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THE SEISMICITY OF CORNWALL AND DEVON

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In the 36 years since ATJ Dollar presented his paper on the seismicity of the Cornubian Peninsula in relation to structure, a great deal has changed in the understanding of British seismicity, both in terms of knowledge of its distribution and parameters, and in terms of its geological and tectonic setting. This is as true for Cornwall and Devon as for other parts of the UK. Since the late 1970s a large amount of effort has been directed into research on historical earthquakes in the UK, undertaken with a critical approach to the appraisal of historical sources, something previously lacking yin studies of historical earthquakes. During the same period, modern instrumental monitoring has been improved. The need for seismic monitoring of the geothermal energy project at Rosemanowes led to a dense local network capable of recording and locating even very small natural events. In terms of average UK seismicity rates Cornwall and Devon are neither as seismic as the most active areas (such as NW Wales) nor as quiet as the most inactive areas (such as NE England). While earthquakes in the area occasionally cause public alarm, they seldom exceed 4 ML in magnitude and have caused very little damage in the last 250 years. The distribution of seismicity is irregular; most activity is concentrated in three zones: the Penzance-Helston area; an area running from off the north coast of Cornwall, through eastern Cornwall to south Devon, and the Barnstaple-Ilfracombe area. Relating this distribution to geological structure is a contentious issue. Some major structures such as the Sticklepath Fault, (which has a reputation as being "active" seismically) do not show up at all. It is likely that the distribution is influenced by the interaction of local structures and reactivation along lines of old E-W thrust faults of Variscan age.

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INTRODUCTION

Since Britain is not an area where earthquakes are perceived as a serious problem, the amount of research devoted to British seismicity in the earlier years of seismology was not very great. Between 1889 and 1926 active work specifically on British earthquakes was to a large extent limited to the work of one man who was in fact an amateur seismologist, being a mathematics teacher by profession; his name Charles Davison. Davison's (1924) study of British earthquakes was the first work to attempt to derive numerate parameters for British earthquakes in terms of intensity. This study included the results of his own macroseismic monitoring of earthquakes, together with an assessment of historical earthquakes in Britain. Davison believed, rather optimistically, that macroseismic data could be used to derive precise estimations of the fault movement producing any earthquake.

When Davison retired from seismology, his work was largely taken over by Dr ATJ Dollar, at Emmanuel College Cambridge, then University of Glasgow and later at Birkbeck College, London. After 1931 Dollar was the only person in the UK undertaking macroseismic investigations until regular macroseismic monitoring was begun by BGS (then IGS) in 1974. The paper by Dollar (1963) in the first volume of the Proceedings of the Ussher Society on the seismicity of the Cornubian Peninsula is based largely on the work of Davison, supplemented by Dollar's own work (although the period 1924-1963 was rather quiet in terms of earthquakes in this region). Dollar's geological interpretation of the seismicity is based on the assumption that the long axis of isoseismals indicates the strike of the generating fault. This is sometimes true, but is not a reliable method, particularly not in the case of small British earthquakes which have very small sources. Isoseismal shape can be influenced by source mechanism, local geology, and in some cases, even population distribution. In the years since the publication of Dollar's (1963) paper, much has changed, both in the knowledge about earthquakes and the study of them, and in application to Cornwall and Devon. In particular, one would cite:

- Advances in instrumental monitoring, and improvement in monitoring of British earthquakes;
- Advances in the studies of historical earthquakes; and
- Advances in the understanding of the causes of earthquakes.

INSTRUMENTAL SEISMICITY

In 1963 instrumental monitoring of earthquakes in the UK was still largely confined to the use of seismometers of which the primary purpose was to observe large teleseisms. These instruments were insensitive to small British earthquakes, and the only regional event up to that date for which seismograms existed was the 1925 Brittany (offshore) earthquake (magnitude 5.1 ML). The use of short-period, high-gain instruments suitable for recording the small earthquakes typical of British seismicity only began around 1970, initially in the area around Edinburgh. As part of the experiments in hot dry rock geothermal research conducted in the Carnmenellis granite, a dense seismic network was installed in Cornwall by BGS in 1980-1981 (Turbitt *et al* 1984). This was subsequently incorporated into the BGS national seismic monitoring network, which is run with the support of a Customer Group led by the Department of Environment, Transport and the Regions. Currently there are fifteen seismometer stations in Cornwall and Devon, three with three-component sets and a low-gain instrument (to minimise saturation in large events), and one with a strong motion instrument. This network is capable of locating any earthquake over magnitude 2.0 ML in Cornwall and Devon (Walker 1999).

HISTORICAL EARTHQUAKES

At the time of Davison's research into British earthquakes, any investigation of historical earthquakes tended to be done by seismologists who knew nothing of the proper techniques of historical research, which frequently led them into error. Neglect of correct handling of sources has led to a number of mistakes - for example, a reputed earthquake in 1275 said to have destroyed St Michael's Mount

Day	Month	Year	Hour	Min	Lat	Lon	Depth	Mag	Notes
15	7	1757	18	15	50.13	-5.46	15	4.4	
2	4	1769	5	0	51.1	-3.86	0	3.2	
10	8	1783	16	0	50.63	-4.31	9	3.6	
20	10	1837	14	0	50.6	-4.28	0	3.2	
12	8	1852	7	40	50.49	-4.27	5	3.4	
21	10	1859	18	45	50.57	-5.06	7	4	
13	1	1860	22	54	50.46	-5.31	8	4	
25	6	1883	13	39	50.61	-4.46	11	4.2	
25	6	1883	14	7	50.6	-4.32	0	3.4	1
4	1	1886	10	19	50.3	-3.63	2	3.1	
7	10	1889	13	45	50.65	-4.63	4	3	
1	7	1914	13	10	50.53	-4.05	0	3.1	2
2	9	1920	23	17	51.19	-4.07	4	3.3	
25	12	1923	19	35	50.47	-3.86	3	3.3	
23	7	1966	1	50	50.09	-5.22	18	4.1	3
25	2	1981	20	32	50.11	-5.17	5	3.5	
17	8	1995	16	1	49.88	-4.26	11	3.1	
10	11	1996	9	28	50	-5.58	8	3.8	

Table 1. *Earthquakes in Cornwall and Devon with magnitude <3.0 ML. Latitudes and longitudes are decimal degrees, west written as negative; depths are in kilometres; magnitudes are local magnitude (ML).*
Notes:
1 Aftershock of the preceding event
2 Possibly not an earthquake
3 First instrumentally-recorded Cornish earthquake.

(e.g. Taylor 1932) actually originated much further east and affected not St Michael's Mount in Cornwall but the church of St Michael on the Mount (Tor) at Glastonbury. In the last twenty years especially, much progress has been made in revaluating historical earthquakes according to proper methods of historical study (see Eisinger *et al* 1992), and fake earthquakes have been cleaned out of the catalogues, and new, previously unknown events added. In addition to earthquakes mislocated in Cornwall and Devon through confusion with other earthquakes, a number of events in the region have previously been attributed to earthquake, though actually arising from other causes, notably naval gunnery practice. In 1988 a complete investigation of the historical seismicity of Cornwall and Devon was made, in which all the local archives were used, resulting in a definitive catalogue of historical earthquakes in the two counties (Musson 1989).

RESULTS

Figure 1 shows all the known earthquakes larger than magnitude 3.0 ML (local magnitude) in Cornwall and Devon; they are listed in Table 1. The use of this minimum magnitude value gives a greater

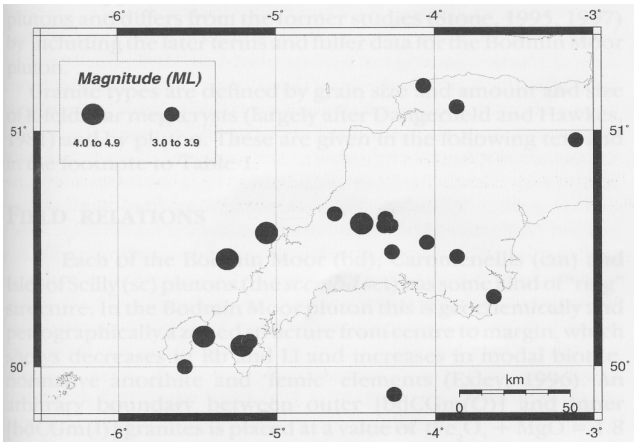

Figure 1. *Earthquakes in Cornwall and Devon with magnitude 3.0 ML.*

degree of consistency to the pattern; if one plotted all events together small earthquakes recorded over the last twenty years would be disproportionately represented.

The spatial distribution is by no means uniform. Events can largely be apportioned to one of three groupings: events in the Helston-Penzance area; events in North Devon (Barnstaple-Ilfracombe); and a roughly arcuate zone running from offshore Newquay, through Launceston and Dartmoor to the Dartmouth area.

The magnitude-frequency is shown in Figure 2. The recurrence of earthquakes can be described by the equation

$$\text{Log } N \; 1.37\text{-}0.81 \; M$$

where N is the number of earthquakes per year equal to or greater than magnitude M. This means that one expects on average an event of magnitude 3.0 ML or greater every ten to twelve years. However, there is a notable absence of larger earthquakes. The largest appears to be the Penzance earthquake of 1757; however, the parameters of this earthquake are not very well constrained. The epicentre may be south of the position shown for it, and the magnitude may be less. Excluding this event for which the magnitude is not well-determined, the largest earthquake is the 1883 Launceston event at 4.2 ML. This contrasts with other seismically active areas of the UK where magnitudes may exceed 5.0 ML.

Earthquakes in this area are generally quite shallow. The mean depth of the earthquakes plotted in Figure 1 is 8 km, compared to, for example, a mean of 16 km for earthquakes in Wales and the Marches. Also, the two deepest events (1757 and 1966) do not have very well constrained depths, so the true mean may be slightly less.

Effects of earthquakes in Cornwall and Devon have never been very severe, and only very minor damage has ever been reported, with two possible exceptions, neither listed in Table 1 as magnitudes for both are presumed to be less than 3.0 ML. The first is the earthquake of 23 February 1752 which threw down a pinnacle from the spire of the church at Widecombe in the Moor, and caused unspecified damage to houses. The second is a poorly documented and perhaps doubtful event at St Austell on 10 September 1775, two days after a large Swansea earthquake. Supposedly several stacks of chimneys were thrown down and some sort of stable collapsed, but the sole source is not local and of uncertain trustworthiness.

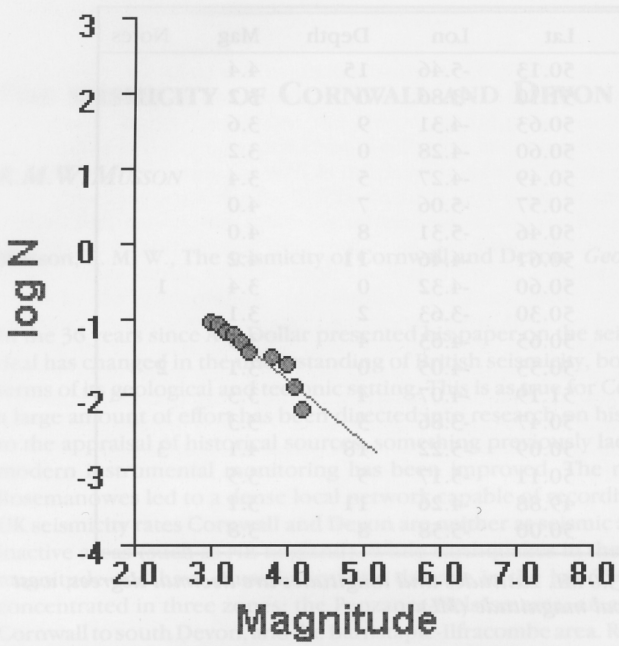

Figure 2. Magnitude-frequency plot for Cornwall and Devon. The line shows the equation Log N = 1.37 - 0.81 M (where N is the cumulative number of events per year exceeding magnitude M).

One presumed fatality has occurred from earthquake, at Penryn. At the time of the 1757 Penzance earthquake a certain Stephen Thomas was sitting at an open upstairs window; the earthquake alarmed him so much he toppled backwards and fell out, and was described as not likely to recover from his injuries.

The original accounts of all these earthquakes are reproduced in their entirety in Musson (1989).

RELATION TO STRUCTURE

The business of attributing earthquakes in Britain to specific faults is fraught with difficulty. A combination of uncertainties in epicentral location, the lack of knowledge of fault structures at seismogenic depth, the abundance of faults, a shortage of well-determined focal mechanisms, and the small source sizes of British earthquakes, means that fault identification cannot usually be made with any degree of reliability. There has been a tendency in the past for regional earthquakes to be ascribed to one or two prominent structural features, especially the Sticklepath-Lustleigh Fault, on the basis of little more than wishful thinking. There is no lineation of epicentres to suggest that this fault is still active, as has occasionally been claimed.

The root cause of earthquakes in Britain is the reactivation of old structures in response to the prevailing stress field, which is dominated by a direction of maximum compressional stress from the north-west, due to the opening of the North Atlantic. In response to this, the most likely form of reactivation is as strike-slip movement along features with preferentially a N-S or E-W orientation. In addition, the distribution of units of relatively strong and weak rocks is likely to set up patterns of local stress concentrations that may account for some of the spatial irregularity in the distribution of British earthquakes. The recent map of tectonic features in the British Isles (Pharoah *et al* 1996) does in fact show a number of broadly E-W (Variscan) trending faults in areas of Cornwall and Devon where seismicity is more prevalent (for example, the Carrick Thrust in the Helston-Penzance area). While information on focal mechanisms of earthquakes in this area is very limited, two solutions which have recently been determined do in fact show strike-slip faulting on N-S or E-W focal planes (MEA Ritchie, pers. comm. 2000). Thus, while a precise relation of seismicity in terms of structure is still premature, there are indications that the seismicity pattern may ultimately be explicable in terms of the interaction of the regional stress field with local tectonic features.

CONCLUSIONS

A combination of extensive historical research with intensive instrumental monitoring means that the seismicity of Cornwall and Devon is well investigated. By comparison with average British seismicity, that of Cornwall and Devon can be described as moderately active, rather shallow, and with a fairly low maximum magnitude. There seems to be a correspondence between the more seismically active areas of the two counties and the distribution of larger E-W trending faults.

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