ANDYSEZ 61 Earthquakes and caves – Did the earth move for you?

Andy Spate

Recently both Ian Eddison and I posted a link on the mailing list from the United States Geological Survey regarding safety in caves when earthquakes occur. We hope you find such postings of interest. Here is the link again https://www.usgs.gov/faqs/can-you-feel-earthquake-if-youre-a-cave-it-safer-be-a-cave-during-earthquake

Basically, the message, at Yarrangobilly, is to go to Jillabenan and avoid South Glory. Or, at Jenolan, go for the Imperial Cave rather than Lucas or the Devil's Coach House.

This ANDSEZ will talk about earthquakes for a while – and then move on to their relevance to caves and karst.

There are four different types of earthquakes:

A **tectonic earthquake** is one that occurs when the earth's crust breaks due to geological forces on rocks and adjoining plates that cause physical and chemical changes.

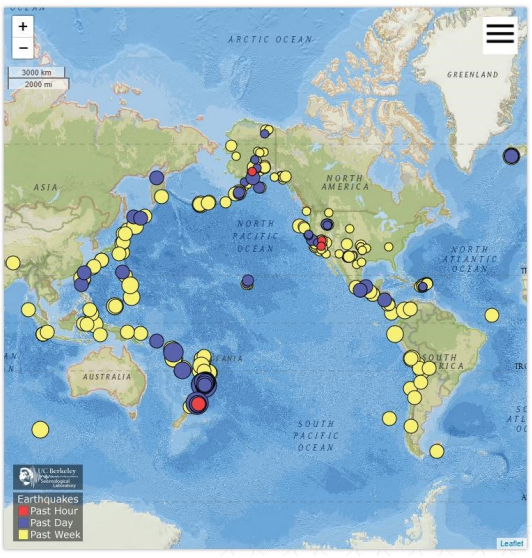
A **volcanic earthquake** is any earthquake that results from tectonic forces which occur in conjunction with volcanic activity.

A **collapse earthquake** is a small earthquake in an underground cavern or mine that is caused by seismic waves produced from the explosion of rock on the surface.

An **explosion earthquake** is an earthquake that is the result of the detonation of a nuclear and/or chemical device.

There may be four types of earthquakes as outlined above but here we are really only interested in two types of tectonic quakes – interplate and intraplate.

Interplate quakes occur when two tectonic (continental) plates rub together—as in New Zealand where the Pacific and Australian plates interact producing many quakes (think of the 'Pacific Rim of Fire' as in Figure 1 adjacent).



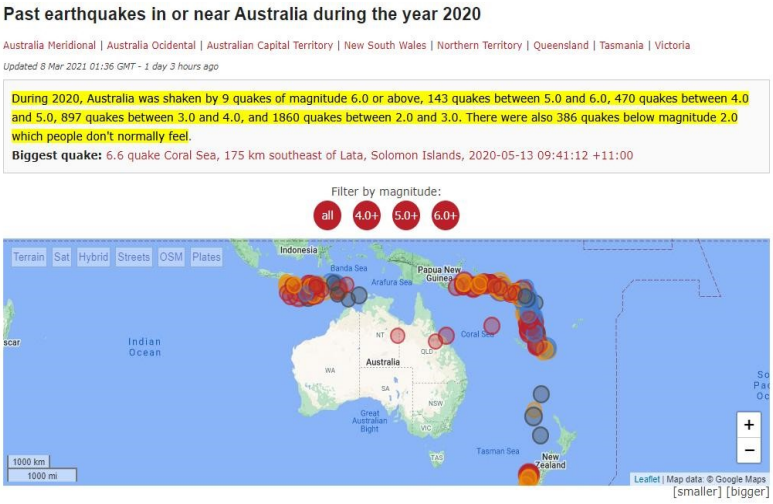
The 'Pacific Rim of Fire' over the week ending 5 March 2021

These are more frequent and powerful than intraplate quakes. In 2010, a magnitude 7.1 struck Christchurch with huge amounts of damage (but few injuries) as it was in the early hours of the morning. Fig 2 shows just how active New Zealand is.

To see Fig 2, you need to copy the below URL into your browser and access the site - *Ten years of New Zealand earthquakes in 20 seconds.*

https://www.stuff.co.nz/national/100611311/heres-what-a-decade-of-nz-quakes-looks-like-in-20-seconds

Intraplate quakes are what we have in Australia – on the continental plate – less magnitude and less frequent but still can do some damage (as we saw in Newcastle) in 1986 – magnitude 6.9 Australia's worst in terms of lives lost and damage costs.



Past earthquakes in or near Australia during 2020

But what has this to do with caves and karst? We will find that out later.

By the way Is Australia volcanically dead? The short answer is no!

Volcanologists use a fairly arbitrary 10,000 years as the cut off between active and extinct. We have had volcanic activity in south western Victoria, south eastern South Australia and in far northern Queensland well under 10,000 years ago. In the south, these eruptions are very wonderfully backed-up by the Indigenous oral histories of the regions.

A lecture I watched on Zoom a few days ago had a vulcanologist say that we could well expect an eruption (with only a few days to weeks warning) in the next few thousand years. Do we have plans to cope with such a happening?

The short answer again is no! We know that our friends across The Pond in the Shaky Isles (as they were known to Australians in the late 19th C) are certainly not volcanically dead as we saw in Figure 2.

Earthquake magnitudes

The strength (magnitude) of earthquakes is calculated in a variety of ways but the 'M' numbers are much the same. The table on the following page indicates what damage we might expect from earthquakes of differing magnitudes.

Magnitude	Effects	Est No Each Year
<2.5	Usually not felt but can be recorded by seismograph.	900,000
2.5-5.4	Often felt, but only causes minor damage.	30,000
5.5-6.0	Slight damage to buildings and other structures.	500
6.1-6.9	May cause a lot of damage in very populated areas.	100
7.0-7.9	Major earthquake. Serious damage.	20
>8.0	Great earthquake. Can totally destroy communities near the epicentre.	One every 5 to 10 years

But what has this to do with caves and karst?

We have had at least three earthquake events in Australia relating to caves that I know of – there will be many others … And I hope in the next Journal there will be more accounts of quakes and cave impacts in New Zealand from our cousins across the pond.

The Western Australian town of Meckering was struck by an earthquake on 14 October 1968. The earthquake occurred with a moment magnitude of 6.5 … Total damage amounted to $2.2 million with 20–28 injured. It damaged roads including the Great Eastern Highway, the Eastern Goldfields Railway, and the Goldfields water pipeline.

Jewel Cave was shaken by the Meckering quake with fridges toppling over in the shop (as I recall) – nobody underground felt a thing.

The 1979 Cadoux earthquake (magnitude ~ 6.0) caused over $4 million damage.

Pete Bell was on a trip to Winjans Cave in Witchcliffe during the Cadoux quake - he knew nothing until returning to Perth and heard media comments.

John Brush has found a reference or two in TVL (TVL = *The Very Latest* is the Canberra Speleological Society's newsletter) to an earthquake at Wee Jasper.

TVL Vol 3(2), Aug 1967:

> Trip Reports – Wee Jasper 24-25 June: This was the earthquake trip – an experience that all in the party will probably never forget. The Saturday was spent digging in a good prospect on Punchbowl Hill. The earthquake occurred at 4.36 p.m., with a very loud subterranean roar and a distinct earth movement. An evening trip, taking about 20 minutes in all [what?!!!], into Punchbowl revealed no damage. Sunday went into the Dip and looked very hard for the entrance into No. 3 extension before realising that the boulder choke had settled and was in a very dangerous condition.

And in TVL Vol 3(5), Feb 1968:

> WEE JASPER, DECEMBER 1967 [extract]
>
> … A systematic search revealed that the alternate route to No. 3 extension was still negotiable, despite numerous new cracks and fissures. The extension itself, however, was a mere shadow of its former self. What an earthquake could not do, Homo sapiens had accomplished with no effort whatsoever.

Peter Scott remembers this trip a little differently:

> I remember that quake! Neil Anderson had just dynamited the bottom of a shaft up on a rubbly hill. Whilst huddling behind a large rock from the blast, we thought that it was going to bring the hill down! Later we found that it was a local tremor. I later went on to do three years of Seismology (and then an MSc, in geology) but at the time we had a bigger-than-needed attitude towards the six sticks we set off.

My friend, Ian Cathles – long term resident of Wee Jasper remembers vividly a tremor around that time a few kilometres from Wee Jasper.

But … it was 57 years ago …

So what?

This leads me into the use of caves to investigate speleoseismicity. What the hell is this you, rightly, ask? It is the use of stalagmites to investigate the long-term history of earthquake events.

Paolo Forti (2004, page 565) says:

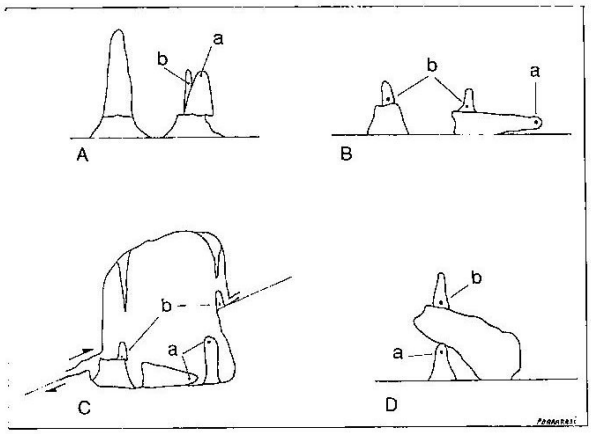
> Over the last few decades, seismotectonic studies of speleothems have proved that broken speleothems and actively growing stalagmites are the most powerful tools for the quantitative and chronological reconstruction of seismotectonic events. … They may be used as a tool for the detection of ancient era, and the relative and absolute dating of speleotectonic activity, the determination of its magnitude, and for improving general seismic hazard evaluation.

Becker et al (2006) sum it up as follows:

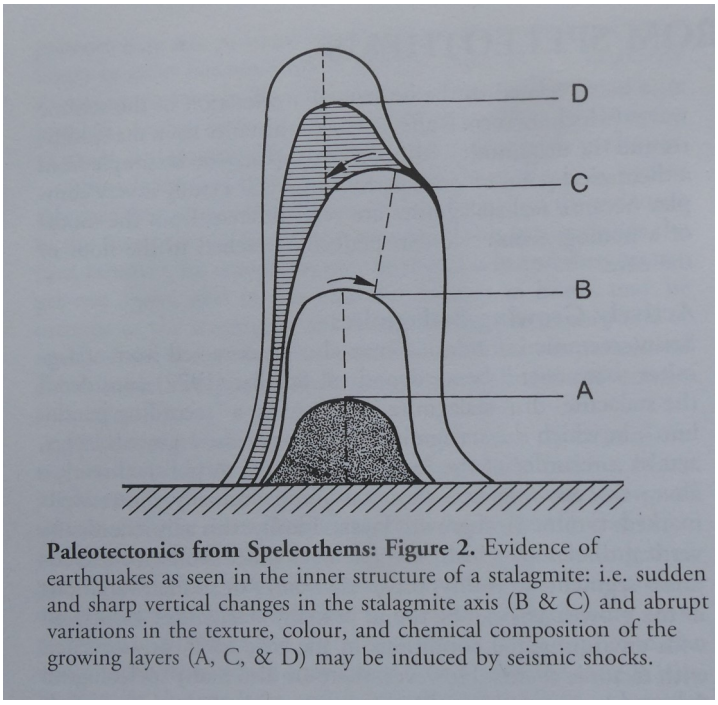
> Speleoseismology is the investigation of earthquake records in caves. Traces can be seen in broken speleothems, growth anomalies in speleothems, cave sediment deformation structures, displacements along fractures and bedding plane slip, incasion (rock fall) and co-seismic fault displacements. Where earthquake origins can be proven, these traces constitute important archives of local and even regional earthquake activity. However, other processes that can generate the same or very similar deformation features have to be excluded before cave damage can be interpreted as earthquake induced. Most sensitive and therefore most valuable for the tracing of strong earthquake shocks in caves are long and slender speleothems, such as soda straws, and deposits of well-bedded, water-saturated silty sand infillings, particularly in caves close to the earth's surface. Less easily proven is a co-seismic origin of an incasion and other forms of cave damage. The loads and creep movements of sediment and ice fillings in caves can cause severe damage to speleothems which have been frequently misinterpreted as evidence of earthquakes.

For the dating of events in geological archives, it is important to demonstrate that such events happened at approximately the same time, i.e. within the error bars of the dating methods. A robust earthquake explanation for cave damage can only be achieved by the adoption of appropriate methods of direct dating of deformation events in cave archives combined with correlation of events in other geological archives outside caves, such as the deformation of lake and flood-plain deposits, locations of rock falls and active fault displacements. [Abstract]

How do they do it? Let's look at some examples from Forti (2004) and the invaluable *Speleothem Science* (Fairchild and Baker 2012).



Paleotectonics from Speleothems: Figure 1. Characteristic breakage of speleothems, induced by seismic stress. Resonance-induced stalagmite fractured along a subhorizontal plane: (A) the upper part is still standing on its base, being only slightly translated and / or rotated from its original position; (B) the broken upper part lies on the floor close to its base; (C) stalagmite collapse caused by the displacement of the adjacent wall; (D) new stalagmite growing over a fallen rock, which covered an older stalagmite. Positions (a) and (b) indicate characteristic sampling points for absolute (U / Th and / or ^{14}C) dating of deposits which occurred just before (a) or after (b) the seismic event.



Paleotectonics from Speleothems: Figure 2. Evidence of earthquakes as seen in the inner structure of a stalagmite: i.e. sudden and sharp vertical changes in the stalagmite axis (B & C) and abrupt variations in the texture, colour, and chemical composition of the growing layers (A, C, & D) may be induced by seismic shocks.

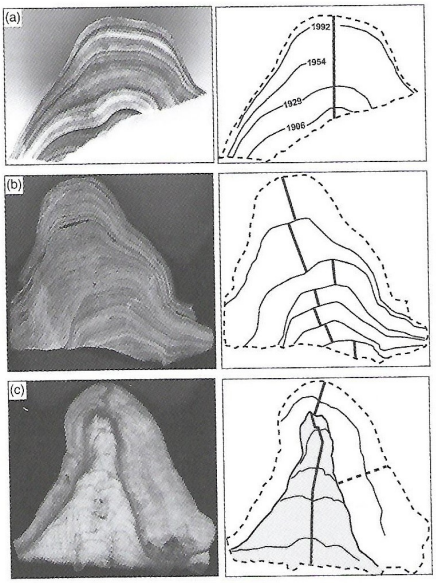


Fig. 7.B2 Polished and scanned images of (a) Asfa-3, (b) Merc-2 and (c) Achere-4 stalagmites from the Mechara caves. Corresponding sketches to the right of each stalagmite show the manifestations of earthquake activities in their growth: Asfa-3 by anomalous growth bands, Merc-2 by deviation of growth axis from vertical, and Achere-4 by a prominent hiatus with distinctly differing stalagmite shapes on either side.

Figure 7 (below) is a view of a stalagmite from Jillabenan Cave sliced vertically to allow wheelchair access to the cave. Attempts to date it failed, unfortunately. But what is interesting is how the drip source has clearly moved from left to right through time. The reasons for this are unknown – and there could be a number of explanations and interactions – and earthquakes probably do not fit this site.

Stalagmite in Jillabenan Cave, Yarrangobilly, NSW. Photo Regina Roach

Figure 8 is from Lynds Cave at Mole Creek and displays a major crack in massive flowstone induced by a magnitude 4-5 quake with its epicentre at Lake Mackenzie not far from the cave. The quake occurred on 24 September 1997 at 3.30 am on a Sunday morning.

The National Library's invaluable Trove lists some locals as sleeping though it, but others said, "his mother started the washing machine"; "it was UFOs"; "toys fell over"; "my chess game was ruined" and "plates and pictures fell off shelves and walls". It was alleged that the quake was felt in New Zealand.

Cathie Plowman remembers the quake:

> I remember the earthquake VERY well. It was in the very early hours of a Sunday morning in 1997. I was in David's then house in Launceston and woke in the darkness to the sound of what seemed like a truck about to come through the wall. I can still relive the event in my mind as if it was yesterday.

And there was a minor quake at Yarrangobilly a few days before …

Earthquake cracked flowstone at Lynds Cave, Mole Creek (photo—Dave Gillieson)

…… but I am looking forward to further cave/earthquakes tales from Australia and New Zealand in the next Journal.

References

Becker, A, Davenport, CA, Eichenberger, U, Gilli, E, Jeannin P-Y and Lacave, C, (2006), Speleoseismology: A critical perspective, *Journal of Seismology*, 10:371–388

Fairchild, I and Baker, A, 2012, *Speleothem Science: From Process to Past Environments*, Wiley-Blackwell, Chichester, UK

Forti, P. 2004, Paleotectonics from Speleothems, p 565-566, in Gunn, J. (ed), *Encyclopedia of Caves and Karst Science*, Fitzroy Dearborn, London

Around the show caves

Peter Chandler, NZ V-P, reports on events in New Zealand and at Waitomo:

New Zealand has just passed a year since the COVID-19 virus pandemic forced the country into a restrictive level 4 lockdown, one which effectively meant no cave visitors until times permitted us to resume life at level 2 restrictions. So, since May 2020, this is how it has been for us.

After the initial wave of Kiwi visitors getting out and about in mid-winter, things have changed to a steady diet of school holiday and long weekend visitors together with a trickle of Kiwi road trippers, many of them retired, in between.

The lack of international visitors has been especially noticeable over the peak visitor season (November to April). At a guess, this means cave operators are operating at 5% to 15 % of their normal visitation levels. This is a huge downturn for an industry which has grown steadily over the last 50 years – one which, of course, has had its ups and downs throughout this period.

Although it has, perhaps, been toughest on food, transport, information and accommodation providers, the five cave operators in Waitomo have been eligible for a STAPPS (strategic tourism asset protection) grant to assist their survival. In addition, the Otorohanga Kiwihouse has received funding. However, this funding did not include the Museum or Glowing Adventures.

The Waitomo Caves Museum is only open for postal services on weekdays – staffed by Bridget Mosely plus volunteers (plus Toni Hawkes Board and volunteers on weekends). The Waitomo Hotel and Roselands are closed.

At Spellbound, we have moved our office closer to the cave; this appears to be well received by our Kiwi customers. With the continuation of some Waitomo village pickups, this gives us 195, 145 and 85 minute tour options for clients. Taking one or two customers on a tour rather than setting a minimum number seems to be working OK but limiting departures on the really quiet days combined with letting others join on the tour if they arrive in time.

At THL, the Waitomo Glowworm Cave and Black Water Rafting, some staff are employed on 'jobs for nature' with the Department of Conservation. This scheme means they can be recalled for cave tourism, but do conservation work otherwise. Caveworld are also doing this and Kiwi Cave Raft Guides have been volunteering at the Kiwihouse.

Meanwhile, over the last 10 days or so, much of NZ has been basking in an Indian summer, caused by the stationary high-pressure system associated with the extreme rainfall event in eastern Australia.