THE VALUE OF HISTORICAL RECORDS: THE WARRNAMBOOL EARTHQUAKE OF JULY 1903

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ABSTRACT: Historical information drawn mainly from old newspapers was examined to draw up a representative isoseismal map of the larger of the two earthquakes at Warrnambool, Victoria, in 1903. This occurred on July 14. The map was used as a basis for locating the earthquake's epicentre and magnitude. The damage and notable secondary effects such as liquefaction are discussed, in an effort to draw the attention of town planners, engineers and architects to the possible consequences of building in areas of even minor seismicity.

THE EARTHQUAKE

At 2029 local time on the 14th July 1903, an earthquake was widely felt throughout south-western Victoria. Perceptible ground motion did not extend as far east as Melbourne, north as Horsham or west to South Australia and damage was confined to a small area around Warrnambool on the south coast. There was no loss of life or serious injury.

A more detailed examination of the earthquake's effects was made using contemporary newspapers, in particular the Warrnambool *Standard*, Melbourne *Age* and Geelong *Advertiser*. This information was supplemented with entries from some lighthouse keepers' logs to draw up the isoseismal map of Fig. 1. The epicentre suggested by the map is a few kilometres southeast of Warrnambool, which is supported by reports that movement at Warrnambool was a 'thumping up and down' as distinct from the 'undulating' one at Port Fairy, 20 km west.

It has not generally been possible to link Australian earthquakes, especially historical events, with particular faults, although Hills (1975) has associated the 1932 Mornington earthquake with Selwyn's Fault on the eastern side of the Port Phillip Sunkland. Warrnambool is situated near the eastern edge of the Portland Basin about 100 km east of Boutakoff's (1963) Kanawinka line of weakness along the Basin's western edge. This line of weakness has a fine structure of faults rejuvenated in the early Quaternary but not currently seismically active.

Victoria's most recent volcano, Tower Hill, which Gill (1943) recognised to have been of Holocene age, last erupted only five thousand years ago. It is located about twenty km west northwest of the earthquake epicentre but there is no apparent causal relationship between the two.

The earthquake's magnitude has been estimated at ML 5¼ using the approximate equation below (McCue 1977) which is a quasi-empirical formula based on the radius of perceptibility (Rp) measured in km.

$$ML = 1.05 + 1.85 \text{ Log } Rp + 0.8\ Rp/1000$$

This moderate magnitude is supported by the short duration experienced close to the epicentre at Warrnambool, reported variously as between 4 and 12 seconds. There was considerable damage for an earthquake of this magnitude which by comparison is about the same size as the 1954 Adelaide event, Australia's most damaging earthquake, but energy-

TABLE 1
1903 WARRNAMBOOL EARTHQUAKES

Date	*Time* (L.T.)	*Latitude*	*Longitude*	*Maximum Intensity*	Rp	ML
7/4/1903	0952	38°26'S	142°32'E	VII	—	5.0
14/7/1903	2029	38°26'S	142°32'E	VII$^+$	160–170	5.3

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wise about 1000 times smaller than the disastrous February 1976 earthquake in central Guatemala which caused 22,000 deaths and left a quarter of the population (1.5 million) homeless. The October 1968 earthquake of magnitude 6.9 (ML) that destroyed the Western Australian wheatbelt town of Meckering (Everingham & Gregson 1970) is rated amongst the largest to have struck within the Australian continent. Victoria's largest earthquake this century, ML 5¾, occurred near Mt. Hotham in May 1966, but caused little or no damage due to its distance from population centres. Several small aftershocks were felt in Warrnambool during the week following the earthquake.

Just three months previously the same area had been severely shaken by another earthquake, the so-called Great Warrnambool Earthquake. Intensity at Warrnambool was assessed at VII (Modified Mercalli Scale) on both occasions, though the damage due to the earlier event was slightly less severe and its felt area smaller. The amplitude of the July event as recorded on the Melbourne seismograph was almost double that of the April earthquake, indicating a difference of about 0.3 in magnitude.

The observation that the duration of the April shock in Warrnambool was longer than that of July may indicate that its focus was further south, but in Table 1 summarising the parameters the same epicentre is assumed.

PAST SEISMIC HISTORY

The earliest report of an earthquake in the district, as noted in a diary of a pioneering resident, occurred in November 1848 (Osburne 1887). At least eight others including the two above occurred in the district between 1900 and 1959 (Underwood 1972), of which the largest was undoubtedly that of July 1903. This brief summary serves to highlight the continuing seismicity of the region despite its

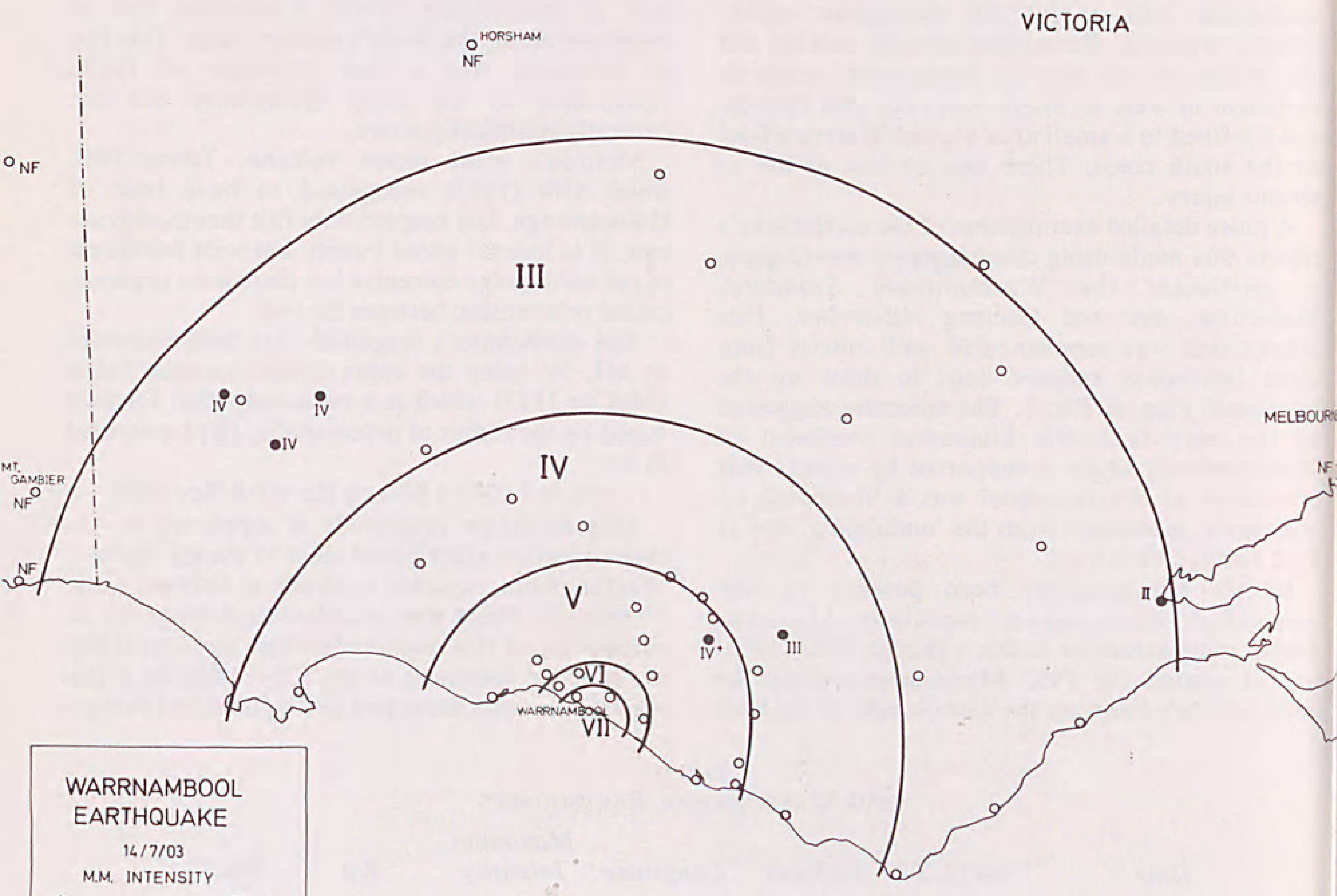

FIG. 1 — Isoseismal Map (Modified Mercalli Intensity) of the July 1903 Warrnambool Earthquake in Victoria. Open circles represent spot intensity values within the labelled range.

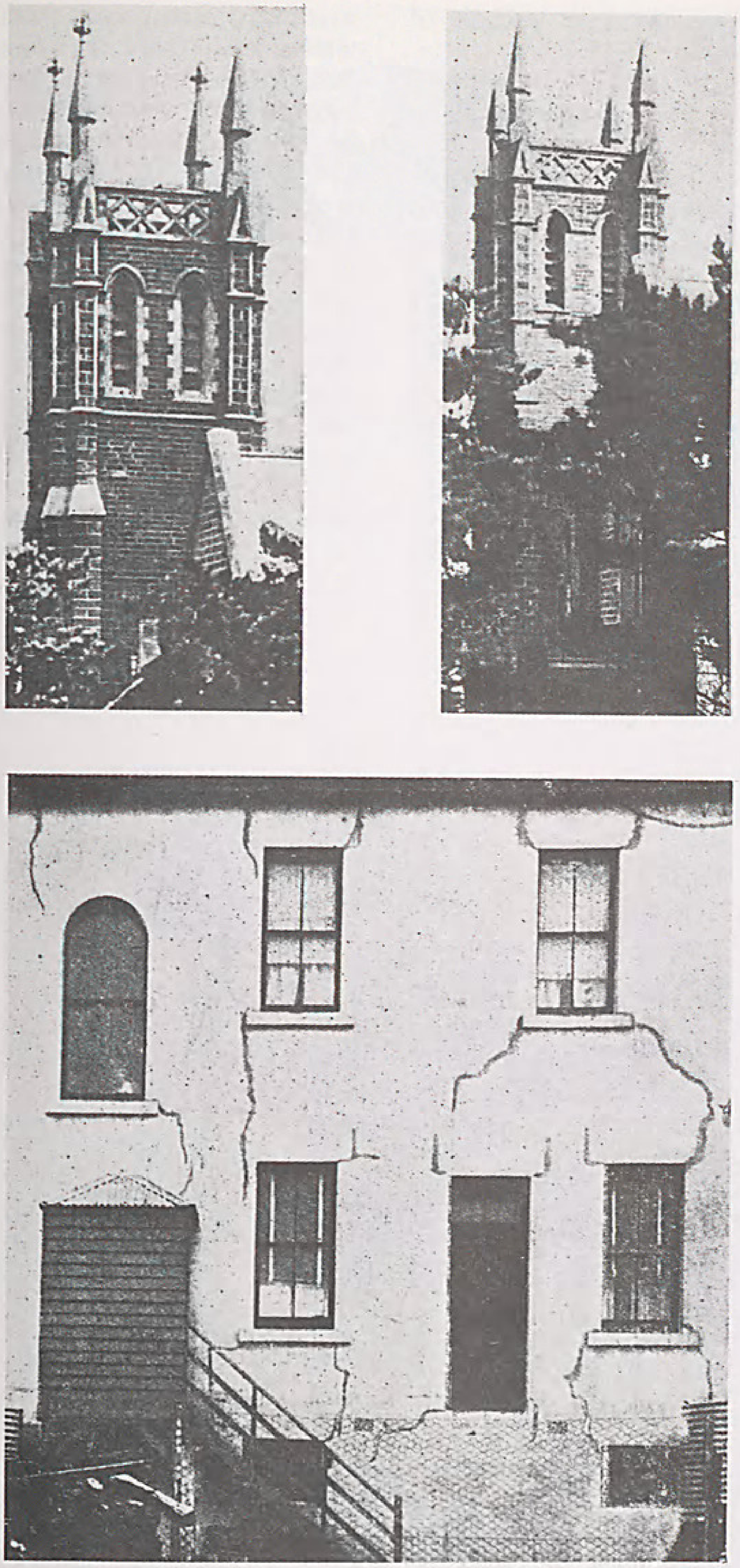

PLATE 18

(*Above*) Presbyterian Church after the first (April) and second (July) shocks. Note the crosses.

(*Below*) Cracks at the back of the Brian Boru Hotel which reflect the stress concentration at the openings. (*Both photographs from the Warrnambool 'Standard'*.)

apparent quiescence during the last decade of improved instrumental coverage.

DAMAGE

Primary: There were apparently no large, important, engineered structures in the region of strong shaking but an interesting comment on the damage distribution was made in the *Argus* (16/7/1903): 'Stone buildings in the low-lying parts of the town and the Hopkins River have sustained the most damage'. This observation has two parts: firstly it is a comment on local construction techniques and secondly on the foundation materials.

Two residential buildings, one of two storeys, were sufficiently damaged to be condemned but none collapsed outright. Elsewhere, in churches, banks, hotels and public buildings, most damage involved fallen plaster from cornices, ceilings and walls, dislodged or fallen ornaments such as balustrades, or church crosses weighing up to 2½ cwt. (see Pl. 18, above) and collapsed chimneys. Many walls were cracked (see Pl. 18, below) and in the two buildings declared unsafe for habitation whole sections of the wall had fallen out.

In the cemetery, tombstones were shifted, many twisted, and some columns and headstones had fallen or sheared off at the base (see Plates 19, 20). The more severe damage in the July than in the April event may have been in part the result of cumulative effects of the two earthquakes. Cracks from the first earthquake were found to have been re-opened or widened by the second.

The church steeple at St. Josephs was twisted and sheared through seven metres from the top which, after the earthquake, was found to be offset some 2 cm east relative to the lower section. The steeple

PLATE 19

Tombstone shifted in the Warrnambool Cemetery. (*Photograph from the Warrnambool 'Standard'*.)

PLATE 20

Tombstone in the Warrnambool Cemetery rotated. Note displacement of top. (*Photograph from the Warrnambool 'Standard'*.)

top was subsequently shortened whilst being rebuilt. A large stone block was ejected from the steeple and its initial velocity, hence that of the steeple, must have been about 1 m/sec since it landed nearly four metres out from the wall where 'it made a hole about a foot deep in the earth'. This would accord with the comment of a passer-by that 'during the earth tremors the steeple swayed to and fro in a very alarming manner'. Several large (1000 gallon) full iron water tanks burst at their bases and a pedestrian suspension bridge over the Merri River was twisted and distorted.

The overall repair bill does not appear to have been costed but it was 'estimated at thousands of pounds' and a few individual estimates were made: St. John's Church £250, a similar amount for St. Joseph's Church, Victoria Hotel £80, the cemetery £600 — £800, a residence at Sherwood Park £800. To convert to 1977 $ values, these figures should be multiplied by about 24 which is twice the change in the retail price index over that period.

Secondary: One perhaps surprising but noteworthy effect from an earthquake of this size was the widespread evidence of liquefaction in the intertidal zone at the mouth of the Hopkins and Merri Rivers. Liquefaction of a saturated soil occurs under cyclic loading when the pore-water pressure equals the confining pressure, at which point the effective stress on the soil structure is reduced to zero. Large deformation of overlying materials or structures may result depending on the confinement conditions.

Sand 'boils' or 'volcanoes' indicate that a flow path has opened to the surface venting the excess pore pressure. At Warrnambool, the ejected material, seemingly a black silty sand and water, came from a depth of at least two metres, the depth of the fissures, and formed craters up to two metres across and half a metre high. The subsidence of sand embankments along both rivers was no doubt associated with liquefaction of the underlying saturated sand layer.

Foundation failure may have been a prime cause of the severity of damage to low-lying buildings in the town. According to Gill (1943) one of the characteristics of the dune sandstone in the Warrnambool area is the presence of buried soil horizons which 'vary in thickness from 2 feet to a few inches'. A geomechanical investigation would soon indicate whether these dark, sandy soil horizons underlie, at shallow depth, the damaged areas. It is also likely that these low lying areas are either earlier courses of the Merri River or former swamps impounded by the aeolian dunes. Many of these swamps have since been reclaimed. During the April shake, the water appeared to boil, although 'sand boils' were not observed, presumably because they were underwater. Similar sand 'volcanoes' and boiling were observed close to the waterfront at Kingston, Robe and Beachport in South Australia, after the much bigger May 1897 earthquake there.

DISCUSSION

(1) Despite the relatively small size of this earthquake considerable damage was occasioned to rigid structures — the stone buildings and tombstones. This is explicable in terms of their lack of ductility coupled with the fact that their resonant frequency would lie in the peak range of the response spectrum for a *close* earthquake. Care should be taken in constructing non-ductile buildings in seismic zones, especially important rigid structures and particularly those with attachments of different natural frequency like nuclear containment vessels. Strict care should be observed even when large earthquakes are negligibly remote events.

(2) Given appropriate soil conditions, even a moderate earthquake (say magnitude above 5) can cause liquefaction, which could be disastrous for important structures whose foundations were not adequately designed for such effects. Designers of facilities sited close to the sea or to a lake or river, to make optimum use of port access or the convenient water supply, should be aware of the heightened environmental risk in a seismic zone. Local geology can compound the liquefaction problem in the case where a confined saturated silty sand overlies a relatively rigid basement, when energy will be trapped in the sand layer rather than radiated back into the bedrock. This can lead to a dramatic increase, relative to bedrock, in the duration of shaking, and either an increase or decrease in level depending on the time taken for the layer to fail.

(3) Both the above points depend on identification of active seismic zones. The discussion of the 1903 earthquakes and the brief résume of pre-1959 activity underscores the activity, minor though it is, of southwestern Victoria and forcefully illustrates the benefits of historical seismic studies.

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