 19 NOV 1927 (4.9 ML). THEIR EPICENTRES WERE PROBABLY TO THE EAST OF JERSEY NEAR THE NORMANDY COAST.

F A X

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

TEL: 031 667 1000
TLX: 727343 SEISED G
FAX: 031 667 1877 GSRG BGS

TO:				
B R MARKER	- DOE		N J FULFORD	- BRITISH GAS
J COLLOFF	- BNFL		T JONES	- NIREX
A LORD	- BNFL		J P McFARLANE	- SCOTTISH NUCLEAR
C WILSON	- DED		P J FORD	- UKAEA
D J MALLARD	- NUCLEAR ELEC		T M JOWITT	- BRITISH COAL
C F ALLEN	- NUCLEAR ELEC		K CASSIDY	- H&S EXEC
W P ASPINALL	- AA		F D KANE	- DOE(NI)
C BEAK	- HYDROBOARD			
R J STUBBS	- NII		DIRECTOR	- BGS
C PATCHETT	- NII		R T HAWORTH	- BGS, KEYWORTH
			M RAINES	- BGS, KEYWORTH
			B TAYLOR	- BGS, INFO SERVICES

FROM: M E A RITCHIE

DATE: 11 JULY 1990

TIME: 3.05 ONWARDS

PAGES TO FOLLOWS: NONE

FELT EVENT 10 JULY 1990, 01:26 GMT, 2.2 ML

FOLLOWING THE FAX ON 10 JULY 1990, ANALYSIS OF ANALOGUE TAPES HAS CONFIRMED AN EARTHQUAKE DID OCCUR. A PRELIMINARY LOCATION IS GIVEN BELOW:

DATE:	10 JULY 1990
TIME:	01:26 16.0 GMT
MAGNITUDE:	2.2 ML
LOCATION:	350.2 KmE, 310.6 KmN
DEPTH:	7.8 Km
SOLUTION QUALITY:	GOOD
EPICENTRAL ERROR:	± 1.7 Km
DEPTH ERROR:	± 4.4 Km

IT WAS FELT MAINLY IN THE SHREWSBURY AREA - (BAYSTON HILL, EXFORDS GREEN, HAUGHMOND HILL), TELFORD, CLUN, CLUNBURY, LYDBURY N AND CHURCH STRETTON.

THE LOCATION IS APPROXIMATELY 4 KM S OF CENTRAL SHREWSBURY. A FOCAL MECHANISM FOR THE EVENT IS BEING DETERMINED.

ANNEX C

ANNEX D

BGS STAFF WITH INPUT TO THE PROJECT

Dr C W A Browitt
Mr P S Day
Mr G D Ford
Mr C J Fyfe
Mr D D Galloway
Mr D J Houliston
Mr N S Hunt
Mr J Laughlin
Mrs Y Liu
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 D W Redmayne
Mrs J A Richards
Mrs M E A Ritchie
Mr B A Simpson
Mr D A Stewart
Mrs J H Shaw
Mr T Turbitt
Mr W A Velzian
Miss A B Walker
Mrs F Wright
Mr R M Young

GEOGRAPHICAL CO-ORDINATES OF BGS SEISMOGRAPH STATIONS: DECEMBER 1990

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-	4R	BGS
MDO	DOCHFOUR	57.441	-4.363	258.17	841.43	366	81-	1	BGS
MFI	FISHRIE	57.6116	-2.2953	382.36	857.97	220	88-	1	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	270.8	894.7	198	84-	1	BGS
KYLE									
KAC	ACHNASHELLACH	57.4999	-5.2982	202.4	850.3	330	83-	1	BGS
KAR	ARISAIG	56.9175	-5.8302	166.9	787.2	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	193.3	818.4	70	83-	1	BGS
KSK	SCOVAL	57.4653	-6.7020	118.1	851.4	250	89-	1	BGS
LOWNET									
EAB	ABERFOYLE	56.1881	-4.3400	254.80	701.95	250	69-	1R	BGS
EAU	AUCHINOON	55.8444	-3.4547	308.92	662.20	350	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	56.9189	-2.5392	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	732.23	495	69-	1R	BGS
ESY	STONEYPATH	55.9177	-2.6144	361.60	669.56	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	269.0	679.3	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
ESKDALEMUIR									
ESK	ESKDALEMUIR	55.3167	-3.2050	323.53	603.17	263	65-	4R	BGS
ECK	CAULDKAINE HILL	55.1812	-3.1271	328.23	588.02	337	81-	1R	BGS
XAL	ALLENDALE	54.8617	-2.2147	386.2	551.8	462	83-	1R	BGS
XDE	DENT	54.5058	-3.4897	303.5	513.3	291	83-	1R	BGS
XSO	SOURHOPE	55.4925	-2.2511	384.13	622.11	495	83-	1R	BGS
GALLOWAY AND N IRELAND									
GAL	GALLOWAY	54.8664	-4.7114	226.02	555.78	105	89-	4	BGS
GCD	CASTLE DOUGLAS	54.8638	-3.9417	275.39	553.84	189	89-	1	BGS
GCL	CUSHENDALL	55.076	-6.130	136.4	583.7	275	89-	1	BGS
GIM	N ISLE OF MAN	54.2923	-4.4670	239.45	491.34	366	89-	1	BGS
GMK	MULL OF KINTYRE	55.3459	-5.5936	172.18	611.65	160	89-	1	BGS
GMM	MTNS OF MOURNE	54.239	-5.951	142.6	489.8	140	89-	1	BGS
LANCASHIRE									
LBO	BOWLAND	53.9790	-2.5728	362.44	453.83	320	89-	1	BGS
LBH	MORECOMBE B102	54.0259	-2.9058	340.68	460.0	-85	90-	1	BGS
LCK	CROOK	54.3595	-2.8715	343.37	496.36	200	89-	1	BGS
LKL	KIRKBY LONSDALE	54.2185	-2.5345	365.15	480.46	396	89-	3	BGS
LLO	LONGRIDGE	53.8503	-2.5598	363.18	439.51	247	89-	3	BGS
LLY	LYTHAM ST.ANNES	53.7976	-2.9069	340.27	433.88	33	89-	1	BGS
LMI	MILLOM	54.2206	-3.3070	314.79	481.35	140	89-	3	BGS

GEOGRAPHICAL CO-ORDINATES OF BGS SEISMOGRAPH STATIONS: DECEMBER 1990

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (m)	Yrs Open	Comp	Agency
LEEDS									
HPK	HAVERAH PARK	53.9554	-1.6240	424.67	451.12	227	78-	4R	BGS
NORTH WALES									
WBR	BRONABER	52.8560	-3.8941	272.48	330.43	340	85-	1	BGS
WCB	CHURCH BAY	53.3782	-4.5465	230.63	389.86	135	85-	3	BGS
WFB	FAIRBOURNE	52.6830	-4.0378	262.26	311.46	325	85-	1	BGS
WFF	FFESTINIOG	52.9788	-3.9877	266.55	344.26	500	85-	2	BGS
WIM	ISLE OF MAN	54.1472	-4.6735	225.41	475.70	365	85-	1	BGS
WLC	LLYN CONWY	52.9956	-3.7788	280.63	345.76	440	85-	3	BGS
WLF	LLYNFAES	53.2893	-4.3966	240.26	379.63	65	85-	1	BGS
WME	MYNDD EILIAN	53.3966	-4.3034	246.86	391.36	130	85-	1	BGS
WPM	PENMAENMAWR	53.2583	-3.9049	272.94	375.19	350	85-	1	BGS
WST	STWLAN	52.975	-3.989	266.45	343.85	580	86-	1	BGS
WVR	VYRNWY	52.7974	-3.6051	291.79	323.44	580	85-	1	BGS
YRC	RHOSCOLYN	53.2506	-4.5741	228.28	375.74	24	84-	1	BGS
YRE	YR EIFL	52.9810	-4.4254	237.18	345.41	197	84-	1	BGS
YLL	LLANBERIS	53.1402	-4.1704	254.84	362.56	162	84-	1	BGS
YRH	RHIW	52.8335	-4.6289	222.93	329.5	300	84-	1	BGS
KEYWORTH									
CWF	CHARNWOOD FST	52.7382	-1.3071	446.78	315.88	185	75-	3R	BGS
KBI	BIRLEY GRANGE	53.2551	-1.5275	431.52	373.26	270	88-	1	BGS
KEY	KEYWORTH	52.8774	-1.0751	462.24	331.54	75	88-	1	BGS
KSY	SYSTON	52.9642	-0.5873	494.87	341.73	123	88-	1	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-	1	BGS
KWE	WEAVER FARM	53.0165	-1.8412	410.65	346.62	330	88-	1	BGS
EAST ANGLIA									
ABA	BACONSTHORPE	52.8875	1.1471	611.7	336.9	13	82-	1	BGS
APA	PACKWAY	52.2999	1.4779	637.1	272.6	35	84-	1	BGS
AWH	WHINBURGH	52.6299	0.9512	599.70	307.70	60	80-	1R	BGS
AWI	WITTON	52.8324	1.4460	632.1	331.7	35	83-	1	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	229	78-	4	BGS
HAE	ALDERS END	52.0376	-2.5475	362.45	237.88	224	82-	1	BGS
HCG	CRAIG GOCH	52.3224	-3.6567	287.1	270.7	511	80-	1R	BGS
HGH	GRAY HILL	51.6380	-2.8064	344.2	193.6	210	80-	1	BGS
HLM	LONG MYND	52.5169	-2.8878	339.8	291.4	259	84-	1	BGS
HTR	TREWERN HILL	52.0790	-3.2697	313.0	243.1	329	82-	1	BGS
SSP	STONEY POUND	52.4177	-3.1119	324.39	280.59	417	90-	3	BGS
SOUTH EAST ENGLAND									
TFO	FOLKSTONE	51.1136	1.1406	619.8	139.6	188	89-	1	BGS
TEB	EASTBORNE	50.8188	0.1459	551.3	104.5	70	89-	1	BGS
TSA	SEVENOAKS	51.2427	0.1558	550.4	151.5	170	89-	1	BGS
TBW	BRENTWOOD	51.6549	0.2911	558.4	197.8	82	89-	1	BGS
TCR	COLCHESTER	51.8349	0.9215	601.2	219.2	40	89-	1	BGS

GEOGRAPHICAL CO-ORDINATES OF BGS SEISMOGRAPH STATIONS: DECEMBER 1990

Code	Name	Lat	Lon	GrE (Kms)	GrN (Kms)	Ht (m)	Yrs Open	Comp	Agency
CORNWALL									
CCA	CARNMENELLIS	50.1864	-5.2277	169.62	36.87	213	81-	1	BGS
CBW	BUDOCK WATER	50.1482	-5.1144	177.52	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
CME	MENERDUE FARM	50.1760	-5.1903	172.23	35.60	178	82-	3	BGS
CPZ	PENZANCE	50.1560	-5.5835	144.06	34.65	198	81-	1	BGS
CR2	ROSEMANOWES 2	50.1669	-5.1687	173.7	34.5	152	81-	3	BGS
CRA	RAME	50.1648	-5.1921	172.06	34.36	198	82-	3	BGS
CRQ	ROSEMANOWES	50.1672	-5.1728	173.44	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	34.46	191	82-	3	BGS
DEVON									
DCO	COMBE FARM	50.3200	-3.8724	266.72	48.42	410	82-	1	BGS
DYA	YADSWORTHY	50.4352	-3.9309	262.89	61.33	280	82-	3	BGS
HTL	HARTLAND	50.9944	-4.4850	225.63	124.66	91	81-	4R	BGS
HSA	SWANSEA	51.7478	-4.1543	251.3	207.7	274	87-	1	BGS
HPE	PEMBROKE	51.9371	-4.7745	209.27	230.18	355	90-	1	BGS
JERSEY									
JLP	LES PLATONS	49.2428	-2.1039			131	81-	1	BGS
JSA	ST AUBINS	49.1879	-2.1709			21	81-	1	BGS
JRS	MAISON ST LOUIS	49.1924	-2.0917			53	81-	3	BGS
JVM	VAL DE LA MARE	49.2169	-2.2068			64	81-	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 and the agency operating the station (in this list they are all BGS).
3. The 'R' against some station components indicates that station details have been registered with international agencies for data exchange purposes.

PROJECT PUBLICATIONS **ANNEX F**

BGS SEISMOLOGY REPORTS

1990

WL/90/13	Browitt, C.W.A. UK Earthquake Monitoring 1989/90, BGS Seismic Monitoring and Information Service, First Annual Report.
WL/90/23	Musson, R.M.W. The 16 November 1847 Newport earthquake.
WL/90/26	Musson, R.M.W. Fatalities in British earthquakes.
WL/90/28	Musson, R.M.W. A provisional catalogue of UK earthquakes greater than 4 ML, 1700-1990.
WL/90/32	Ritchie, M.E.A., Musson, R.M.W. and Woodcock, N.H. The Bishop's Castle earthquake of 2 April 1990.
WL/90/33	Musson, R.M.W., Neilson, G. and Burton P.W. Macroseismic reports on historical British earthquakes XIV: 22 April 1884.
WL/90/37	Musson, R.M.W. The Colchester Forgeries: Faking photographic evidence of earthquake damage.
WL/90/43	Ritchie, M.E.A. and Musson, R.M.W. The Shrewsbury earthquake of 10 July 1990.
WL/90/47	Walker, A.B. The Jersey earthquake of 30 April 1990.
WL/90/49	Turbitt, T. (Ed.), Galloway, D.D., Hunt, N.S., Marrow, P.C., Musson, R.M.W., Redmayne, D.W., Richards J.A., Ritchie, M.E.A., Simpson, B.A. and Walker, A.B. Bulletin of British earthquakes 1989.

1991

WL/91/14	Musson, R.M.W. Single diagnostic analysis of earthquake effects.
WL/91/17	Musson, R.M.W. Macroseismic data for the 17 March 1871 Kendal earthquake.
WL/91/22	Ritchie, M.E.A. and Walker, A.B. Focal Mechanisms and the determination of stress directions in western Britain.

In addition, nine confidential reports were prepared for commercial customers and bulletins of seismic activity were produced monthly, one month in arrears for the Customer Group sponsoring the project.

EXTERNAL PUBLICATIONS

Musson R.M.W., 1990. Deadly British earthquakes, *Geophys. J. Inter.*, **101:1**, 293.

Musson, R.M.W., 1990. An unknown 18th century seismological manuscript, *BSSA,* **80:4**, 1026-1027.

Ritchie, M.E.A. and Musson, R.M.W., 1990. Bishop's Castle earthquake, *SECED Newsletter,* **4:3**, 7-9.

Ritchie, M.E.A., Musson, R.M.W. and Woodcock, N.H., 1990. The Bishop's Castle earthquake of 2 April 1990, *Terra Nova,* **4,** 390-400.

Turbitt, T. & Browitt, C.W.A., 1990. Seismograph networks of the United Kingdom; present and future, *Cahiers du Centre Européen de Géodynamique et de Séismologie,* **1**, publ. Joseph Beffort, Luxembourg.

UK EARTHQUAKE MONITORING 1989/90

C W A Browitt

Following a number of years of ad hoc seismic monitoring in the UK by the British Geological Survey and an increased need for the assessment of earthquake risk, the Department of Environment, together with the Natural Environment Research Council, have coordinated the provision of information on seismic events with the support of a number of public and private sector sponsors. The first year of the project, reported here, has yielded a significant improvement in the coverage of the UK with seismic monitoring stations. In addition to the many small events recorded during the year, an earthquake centred near Bishop's Castle in Shropshire, on 2 April 1990, proved to be one of the largest in Britain this century with a Richter magnitude of 5.1. It was felt over most of England and Wales and in southern Scotland and eastern Ireland with minor damage being sustained in Shrewsbury, Wrexham and villages near the epicentre.

THE 16 NOVEMBER 1847 NEWPORT EARTHQUAKE

R M W Musson

The 1840s appears to be a period of British seismic history which has been neglected in the past, leading to a number of events being ommitted from previous catalogues. One of these is the 16 November 1847 Newport earthquake, which had a magnitude of 3.2 ML and a maximum intensity of 5 MSK.

FATALITIES IN BRITISH EARTHQUAKES

R M W Musson

The number of recorded fatalities from British earthquakes is low. Over the period for which records are reliable only eleven deaths can be substantiated, of which only eight were directly due to the earthquake, and only four were due to falling masonry. The number of events causing deaths is eight, ranging in date from 1580 to 1940.

The earthquakes which have caused deaths in Britain are not always the largest, confirming the general trend in earthquake epidemiology that magnitude and fatalities do not correlate well.

A PROVISIONAL CATALOGUE OF UK EARTHQUAKES GREATER THAN MAGNITUDE 4 ML, 1700-1990

R M W Musson

A new catalogue of British earthquakes is presented, covering the area 10°W -2°E, 49-62°N. All known earthquakes of magniutde 4.0 ML and greater are included for the period 1700-1990. For these parameters the completeness of the catalogue is reasonably homogeneous for the onshore UK. Before 1700 relatively few events can be accurately determined.

For each earthquake, data, epicentre, magnitude and location are given, with codes indicating the agencies from which the epicentres and magnitudes have been derived. Times are only given when more than one event occurs on the same day. The catalogue is provisional in status and further updates are planned.

THE BISHOP'S CASTLE EARTHQUAKE OF 2 APRIL 1990

M E A Ritchie, R M W Musson and N H Woodcock

A large earthquake, by British standards, occurred near Bishop's Castle in the Welsh Borders on 2 April 1990 at 1346 GMT. This magnitude 5.1 ML event was felt over a wide area of Britain, from Ayrshire in the north to Cornwall in the south, Kent in the east and Dublin in the west. The epicentre was near the village of Clun, 7 km SSW of Bishop's Castle. Damage was minor and limited to the epicentral area, north to Wrexham and in particular Shrewsbury, which suffered most. Results from a macroseismic survey by the BGS revealed that the maximum intensity in the epicentral area was 6 MSK.

The mainshock had a focal depth of 14.3 $\pm$4.7 km; however, better located aftershocks further constrained the mid-crustal seismicity to 15 $\pm$0.2 km in the best cases. The limited number of aftershocks contrasts with some previous similar magnitude events for intraplate earthquakes in Britain and throughout the world, and may represent a large stress drop due to almost total relief of strain energy by the mainshock. The aftershock epicentral distribution shows a preference for an approximately N-S orientation which is consistent with one of the focal planes of the mainshock focal mechanism and suggests that this is the fault plane. Movement on this plane was predominantly strike-slip with a component of thrust and was consistent with a maximum compressive stress axis orientated NW-SE. The NE striking Welsh Borderland Fault System dominates the epicentral area; however, there is no surface fault which can clearly be related to the seismicity.

MACROSEISMIC REPORTS OF HISTORICAL BRITISH EARTHQUAKES XIV: 22 APRIL 1884 COLCHESTER

R M W Musson, G Neilson and P W Burton

The Colchester earthquake of 22 April 1884 was the most damaging one to affect the UK since the Dover Straits earthquake of 6 April 1580. It is also the best illustrated, with many contemporary photographs and drawings of the damage extant, and perhaps also the most famous British earthquake.

Although a number of modern studies of this earthquake have been completed since the 1970s, the present study is the most comprehensive, and the first since Meldola and White (1885) to give due attention to the far-field effects.

The epicentral intensity is estimated as 8 MSK, the epicentre being about 10 km south of Colchester. The magnitude is estimated as 4.7 ML, with a focal depth of 2 km.

THE COLCHESTER FORGERIES: FAKING PHOTOGRAPHIC EVIDENCE OF EARTHQUAKE DAMAGE

R M W Musson

The photographic archive of the 22 April 1884 Colchester earthquake, the most damaging British earthquake in the last 400 years, is well-known. Evidence has come to light that at least two of these photographs are partly or wholly faked. This shows that not event the camera can necessarily be relied upon to accurately portray the extent of damage from historical earthquakes.

THE SHREWSBURY EARTHQUAKE OF 10 JULY 1990

M E A Ritchie and R M W Musson

A small earthquake occurred on 10 July 1990 at 01:26 GMT and was felt strongly in Shrewsbury. The magnitude of the event was 2.2 ML, a relatively frequent occurrence in Britain, with a few of this magnitude and greater occurring on average every month. The media attention and public response to this small earthquake were unexpectedly high considering its size. The reason for this overraction was its proximity to the epicentre of the Bishop's Castle event of 2 April 1990 which, at magnitude 5.1 ML, was one of the largest in Britain this century and generated immense media attention (Ritchie et al, 1990). This study examines the possibility of a tectonic relationship between the two events or whether they represent isolated centres of seismicity.

THE JERSEY EARTHQUAKE OF 30 APRIL 1990

A B Walker

On 30 April, 1990, an earthquake with a Richter magnitude of 3.5 ML was felt throughout the island of Jersey; in many places with an intensity sufficient to awaken people and dislodge unstable objects. Elsewhere, it was experienced with intensities like a heavy object falling and with doors, windows and the walls of houses shaking, but there was no structural damage. It was also felt in Guernsey, 45 km to the north-west, at a lower, less alarming, intensity but there were no reports from the French coast, a similar distance to the east.

The magnitude, precise time and location of the event were determined using the Jersey seismograph network which was installed in 1981 by the Jersey Meteorological Department, Jersey New Waterworks Company and the British Geological Survey. The earthquake, together with a number of aftershocks had epicentres approximately 8 km south of St Aubins bay at depths of around 8 km. The aftershocks were much smaller with magnitudes in the range -0.8 to 1.2 ML and were not felt by the people of Jersey.

An interpretation of the focal mechanism of the mainshock and the larger aftershocks shows that movement was thrust faulting with a component of strike-slip on a plane either striking approximately NW and dipping 35° to the WSW, or striking ENE and dipping 76° to the NNW. The result is consistent with the approximately NW-SE compressive stress direction determined for other localities in the UK and France.

BULLETIN OF BRITISH EARTHQUAKES 1989

T Turbitt (Editor)

The largest earthquakes of the year, on land, occurred on 23 April at Gainsborough, Lincolnshire and on 5 September at Loftus, Cleveland, both with magnitude 2.4 ML. The former event, having a deep focus, was not felt but the latter, being shallow, reached intensity 5 MSK at Loftus.

Swarms of small earthquakes occurred at Stoke-on-Trent in Staffordshire (30 events) and at Thoresby in Nottinghamshire (24 events, 15 of them felt at intensity 2). The Thoresby events are related to mine-workings.

Other notable natural earthquakes that were reported felt were: Ullapool, 28 February (2.2 ML; Intensity 2), Loch Nevis, 22 October (2.2 ML; Intensity 2), Ettrick, 10 October (1.6 ML; Intensity 3) and Bargoed, 24 March (1.5 ML; Intensity 2).

A number of coal mining areas were affected by mining-induced earthquakes. In addition to the Thoresby area of Nottinghamshire, the Fife/Clackmannan and Midlothian coalfields in Scotland and the coalfields around Manchester, Cheshire, Nottinghamshire and the north east of England all experienced events, a number of which were felt. With the cessation of mining in the latter part of the year, the number of events detected in the Midlothian coalfield has rapidly decreased.

Aftershock activity, following the 5.4 ML earthquake on the Lleyn Peninsula in 1984, has continued at a low level (14 events). All of these aftershocks are at more than 21 km focal depth and none were felt at the surface.

Offshore, magnitude 3.8 ML and 3.9 ML earthquakes occurred in the Bay of Biscay on 6 April and 21 August, respectively, and on 9 October a magnitude 3.2 ML earthquake was detected in the southern North Sea.

SINGLE DIAGNOSTIC ANALYSIS OF EARTHQUAKE EFFECTS

R M W Musson

Single diagnostic analysis is a technique designed to provide a new way of examining macroseismic data. It provides an alternative to conventional macroseismic analysis using intensity scales and circumvents the element of subjectivity inherent in the use of conventional scales. The technique is illustrated with respect to the effects of the 19 July 1984 Lleyn earthquake in North Wales.

MACROSEISMIC DATA FOR THE 17 MARCH 1871 KENDAL EARTHQUAKE

R M W Musson

The earthquake of 17 March 1871 was one of the strongest to affect the north of England. The files of 104 local newspapers have been searched, and the data relevant to this earthquake has been extracted, sorted by place, and presented in a form suitable for further analysis.

FOCAL MECHANISMS AND THE DETERMINATION OF STRESS DIRECTIONS IN WESTERN BRITAIN

M E A Ritchie and A B Walker

Microseismicity in Britain can be used to provide valuable evidence on the nature of the brittle crust, the ambient regional stress regime and local deviations. Earthquake focal mechanism analysis can provide constraints on the principal stress directions for depths anywhere within the brittle crust and thus has the advantage over other methods which sample only the top 3 km of the upper crust. Fault plane solutions were obtained for 43 small magnitude (-0.5 to +2.4 ML) earthquakes in North Wales and Cornwall at depths ranging from 3.2 to 20.3 km. The principal stress axes were constrained by combining the fault plane solutions in each region in order to find segments common to all solutions within the compressional and dilatational quadrants. Data from Cornwall suggests that the horizontal axis of maximum compression is aligned NW-SE; however, most mechanisms in North Wales are consistent with horizontal compression acting in a NNW-SSE direction. Local deviations of the regional stress tensor are thought to correlate with major geological features.

The principal axis of compression shows an apparent clockwise rotation of approximately 25° between Cornwall and North Wales and is thought to reflect the regional trend associated with spreading at the mid-Atlantic ridge. The focal mechanisms examined suggest that the driving force for earthquakes in Britain is ridge-push from the mid-Atlantic ridge system, and the dominance of strike-slip solutions indicates that the brittle crust is subject to high horizontal stresses.

AN UNKNOWN 18TH CENTURY SEISMOLOGICAL MANUSCRIPT

R M W Musson

The chief claim to seismological fame of the Cornish antiquarian William Borlase (1695-1772) rests on his study of the 15 July 1757 Penzance (Cornwall) earthquake (Davison, 1924). Borlase was also instrumental in gathering information on the effects in Cornwall of the 1 November 1755 Lisbon earthquake for the Royal Society (Borlase, 1756). However, a previously unknown manuscript by Borlase has recently come to light (Pool, 1986) which shows that Borlase continued to take an interest in earthquakes, although, like a number of his other works, this study was neither completed nor published.

The manuscript was discovered in the library of the Castle, Mount St. Michael, Cornwall. It takes the form of a large notebook, and the title is "Memorandums or Sylloge of earthquakes". It appears to have been started around 1761. Three earthquakes are studied in detail: the 1 November 1755 Lisbon earthquake, the 30 October 1759 Baalbec earthquake, and the 2 April 1762 Chittagong earthquake. The manuscript then continues with descriptions of various eruptions of Vesuvius, and then breaks off.

The material cited is all from secondary sources, chiefly the *Philosophical Transactions of the Royal Society.* What makes the work interesting is the tabular way in which the data are laid out. For each earthquake, the information is arranged on a place-by-place basis, with the following column headings: "Place," "Long & Lat," "Beginning," "Duration," "Wind & Weather," and "Degree of violence by Land, Sea Lake or Pond & Fountain".

This scientific, as opposed to anecdotal, arrangement of seismological data is very unusual, if not unique, for such an early date. The examination of intensity by place, rather than by shock as in some early Italian studies, is a clear anticipation of macroseismic techniques to be developed in the following century, as is the careful appending of latitude and longitude values to each observation. The one step Borlase did not take was to develop any system of classifying the observed intensity into a scale.

While it would be wrong to claim too much importance for this manuscript, which has lain in a state of total neglect for more than 200 years, it is certainly an interesting sidelight on the emergence of seismology in the 18th century.

SEISMOGRAPH NETWORKS OF THE UNITED KINGDOM: PRESENT AND FUTURE

T Turbitt and C W A Browitt

For over a decade now BGS has recorded seismic information from a national network of short-period seismometers onto slow-running, frequency-modulated tape recorders. The dynamic range of the system is limited to about 45 dB with a bandwidth of 16 Hz. Recent developments permit digital, triggered recording to 72 dB (and eventually 96 dB) with remote access to the data via modem and telephone line to give almost real-time response to seismic events.

Natural
Environment
Research
Council

The collapse of a disused salt mine at Carrickfergus, Co. Antrim on 19 October 1990 had the seismic effect of a magnitude 2.5 earthquake. (Photograph: BGS Belfast Office)