SAA Newsletter

#3/2024

From the Editor We encourage members to submit articles with an earthquake connection of interest to members but accepting they may be edited or not published, at the discretion of the editor. Contributions to: mccue.kevin@gmail.com

Contents

Major Quakes Worldwide	1	On becoming a seismologist	3	Dr David Denham - obit.	7
Another Peismo on line	2	Jamestown SA earthquake	6	NSH23 Hazard - A critique	8
Maps of Earthquakes	2	Aftershocks Jamestown	7	What is pga?	14

Major Earthquakes Worldwide, April - June 2024

Another two major earthquakes occurred in this quarter, in China and Peru.

Figure 1 Major earthquakes in the 2nd quarter of 2024 from the USGS.

The eastern coast of Taiwan, near Hualien, was struck by a powerful 7.2-magnitude earthquake on Wednesday morning, April 3rd, at 8 a.m. local time. The quake was followed by several powerful aftershocks—one at magnitude 6.5. Damage was significant, resulting in the collapse of several high-rise buildings and many homes. The earthquake also generated a 1m high tsunami locally.

Up to 18 people were killed including two Australians, and more than 1,140 people were injured. The quake triggered massive landslides in the mountainous region of Hualien, causing some buildings to tilt dangerously, making rescue efforts very challenging.

No deaths and only 8 injuries were sustained during the Peru earthquake. Roads were damaged by landslides and a small tsunami was generated.

Major earthquakes Worldwide, April - June 2024

Date UTC	Time UTC	Latitude	Longitude	Depth km	Mww	Place
2024-04-02	23:58:12	23.84	121.60	40	7.4	Hualien City, Taiwan
2024-06-28	05:36:38	-15.81	74.45	28	7.2	Atiquipa Peru

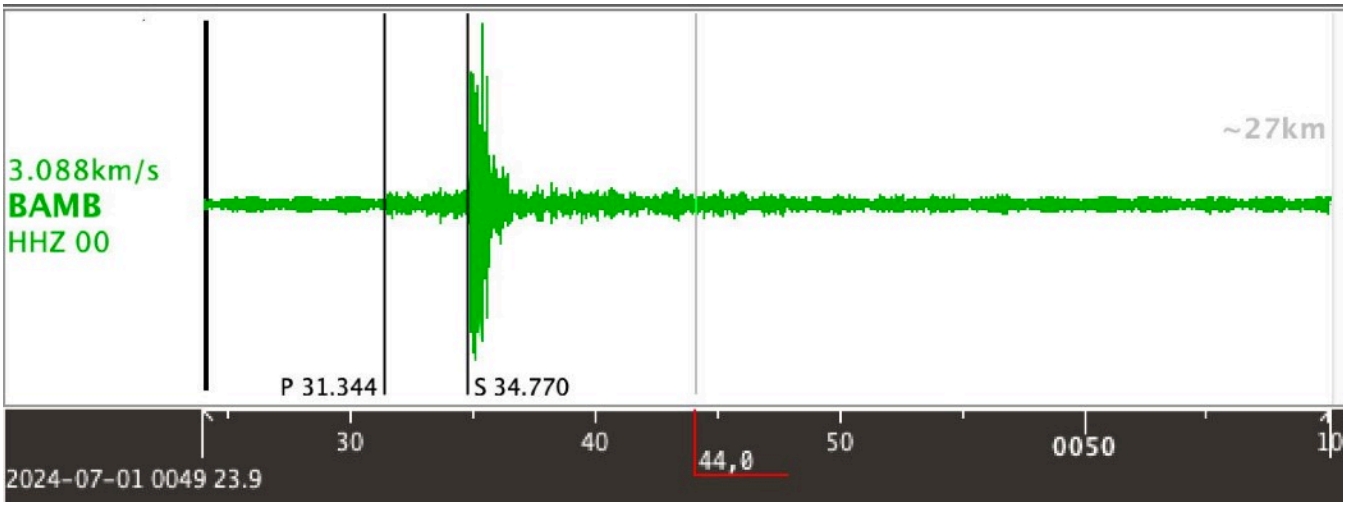


Figure 2 Seismogram of a magnitude 1.7 earthquake near Gunning NSW recorded about 27km away at the new site BAMB, in Forde ACT operated by member Bruce Boreham. The Willmore Mk3A seismometer sits on the concrete floor slab in his garage.

Another PEISMO joins Network

The fourth SAA designed Peismo, (Colin Love, with help from Eric and David Love) and constructed by John Millard, is now running in Forde, a northern suburb of Canberra. And as we have come to expect soon after installation, on 1st July 2024 it recorded a very small earthquake about 27km away in the Gunning region. It joins stations LILH and PLYP on the Melbourne University server https://meiproc.earthsci.unimelb.edu.au/eqserver/

Follow the project on https://github.com/colinlove/peismo

Maps of Earthquakes April to June 2024

The first map shows continental Australia in its plate tectonic setting. The plate boundaries are

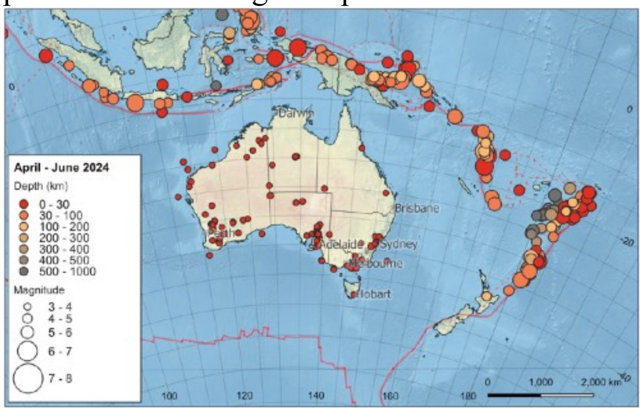


Figure 3 Australian Plate region earthquakes, April to June 2014 (maps by Clive Collins).

the thin red solid lines (USGS version). The intraplate earthquakes are mainly in old, cold,

The Seismological Association of Australia Inc.
PO Box 682, Mylor SA 5153

website: https://earthquake.net.au/

Membership of the SAA is open to anyone interested in earthquakes and applies for the calendar year (January through to December).

Committee

Chair - Blair Lade
m: 0407 189 061
e: blair.lade@gmail.com

Chief Seismologist - David Love
p: 08 8336 8003
e: david@earthquake.net.au

Public Officer - Paul Hutchinson
m: 0419 829 216
e: windfarmer@bigpond.com

Treasurer & Secretary - Joe Grida
m: 0407 558 036
e: joe.grida1@bigpond.com

Newsletter Editor - Kevin McCue
m: 0405 082 306
e: mccue.kevin@gmail.com

Committee members
- Gary Gibson
m: 0457 699 277
e: gary@earthquake.net.au
- Col Lynam
e: c.lynam@hotmail.com

Membership fees: Full member $50/yr

thick continental crust and are smaller and less frequent, whereas the interplate earthquakes are mostly in younger thinner oceanic crust and can be larger and more frequent.

We have plotted everything above ~M4.5 on the plate boundary but above M3 intraplate. These limits are about what is practicable with the existing seismograph network. Note how quiet NZ is at the moment, and the southern boundary of the Australian Plate.

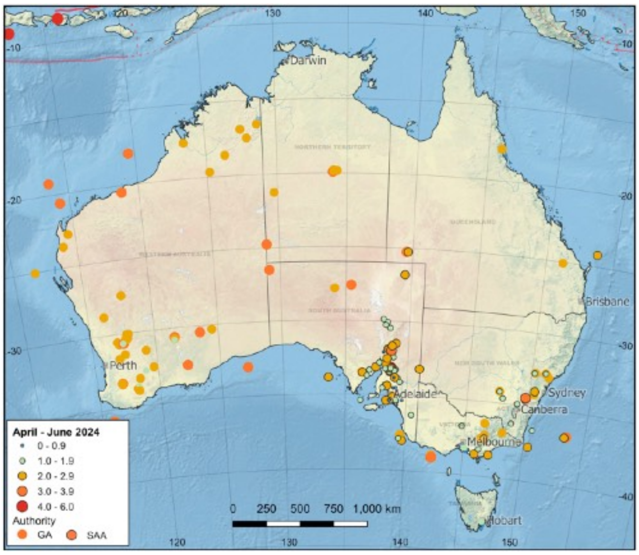


Figure 4 Australian earthquakes (April to June 2024)

In continental Australia, the largest earthquake in the quarter was the M4.2 earthquake near Jamestown, SA which had hundreds of small aftershocks. SAA seismologists decided to install 4 additional seismographs in the immediate area to attempt to use aftershocks to delineate the fault plane and get accurate focal depth measurements.

Another, magnitude 3.9, occurred near Crookwell NSW and solicited more than 500 felt reports according to GA, including many from Canberra residents (but not this one). No damage was reported.

Two earthquakes in Victoria were particularly interesting, on the continental shelf south of Warrnambool which was damaged by two moderate-sized earthquakes in 1903.

There were 38 earthquakes of magnitude 3 or more located, epicentres scattered through the States and Territories, apart from Tasmania and the ACT. Nearly half of the earthquakes were in WA. In all sixteen of the earthquakes were reported felt

In South Australia, Figure 5, the pattern of just 3 months of recorded earthquakes reflects very well the long term pattern, most of the epicentres in the Mount Lofty and Flinders Ranges but others along Eyre Peninsula and offshore the southeast of the State where the largest known SA earthquake, M6.5, struck Beachport and Kingston on 10 May 1897.

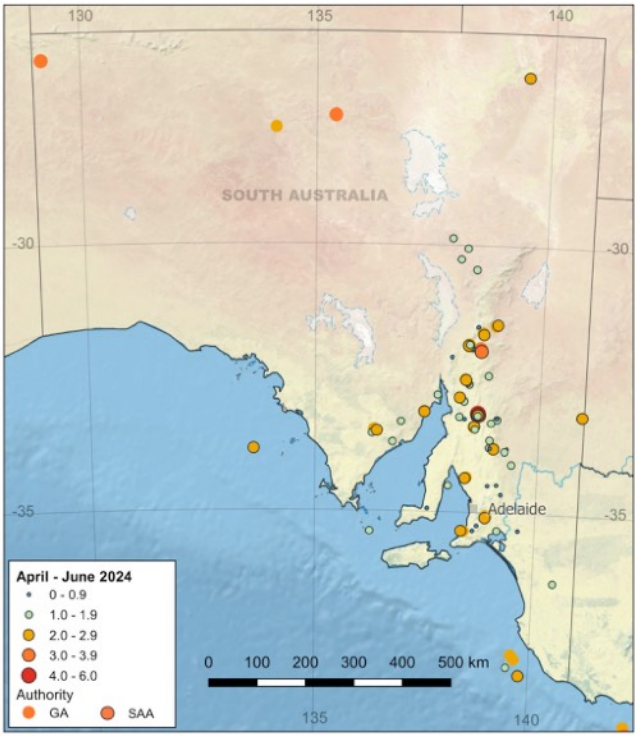


Figure 5 South Australian earthquakes (April to June 2024)

Once again, there were no surprises in the Australian epicentral locations though Tasmania and Queensland remain very quiet.

On becoming a seismologist

by Blair Lade, Founding Chair of SAA

This story starts somewhere around 1972/1973 when I commenced my first job out of school as an audio-visual technician at the then Torrens College of Advanced Education (TCAE) (ex-Thebarton Teachers College of South Road) working half time in the ‘AV’ department and the other half in the music department.

The work involved setting up black and white video recording equipment and 16mm film projectors for lecturers, repairing AV equipment, panel beating brass musical instruments, copying music minus 1 (music minus 1 instrument onto cassette tapes for students to practice their chosen instrument with), copying (photographing) art work to make slide sets for our remote art students and helping in the 'toy library' that was alongside the 'AV department'

I really enjoyed my 18 months at TCAE when I saw a couple of jobs advertised in the newspaper for Geopeko Ltd. in of all places, Tennant Creek in the Northern Territory. One job was for 'gridding crew' to assist in mineral exploration and the other was for a technician to work at the ANU's Warramunga Seismic Array, WRA, for which Geopeko had the contract to supply staff.

The job at WRA required repair skills in almost every branch of electronics , UHF, VHF and HF radio communications, analogue and digital electronics, inverters, battery chargers, solar power, precision mechanical with some heavy mechanical skills; using a tractor, servicing vehicles, generators and air conditioners etc. a 'who's who' in electronics and bush mechanics — way past my skill set.

I wondered at the time, how anyone would actually get expertise in all those areas and applied for the gridding crew job, adding that I was working as an 'AV tech' and had an interest in electronics.

I sent off my application and really didn't expect much. Sometimes, things 'just happen' and what happened was this. The then OIC from the Seismic Station (David Daffen) was in Adelaide on holidays, and he was very desperate for a tech. He and Geopeko had advertised for several months for a tech and hadn't had any success finding someone.

Geopeko contacted David and said "go check out this person for us" and Dave 'turned up' at TCAE. I was out doing a job on the campus and came back to my office to see my current boss, Peter Bosch, the Department head and David in deep conversation, about me!

David had apparently explained who he was and what he was looking for (a very keen technical person), and they had all decided that my career would be progressed a lot if I went to Tennant Creek and worked at the Seismic Station!

After my introduction to David, the situation was explained and Peter said "We've decided you are going to Tennant Creek to work at WRA with David!"

Er "OK", I said and he went further to say that if I didn't fit in, I could have my job back in the AV department.

So I borrowed 90 dollars from my grandma and bought a ticket to fly to Tennant Creek about a month later. The College director gave me a great send off in front of a few hundred students saying they would all miss me because I had made a massive difference to all the College's outreach programs.

I left Adelaide on TAA's DC3 'milk run' and arrived in Tennant Creek around 3pm that day. I was met at the airport by the local member (Ian Tuxworth) as all the Geopeko staff were out working and he introduced me to all the business people around town. The impression I got, was that this job was a pretty 'big deal', little did I know.

That night I met David Daffen again and the senior geologist at Geopeko, Paul le Messurier, the workshop staff and the mess cook. I was told I'd be working in the Geopeko workshop for a couple of weeks to learn how to maintain my new 4wd Toyota, to repair tyres and learn a few bush skills so I would survive 'in the sticks'.

Next morning, I went to the workshop and was shown how to repair a punctured 4wd tyre, and mastered that pretty quickly, hoping to move onto more 'important skills, only to be shown a room full of some 50 punctured tyres that needed repairing for the 'drillers and gridding crews'. I got bloody good at repairing them! Having mastered that, I learnt how to service and clean 4wd's and diesel generators, how to weld, use a lathe and other workshop tools for basic stuff, tune HF radios and antennae (now we're talking!) and became the general ‘dogs body’ around the workshop.

I went out bush with a couple of drillers to service a generator and they taught me how to ‘drive in the bush’ to avoid if possible, hitting termite mounds and burnt bushes as those really mess up the tyre. That explained why there were so many I had to fix in the workshop. I got a couple of ‘flats’ while driving and became instantly proficient in changing flat tyres whilst the 2 drillers stood back and watched, it seemed that this was punishment (no, education) for not being careful enough while driving. Excellent bush skills that have served me for the last 50 years.

Two weeks of this and I was finally ‘educated enough’ to go out to the seismic station, some 30 miles south of Tennant Creek, finally, a nice quiet office job. — Well, not quite.

First job of the day was making the morning brew for the others who were already out in the ‘sticks’ working. In those days, Tennant Creek didn’t get fresh groceries, so everyone drank tea with powdered milk.

As the ‘staff’ came in, I got introduced to them all, there was David Daffen Station OIC, Peter Robinson from the UK, Doug Christie from the ANU and a couple of others whose name I don’t remember. They all looked worn out and it was only morning tea time. They had been putting up wooden telegraph poles for the micro-barograph array that Doug was installing.

I spent the rest of the day cleaning the floor and kitchen of the station… a man’s got to earn his dues…. It was in no other terms, bloody disgusting. Anyway, It scrubbed up nicely and everyone seemed to be happy with the new guy.

The next day, I got to service the generator under the watchful eyes of David, and then joined the others and helped bolt wooden cross arms to the telegraph poles, there were hundreds of them!

The next day, David took me to meet the local PMG linesmen , led by Arthur Winger as he wanted some advice on installing the aluminium wire we had onto the telegraph poles. Arthur suggested we should go and work with his linesmen crew for a couple of days to ‘really learn the right way to put telegraph wires up’. Arthur was concerned that we didn’t have any vibration dampeners for the wire and explained that the wire under tension in the wind would ‘sing’ and become work hardened where it contacted the insulators and it would break. We passed that onto the ANU, and they said it would be fine.

As it happened, Arthur’s linesmen were replacing some lines another 10 miles south of the station turn-off, so we went and saw them. For the next couple of days, we became apprentice PMG linesmen.

Back to the station, we started putting up the aluminium wire for Doug’s project. I think we probably got 2 runs of half a mile of wire up the first day and felt pretty chuffed. While it was hard work, we thought we could handle it ok, back to town for the evening.

An early start to the station, we were confronted with the aluminium wire we had just put up the day before having broken from vibrating overnight. Not just a break, but almost at every pole!

We went back to see Arthur and he arranged to get us a pile of vibration dampeners. We had 40km of wire to put up on site, Doug was not happy.

Anyway, the vibration dampeners (pieces of slit plastic tube that were wrapped around the wire) did the job. We repaired the downed wires using ‘figure 8’ fencing knots and put the rest of the wire up.

After about a month, station life settled down somewhat into a routine, which was:

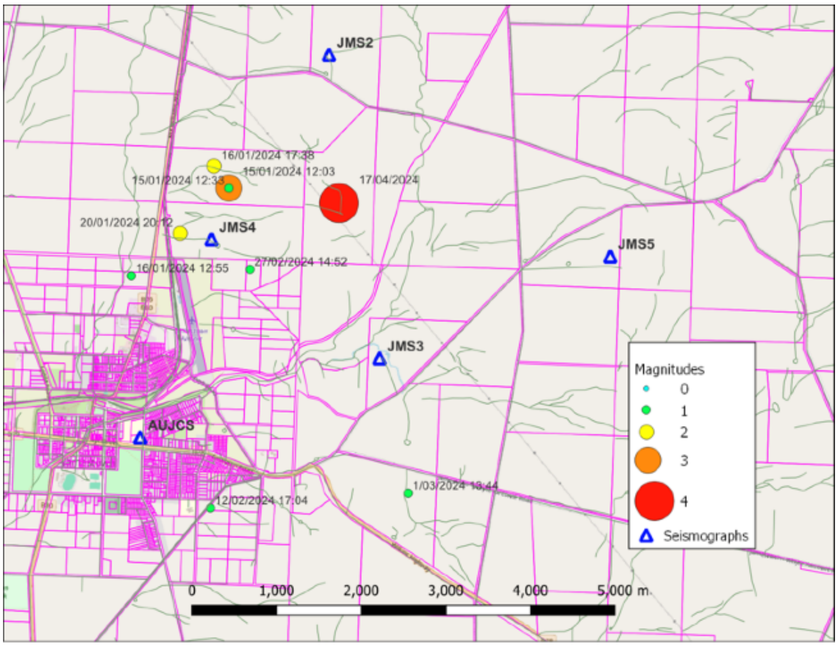
Leave town about 8:30am and drive 30 miles south to the station. On arrival, put the kettle on, walk to the power house and check the generators (mainly for loose things or oil leaks, note level of fuel on way back, make tea, check and adjust the station clock against VNG, change the helicorder charts, check the battery voltages then see what the seismic instruments were up to.

The station had been through 2 bush fires and the cabling to the seismic pits had been burnt out twice before my time, and we slowly installed radio transmitters to bring the seismic signals to the station where it was plotted on a helicorder and stored on magnetic tape for postage to the ANU and UK.

Roughly 6 months after I had arrived, about 80 percent of the seismic stations were back on line, so tape changes happened every 3 days.

Generators had to be serviced every 2 weeks, fuel arranged every 2 months, water delivered when we ran low.

Lots of field work installing stuff.



As the ‘wet’ was coming, the extra staff went back to the UK or Canberra and that left Dave and I at the station. Dave left the station after the wet to seek his fortune in the west in the mining boom and I inherited the tech OIC position at WRA. I stayed there for 4 years before moving on (~1978), missing out on the incredible sequence of earthquakes that rocked Tennant Ck in 1988.

Thirty five years later, I was working for defence and at a meeting when we were discussing the scramjet program and how to find the spent rockets and payloads where they impacted the ground. I suggested that I could deploy seismometers to pick up the impact and should be able to determine a rough location from the impacts.

I got $20k to hire some instruments from Adam Pascale (ES&S) and contacted the then SA Seismologist David Love as to how to go about this.

The seismometer deployment was successful, I was able to tell them roughly where the rocket had impacted and recovery was done (it’s always important to have success on the first go - if you don’t, often the program doesn’t get any more funding).

I stayed in contact with Adam and David and a few years later the SAA was formed. The rest is as they say history.

The Jamestown earthquake SA

Modern technology helps us define and refine our knowledge of earthquakes. I was stunned by this 13s video on the ABC:

https://www.abc.net.au/news/2024-04-17/earthquake-strikes-jamestown-south-australia/103736868?utm_campaign=abc_news_web&utm_content=link&utm_medium=content_shared&utm_source=abc_news_web

no words needed to quantify the sound, strength and duration of the earthquake, a real shock, obviously very close to Jamestown, with a permanent offset of the camera.

Resident Ms Dewell's house was damaged during the 4.2 magnitude earthquake.The ceiling cornice fell into the lounge room, missing her daughter in the room at the time. She is holding off on claiming insurance while the aftershocks continue. Other residents have reported various cracks and minor structural damage to buildings. Ms Dewell said residents were worried about what was going to happen next. "If it would just stop, it would be lovely, but Mother Nature doesn't want to give us a break just yet."

Aftershock Survey - Jamestown SA

The day after the magnitude 4.2 earthquake struck Jamestown, David Love and Blair Lade from SAA installed 4 seismographs (JMS2 to

JMS5 in the figure) around the epicentre to record aftershocks. They also recovered data from a 5th station AUJCS operated by the ANUs Seismometer in Schools program.

David Denham

21 March 1937 - 22 June 2024

David was awarded a PhD in Geophysics at Leeds University in the UK and was recruited by the Australian Government Bureau of Mineral Resources as Observer-in-Charge of the Port Moresby Geophysical Observatory in 1964. He was ambitious. From PNG he moved to BMR Canberra to lead the Observatory Group in 1969. In 1986 he established the out-posted Australian Seismological Centre, to monitor earthquakes and nuclear explosions, and then became Chief of the Geophysics Division and assistant Director of BMR in 1988.

In the 1970s he coordinated and partially funded disparate state and territory seismology units to exchange data and establish a national earthquake database. He organised several national earthquake symposia to get academic and state government seismologists talking to each other and discuss the magnitude problem. David was founding Chair of the Specialist group on Solid Earth Geophysics. He was a respected Australian earth scientist with a healthy sense of humour which he rarely lost.

He authored or coauthored over 40 publications on topics ranging from crustal structure and earthquake risk to tectonics and intra-cratonic stress.

From 1976 to 1981 he wrote the 'Science in Government' column in Search. David Denham also wrote a regular column 'Canberra Observed' in Preview, the bi-monthly journal of the Australian Society of Exploration Geophysics until April this year.

He was a member of the editorial board of the Australian Journal of Earth Sciences. Between 1978 and 1984 he was Chairman of the Australian Academy of Science Subcommittee on Seismology and Physics of the Earth's Interior. He was the Australian representative on the Governing Council of the International Seismological Centre from 1977 to 1998, and was Chairman of the IASPEI Sub-commission on the Quantification of Earthquakes.

David Denham spent 40 years involved with many aspects of the earth sciences and worked with both industry and government. He held the roles of Chairman of the Governing Council of the International Seismological Centre 1995-1998, President of the Geological Society of Australia, Vice-President of the Federation of Australian Scientific & Technological Societies and President of the Australian Geoscience Council.

In 1984 he became a Member of the Order of Australia for service to seismology and soon after led two delegations to Beijing to write and sign an MOU with the emerging Chinese government on matters seismological; earthquake and nuclear monitoring. Gary Gibson was on both visits, Kevin McCue on the second. Gary mentions that the Australian Embassy Officer co-wrote the MOU with David in Beijing was Kevin Rudd.

When he retired in 1999 David was Chief of the Minerals Division of AGSO. Post-retirement he joined and then led the Griffith Narrabundah Community Association to lobby for better amenities in their suburbs.

He died in Canberra Hospital on 22 June 2024, a great loss for colleagues, his wife Pat Ann and two children, Rachel and Angus.

COMMENTS ON NSHA23 HAZARD
by Gary Gibson

1. SUMMARY

The revised NSHA23 includes many new improvements, but the results are inadmissible, cities such as Adelaide appearing to have only 30% of the hazard previously determined by measurement. The method used considers the characteristics of the earthquake source, seismic wave travel path, and site factors, both seismograph sites and the sites being considered for the hazard study to ESTIMATE ground motions.

The NSHA23 methods involve the use of moment magnitude but do not clearly define how to use this in the ground displacement estimate to produce estimates of ground motion displacements, especially with respect to details described in section 2, regarding ground motion.

During earlier decades of hazard analysis, the recurrence of ground motion displacement was based on a direct MEASURE of ground motion (acceleration, velocity and/or displacement), all converted to the Richter-Gutenberg magnitude ML, and later as converted to a revised value considering relevant source, seismic wave travel path and site factors as developed in NSHA23. The two methods should give the same results, but only if all factors are valid, especially those related to stress release. Unfortunately, computed Mww values especially between M4 and M6 are highly variable due to stress drop variability.

The stress drop measurements of Australian events is typically between 20 and 50 MPa compared with the stress drop in Plate boundary earthquakes of 2 to 5 MPa.
These comments could be extended if you wish.

2. EARTHQUAKE CHARACTERISTICS

The source parameters of an earthquake include the location of the hypocentre, the point where the rupture began (longitude, latitude, and depth).

For a simple single fault earthquake, the magnitude is usually relatively small, less than ML 5.0. Geometric location will outline the rupture and indicate its area. If an aftershock seismograph network has been installed, the fault rupture area can also be estimated by the distribution of aftershocks, and an estimate of fault displacement can be made.

Small earthquakes less than M 4 to 5 (rupture area 1 to 9 km^2) are usually a single rupture, while those larger than M 7 to 8 (rupture areas of 1000 to 10000 km^2) often involve multiple ruptures.
Note that a rectangular fault rupture with uniform displacement has never occurred – they are all unique, and displacement drops to zero at the fault boundary, or at the surface rupture if it exists.

2.1 Plate Boundary Earthquakes

Plate boundaries are mainly very long, so can have very large earthquakes, M 9 or more along the coast of Chile. The relatively rapid speed of the plates also results in many smaller earthquakes giving a b-value of 1.2 to 1.4 or higher, resulting in a weak fault and a low stress drop, typically about 2 to 5 megapascal (MPa). Plate boundaries may include asperities where the fault is stronger and does not rupture until the stress exceeds the fault strength, resulting in higher stress drop at asperity locations.

2.2 Stable Continental Earthquakes

"Stable" continental regions vary from places that may have very few earthquakes because of very low crustal stress levels, or deformation of sediments or soft rocks, to places with strong rocks (igneous and metamorphic), and strong faults (typically 20 to 50 MPa).
Continental faults are shorter than those at plate boundaries, rarely with a maximum magnitude potential of M 7.5. The relatively slow speed of continental deformation results in strong faults, high stress drops, low b-values (typically 0.7 to 0.9) and produces fewer earthquakes per unit area of any magnitude than at plate boundaries.

The emphasis on peak ground acceleration is not relevant for the hazard requirements of large structures. For example, see the Eugowra earthquake in section 4 and followup article on pga.
Values of *pga* exceeding 0.5 g are often recorded when an aftershock network has been installed near to the epicentre (less than about 15 to 20 km

depending on earthquake depth), Unfortunately recordings usually do not include the mainshock ground motion because the nearest seismograph is too far from the epicentre.

Some large earthquakes are preceded by foreshocks, either in hours or days, and at the other extreme in clusters of events at intervals of weeks or months. Especially in regions of high stress, the majority of clusters are not followed by a mainshock, until much later (hundreds to thousands of years) when the stress reaches the fault strength.

Repeated clusters provide useful geological information from smaller events even if the mainshock does not occur. An aftershock network (about 6 to 10 or more recorders within about 2 to 20 km of the clusters depending on earthquake depth) can be very useful (see David Love's article on the Jamestown aftershocks)..

3. AUSTRALIAN EARTHQUAKES

Our initial estimates of ground motion hazard using fault motion and friction significantly underestimated the hazard, by a considerable amount. It soon became apparent that we had considered only the fault motion, and not the stress release.

3.1 Tennant Creek, 1988-01-22, 3 mainshocks Mw 6.6, 6.3 and 6.6

These events follow a series of earthquake clusters from 1987-01-05 to 1987-09-30 including two of M 5.0 and one M 5.4. The main sequence then started on 1988-01-22. It was followed by 15 events of M 5.0 to 5.5, and another on 2019-08-01, several giving PGA values exceeding 0.6g. A total of 1710 aftershocks have been large enough to precisely locate, the most recent on 2024-06-05.

3.2 Newcastle, 1989-12-27, ML 5.6

The Newcastle earthquake, its magnitude only M 5.6, yet it caused over 2 billion dollars of damage, and 13 fatalities. ISC contrasted it with several Algerian earthquakes which had relatively low cost, but many more fatalities. They were regarded by ISC as the lowest magnitudes with most significant effects. Newcastle had no nearby seismographs to record the mainshock. Our five seismograph aftershock network recorded only one aftershock of magnitude 2.8 on 1989-12-29.

3.3 Eugowra, 1994-08-21, ML 4.1

The highest PGA recorded in Australia was at Eugowra, NSW, where a magnitude ML 4.1 earthquake occurred at a depth of 800 metres and an epicentral distance of 800 metres. The seismograph recorded 0.97g, and the event produced a very loud noise heard very strongly in the surrounding region. The damage at the Eugowra Central Hotel where a seismograph was located was a cracked window. However, the mainshock and many foreshocks and aftershocks (and uncertainty about whether the M 4.1 event was indeed the mainshock) caused many people to temporarily leave Eugowra (it was the mainshock).

3.4 Gippsland, 1990 to 2024

Many earthquakes have occurred in southwest Gippsland, southeast of Melbourne, in the Strzelecki Ranges, and southwest of Sale.
Events larger than M 4.0, together with a dense seismograph network allows for detailed studies including focal mechanisms, stress drop measurements, etc, for more than 15 earthquakes, including clusters at Korumburra, Thorpdale, and other sites.

3.5 Woods Point, 2021-09-21 2315, ML 5.8

After 15 foreshocks over the preceding 14 years, and before 580 aftershocks to 2024 04-24 (including 2 larger than ML 4.0). The mainshock was felt widely over central and eastern Victoria, and there was considerable damage in the epicentral area in a remote area northwest of Woods Point. It did considerable damage to a building in Chapel St Prahran at about 160 km, with 6 damaged chimneys in the vicinity.

3.6 Apollo Bay, 2023-10-21 1511, ML 5.3

More damage in a rural area SW of Melbourne near Cape Otway.

4. ORIGINAL EARTHQUAKE GROUND MOTION MEASURES

The first measure of ground motion was intensity, as represented by the Modified Mercalli scale. Intensities 0 to 5 correspond to increasing effects on people, and 6 to 12 to increasing levels of building damage.

This is an abbreviated one-page version of the actual Modified Mercalli definitions.
1 Not felt, except under especially favourable circumstances.
2 Felt by persons at rest, on upper floors, or in favourable places.
3 Felt indoors. Hanging objects swing. Vibrations like a passing light truck. Duration estimated. May not be recognised as an earthquake.
4 Vibration like a passing heavy truck. Sensation like an object striking walls. Windows, dishes and doors rattle, crockery clashes. Standing cars rock. In upper ranges, wood walls and frames creak.
5 Felt outdoors, direction estimated. Sleepers wakened. Small unstable objects displaced or upset. Doors swing closed or open. Pictures move. Liquids disturbed, some spilled. Some cracked plaster.
6 Felt by all. Many frightened and run outdoors. People walk unsteadily. Windows, dishes, glassware broken. Small items fall from shelves. Pictures off walls, furniture moved or overturned. Weak plaster and masonry D cracked. Trees shaken visibly.
7 Difficult to stand. Noticed by car drivers. Furniture broken. Damage to masonry D, some cracks in masonry C. Waves on water. Small slides and caving in along sand and gravel banks.
8 Partial collapse of masonry C, damage to masonry B, none to masonry A. Car steering affected. Twisting or fall of chimneys, monuments, towers and tanks. Frame houses moved if not bolted down. Tree branches broken. Cracks in wet ground and on slopes.
9 General panic. Masonry D destroyed, masonry C heavily damaged, masonry B seriously damaged. General damage to foundations. Frames cracked. Underground pipes broken.
10 Most masonry and frame structures destroyed with their foundations. Serious damage to dams. Large landslides. Rails bent slightly.
11 Rails bent greatly. All underground pipes destroyed.
12 Near total damage. Objects thrown into the air.

Masonry A Good workmanship, mortar; reinforced and designed to resist lateral forces.
Masonry B Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.
Masonry C Ordinary workmanship and mortar; no extreme weaknesses, but neither reinforcement nor design against lateral force.
Masonry D Weak materials, such as adobe; poor mortar; low standards of workmanship;
weak horizontally

5. DEFINITION OF EARTHQUAKE MAGNITUDE

The attenuation of ground motion is high for acceleration, moderate for velocity, and low for displacement, and will vary with geology. So individual ground motion models are required for different sites. The optimal recorders can be used (e.g. using accelerometers for strong motion, velocity seismometers for velocity motion, and displacement for larger and usually distant earthquakes).

For early decades of hazard analysis, the recurrence of ground motion displacement was based on ground motion (acceleration, velocity and/or displacement), all converted to the Richter magnitude ML, based on $\log_{10}$ of the horizontal ground motion displacement measured in micrometres on a Wood-Anderson seismograph for a specified ground motion model at a particular site in California at distances from 0 to 600 km. A displacement of 1mm at a distance of 100 km, corresponds to a magnitude of ML 3.0.

Many other ground motion models have been developed, both for this Californian site and other sites, both seismograph and hazard related.

Hazard can be analysed in different ways. These comments concern ground motion hazards, and the advantages of using measured ground motion rather than estimates, considering accuracy of hazard, much lower computation times (and cost) than the estimate method. It relies on having a reasonable local seismograph network, but an even better network is required for the estimate method.

The original hazard studies were based on measured ground motion displacement (the Gutenberg-Richter magnitude, with appropriate corrections to ensure consistency between magnitude types.

5. 1 Modern Earthquake Magnitudes There are numerous earthquake magnitudes. Some used a local version of the original Richter ML were a measure of ground motion (displacement, velocity, or acceleration) for earthquakes within 600 km.
Others such as MB, mb, MS were defined for more distant earthquakes, using specified body waves or surface waves, and were defined to give values numerically equivalent to ML.
Other measures such as duration of motion (MD), and distance or radius of perception (MP) are used for historical earthquakes, also defined to be equivalent to ML, being calibrated using data from recent events.

M (sometimes Mx) are used for ground displacement based on other magnitudes, all with limited ranges of magnitude values and epicentral distance. For example, ML is strictly for magnitude less than 6.0 and distance less than 600 km, mb for magnitudes less than 6.0 and distance more than 2000 km.

These are the most relevant measures of hazard for large structures and are usually concerned with periods from 0.2 seconds to 5 seconds (or rarely 0.1 to 10 seconds).
Other scales based on velocity are sometimes relevant, such as mine or quarry blasting, with periods 0.05 to 2.0 seconds. For very sensitive instrumentation such as some surveying equipment, then acceleration is relevant with periods from less than 0.001 to 0.1 seconds (see section 7).

Different organisations measure magnitude using different methods which give rise to different measures.

5.2 Moment magnitudes These are based on moment or energy and should relate closely to stress and stress drop. The relationship between M and Mw is a smooth curve, and for convenience the Mw value was defined to be numerically equivalent to the M value between M = 6.5 and 7.0, with reasonably close values between 6.2 and 7.8. Most of both higher and lower Mw values are higher than M. In the magnitude range from about M 4.0 to about M 6.2, the difference between M and Mw can vary widely depending on local tectonic stress drop.

6. EARTHQUAKE GROUND MOTION HAZARD

The aims of earthquake hazard studies vary widely, from high frequency effects on a sensitive scientific instrument e.g. gravity wave detectors which is emphasised by acceleration, to the lower frequency motion relevant for large structures.

The following summary shows the four most common hazard frequency ranges for hazard studies. Special issues relating to the hazard may need a modified frequency range, choice of ground motion type (acceleration, velocity, or displacement), choice of input data, etc.

6.1 High audio frequency The best known hazard is very sensitive scientific instruments, and in the past large computer discs. Acceleration works best.
6.2 Low audio frequency The most common request was to reduce quarry blast noise for neighbours. Adoption of explosive grids was found to not only reduce noise but have very improved rock or ore recovery for quarries and mines. Velocity of the seismic waves is used.

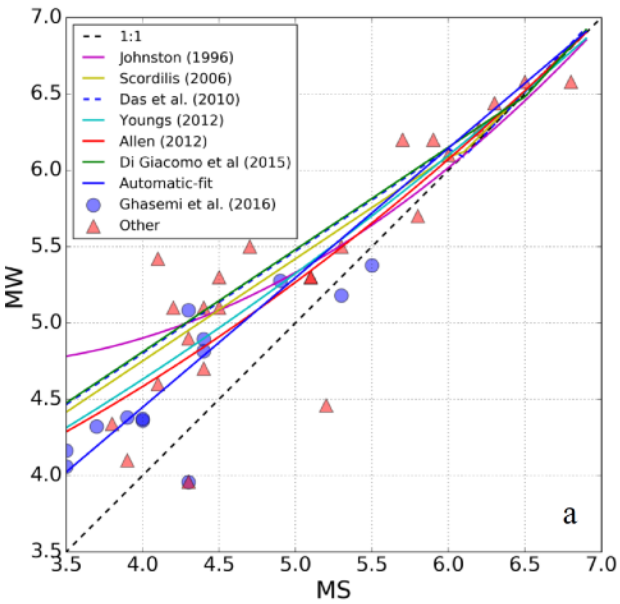
6.3 Low frequency The vast majority of hazard studies, what NHSA23 is all about, are for resonance damage of structures, buildings, towers, dams, mines etc. For most structures from 0.2 to 5 sec period (5 to 0.2 Hz) but the range is sometimes extended, for example from

0.1 to 10 sec (10 to 0.1 Hz). Displacement is used for the measurement.

6.4 Very Low frequency, long period (greater than 18 seconds) Very sensitive surveying equipment cannot cope with surface waves from earthquakes larger than M 8.0 for 3 days or more, so the surveyors like to know when they can return to work. Displacement is used for the measurement of ground motion.

Magnitudes Mw, Ms or ML

Converting from one magnitude scale to another can be very important.



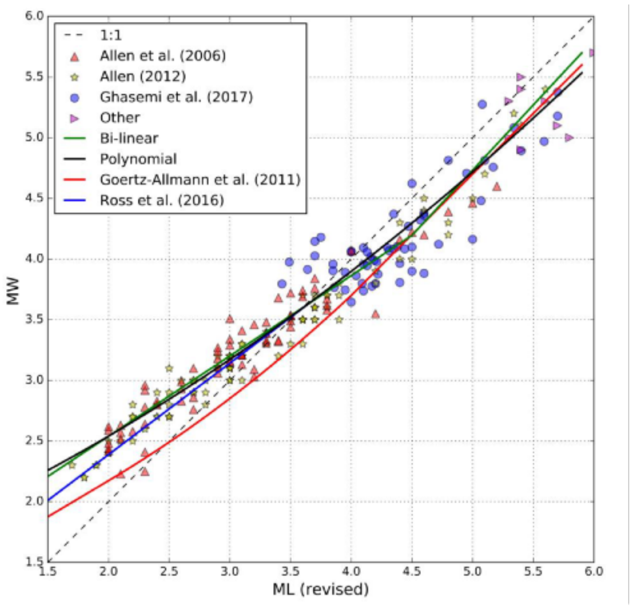
Note the wide variation up to magnitude MS 6.0 due to asperities, and low variation over MS 6.0.

Mww is the average moment magnitude for California, USA, with assumption of average stress drop events, usually about 2 to 5 MPa. All active plate boundaries have frequent earthquakes, so faults are typically weak, resulting in low stress drops. This means that Mww is usable for most plate boundary earthquakes in other countries where the stress drop is also low.

The rocks in stable continental regions, especially Australia, are strong, their faults are strong, with stress often building to values of 20 to 50 MPa with or without failure, so earthquakes are very infrequent, but the released energy in the stress drop can be considerably higher than the fault displacement friction.

Other moment magnitudes, Mwb, Mwc, Mwp etc have been defined considering the variations of stress drop in different regions, most within USA. These are not precise and vary depending on stress drop in asperities.

Another questionable point of the NSHA23 method is the emphasis on acceleration, and PGA. See examples in section 4 on some relevant Australian earthquakes.



Mw is a very poor estimate of ML for magnitudes below ML6.

7. EARTHQUAKE HAZARD

There are many different earthquake mechanisms, ranging from activity at or near tectonic plate boundaries, through to "stable" continental regions with hard rock and strong faults.

There are many earthquakes on most plate boundaries, with large earthquakes occurring within hundreds of years, and many smaller earthquakes between them (a high b value over 1.0, often 1.4 or higher). This means that the faults will be relatively weak, so they rupture at low stress levels, typically 2 to 5 MPa, but they will occur frequently.

The strong faults in "stable" continental regions do not fail until the strength of the fault is reached, often 20 MPa, sometimes 40 to 50 MPa. This reduces the recurrence rates, especially for smaller earthquakes, leading to a low b value, usually from 0.7 to 0.9.

In plate boundary regions, the Californian average Mww produced assuming 2 to 5 MPa, can be used for sites on other plate boundaries with similar low stress release.

In stable continental regions, using NSHA23, the inclusion of moment magnitude gives a direct measure of stress drop, giving a significantly greater contribution to ground motion, consistent with measured ground motion recurrence used in pre-2002 Australian earthquake hazard models.

Unfortunately, the USGS web site suggests that even if the analysis is in a stable continental region such as Australia with high stress drops, Mww may still be used.

8. CONCLUSION

The main problem with NSHA23 is that the Stress Release is not considered by most users. This is not relevant for California users the plate boundary events are considered in Mww and other Mwx magnitudes.

These are reasonably applicable for other world plate boundaries because of their low stress drops, but do not apply for continental USA events, and do not apply for any Australian events, despite the USGS web site comment.

It is very easy to modify the existing NSHA23 computations, to ensure that the stress drop is considered in the computations. However, the time and work involved in considering all source, seismic wave paths and site factors are still greater than using the measure method, and not as accurate for ground motion hazard studies.

An improvement in both methods would be to define magnitudes including the radiation pattern of the focal mechanism, thus reducing the standard deviation from a typical 0.25 to about 0.1. This would require much more focal mechanism work, and limits in values may not make it worthwhile.

WHAT IS PGA?

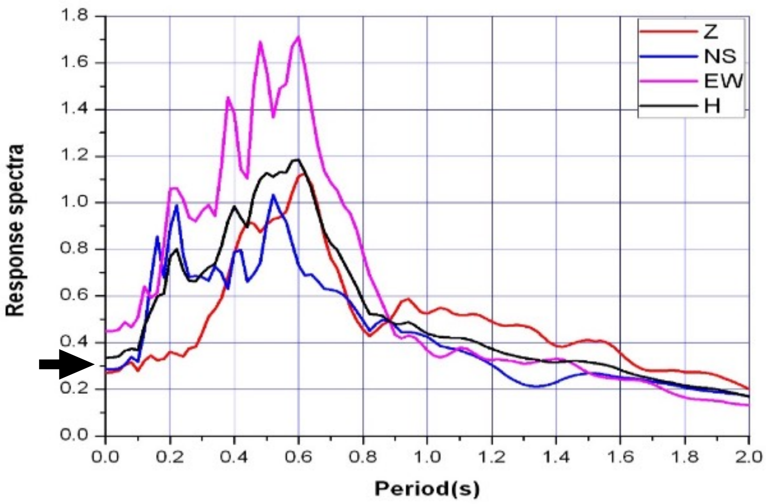
by Kevin McCue

Intensity (on the Modified Mercalli or any other intensity scale) is an estimate of how strongly the Earth shakes at any place during an earthquake. It starts at low intensity, whether people feel the shaking and if so how strongly, and then, higher up the scale, building damage and how severe and widespread the damage (see Gary Gibson's article, page 10).

Back in 1974 at the 5th WCEE, invited speaker Professor Nick Ambraseys showed that there was no correlation between peak ground acceleration pga and Intensity i.e. no correlation between pga and damage.

The best that can be said about pga is that in an acceleration response spectrum it anchors the spectrum at zero period, a rigid body response.

Figure Spectral acceleration derived from the 1994



North Lambton NSW accelerogram. The units on the Y-axis are in m/s^2 (1g = 9.8m/s^2). The ordinates at zero period are the pga of each component. We assume the spectrum of the nearby Newcastle earthquake was similar, only stronger, and in Newcastle damage was to buildings with periods in the 0.1 to 0.3s range, quite unrelated to pga.

The zero period ordinate value is the pga, for this and every accelerogram and response spectrum. The response spectrum of the 6th August 1994 Ellalong earthquake at the North Lambton site is shown in the figure. The separate horizontal and vertical components are plotted and the black line is the square-root of the sum of squared amplitudes of the horizontal components.

The ordinates at zero period are the pga of each component. The arrow marks the vertical component pga.

We assume the Newcastle earthquake spectrum shape was similar. In Newcastle damage was to buildings with periods in the 0.1 to 0.3s range, quite unrelated to pga.

Reference

Cvetan Sinadinovski, Kevin McCue, Snjezana Markusic, Lazo Pekevski and Ines Ivancic. 2020. What do earthquakes at Zagreb 2020, Newcastle 1989 and Rabaul 1978 have in common? Australian Earthquake Engineering Society, November 2020.

Mystery Seismic Event at Moura Qld

By Mike Turnbull and Kevin McCue

At 07:02 am on Saturday 1 June 2024 (local time) Kevin alerted Mike to a seismic event on the EIDS (GA Eidsvold) station that looked, to him, to be an earthquake. Mike immediately downloaded recordings from monitoring stations in the region and was able to use data from six stations to obtain a very well confined location. The event was well recorded on the ANU station AUMOU at the Moura High School, only 15 km from the event epicentre. It was located precisely to the heart of the southern section of open-cut coal extraction in the Dawson Mining Complex operations (the Moura Mine) (See Figure 1).

This event being in daylight hours (sunrise was at 06:38 am), the location being right in the middle of the active coal extraction complex, and the fact that this particular mine conducts extraction blasts almost daily, brought into speculation whether it was an earthquake (as initially thought) or an early blast. Adding to this speculation was the visual presence of what appeared to be prominent surface wave signature in the back end of the AUMOU seismogram (See Figure 3).

Although some of the open-cut coal mines in southern and northern Queensland send Mike regular notifications of upcoming extraction blasts, Management of the Dawson Mining Complex have consistently never responded to his several requests to be added to their notification list. We therefore, unfortunately, had no way of formally confirming the nature of this early morning event.

Fortunately Mike's many years of working throughout Queensland has allowed him to acquire many friends and associates – one of whom happens to work, let's say, in the Moura district. After a couple of days making enquiries,

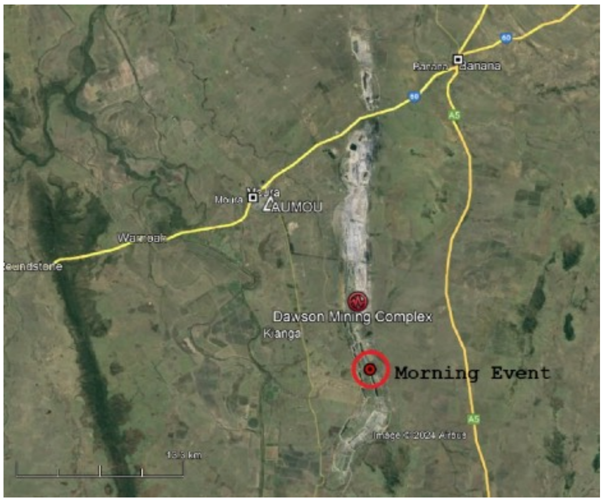


Figure 1: Early morning seismic event at the Moura Mine.

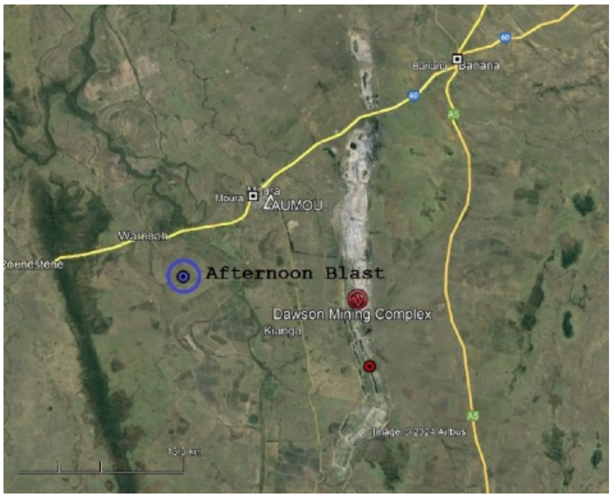


Figure 2: Afternoon Moura blast location.

this acquaintance was able to confirm that there was no early morning mine blast, thus leaving the alternative – that the early morning event was indeed an earthquake under the mine operations.

The information source also informed us that there was a blast scheduled for the afternoon of that day, between 14:00 and 16:00. That blast was conducted at 14:12, and Mike performed a location of it using data from five stations,

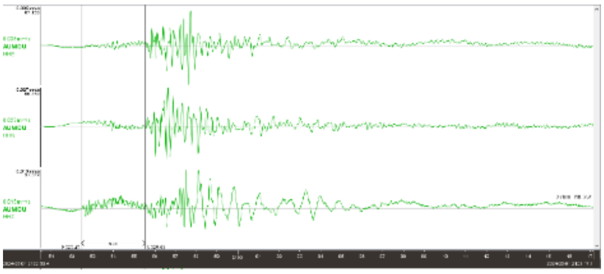


Figure 3: AUMOU seismogram of the early morning event.

including AUMOU. My location of the afternoon blast is shown in Figure 2.

Although the discrepancy in the blast's location is obvious, being some 14 km too far west, we know from local information that it was, in fact, located within the mine's operational boundaries.

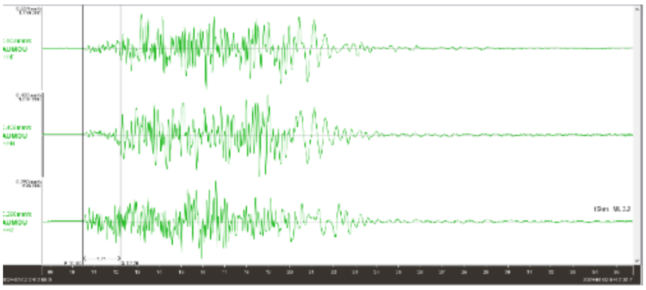


Figure 4: AUMOU seismogram of afternoon blast.

The AUMOU seismogram of the blast is shown in Figure 4. As with the seismogram of the early morning earthquake event, the appearance of a prominent surface wave can be seen in the trailing end.

Clearly the blast occurred much closer to the AUMOU station (only 8 km) and this is consistent with the blast having been conducted in the northern section of the mining operations. The availability of clear seismograms from a station so close to the source events which occurred within hours of one another provides an excellent opportunity to perform a comparison analysis on some of the seismogram characteristic. Quite apart from the fact that both events generated noticeable surface wave components, we thought it would be interesting to compare the spectrographic characteristics of the two events.

(note: for Figure 10 read Figure 5)

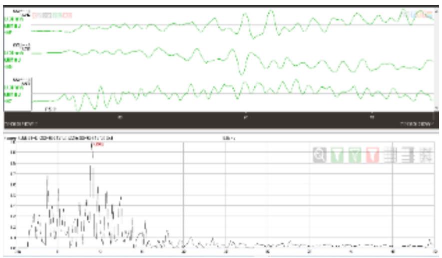


Figure 10: Morning event P train spectrum.

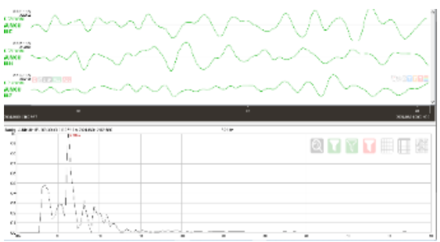


Figure 10: Morning event S train spectrum.

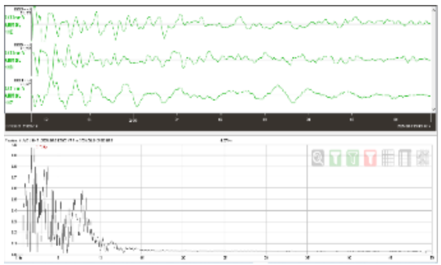


Figure 10: Morning event Surface train spectrum.

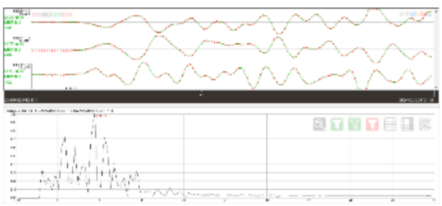


Figure 10: Afternoon event P train spectrum.

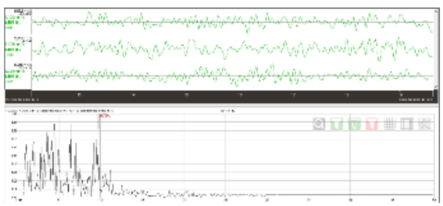


Figure 10: Afternoon event S train spectrum

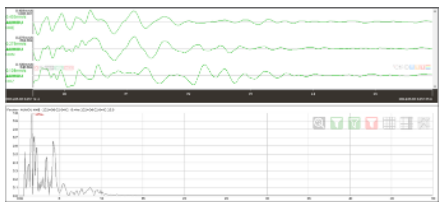


Figure 10: Afternoon event Surface train spectrum