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EARTHQUAKES IN SOUTH AUSTRALIA

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DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
ENGINEERING DIVISION

EARTHQUAKES IN SOUTH AUSTRALIA

(Proposed Mineral Information Series Pamphlet)

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INTRODUCTION

In the early hours of the 1st March 1954, most of the inhabitants of the city of Adelaide were awakened by a loud rumbling noise followed by a shaking severe enough to crack the walls and loosen plaster from many houses. For most people in Adelaide this was their first experience of a major earthquake, and it was the first record in almost a hundred years of any significant movements in the earth's crust in the vicinity of the city. Although a relatively minor one by the standards of countries prone to earthquakes, it was sufficiently severe to cause material damage to many buildings, as the possibility of earthquake damage had never been taken into consideration in their construction. There were no personal injuries resulting from the earthquake.

This event stimulated a renewed interest in South Australian seismicity and its relationship to world earthquake patterns.

CAUSE OF EARTHQUAKES

The earth's crust is subject to constant movement, mostly too small to be detected without the aid of sensitive instruments. These movements are caused by a variety of phenomena and those which result in sudden disturbances are called earthquakes.

Study of world earthquakes has shown that well-marked belts of earthquake activity occur in the earth's crust. These are zones where earthquakes are most frequent and where greatest damage is caused by their effects. Australia lies to the south of an earthquake belt which runs from Japan down through Papua-New Guinea and across to New Zealand.

The existence of a definite pattern of earthquake belts throughout the world together with strong evidence that the continents have drifted away from each other in the past led to the modern theory of Plate Tectonics. This theory gives a good explanation for the mechanism behind major earthquake activity and can be summarised as follows:-

..... The Earth consists of an outer layer of relatively strong and brittle rocks up to 100 km thick called the lithosphere underlain by a weaker substratum called the asthenosphere which deforms by flow.

..... The lithosphere is divided into a series of rigid "plates" of irregular shape.

..... Most world earthquake activity is concentrated at the edges of these plates where they move relative to each other. This movement which can be as high as 10cm/year is probably caused by convection currents in the asthenosphere.

Figure 1 shows why Australia, which forms part of the Indian Plate, does not lie in an active seismic area. The section illustrates what is believed to be happening at the junction of the Indian and Pacific Plates. Relative movement between the plates is forcing the edge of the Pacific Plate underneath the Indian Plate and stresses set up in the brittle lithosphere and below are released as earthquake energy.

Although Australia does not lie on the edge of a crustal plate it is still subject to seismic activity. This is probably because the "plates" are not rigid as was originally supposed and may themselves consist of a series of sub-plates. Research is now being directed to discover how the pattern of these sub-plates affects Australia and this may eventually lead to the more accurate prediction of areas of future earthquake activity.

NATURE OF EARTHQUAKES

The shaking associated with earthquakes is produced by a sudden displacement which is often caused by slipping along an existing geological fault. In some earthquakes completely new faults or fractures are produced. The 1954 Adelaide earthquake is thought to have been caused by a small movement along the Eden-Burnside Fault although there was no definite visual evidence of this.

The area within the earth's crust at which the movement causing the earthquake takes place is called the <u>focus</u>, and the area on the earth's surface directly above this is known as the <u>epicentre</u>. Earthquakes can have depths to focus of up to 700 km although Australian earthquakes tend to be shallow and the 1954 Adelaide earthquake had its focus at less than 10 km below ground surface.

Prediction of future earthquake activity is extremely difficult and relies chiefly on the statistical treatment of large amounts of accumulated seismic data. Sufficient data is not yet available in South Australia for this to be done with any accuracy.

Measurement of the rate of movement along active faults has also been used to predict earthquakes, particularly along the spectacular San Andreas Fault in North America, and encouraging results have been obtained by this method where movements are rapid enough to be readily detected.

EARTHQUAKE INTENSITY AND MAGNITUDE

The difference between the intensity and magnitude of an earthquake should be made clear. The intensity is a relative concept relying on effects felt by an observer and generally diminishes away from the epicentre, while the magnitude is an instrumental measure related to the total energy released during the earthquake.

Estimates of intensity may be used to determine the approximate epicentre of an earthquake. For this purpose the Modified Mercalli Scale is generally used (Table 1). Reports from the public are used to draw isoseismal intensity contours and these can indicate the epicentre if sufficient data is available. This was done for the 1954 Adelaide earthquake (Fig. 2).and results showed that the epicentre was located in the Darlington area where a maximum intensity of 8 was recorded.

Earthquake magnitude is determined by instrument measurements. It is a more fixed and objective means of measuring the engrgy released by the earthquake and for this reason is more frequently used than intensity in scientific work. Magnitude is commonly measured on the Richter Scale. This scale is logarithmic and open-ended, although no earthquake greater than 9 has yet been recorded on it. A shock of magnitude 2 is the smallest normally felt by humans and the 1954 Adelaide earthquake had an estimated magnitude of 6. A comparison between Australian and other major world earthquakes is given in Table II. In reading this table it must be remembered that the Richter Magnitude Scale is logarithmic so that a magnitude of 7, for example, represents a disturbance with ground motion amplitude 10 times that of a magnitude 6 earthquake.

Duration of the shaking caused by earthquake activity can be highly variable. Ground shaking during the 1964 Alaskan earthquake lasted for nearly two minutes while duration of the 1954 Adelaide earthquake did not exceed 20 seconds.

EARTHQUAKES IN SOUTH AUSTRALIA

The majority of South Australian Earthquakes occur within a belt extending from Kangaroo Island in the South through the Mount Lofty and Flinders Ranges in the North. Other seismic zones occur on the southeastern Eyre Peninsula and in the Simpson Desert and the approximate areas of the main zones are shown in Fig. 3. These zones have been established from observations carried out by the Adelaide University Seismograph Stations and are based largely on small earth tremors, the vast majority of which have magnitudes of less than 3. They serve to indicate the broad areas in which seismic activity may be expected and do not necessarily imply the probability of a catastrophic earthquake.

Intense earthquake shocks have also been felt in the Kingston-Beachport area of South Australia. They were probably related to volcanic activity as volcanic craters are known in this area. These are fairly isolated occurrences which may not be connected with the main zones of seismic activity and for this reason have not been shown as such on Fig. 3.

Although earthquakes are generally connected with existing geological faults there is no evidence in South Australia that continued activity is associated with any one particular fault. Shortly after the 1954 Adelaide earthquake the location of the Eden Fault, which is buried beneath a cover of soil along most of its length, was located accurately by the South Australian Department of Mines. All other major faults in the Adelaide Metropolitan area are now reasonably well-known and their distribution is shown in Fig. 4. A larger scale version of this map is available for public inspection at the Department of Mines and all faults shown on the map must be regarded as potentially active.

EARTHQUAKES AND ENGINEERING

Direct Measurement of earthquake shock is usually carried out by seismographs, accelerometers or vibrometers. These instruments are all basically the same and operate by movement of a mass suspended on a spring. Continuous records of all ground movements in South Australia are recorded by seismographs installed permanently in special stations and the locations of the seven seismograph stations operated currently by Adelaide University are shown in Fig. 3.

Study of instrument readings and of visible damage caused by earthquake shaking has shown that horizontal movement causes the greatest damage to engineering structures. Vertical movement is also a component of earthquake shaking and is particularly important in settlement of embankments and foundations. Many parts of the world, subject to regular seismic activity have been zoned according to earthquake risk. This has been done in New Zealand and zones are currently being established for Australia by the National Committee on Earthquake Engineering, set up by the Standards Association of Australia. Experience from earthquake prone areas allows the following generalisations to be made regarding the effects of earthquake shock on civil engineering structures:-

Buildings....... Steel framed tall buildings in which the frame supports all wall and floor loads generally behave well during earthquakes. Reinforced concrete buildings such as grain elevators also fare satisfactorily although cracks may develop in walls and piers. Masonry-bearing walls with wood interior construction, such as many of the older buildings in Adelaide, prove to be very vulnerable particularly if the lime-cement mortar has deteriorated. Modern houses with roofs, walls and foundations tied into one rigid unit behave well particularly if they are built to established Building Codes. The most suitable houses for earthquake prone areas are made entirely of wood and other flexible materials and construction of this type is common in New Zealand. Brick veneer construction falls in between the two extremes. Its flexible wooden frame can absorb earthquake shock although some collapse of the brick veneer walls could be expected.

Most earthquake hazards in the cities are not due to major structural failures but rather to falling debris from parapets, filler walls and displays and to the disruption of public utilities such as electricity, gas and water. Fire caused by ruptured gas mains or electric short-circuits is an important contributing factor in urban earthquake disasters.

Foundations..... Shallow foundations are more sensitive to an earthquake shock than deep piled foundations. For light structures, bedrock makes the best foundation and is used wherever possible in earthquake areas. Stiff soils such as clay and clayey gravel also generally provide adequate foundations. Loose sand or silt may be considerably affected by vibration particularly if the water table is shallow when the material can behave thixotropically. In this case liquefaction may occur, often with disastrous consequences and there are many records of this phenomenon occuring in coastal delta regions.

During the 1755 Lisbon earthquake a new quay built entirely of marble at immense cost sank without trace into the sea floor. At Valdez, in Alaska during the 1964 earthquake a wedge of coast extending 150 m inland and having an estimated volume of 75 million cubic metres slid into the sea destroying harbour facilities.

Slopes and Embankments....... Settlement of embankments is common particularly when thixotropic materials are involved. This can be minimised by careful by careful compaction control during construction but even then settlement can occur. During 1931 a 6 year old 7 m highway embankment in New Zealand decreased in height by 1 m during a series of earthquakes.

Rock and earthslides as a result of earthquakes have been the cause of many deaths particularly in residential areas. Careful design of highway and rail cuttings and avoidance of steep slopes for residential development is necessary in areas subject to seismic activity.

Many earth of mud slides have been caused by liquefaction of loose sandy lenses as a result of ground vibration.

__Dams__.... Earth and rockfill dams such as those most commonly constructed in South Australianusually stand up well to earthquake shock. During the 1906 San Francisco earthquake movement of up to 1½ m was recorded along the San Andreas Fault where it passed beneath the abutment of a rock-fill dam. However no offset was produced in the dam itself although a tunnel from the overflow wier was cut in two and partly crushed. Earth or rockfill dams having an upstream concrete deck are more vulnerable and during the 1971 San Fernando earthquake two thirds of the concrete deck of the Van Norman earthfill dam collapsed and fell into the reservoir.

Concrete arch dams are particularly vulnerable to seismic shock often as a result of rock movement beneath the abutments. Minor cracks in the concrete wall of the Barossa Dam in South Australia are thought to have been partly caused by the effects of the 1954 Adelaide earthquake.

__Tunnels__...Many rock tunnels intersect geological faults along part of their alignment and are often seriously affected by movement. In seismically active areas special design of tunnels is necessary as rupture of the lining may cause flooding or partial collapse.

Earth tunnels are less affected by earthquake vibration unless liquifaction of surrounding materials takes place.

Elevated Tanks....Tank towers of the rod-braced type have been extremely vulnerable to earthquake damage. There is some evidence that tanks placed on concrete footings, tied up and resting on piles, are more stable than those on conventional shallow spread footings.

EARTHQUAKES AND INSURANCE

Approximately 30 000 dwellings were affected by the 1954 Adelaide Earthquake resulting in a total cost to Insurers of some $6 million, the average claim amounting to $200. The cost today of an earthquake of similar magnitude has been roughly estimated as $35 million. For comparison the cost of claims for the 1974 Brisbane Flood Disaster will reach an estimated $100 million, which is about the same order as total costs to Insurers of the 1972 Managuan Earthquake in Nicaragua.

Automatic cover against earthquake fire and shock is given by almost all Insurance Companies in Australia under their House owners and Householder's Insurance. Because of the large number of minor claims made in 1954 for cracking which could have been due to other causes, most Householder's policies now contain an excess of $100.

Cover against earthquake fire is generally an optional extra for Commercial Fire Insurance when an excess of 1% insured value of $10,000, whichever is the less, is usually held over the Policy.

Further Reading

"Elementary Seismology" by C.F. Richter Freeman Publishers, San Francisco.

"Geology and Engineering" by R.F. Legget McGraw-Hill Book Co. Inc.

"The Interior of the Earth" by M.H.P. Bott Edward Arnold (Pub.) Ltd.

"Principles of Engineering Geology and Geotechnics" by D.P. Krynine and W.R. Judd. McGraw-Hill Book Co. Inc.

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July 24th, 1974

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TABLE I

Modified Mercalli Intensity Scale (abridged).

I	Detected only by seismograph
II	Felt only by a few people at rest.
III	Felt noticeably indoors especially on upper floors. Some hanging objects swing and parked motor cars rock slightly.
IV	Felt indoors by many, outdoors by few. Hanging objects swing and windows, dishes, doors rattle.
V	Felt distinctly outdoors. Sleepers awakened, liquids spilt and pendulum clocks stop.
VI	Felt by all and many are frightened and run outdoors. Windows, dishes, glassware broken. Pictures fall from walls and objects from shelves.
VII	Difficult to stand and noticed by drivers of motor cars. Damage to buildings of unsuitable design. Fall of plaster, tiles, cornices.
VIII	Fall of chimneys, factory stacks, monuments, towers and elevated tanks. Partial collapse of some masonry buildings. Changes in flow of springs and wells. Cracks in ground and disturbance to persons driving motor cars.
IX	General panic. Unbolted frame houses shifted off foundations. Destruction of some masonry buildings. Underground pipes broken. Liquefaction and sand craters in some alluvial areas.
X	Most masonry and frame structures destroyed. Ground badly cracked and some bridges destroyed. Damage to dams and embankments. Landslides and general shifting of sand and mud.
XI	Railway tracks bent. Few masonry structures remain standing. Total disruption of underground services and broad fissures seen in ground.
XII	Damage total. Lines of sight and level distorted. Objects thrown in air and waves seen on ground surfaces.

TABLE II

Comparison between Australian and other World Earthquakes

Date	Earthquake	Richter Magnitude	Dead
1755	Lisbon, Portugal	8.7	60,000
1906	San Francisco, U.S.A.	8.3	700
1920	Kansu, China	8.6	180,000
1923	Tokyo, Japan	8.3	143,000
1935	Quelta, Pakistan	7.6	60,000
1941	Meeberrie, W.A.	6.5	NIL
1954	Adelaide, S.A.	6.0	NIL
1960	Chile,	8.4	1,000
1961	Robertson, N.S.W.	5.5	NIL
1964	Skopje, Yugoslavia	5.4	1,000
1964	Alaska, U.S.A.	8.4	125
1968	Meckering, W.A.	6.8	NIL
1970	Peru	7.8	250
1970	Canning Basin, W.A.	6.7	NIL
1971	San Fernando, U.S.A.	6.6	65
1972	Managua, Nicaragua	6.2	10,000
1972	Simpson Desert, S.A.	6.2	NIL
1973	Picton, N.S.W.	5.5	NIL

PLATE X

Damage caused by 1934 Earthquake to house in [illegible]eacombe Park.

Neg. No. 7428

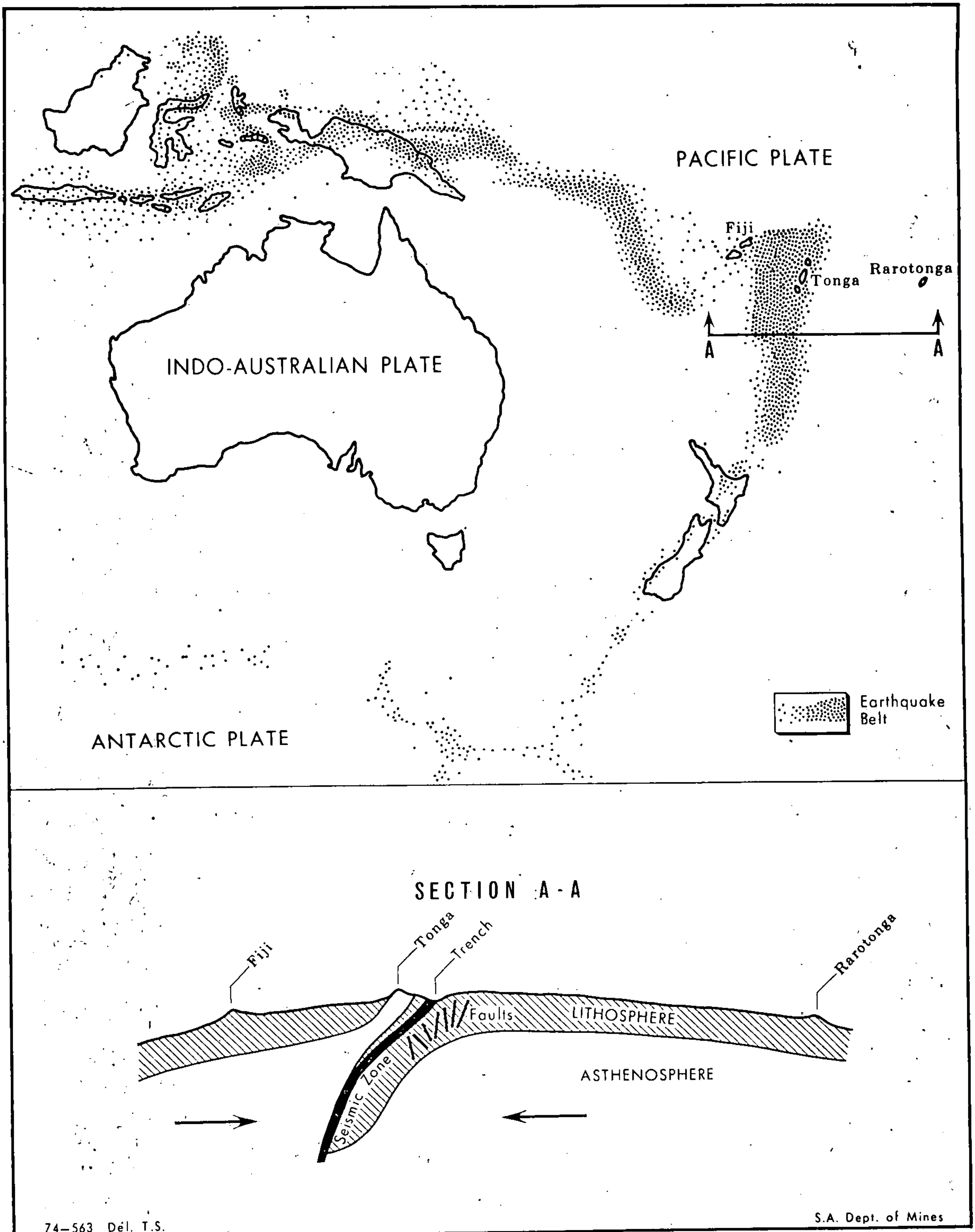

Fig. 1 Australia and the Theory of Plate Tectonics

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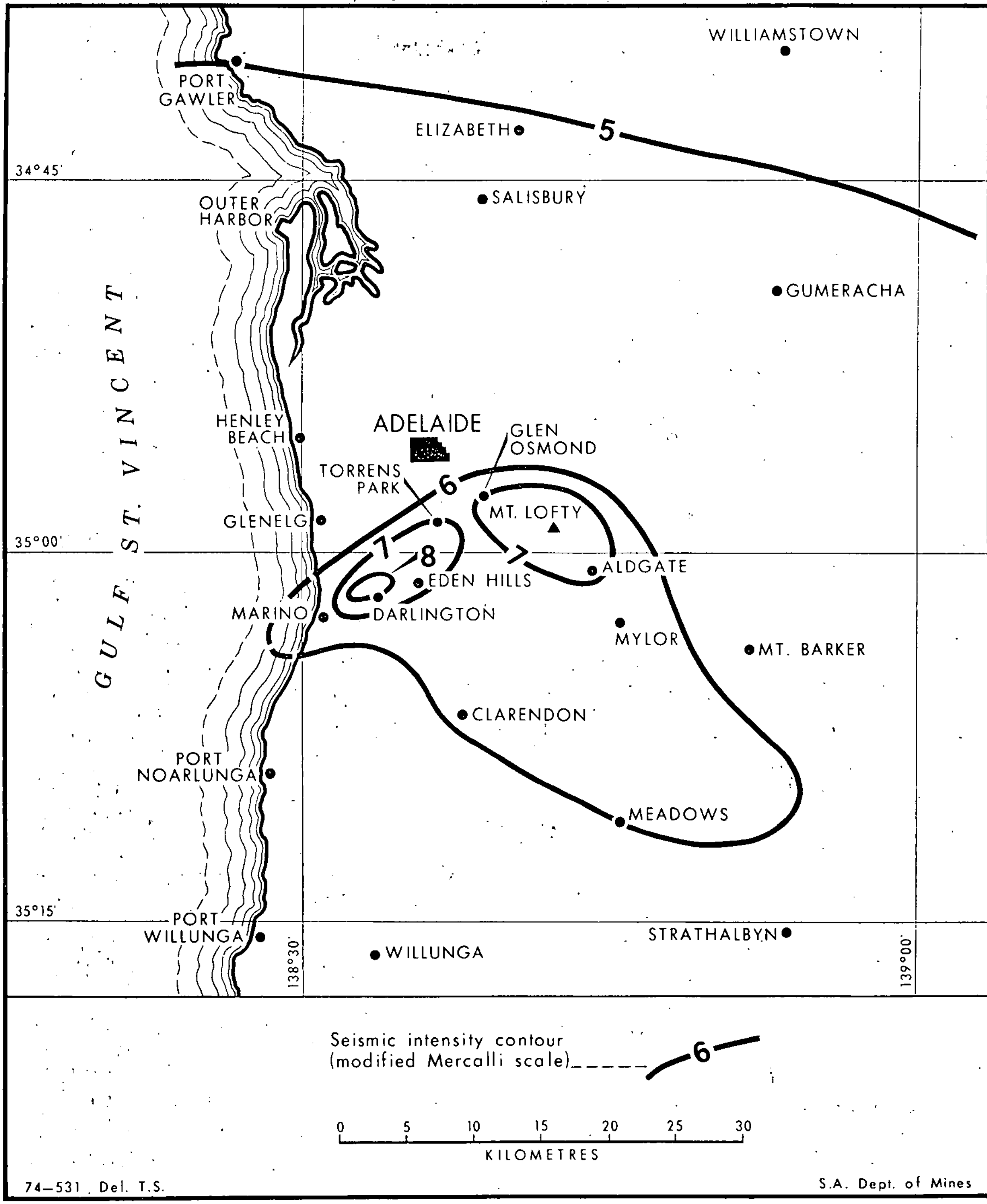

Fig 2 Epicentre of the 1954 Earthquake

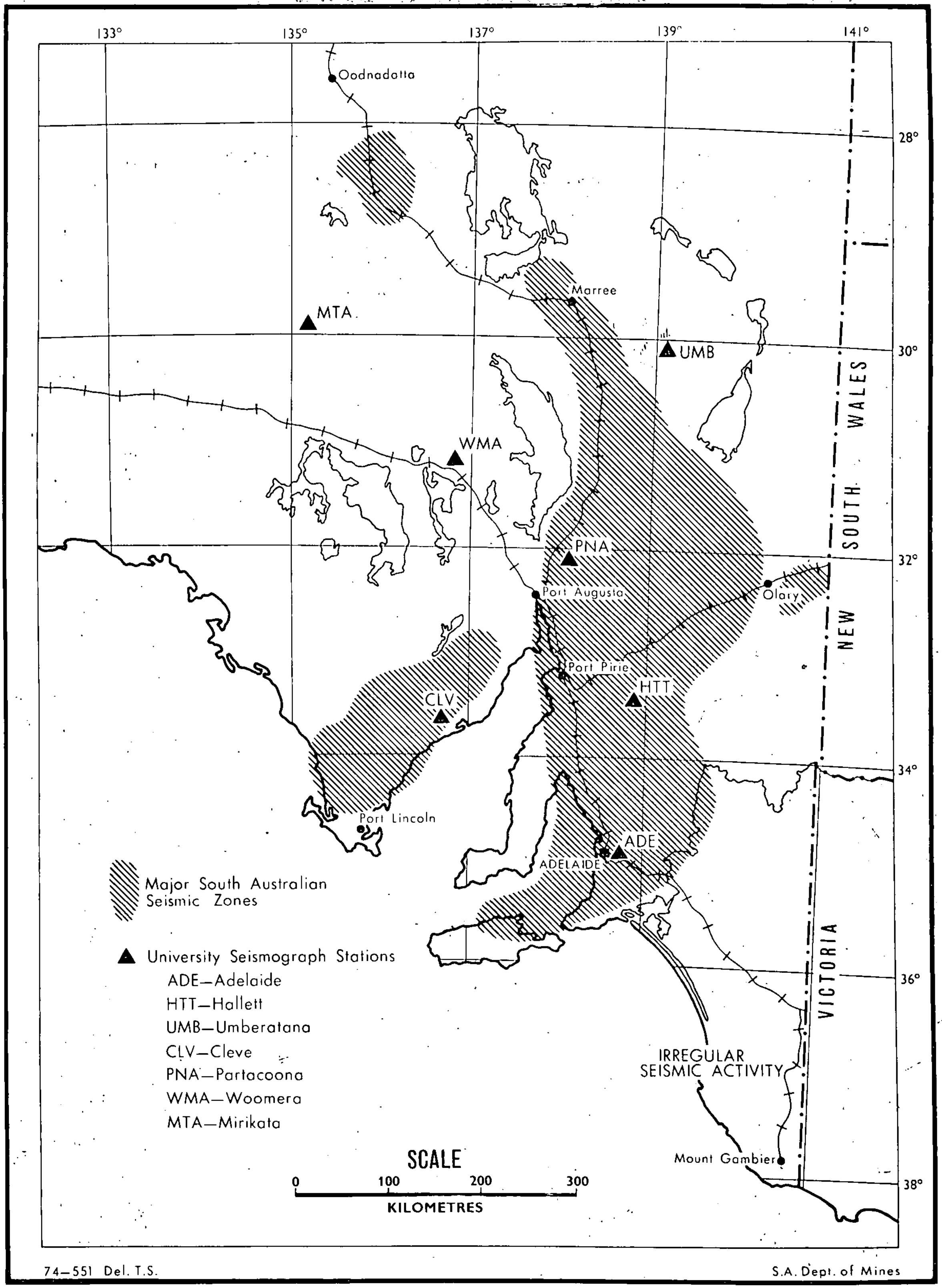

Fig. 3 Major South Australian Seismic Zones

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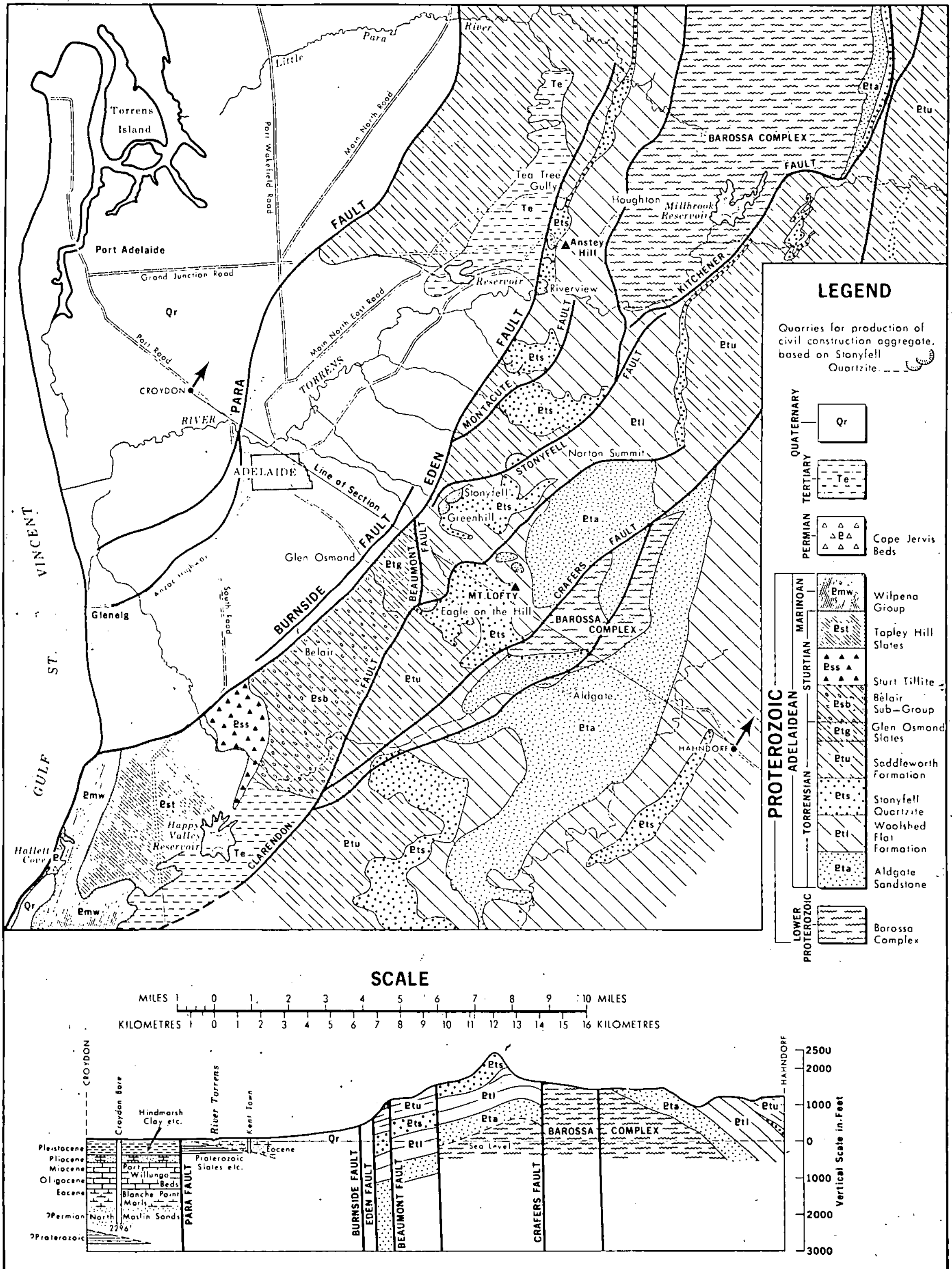

Adapted from Adelaide and Echunga 1 mile Geological Sheets, Geological Survey of South Australia

70–62 Del C.R.S. N.H. Ludbrook 1969 S.A. Dept. of Mines