DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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FIRST REPORT ON THE PROJECT

LOCATION OF OIL SEEPS BY MICRO-TREMOR ANALYSIS

GEOLOGICAL SURVEY

by

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INTRODUCTION

The proposal for this project was formulated early in 1987 following a fortuitous occurrence in December 1986. A large amount of bitumen was washed ashore on the south coast of Kangaroo Island on December 7th 1986, and analysis of samples indicated that the stranding consisted of what was almost certainly naturally occurring crude oil of primary algal origin, inferred to have been released from a submarine seep in the offshore Duntroon or Otway Basins. A small seismic tremor of magnitude 2.2 had occurred in the offshore Otway Basin 22 days prior, and it was postulated that this tremor had caused the hydrocarbons to be released.

Periodic coastal strandings of this nature have been described frequently since European settlement began in South Australia. Sprigg (1986, pp184-187) documents much of the history of such reports, citing in the same discussion previously noted associations of earthquakes with bitumen strandings (e.g. earthquakes of 1897,1915, and 1948) His analysis of seasonal current flows (south to north in summer) lends credence to strandings on southern Kangaroo Island beaches from an Otway Basin earthquake occurring in December 1986.

An application for a grant was submitted to SENRAC in August 1987. The objectives of the project were:

a) to purchase and establish 4 onshore digital seismograph stations to permit a greater detection rate and more detailed evaluation of microtremors;
b) to analyse available seismic reflection data in the vicinity of located epicentres to determine causative faults and potential oil traps;
c) sample coastal bitumen;
d) To fully document any tremors leading to oil strandings including ocean currents and winds.

The project was approved during 1988 with funding to be supplied by Cultus Resources and SENRAC. Funds became available from both parties in November 1988 and orders for equipment were placed soon thereafter.

To date most of the effort devoted to the project has been in operational matters, ensuring the continued running of seismographs near the area and the establishment of the new ones.

There have been four significant earthquakes although none of the three offshore events led to oil or bitumen being stranded. The occurrence, however, led to a plan for future large events.

A few oil samples have been taken and analysed.

OPERATIONAL REPORT
SENRAC/Cultus Funded Stations

Equipment ordered

Following the availability of funds from both parties in November 1988, quotes were sought and orders were placed for the principle equipment which included:

- four digital recorders in December 1988, which were received in June 1989;

- two short period 3 dimensional seismometers in Jan 89, which were received in June 1989;
- one long period 3D seismometer in January 1989 which was received in April 1989.

As work progresses the following capital items will be or have been ordered:

- permanent housings for the equipment were ordered, and received January 1990;
- telephone connections as required;
- modems as required.

Naracoorte

During July and August 1988 a site in Naracoorte Caves was tested but found to be not very suitable.

Following a survey around the area, a portable seismograph was set up a few kilometres south of Naracoorte in August and September 1989 with the owner of the property changing paper daily. In November 1989 a digital recorder with a short period 3D seismometer was installed and has been operating continuously since. The Beachport events of January and February 1989 were recorded and also the 8th March 1989 Penola event. A telephone connection was ordered on March 20th. This was completed on 28th June and the instrument has since been monitored by phone from Adelaide.

The permanent housing has not yet been established.

The noise at this site seems to be relatively low. It is much better than the Mount Gambier area, but not as good as Willalooka.

Parndana

This site was first used in a microtremor survey in February 1988, and had the great advantage of being highly accessible and being owned by a very competent and helpful farmer. A site survey of the western part of Kangaroo Island was carried out in April 1989, and as no other site appeared to be substantially better, this one was chosen. Installation of the digital unit was delayed until it was considered that we had sufficient expertise to do it quickly and correctly without further trips, and until the software of the digital unit had improved. Installation was carried out on 8th March 1990, and since then the unit has been operating most of the time.

A telephone connection was ordered on the 20th March 1990 and completed on 22nd June with the farmer carrying out the modem installation and restart by telephone. It suffered problems which were presumed to be due to the poor quality of the telephone line. However these have been solved by exchanging the modem.

Lake Hawdon #1

The decision to attempt to install a downhole seismograph was taken for a number of reasons. Firstly, there is little or no hard rock outcropping in the coastal area, except in the south toward Mount Gambier, or the north near the existing Willalooka site. As hard rock normally gives a better frequency signal, this was considered desirable. Secondly, being downhole should reduce any problem caused by cavernous formations near the surface. Thirdly, Lake Hawdon #1 was being drilled about the time and we had the opportunity to have it plugged and abandoned as requested. Also the Geophysics Section has expertise and equipment for borehole logging operations.

Unfortunately no-one else in Australia has yet set up a downhole seismograph station except in shallow, specially drilled holes.

The hole was abandoned by Hartogen in November 1988. The hole was relogged on 19th August 1989 before rehabilitation had been completed and a short test carried out with the seismograph using the logging truck winch.

After rehabilitation an extended test was carried out during November and December 1989 with the owner changing paper records. This test showed that there were severe problems to be overcome before the site could be useful.

These problems appear to be related to self potential signals, or chemical reactions along the logging cable being larger than the seismic signal. It is thought that these problems may be overcome by use of a special cable, and by purpose built electronics to convert the minute seismic signal to an easily transmitted frequency modulated signal which is then reconverted at the recorder. The electronics modifications are being built, and a cable has been ordered but not yet received. This will be tested in a hole close to Adelaide before being tried again at Lake Hawdon.

Fourth Unit

A fourth unit was planned to be installed near Portland. The particular reason for this was to get the best possible circular coverage around the South Australian portion of the Otway Basin, particularly that part offshore from Mount Gambier. As the circular coverage around a recorded earthquake decreases, the accuracy of the located epicentre also decreases, and under most circumstances no more than a 180 degree gap is acceptable. Such coverage around the Otway Basin is not possible until ocean bottom seismographs are installed, and Portland seemed the best general area from the point of view of geometry.

Following the 8th November 1989 earthquake near Beachport, the fourth unit was required in Canunda National Park to record aftershocks. Unfortunately, one of the delicate signal coils of the seismometer was damaged by moisture and the instrument was shipped to the United States for repair on 25th January 1990. As of November 1990 it had yet to be returned.

Another seismometer from the Adelaide area was used briefly at Canunda and was fortunate to record the 21st January 1990 event before being removed.

Recently there has been a proposal by the Victorian seismograph network to install an instrument near Portland, consequently the fourth unit will probably be installed somewhere in the Millicent-Rendelsham district.

SADME Stations

Willalooka

This station was established in 1979 and has been running continuously since. It has had a few minor problems since November 1988. It is an extremely high gain station and records events that are not visible on many other recorders in the southeast of Australia, but goes off scale with even moderate sized events and is only a one dimensional (vertical) analogue station.

Mount Gambier

There was discussion in 1988 about setting up a recorder at the Lady Nelson Centre at Mount Gambier to replace another station at Mount Gambier that had closed. The main problem has been finding a suitable seismometer site. The old site at The Bluff was too noisy, and caused radio interference to other users. Of the 6 sites that have been tried, (3 of these being downhole sites) none have been acceptable. Throughout the testing a portable instrument has been maintained by Jeff Lawson,

the SADME geologist at Mount Gambier. As it is considered that the current location is the best of a bad bunch, it will be made a semipermanent site with the recorder at the SADME office. This site is the most southerly at present and also has the lowest gain.

Kelly Hill Caves

This site was first used in January 1988 and has been running almost continuously since. It is only a portable recorder and a vertical seismometer, and paper changing and time correction are carried out by officers and guides at the National Parks office. It is a fairly high gain station and has produced some beautiful earthquake records, but suffers from timing and power problems because of its location away from the main office.

It is hoped to convert this to a permanent station in the near future, but this will depend on budget and manpower constraints.

Downhole tests

Various tests have been carried out with downhole seismometers since August 88. These have been in various holes around Adelaide, Mount Gambier and Lake Hawdon. The latter was the deepest and magnified problems that were not previously significant.

EARTHQUAKE REPORT

Events

Apart from events in the vicinity of Beachport, which will be discussed separately, there have been very few events south of Victor Harbour and only two in the offshore Otway Basin.

The first of these occurred on the 17th May 1989. No digital records were available and the location was poorly constrained. However, as it was near the epicentre of the December 1986 event and of a slightly larger magnitude, a slick was considered possible. Airlines, shipping and coast guard were notified but no reports were received.

On the 7th September 1989 a smaller event occurred much further out at sea and it was considered not worth following up.

Beachport Events

Background

In 1897 Beachport experienced South Australia's largest earthquake since European settlement. It was approximately of magnitude 6.5 and caused serious damage in the area from Kingston to Millicent, with some minor damage as far away as Adelaide. Aftershocks were felt for up to 2 years afterwards with one aftershock in 1899 being of magnitude 5.3.

The epicentres of most of the activity are thought to have been offshore, and the vibration was noticed by a number of boats at sea. There was no associated tidal wave. In 1948 another earthquake of magnitude 5.6 occurred offshore from Robe, causing some damage. Following these events extensive oil slicks were reported.

The first seismograph to be installed near the area was in 1979 at Willalooka and a further one at Mount Gambier in 1980. The latter was of low gain and experienced a number of problems. The number of tremors recorded since that time have been small, and the circular coverage has been limited, especially where the Mount Gambier record has been poor so that calculated epicentres have been highly inaccurate.

With the installation of an analogue instrument at Kelly Hill Caves, it has been further shown that activity is in fact very low. The area may have a greater ratio of large events to small events, than is usually expected.

1989-90 sequence

On 8th November 1989 without any foreshocks an earthquake of magnitude ML 3.9 occurred in or near Rivoli Bay. It was felt throughout most of the South East. Despite a number of people looking for stranded oil, none was found. This was a surprising and disappointing result, but led to planning for future large events. On a brief check of past activity in the South East it was found that for larger events, there were usually aftershocks of similar magnitude, in the following days and months. An extra unit was deployed soon afterwards at Canunda National Park.

Unfortunately this instrument was damaged by leaking moisture, and was replaced on 11th January 1990 by another instrument. An aftershock of ML 3.7 was recorded by this instrument on 26th January 1990 plus a few other events, but was removed soon after to prevent a repeat of the previous damage.

Isoseismal maps

Questionnaires were sent out to many people in the South East, after roughly gauging the radius of perceptibility by phoning many towns.

This was also done for the two other main events in January and February, although the area over which the later events were felt was much smaller and the maps are of dubious value. (See figures 2-4).

Second event January 1990

This earthquake was widely recorded in south east Australia and up to nearly 1000 Kms away. Thirty arrival times from 15 stations were used to determine an epicentre. The resulting position still has errors in Easting, Northing and depth (2 standard deviations) of around 5 Kms and a gap between recording

stations on the seaward side of 187 degrees which limits the possible accuracy. Fortunately the temporarily installed digital seismograph at Canunda National Park was only about 17.5 Kms from the hypocentre with a clear first arrival showing that the event was to the west north-west. This can be seen by the X and Y segment of the exploded break in figure 6. This station by itself probably gives the most accurate location although depth cannot similarly be estimated. An examination of faulting in the area shows that there are a large number of possible faults in the prevailing direction as well as indications of various other orientations. The greatest drawback is the inaccuracy in depth. The greater amplitude of vertical component of the first arrival suggests that the depth may be over 8 Kms.

To date this would be easily the most accurately located earthquake in the South East. Further study will later be undertaken to determine what else can be gleaned from this earthquake (velocity-depth model, mechanism). The digital record was the best earthquake record yet recorded in the state.

Two aftershocks were also recorded by the digital instrument. These are shown in figure 7. The similarity in waveform is extraordinary, showing that the events occurred at the same place with the same mechanism. The only significant difference is that the second aftershock (in red) was approximately half the amplitude of the first. There is also a strong similarity between these events and the 26th January shock. The arrival times of phases are identical. The larger shock, however, had a greater component of low frequency, due to greater energy release.

Future major event plan

Despite notification of various people and authorities, no observable oil slick resulted from the Beachport earthquakes. This was somewhat surprising and disappointing, given that it is the largest set of events for some time. However it revealed

the need for a plan in case of a future larger shock. Officers of the Department have discussed the matter, and a rough plan has been outlined, which would involve separate parties for aftershock recording and oil slick investigation. It is most likely that such a large shock would be in the Beachport area, with slicks arising from anywhere within a radius heavily dependent on the magnitude of the earthquake. (The 1897 event was felt from Melbourne to Port Augusta).

Penola Event

On 8th March 1990 an event of ML 3.0 occurred SW of Penola. It was widely felt, although no significant damage was noted and an isoseismal map was again produced (figure 5), and a good record was obtained from the digital seismograph at Naracoorte.

OIL SAMPLING

Oil sampling is a complex problem.

Areas of the South East are subject to regular visitations of a marine organism that sometimes gives the appearance of oil in the water. There have been a number of such sightings reported. They are characterised by a brown-grey colour in the surf in areas up to 200 metres offshore and 50 to 200 metres wide. The organism appears as dispersed material, and sinks when dead.

A few oil samples have been sent to us by officers of the National Parks and Wildlife Department from Canunda National Park and the south coast of Kangaroo Island. One sample from Cape Gantheaume had a diesel aroma and was assumed to be refined but turned out after analysis to be a genuine natural seep. Another sample from Geltwood Beach looked to be a natural seep, but turned out to be refined. In each case the samples have been fairly large and conspicuous and relatively new, and given the long time period it is clear that such occurrences are not

regular. Other people as far east as Cape Otway have been notified of our interest, and our freepost address for the forwarding of samples.

Time consuming field trips have been undertaken by the Department in the past, revealing that there are many small inconspicuous samples to be obtained by a trained person, but these may be of any age.

DISCUSSION

To date it can be seen that most work has been on operational matters, keeping existing stations running and establishing new stations and (to Australia) new technology. This is still going to be the situation for the next 6 months with the establishment of the fourth station, the Lake Hawdon station and the improvements to Mount Gambier and Kelly Hill Caves.

The digital recorders have shown that the quality of data can be dramatically improved and with this, locations can be improved considerably. However, except in occasional cases this accuracy improvement is not going to be sufficient to locate causative faults. Any onshore ones will be more accurate with a possibility of locating down to 1-2 Kms if all instruments are working suitably. Offshore events will be improved but are likely to be much less accurate.

The digital instruments do not record the smaller events at present and this problem is being thoroughly investigated. The hit rate has been improving and it is expected that this will continue with improved software from the manufacturer.

The number and magnitude of recent earthquakes has been small and has limited the opportunity of achieving significant results from the project.

TABLE 1

OTWAY BASIN EVENTS

Fron Novenber 1988 to August 1990

Universal Date & Time	Time	Long	Lat	Depth	Magnitude	Accuracy	Place
1988-11-25	1743 13.3	138.003	-35.728	0.2	2.0	D	PENNESHAW
1988-11-28	2337 5.5	136.634	-36.133	0.0	0.0	U	CAPE DU COUEDIC
1989- 5-17	2208 34.3	138.936	-38.177	32.2	3.0	E	OTWAY
1989- 5-24	1314 45.5	138.316	-35.577	0.1	1.8	C	WEST OF VICTOR HARBOUR
1989- 7- 9	0437 44.6	137.437	-38.678	7.2	2.0	F	SOUTHERN OCEAN
1989-10-21	1845 59.7	136.131	-36.013	9.4	0.0	E	WEST OF KHC
1989-11- 8	0506 30.7	140.056	-37.547	13.3	3.9	C	BEACHPORT
1989-11- 8	0634 0.8	139.916	-37.575	19.0	2.8	D	BEACHPORT
1989-11- 8	0713 13.3	139.959	-37.688	7.3	2.8	E	BEACHPORT
1989-11-29	0339 53.3	136.599	-36.233	27.6	2.3	E	SOUTH OF KANGAROO ISLAND
1990- 1-26	2325 11.9	139.987	-37.547	3.8	3.7	C	BEACHPORT
1990- 2-21	0452 16.4	140.073	-37.542	11.7	3.4	D	BEACHPORT
1990- 3- 8	0955 20.6	140.748	-37.499	14.5	3.0	C	S.W. OF PENOLA
1990- 3-27	0810 52.8	140.189	-37.671	27.7	2.3	D	OFFSHORE FROM BEACHPORT
1990- 4- 1	0704 13.9	138.799	-35.772	16.5	1.0	D	SOUTH OF VICTOR HARBOUR
1990- 4- 1	0707 54.2	138.680	-36.401	10.7	1.2	D	SOUTH OF VICTOR HARBOUR
1990- 4- 1	2330 19.6	138.759	-36.090	11.1	2.0	D	SOUTH OF VICTOR HARBOUR

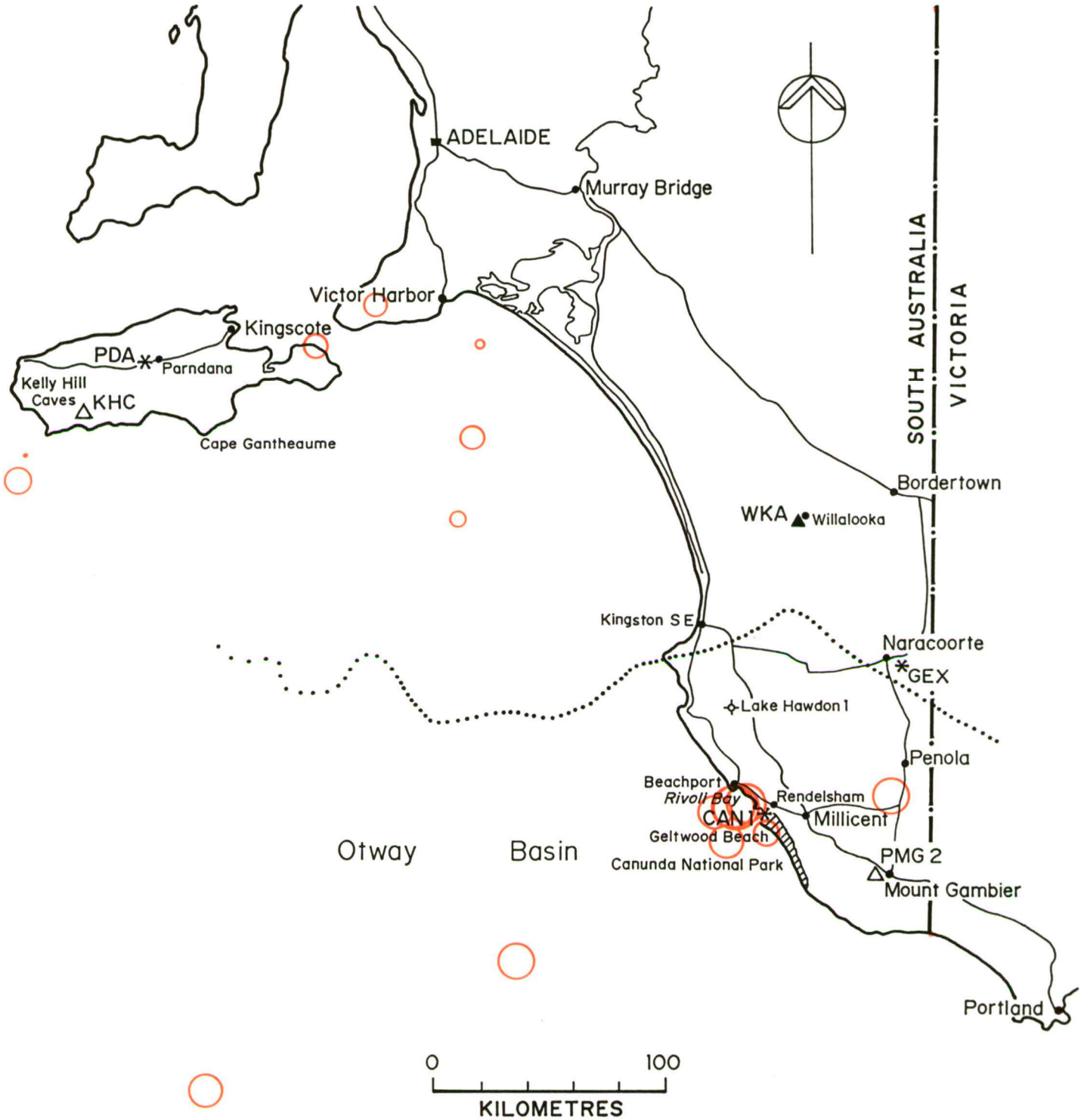

Figure 1 Earthquake epicentres and seismograph stations

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S 21764

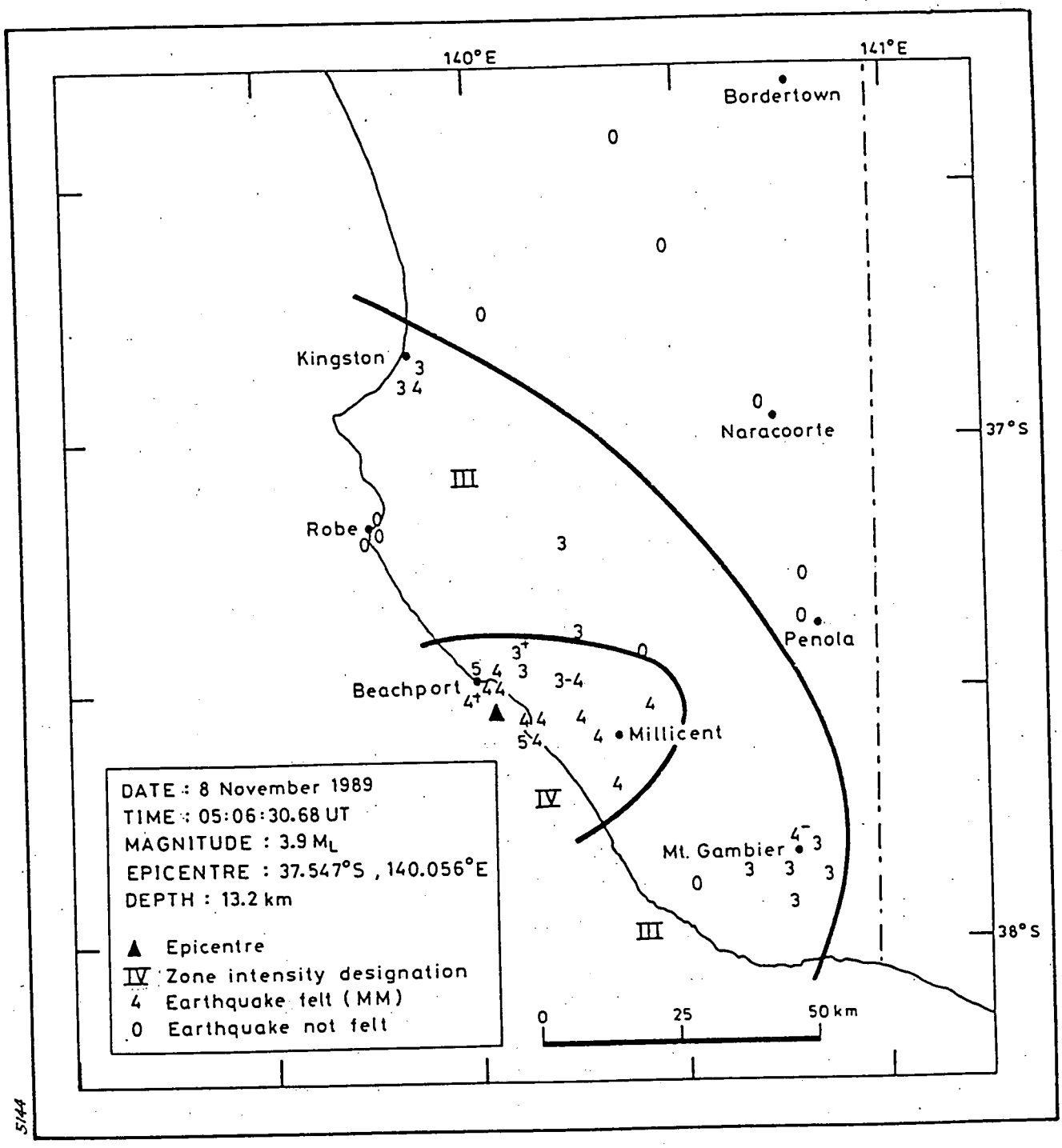


Figure 2. Isoseismal map 8 November 1989, Beachport

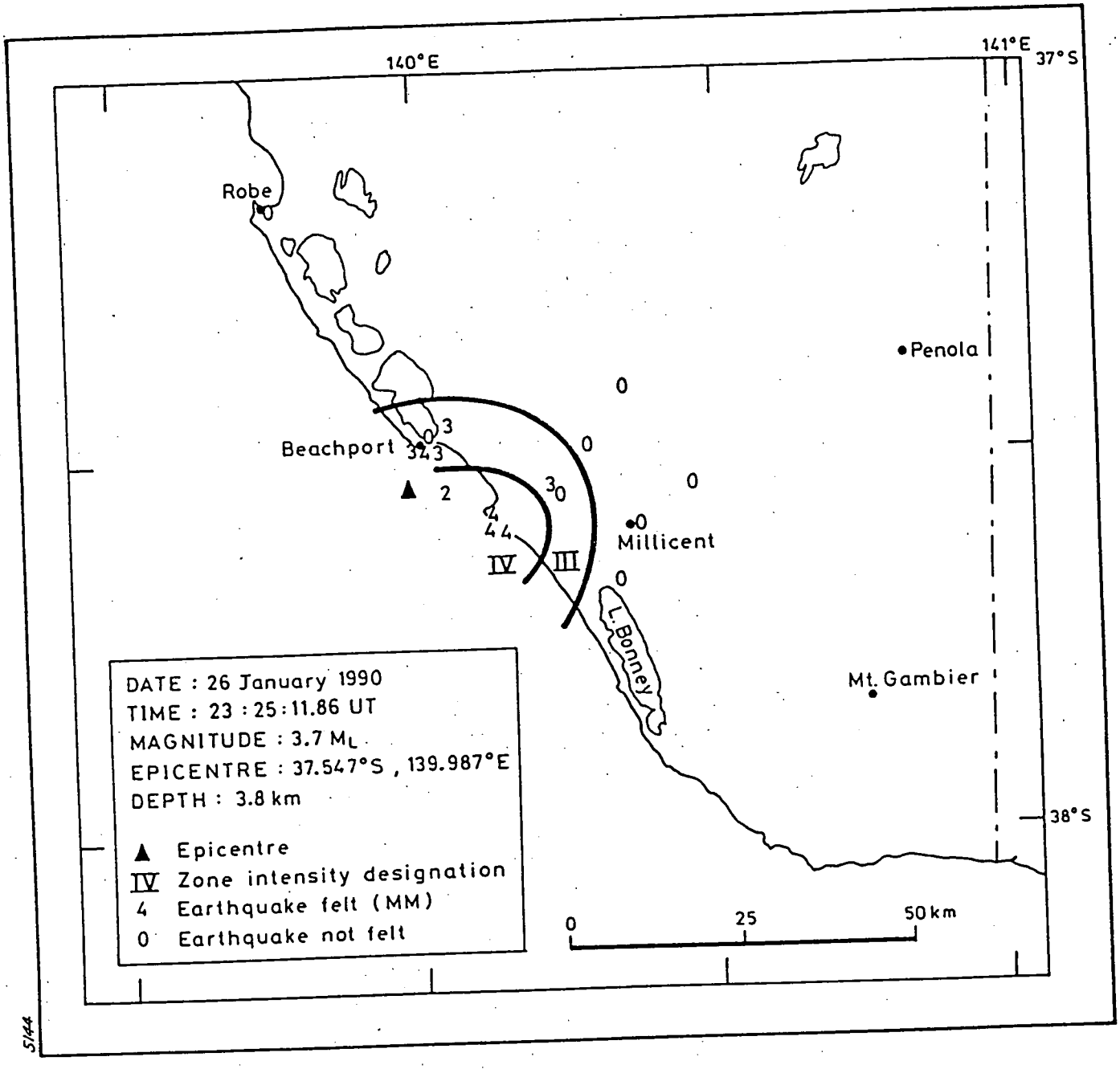


Figure 3. Isoseismal map 21 January 1990, Beachport

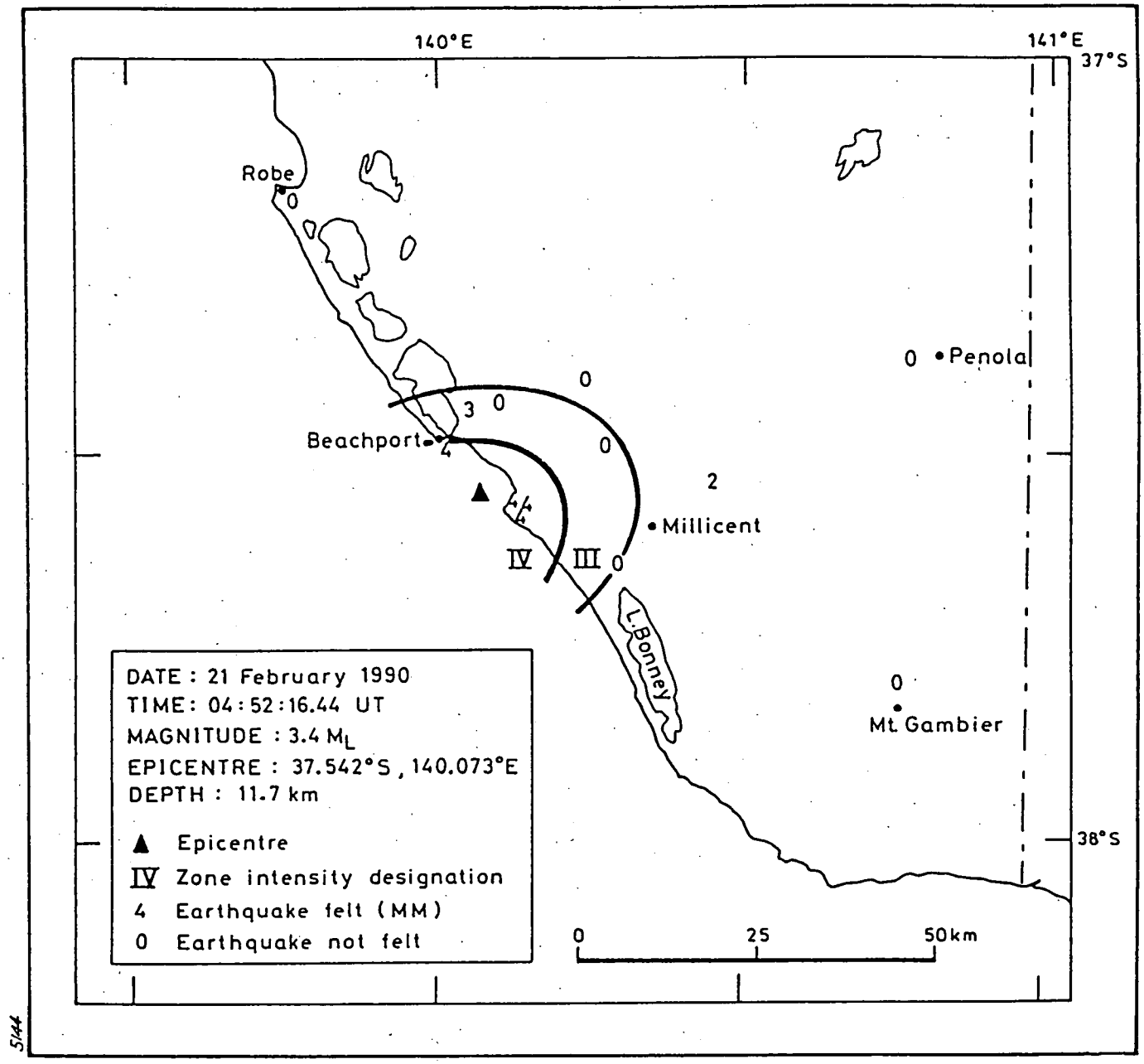


Figure 4. Isoseismal map 26 February 1990, Beachport

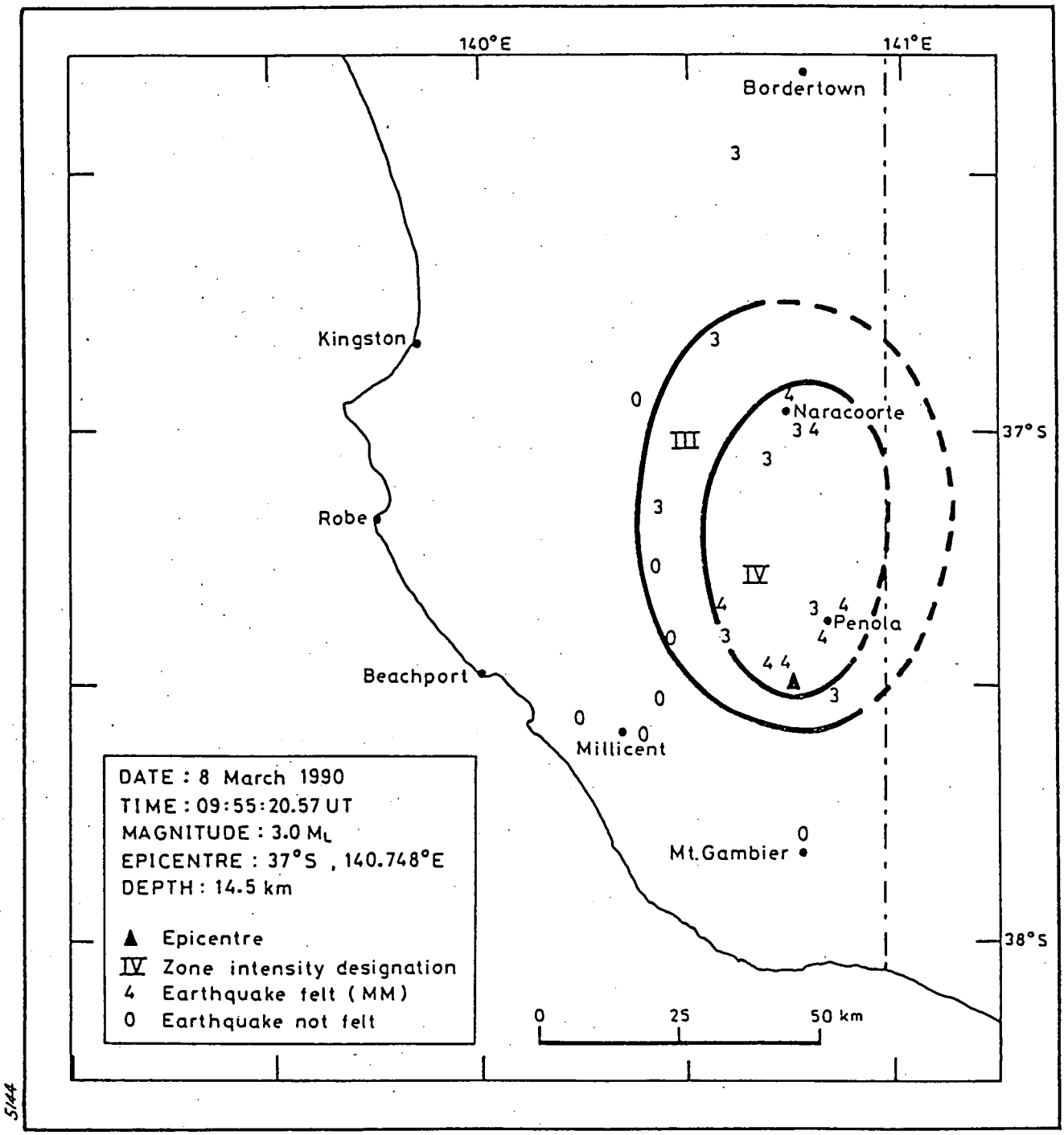


Figure 5. Isoseismal map 8 March 1990, Penola

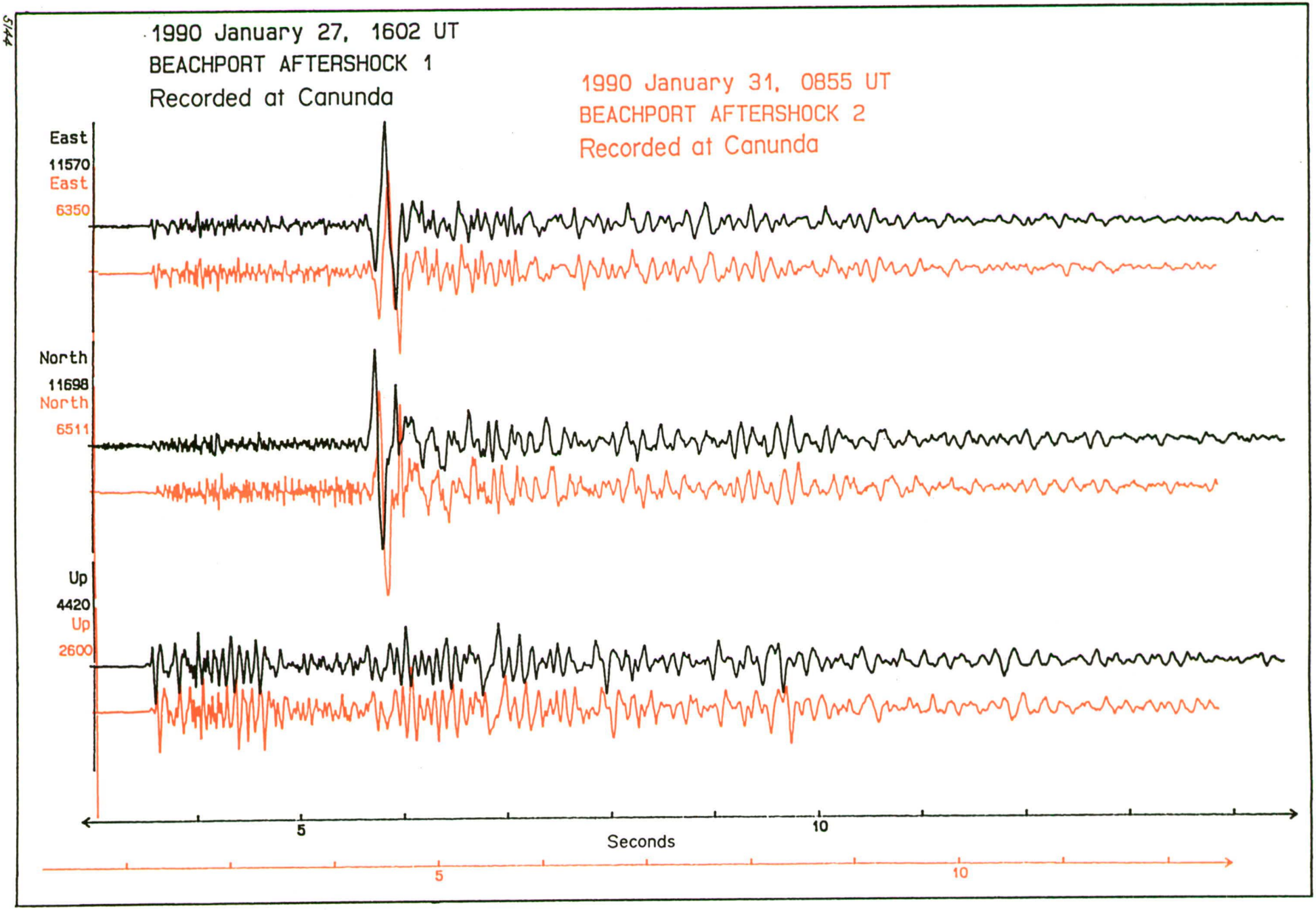


Figure 6. Seismograph record of 21 January 1990 event

SADME S 21769

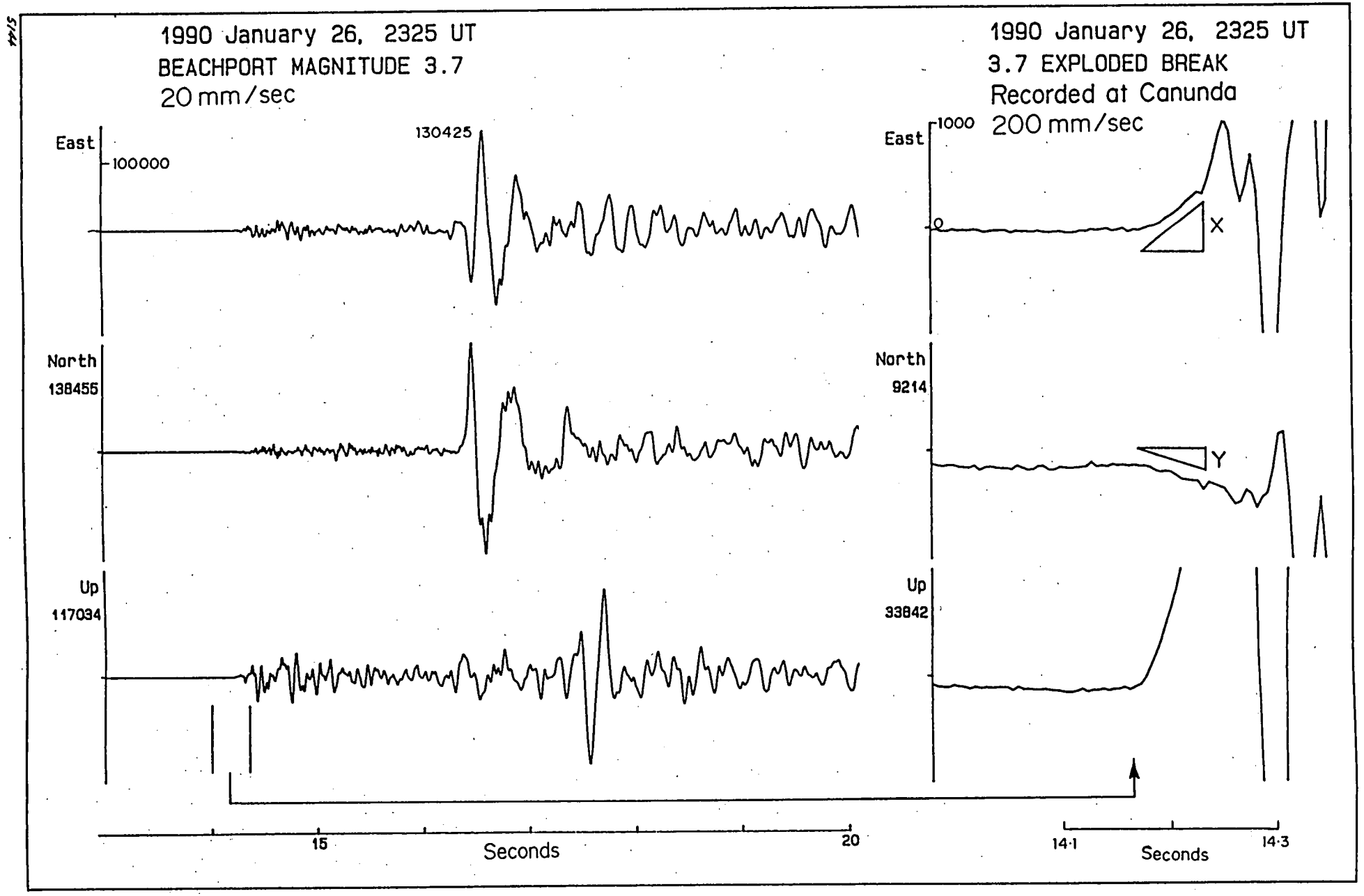
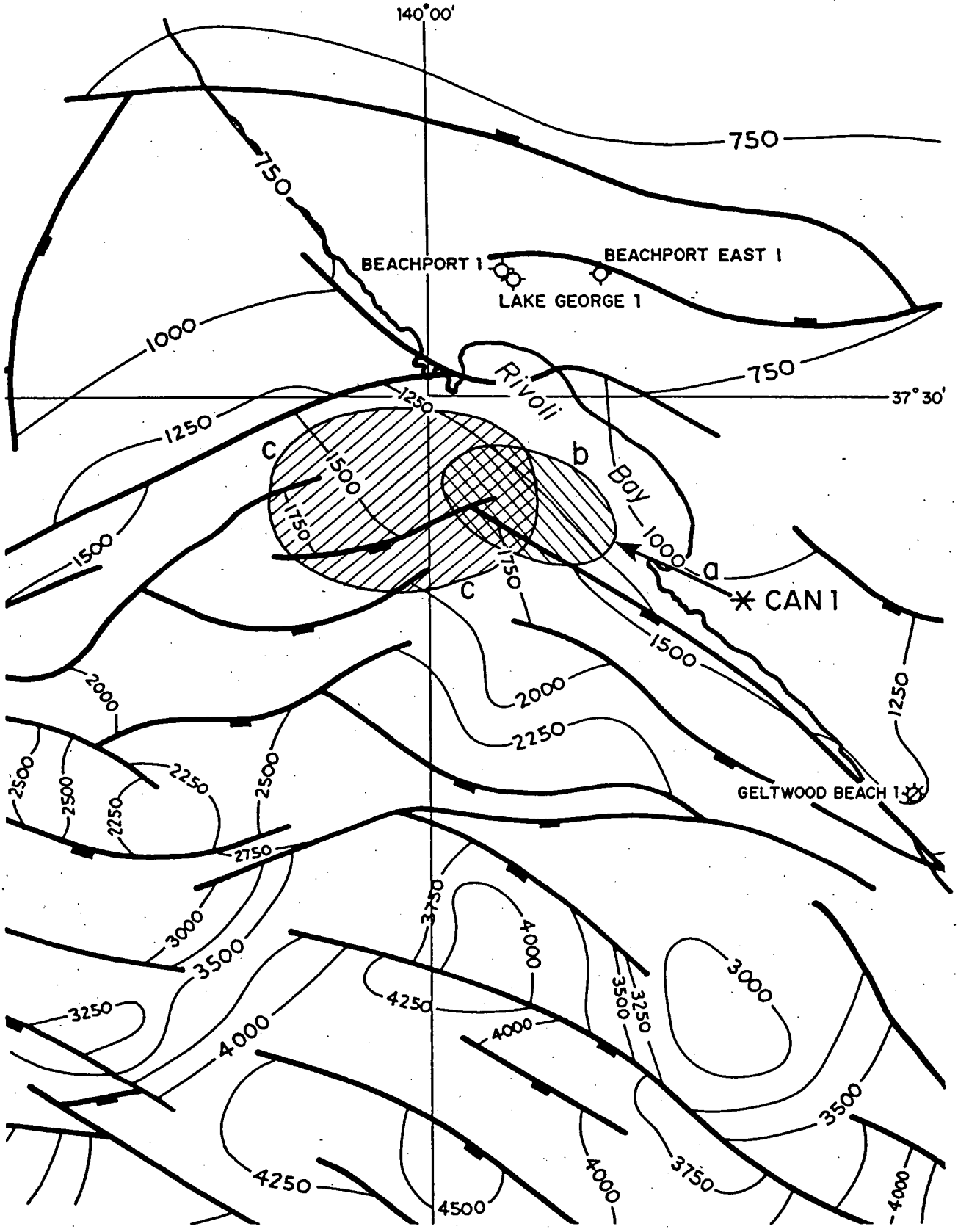


Figure 7. Seismograph records of aftershocks

SADME S21770



Depth to Otway Group in metres, (datum MSL) 3500

Vector from exploded break (Figure 6) ..... a

Expected area using Canunda record only ..... b

Expected area using all records c

Figure 8. Faulting and epicentre estimates Rivoli Bay

SADME S21771