WHY THE BORDER SHOOK ON BOXING DAY

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The British Isles are popularly believed to be located in a stable part of the world, free from disastrous earthquakes. But earth tremors, some of them large, do occur and usually take the British by surprise. Iain Bain examines some of the possible causes of the earthquake which occurred under the small Cumbrian town of Longtown last Boxing Day.

In the British context the earthquake which shook southern Scotland and part of northern England out of its Boxing Day torpor last year was a considerable seismic event. The earthquake measured 5.2 on the Richter scale of magnitude which makes it possibly the largest earthquake felt in Britain since the famous Colchester earthquake (5.25 Richter) in 1885. As a media topic, the shock of the Boxing Day earthquake rapidly died away, eclipsed by events elsewhere. Scientific interest remains strong, however, and it seems that this particular tremor will be the most intensively studied of all British earthquakes.

Perhaps part of the reason for the loss of Press interest was that immediately after the announcement of the basic seismic facts, where and how strong, the experts were unable to offer much more information. This is because although seismic information is recorded instantaneously the data are complex and require lengthy and detailed analysis. Results are beginning to come through now which allow some speculation on the causes of the 'quake.

Scientists at the Global Seismology Unit of the Institute of Geological Sciences in Edinburgh were able to locate the earthquake rapidly using the Lownet network of seismometers. This network comprises seven instruments sited in Central and Southern Scotland, from Dundee to Broad Law in the Southern Uplands, which are linked by radio to a central station in Edinburgh. Earthquake shocks produce a number of different vibrations and the determination of an earthquake epicentre concentrates on the high frequency end of the spectrum. Epicentres are located by measuring delays between the arrival at different stations of P-waves (longitudinal waves which pass through the liquid part of the earth's core) and S-waves (transverse waves which travel only through the earth's crust). In the case of the Boxing Day earthquake the epicentre was located at 55.01°N, 2.97°W at a depth of eleven kilometres. This puts it almost

4 immediately under the village of Longtown in Cumbria just south of the Scottish Border.

Seismic activity is not unknown in this part of the Border. From October to December 1979 the Global Seismology Unit detected four tremors in the Longtown-Gretna area at a depth of two kilometres. Following the Boxing Day earthquake twenty-two shocks were recorded by the GSU up to January 8; most were small but one, on New Year's Day, measured 4.1 on the Richter Scale, in almost the same place as the Boxing Day quake but at only three kilometres depth. A survey of the impact of the Boxing Day earthquake on the people within the area in which it was felt is being carried out by the GSU. A questionnaire form was published in a national newspaper soon after the event and between 3000 and 4000 replies have been received by the GSU. Results will be analysed later this year.

Intensive recording and analysis of the after shocks which follow a large earthquake can tell seismologists a good deal about the character of the initial event and for the first time for a British earthquake this was done at Longtown. A team of geophysicists from the University of Cambridge under Dr Geoff King began setting up a network of eight portable recorders in the locality on December 26 and began recording the next day until January 2. Twenty-seven earthquakes were detected during this period and locations were obtained for twenty-two of them. The Cambridge team put the centre of the aftershock region five kilometres east of Longtown, results which compare in general with those of the GSU. The fault plane solution which they obtained suggested a mechanism for the earthquake and it is believed that the motion is a thrust along a strike aligned east-west and dipping either 35^{o} to the north or 55^{o} to the south. It is suggested that the displacement is about thirty centimetres occurring over an area of nine square kilometres.

In a populated country the possibility of seismic risk is a worrying one, the more so in this area where a nuclear power station is sited not very far away at Chapelcross near Annan. The question, why an earthquake occurred at Longtown, is one to which the answer must remain speculative at the moment. However, the geological background does contain some indications.

Longtown's geological basis is sedimentary, the result of the steady infilling of the Solway Basin, one of the most enduring of Britain's major landforms. At the surface Triassic deposits cover Carboniferous sediments and at depth the area is underlain by the same highly deformed rocks which form the Southern Uplands, Lakeland hills and much of Wales. The Solway also has a considerable tectonic pedigree. In the Cambrian and Ordivician eras (570,000,000 to 445,000,000 years ago) the area which is now the British Isles was divided and the

two halves, effectively North and South Britain, lay on separate tectonic plates on either side of a deep proto-Atlantic sea which geologists have termed the Iapetus Ocean. Gradually the process of continental drift narrowed the Iapetus Ocean and it finally closed in the late Silurian era, about 400,000,000 years ago. It has been suggested that the collision line between the two continental masses, termed the 'Iapetus Suture', runs up the Solway, passes through the head of the Firth and follows roughly the line of the Border. The actual existence of the Iapetus Suture has been a matter of speculation for some time but it is only recently in the late 1970s that aeromagnetic surveys have indicated a juxtaposition of magentic anomaly patterns in the Solway area which point to a possible location for the suture.

It would be tempting indeed to think that this ancient collision has resulted in a line of weakness which promoted the seismic events earlier this year. The problem is one of establishing a convincing link between the two. One clue may lie in concealed faulting in the Longtown area. To the north of Longtown lies the small and now defunct Canonbie coalfield. In general, the coal measures in this area have been eroded from the upper part of the Carboniferous sediments but the Canonbie coalfield exists because it has been let down between a pair of deep faults six kilometres apart. A downward displacement of a few hundred metres has allowed the coal measures to be preserved. The coalfield and the faults are marked by the cover of Triassic deposits.

The village of Longtown lies over the concealed southern boundary fault of the Canonbie coalfield and coincidence of this and the majority of the locations obtained by the seismologists makes movement here a likely explanation for the earthquake. And, possibly, the Canonbie faults may be related to the earlier Iapetus Suture. One problem which still exists is that the Cambridge geophysicists' results point to a thrust along a much shallower angle than the near vertical lines which the Canonbie faults are assumed to take. The answer to this may lie in a reassessment of the dip of the faults. No-one is really sure what happens to faults at depth and it has been suggested by some geologists that they may flatten out to give shallower angles of dip.

Commenting on the suggested dip angle of 35°N / 55°S Fred Dunning of the Geological Museum pointed out that this could relate to the collision of plates in the late Silurian era and the way in which sediments were compressed, distorted and buried under the leading edges of plates. He said that: 'There are numerous fracture structures in the Southern Uplands dipping at 35° north which are part of a postulated accretionary prism structure and the Iapetus Suture itself

may follow the same line of weakness as one of these flat north-dipping structures'. If the dip was 55° south then he thought the shock was more likely to be caused by movement on the coalfield boundary faults.

Consideration of the geological background provides knowledge of why earthquakes occur where they do. What actually causes an earthquake to occur when it does is another matter. In the case of the Longtown earthquake there is a general consensus that the trigger was possible post-glacial isostatic uplift. The weight of glacial ice, particularly in Scotland, caused a depression of the earth's crust and a consequent rebounding of the land when relieved of weight. The stress set up by that readjustment, small in Cumbria since it is relatively far from the main centre of isostatic uplift in the south-west Highlands, may have been sufficient to set off the Longtown earthquake.

EDITORIAL NOTE

Since this Boxing Day earthquake was felt by many of our readers in Stirling and the Hillfoots and is therefore of particular interest, we are grateful to Iain Bain for permission to reprint this article from the *Geographical Magazine* of April 1980. As indicated in our note at the end of the Burton and Neilson paper *Earthquake Swarms in Scotland* in our last issue, we did expect an IGS paper on this subject, but since then the new Head of IGS's Gobal Seismology Unit (Dr Browitt) has been unwilling to allow us such a paper.

For local newspaper notes see: *Glasgow Herald* 28th December, 1979 and 3rd January, 1980, and *Stirling Observer* 26th December, 1979; and on the October 1980 tremor felt by readers in Alva *Alloa Advertiser* 29th October, 1980.