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The shifting goals of earthquake monitoring in Australia, from a personal perspective

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Abstract

The reasons for monitoring earthquakes in Australia have been many, with different clients both internally and internationally over the last 12 decades and not all benefitted Australia. The first seismographs in Australia in 1901-1909 were at the behest of two international organisations, the International Seismological Summary (ISS) and the Society of Jesus (SJ). The ISS stations used Milne seismographs in Adelaide, Melbourne, Perth and Sydney, capable of detecting major earthquakes worldwide and useless for detecting or recording Australian earthquakes, to the dismay of the Australian shareholders. Contrast that with the SJ station installed at Riverview, Sydney in 1909 which soon proved its worth for detecting and locating earthquakes and, later, their magnitudes both local and worldwide.

The development of nuclear weapons at the end of WW2 heralded a new wave of monitoring with establishment of the World Wide Standardised Seismographic Network, equipment and supplies funded by the United States to monitor underground nuclear tests worldwide. This coincided with the International Geophysical Year in 1957/8 which attracted key researchers interested in monitoring Australian earthquakes for science and risk mitigation, at the ANU and Universities of Adelaide, Queensland and Sydney, and the Commonwealth Government.

The rapid increase in Australia's population after WW2 demanded large dams for hydroelectricity generation, water supplies for cities and crop irrigation. Dam safety was an issue which led to private players needing to monitor earthquakes. Other seismographs were installed in special structures.

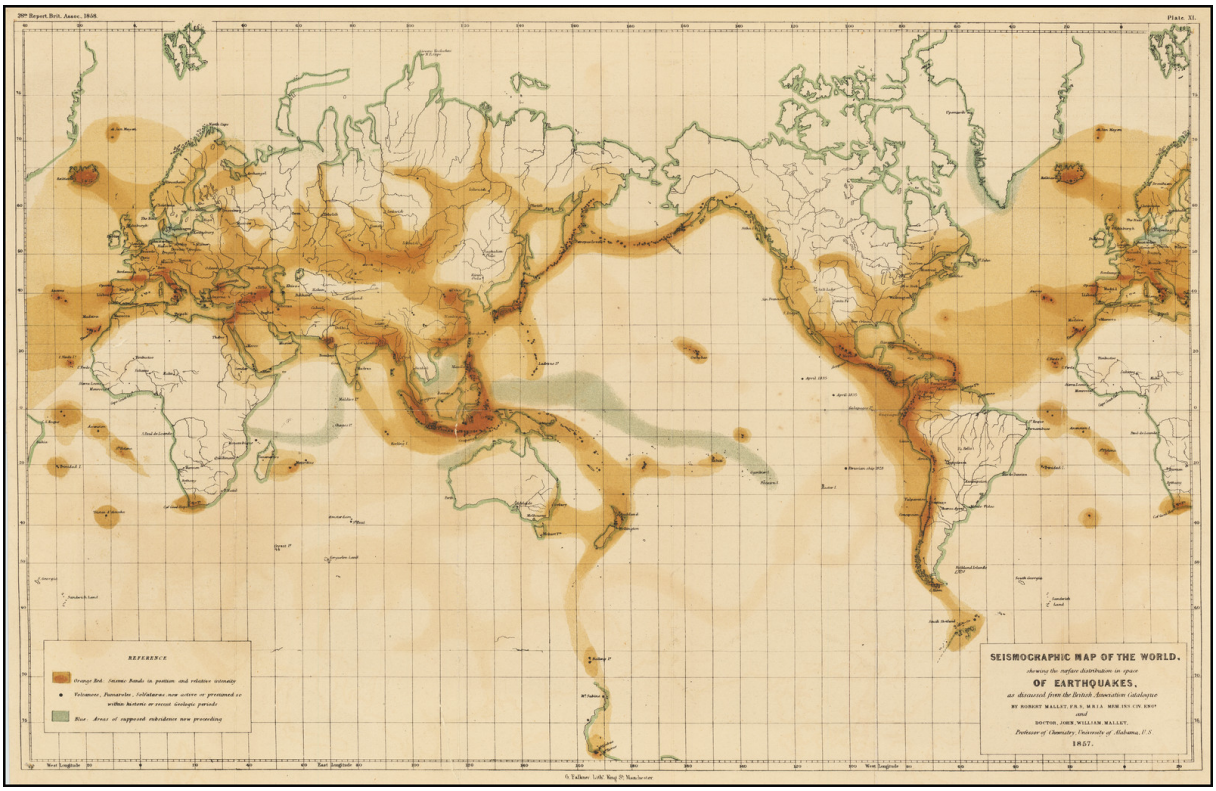
The State and Commonwealth Government, and University networks shared data via the ISS, by then morphed into the International Seismological Centre (ISC). But private networks and some international operators were not interested in sharing data, not at first. Tension between the different players led to the demise of State Government operators and national politics led to general acceptance that making data freely available was beneficial though some of the private operators are still not convinced.

Perhaps the biggest advances in earthquake monitoring over the last few decades have been analogue to digital data, the internet, broad-band seismometers, strong motion instruments for engineering applications and the inception of citizen science.

Keywords:.Australian seismograph networks, instrumentation, data ownership and citizen science

1. Introduction

Irish physicist and engineer Robert Mallet founded the science of seismology and coined the term *seismology* to describe the scientific study of earthquakes. He also invented the words *epicentre*, *seismic focus* and *isoseismal line*. In 1858 he and John Mallett published the first map of global earthquakes (Figure 1) which was based on felt reports alone. Southeast Australia including Tasmania, and the Darwin NT areas



were already by then areas of known seismicity.

Figure 1 *Mallet's map of world epicentres, 1858.*

The advent of the international telegraph about 1865 and the laying of submarine cables between Java and Darwin in 1872 enabled a communications connection between Adelaide and London. Adoption of Greenwich Mean Time in 1884 saw in the first revolution for international seismology with a common time base. The development of seismometers and recorders soon followed by about 1900, enabling worldwide seismographic networks of instruments and databases of earthquakes. It was another 30 years before the first sensible magnitude scales were developed, a goal still not completely satisfied. The adoption of the new technology was rapid in Australia but not necessarily in Australia's interest.

Scientists throughout Australia were anxious to record evidence of local earthquakes reported widely in newspapers from the time of colonisation of each State. None more so than Tasmania where a sequence of some 2500 earthquakes were felt between 1883 and 1892, their location and origin time were hotly debated in letters to the editors of local and national newspapers. Local meteorologist Captain John Shortt (Shortt, 1884) documented more than 2500 of the Tasmanian sequence and fellow investigator A. B. Biggs 1883 built Australia's first seismoscopes to try to locate them.

South Australians were rocked by earthquakes from their arrival in 1836 and large earthquakes in 1897 and 1902 were the impetus for local engineers and scientists led by Sir Charles Todd to lobby, through the Australian Association for the Advancement

of Science (AAAS), even harder for a seismograph to be installed at Adelaide Observatory to try to locate their epicentre, associate the epicentre with mapped faults and understand their cause. The AAAS compiled lists of felt earthquakes which have subsequently been used to locate the epicentre and estimate their magnitude. Despite this pressure it took a decade for government to fund the purchase of an instrument that ended up a huge disappointment.

2.1 Seismographs - Part 1, the promise

British Engineer John Milne, wanting to build an international seismographic network, convinced Australian State Governments to purchase and install his instruments in astronomical observatories in Perth (1901), Sydney (1906) and Adelaide (1909). They rapidly proved to be useless for recording local earthquakes which was the goal of the Australian scientists, called upon by the media to pontificate whenever local earthquakes occurred. These early Milne seismographs were low-gain, undamped pendulums capable of recording great earthquakes worldwide but little else. Such a shame when useful instruments were available and installed by that indefatigable Jesuit teacher/scientist Father Edward Francis Pigot SJ at Riverview Observatory http://www.map.id.au/seismic/edward_pigot.html in Sydney in 1909. Australia was a critical quadrant of the world for the Jesuit international seismograph network.

2.2 Seismographs - Part 2, hiatus

This state of affairs stayed fairly much unchanged until the International Geophysical Year in 1957/58. The Milne seismographs were updated to Milne/Shaw recorders in the mid-1920s which improved their capability a lot but they were still vastly inferior to the Galitzen and Mainka recorders at Riverview. The national capability expanded marginally with installation of a seismograph at the University of Queensland in Brisbane in 1935 with a grant from the local Catholic Bishop.

2.3 Seismographs - Part 3, boom and bust

The IGY stimulated renewed interest amongst universities researchers at Adelaide University and the ANU, Canberra with the unenthusiastic cooperation of a Commonwealth Government dragged in against their will to make use of US-gifted seismographs at Toolangi Vic. and Mundaring WA. Adding seismology to the discipline at the Watheroo/Mundaring and Toolangi magnetic observatories in the late 1950s led ultimately the WA and Victorian State Governments closing the seismograph at their astronomical observatories. The observatories soon closed all their functions seemingly no longer relevant.

Proliferation of nuclear weapons was the next big driver for seismology, in Australia and the world, monitoring underground nuclear explosions following UN agreement to stop testing in the atmosphere and ultimately underground. The Worldwide Standardised Seismographic Network was a US led program (Peterson and Hutt, 2014) to install between 1961 and 1967 more than 117, 6-component sets of identical US built seismographs worldwide to detect illicit testing. Australia and other countries provided the sites and staff, initially at Charters Towers (Qld), Riverview (NSW), Toolangi (Vic), Hobart Tas), Adelaide (SA) and Mundaring (WA) and in Papua New Guinea at Port Moresby and Rabaul. All of these stations apart from CTA were near coastal.

Sometime about 1956 the US, through AFTAC (Air Force Technical Applications Centre), established a secret 4-station linear seismograph array near Alice Springs. Deception (or was it coyness) had the US Government claim the equipment was for *weather* monitoring stations. It was only during a visit by a BMR geologist that Australia

discovered these were seismometers, not weather monitoring equipment. The data recorded in this period has never been shared with the Australian Government.

In 1965 the US negotiated an extension of their 10-year lease and an upgrade of the array, to replace the existing four seismic vaults with a spiral-shaped array of underground seismometers. But the secrecy remained, data were not shared with Australia until the mid-1980s when AGSO had a feed from a single component of the array, even so its site coordinates were kept secret for nearly a decade after that so data could not be used for earthquake locations. Meanwhile in 1965 the UKAEA built an 'L' shaped array at Warramunga near Tennant Creek managed under contract by the ANU who in turn outsourced most of the functions including recruiting (Lade, 2024). The array data were recorded on tape and the tapes were sent to the UK at first but later copied for use by the ANU and then AGSO.

During the 1960s and 1970s Australian universities responded to the technology advances and partnered with infrastructure owners to monitor their facilities, record earthquakes and mine blasts to model crustal structure, and investigate any activity of faults and earthquake mechanisms.

At the University of Tasmania broad-band seismographs were designed and built, by Newstead and his team (Carey and Newstead, 1960) and they designed and installed the World's first telemetered short period seismograph network, engineers working with geologists and physicists/seismologists for the Tasmanian HEC. The data was managed by the University of Tasmania and was then publicly available but now, the network has been outsourced by Hydro Tasmania and the data are not in general publicly available even though it is Government owned business enterprise.

Similar telemetered seismic networks were soon after established in NSW in the Snowy Mountains and Dalton-Gunning regions and also to monitor the large dams providing water for Sydney and for irrigation.

In South Australia the network expanded under Dr Sutton at Adelaide University, many more earthquakes were located, a number of MSc and PhD students graduated.

In Western Australia, network improvements and research were undertaken by BMR/AGSO under Ian Everingham and Peter Gregson, these programs accelerated after the Meckering earthquake in October 1968 when the first co-seismic surface faulting was observed in Australia. Researchers came from all around the world to see the 34km long fault, far enough from Perth that damage there was minimal.

Similarly in Queensland, Wivenhoe Dam, a large dam in the SE of the state, was equipped with a modern telemetered seismograph network, initially staffed by state public servants. But the rest of this the second largest state was equipped with only two seismographs, at Charters Towers (UQ) and Mount Isa (BMR/AGSO).

Privatisation of many of the contracted network services in NSW, Victoria, Tasmania and Queensland saw the function and data privatised, with restricted access for governments, universities and the public.

2.4 Seismographs - Part 4, the digital age.

Manual processing of analogue data was laborious and done days to weeks in arrears of felt earthquakes. Photographic, pen and ink or smoked paper records from remote stations were posted to observatories once or twice a week.

Digitisation and computer processing in the late 1970s and early 1980s saw in the next revolution in seismology and many other fields, and the possibility of near-real-time analysis. This was a saviour for handling media requests, initially newspaper then both radio and TV but meant a 24/7 work cycle for seismologists. Reporters (and at times

government ministers) found your home phone numbers and had no compunction ringing at any hour of the day or night for information about local, regional or international earthquakes felt or reported through wire services such as Reuters or AAP. It was decades before the Federal government accepted they had to organise analysts on shifts to cover the load.

Ironically, this period also saw a boom in historical studies of earthquakes dating back to the first arrival in Australia of European settlers in each state and territory. This was driven by hazard studies, the short period of instrumental recording dating back to the late 1950s was too short to confidently define source areas or recurrence times, let alone set a maximum magnitude or assign foci to mapped faults.

The development of broadband seismographs at Tasmania University (Carey and Newstead, 1960) was way ahead of its time and had to wait for fast data processing and computer software to make use of such data. Equally entrepreneurial seismologists at SRC and Adelaide University in the late 1970s built their own digital seismographs and software to handle the data collected. Only the seismometers were imported.

Digital data was one thing, compiling a database of Australian earthquakes another. A computer database of Australian earthquakes was first compiled by Denham and others (1975) using as the starting point a copy of a deck of cards compiled by author KMc whilst a postgraduate student at Imperial College, London. The cards were punched and verified by Bill McCue at the Australian Bureau of Statistics, Canberra, the author's father. Imagine trying to do that today.

Under BMR David Denham's stewardship in the 1970s the States were encouraged to share their earthquake data and, in exchange, were supported by small annual grants from BMR. This arrangement lasted about 10 years.

In South Australia, the University of Adelaide abandoned seismology after David Sutton's death in 1981, the role taken up by Professor Stewart Greenhalgh at Flinders University for a few years but Flinders University in turn lost interest and the SA Department of Mines agreed to look after the monitoring and people. David Love became the SA State seismologist. That changed in 2017 when State finances were tight and the group was closed down imposing forced retirement on one seismologist, 2 analysts and 2 technical staff. Part of the State/Commonwealth government agreement was that BMR (now GA) would take over some of the seismograph stations. This was a blow at the time but the washout was very positive.

The 1990's saw a lot of changes, the Commonwealth-State agreement unravelled causing States to reassess their priorities and seismology was not one of them. The Queensland, Tasmanian and South Australian state governments chose to abandon their support for seismology and encouraged the private sector (dam owners and Lucas Heights) to take over existing networks and people.The Commonwealth Government kept their NT, NSW, ACT and WA stations running but closed the Mundaring Geophysical Observatory in WA when Foreign Affairs money for nuclear monitoring was diverted by GA to pay for earthquake monitoring.

The WWSSN stations were all upgraded by the USGS with broad band seismographs and a new downhole station at Narrogin WA. They agreed to KMc's proposal to upgrade the privately owned Riverview seismograph and in exchange BMR undertook the upgrade at Mundaring Geophysical Observatory. The near-surface borehole instruments at Alice Springs were relocated down 30m boreholes paid by the Commonwealth Government, nuclear monitoring money from the Department of Foreign Affairs. The ANU kept the management of the array but data was sent directly to the ANU, AGSO, and the US and later to Geneva.

The December 1989 Newcastle earthquake caused the collapse of several buildings in Newcastle NSW with the death of 13 Novocastrians. This is still one of Australia's greatest natural disasters in terms of dollar loss but it had important ramifications. The first Australian-made digital seismographs were installed around Newcastle and recorded the single aftershock the following day. The Kelunji recorder had been under development for some years at the Seismology Research Centre led by Gary Gibson at Phillip Institute of Technology. The group was later absorbed into RMIT, then outsourced to the private sector.

3. Citizen science to the rescue

In 1989 not a single major urban area and just a few individual large dams, the Lucas Heights experimental nuclear reactor and the Animal Health Laboratory in Geelong were adequately monitored for earthquakes. Only in 2024 is the goal to monitor our cities being realised with the advent of citizen science, cheap seismographs, the internet and GPS. Owners do provide data on request for some of these seismographs.

When the SA network was abandoned by the state government in June 2017, some of the stations were taken up by GA, but most were closed. The staff were retired but managed to acquire some of the redundant stations and and equipment. Soon, under David Love's direction, they and other interested scientific, engineering and technical staff formed the Seismological Association of Australia (SAA) and a new network of digital seismographs began to emerge across Southeastern Australia. Data were ftp'd to a publicly accessible server at Melbourne University managed by Gary Gibson and his group. At the time of writing, there were more than 50 stations accessible from this Server including Commonwealth Government stations and individual privately owned and operated stations. South Australia is now better served than ever before. Canberra has about 10 seismographs in the urban area, previously there were two.

Price helped drive the growth in numbers of seismographs. Private sector provider Raspberry Shake has established the largest community-powered seismic network in the world, out of Panama in Central America, monitoring earthquakes globally with cheap hardware and access to ever improving software. In Australia, SAA, SRC and University of Melbourne combined to provide a similar service with some of the World's most sensitive seismographs and a new development, the world's cheapest single component digital seismograph. The Peismo was developed by SAA members Colin, David and Eric Love, data telemetered to Melbourne. Users have access to *Waves*, analysis software developed at SRC, Melbourne. Some 10% of the stations on this network are Peismos built in Adelaide by John Millard.

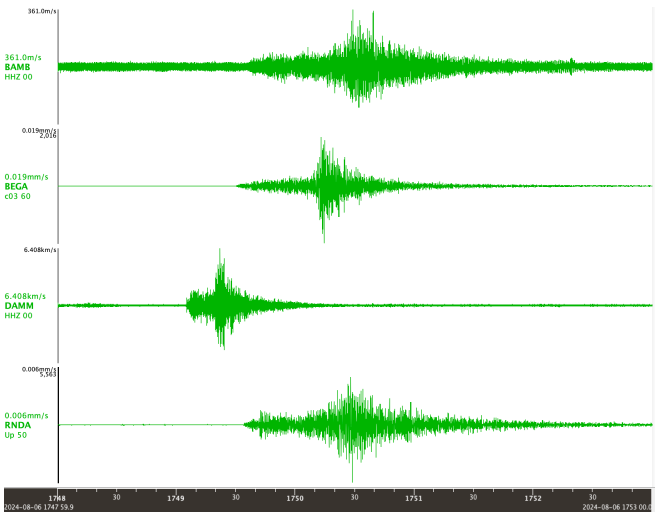


Figure 2 Records of a magnitude 4 earthquake in Victoria recorded by local seismographs (Kelunji and Peismo) built in Melbourne and Adelaide.

SAA has acquired a number of vertical axis seismometers for users wishing to install a Peismo. They are mostly Willmore and L4C seismometers.

4. The future for monitoring in Australia

Australians are dependent on the Commonwealth Government commitment to maintaining a world class national seismographic network with publicly accessible data and database but such agreements have been flakey in the past. This needs to be a watertight commitment, a former manager changed the scope of monitoring on the pretext that it was simply stamp collecting but the great earthquake in Sumatra put paid to that decision. But there is a need for supplementary data, from operators of major dams, structures such as Sydney Harbour Bridge, Opera House and the small nuclear reactor, the Animal Health Laboratory near Geelong, and a radioactive materials storage facility at Mt Walton East WA, the most seismically active State in the Commonwealth. These are critical or nationally important facilities.

A sample of 'normal' buildings in each city should be monitored to ensure Australia has a building code that accommodates the ground shaking from Australia earthquakes which, we know, are unique to Australia. They are not like earthquakes in California. Special buildings too should be monitored to explain any surprises, like those that befell Christchurch engineers in the large 2010/11 earthquakes there, intraplate like ours.

More work needs to be done on the Peismo, to incorporate a triaxial accelerometer and preferably 6-channels. SAA should also set up a Server available to governments, industry and the public, first and foremost the public.

More Australians should be encouraged to join the citizen science seismology project to increase the density of stations, particularly in our cities. The Peismo makes it possible. Other developments on the horizon are anticipated with interest.

We should have an honours list to those who have built Australia's knowledge base in seismology and earthquake engineering, not forgetting the hardware and software developers. The list might start with the Rev. W.B. Clarke who compiled the first list of Australian earthquakes, Charles Todd who contributed so much to the Seismological Research Committee of the Australian and New Zealand Association for the Advancement of Science, Father E. F. Pigot S.J. who built the Riverview Observatory (seismological and astronomical) and made it known internationally. The list need not be too long.

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