by Tim Stahl

Shaky prospects: Anecdotal outlooks on the future of geosciences

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The world is at a critical state of limited resources, growing population, and increasing hazard potential. In the near future, geoscientists will be sought to solve these worldwide woes or face the consequences of a demanding public. Cheap, innovative technology and collaboration among several disciplines are needed to proceed forward and solve the difficult questions that humanity as a whole faces. Years of advances and dilemmas in earthquake prediction highlight a theme that stretches through all of geoscience and society: the need for quick solutions to pressing global concerns.

As I am writing this, a M4.8 aftershock rattles my office and knocks a precariously balanced coffee mug off my desk. I start to duck under my desk in that split instant of panic, and stop midway between my chair and the floor as the room begins its wind-down sway and eventually halts. I pry myself up and stare blankly at my computer screen as the adrenaline wears off. In that moment, everyone in Christchurch breathes an instantaneous sigh of relief that this wasn't the next 'big one'. I, however, am probably the only one left contemplating stability analyses of coffee mugs.

It has been a week and a half since a M6.3 earthquake, itself an aftershock of an earlier and larger event in September, obliterated the infrastructure and heart of New Zealand's second largest city. Current estimates put the casualty count at over 200, though rescuers have only managed to find about 160. Numerous suburbs are without water and power, and those who live within radius of the city centre have been entirely cordoned off from their homes for fear of collapsing buildings. The dried silt and sand from meters of liquefaction blows around the empty streets as military helicopters fly overhead. It is more of a war zone than a city.

This is a tragic part of a tale that was largely one of triumph for the New Zealand community. In September, when a M7.1 earthquake struck at 4:35am about 50km west of the city, there were no casualties. Most buildings withstood the brunt of the ground accelerations, and even families that had the fault trace go in the back door and out the front made it out okay. Costs from the September quake were estimated at NZ\$4 billion. The initial estimates from this M6.3 aftershock are on the order of NZ\$15 billion. The death toll and long term economic costs are causing frustration as eyes and ears turn to geologists for answers. The message has been clear. They want earthquake-proof buildings and predictions, and if they can't get it from scientists, they'll look elsewhere. It's the new trend in society and geosciences today: the need for quick solutions to problems with

no immediate or foreseeable ends. Dwindling resources. Surges in population with increases in the frequency and magnitude of hazards. Environmental disasters. The world needs geoscientists to step up the game, and geoscience needs to be fast tracked to solve the unsolvable.

Earthquake lecture for the Chinese Community of Christchurch, November 2010. It's been two months since the first earthquake and I've been busy outsourcing myself to different audiences that are eager to hear why they've been thrown around like ragdolls for the last few weeks. The Chinese interpreter to my left looks at me nervously after receiving a longwinded question from an old man in the back of the room.

"He wants to know...what actually do you do? He says that you can stand here and talk at us about what happened, but...pardon me...what good does that do?" She finishes and looks down at the ground like she has betrayed me somehow. I scratch my cheek, take a minute to decide if repeating the importance of seismic hazard models and paleoseismology to a man who recently asked if sand volcanoes came from the mantle is worth it, and then turn to the crowd.

"We have a long way to go before we can predict earthquakes." Another hand goes up and the interpreter handles it quickly.

"She wants to know how much you get paid." Same awkward moment. I didn't know if it would be a good or bad thing to tell her that I don't.

Somewhere on the walk home from that lecture, the notion hit me that we need to drastically improve our predictive skills or literally face persecution.

A lesson from recent history. In 2009, seven Italian members of a risk commission, four of them geologists, were actually charged with manslaughter after failing to predict a M6.3 earthquake that killed 307 people. Following a series of foreshocks, personnel of the geological survey and civil defense department were inquired as to whether or not the city should evacuate buildings or close schools. The commission responded that it could not be said either way if a series of small earthquakes would preclude an imminent, larger event. After the earthquake hit, the L'Aquila Prosecutor's Office brought the charges on those members and conducted an inquiry into their shortcomings in 2010.

Back in New Zealand, thousands have condemned geologists and are turning to an astrological dogma. A self-proclaimed quake prophet and "Moon Man" has people all over the country terrified of upcoming dates at which the Moon makes a close approach to the Earth, or produces a higher than average tide, or is full, or new, or is crossing

the celestial equator, or at its maximum declinations. Surely, coupled with increases in sunspots and solar flares, there will be a seismic doomsday just around the corner? With this belief gaining the attention of national media, I decided to dig just a bit deeper to see if indeed the Holy Grail of seismology – prediction – had been found.

There would be no better place to test this theory of prediction than the low tectonic-topographic stress regime of Australia. One would expect the tidal stresses, which are typically two orders of magnitude less than tectonic stresses, to have much greater perturbation, or at least a recognizable one, in such a region. Taking into account the 18 most significant and damaging Australian earthquakes since 1883, we compiled a list of every close moon approach (a perigee), new moon and full moon, and declination/right ascension (coordinates of the moon in a projected or “celestial” sphere around the Earth) for the years in which they occurred. We specifically tested to see if earthquakes could be predicted to within a 5 day, 15 day, and 61 day window of a combination of a perigee and new/full moon (which produces the highest Spring tides of any given year, often called King tides). The results were unanimous for all windows of error. All of the predictions hovered around the same probability of a random guess (and that’s exclusive of all the years without any significant earthquakes). In fact, 5 of the most significant earthquakes in Australian history would not have been predicted at all. A quick literature review would reveal similar results for all studies in lunar effects- a feasible mechanism with only a small effect where it can be properly correlated (Metivier, 2009 and others). It appeared the Holy Grail would have to come from somewhere else, but still the Moon Man followers insisted on the accuracy of his recent predictions. I took my research to the great forum for research and ideas, the Moon Man’s FaceBook Fan Page:

Person 1: I have been spending part of my day researching major world earthquakes randomly right back to the 6.0-6.3 Cape Ann earthquake in 1755 and comparing them with moon phases on those dates and entering them into an excel spreadsheet. What I have found is chilling to say the least. The quakes are always within a few days or on the day of a full moon or new moon in that hemisphere. What scare me about this are not [his] predictions, but the fact that it appears he is right and is being discredited. I just can’t see a coincidence here. Can I just say, Sumatra Dec 26, 2004, 9.3 Magnitude, was a full moon?

Me: Please send me the spreadsheet, I’m extremely interested: timothy.stahl@pg.canterbury.ac.nz. If you’re right, you’ve just made one of the most important scientific discoveries in human history. But I don’t believe you.

Person 1: I’m at home mum, it’s not a discovery, it’s [his] theory. November 18, 1755 was also a full moon by the way - Cape Ann. San Francisco, 17 October, 1989 - 14th Oct 1989 was a full moon. Are you seriously going to tell me that that there is no connection of major earthquakes to moon phases? So can I safely believe that if the moon can pull the oceans around, it cannot influence the land, even though the oceans are stuck to the land? I’m bummed.

Me: It does influence the land. But there is no statistically significant correlation between large earthquakes and new or full moons for major earthquakes in any year. Sometimes, they will fall on a new moon or maybe five days after or before. I have spent a lot of time on this because it is my job as a PhD student to do so. I just ask that people don’t make uniformed, misleading statements as you have to make a point. I’m not going to post any more on this.

Person 1: Quite frankly, when geologists say they bored 1000 metres down in various areas on my land before they hit solid rock each time and then said it was safe to build a motorway, when there’s a major fault running through there, there I lost confidence. Just because I am an at home mum, don’t doubt that I’m not educated Tim. I prefer to be prepared than scared thanks.

Person 2: Sorry to say Tim, but you should change the text books you’ve been reading. Teacher’s are obviously only offering you their one sided view. There’s a whole wide world of possibilities, if you only open your mind.

Person 3: Hahira!! Good job [Person 1]! He [me] starts a post, and a bunch of people spit the dummy down the way ...Well dun u!! :D Shake rattle and roll...

Now, despite the logical fallacies and conspiracy theorist mindset behind some of this, there are still some lessons to be learnt. One is that there is a general lack of faith in the geological community. Even the ones that aren’t evacuating buildings several times a month because the moon is visible tend to view geologists as the ambulance at the bottom of the cliff. Disasters happen and we’re the ones eagerly collecting data after the fact. And to a certain extent, *I agree with them.*

It would be nonsense to say that what we *are* doing doesn’t help. You can’t play the game without first learning the rules, and in many ways that’s where we are in active tectonics. We even try to cheat a bit and design buildings based on available paleoseismic data and hazard models. But of course, it’s impossible to earthquake-proof a building, and when several collapse to kill hundreds of people, no one cares whether or not the ground motion acceleration was 150% of the design code. They wind up caring when a random guy with astrology software can tell them to take the day off work.

A seemingly appropriate digression. 1971. Astronaut David Scott grasps a hammer in the right glove of his newly designed A7L-B space suit and a falcon feather in his left. With the Lunar Module as his backdrop, a crewmember films as Scott inspects each object and explains this surprisingly simple yet impossibly intricate experiment- a multimillion dollar, year-in-the-planning, two week long test that required its participants fly 384,403 km from the surface of the Earth just to achieve the ideal conditions. A tense moment goes by, then Scott flinches and his glove opens as both hammer and feather fall to the dusty floor of the Moon in complete synchronicity. For the first time it is visually confirmed that two object in free fall will accelerate downward at the same rate. Somewhere in Pisa, Galileo is synchronously raising his glass and rolling his eyes.

Of course, we knew full well that the acceleration of gravity was independent of mass centuries before Apollo 15 landed on the Moon (for purposes, might I add, other than tossing hand tools and animal parts about- they were the first crew to be trained for field geology). The crew would have never made it ten meters if not for Galileo’s largely fictional, famous experiment in which he came to that conclusion. But there’s a deeper scientific moral debate to get at here, and it has little to do with astrology or the Moon. Particularly, one could ask whether modern science is capable of handling age-old dilemmas with new outlooks, and whether it can be achieved by throwing money at experimental research and technologies. Especially with geosciences, where many studies seek to apply established concepts to new field areas, how much room is there for truly unique and hypothetical studies like endeavors in earthquake prediction? The

truth is there are several solutions, but none that will draw the manned space mission budget.

Take, for example, the Handy Geoslicer and the method of “peeling” in paleoseismology. Developed just in the last decade, both are relatively inexpensive and can improve the logging accuracy of a trench by documenting up to several meters that would previously have gone uncovered. That could easily mean telling the difference between a temporal cluster of earthquakes and a recurrence interval of thousands of years. The Geoslicer is essentially taking a large thin section of areas where a trench cannot feasibly be extended. A large metal sheet is driven into the ground with the help of a crane, and the recovered deposits are hoisted up, intact, for study at the surface. Where scientists were once relying on ground penetrating radar to virtually extend their trenches with vague results, now they can log up to an additional 3 meters (Nakata, 2003). Likewise, peeling, a process of applying a solidifying epoxy to a geosliced trench wall, allows for long term and more detailed analyses of faults and the proximal strata.

Computer models of earthquakes are also improving well beyond what their progenitors would have dreamed. QuakeSim and its extension, the Solid Earth Research Virtual Observatory, is an attempt to understand the complex patterns and interactions of earthquakes via “state-of-the-art modeling, data manipulation, and pattern recognition technologies” (Donnellan et al, 2006). It uses 3d finite-element code and input from members all over the globe to build an assimilation grid. The goal? Deconstruct the complexity and millions of deterministic unknowns associated with earthquake forecasts. By combining geodetic data (i.e. InSAR), seismic data, and paleoseismic data from thousands of worldwide regions and fault databases, one can start to build a picture of what is actually going on beneath us. The notion that earthquakes are largely a stochastic process may, in the future, be a thing of the past. With enough time and input, earthquake forecasts could be as reliable as weather forecasts.

Initial results have been stunning. In a 2004 USA Today article, Tariq Malik reported that a ten year forecast by John Rundle and Kristy Tiampo had accurately predicted the locations of 15 of 16 M5+ earthquakes in Southern California. Their model was based on historical datasets going back to the 1930's as well as ongoing InSAR measurements of local strain. While the magnitude and time frame of the predictions is something to look forward to, the success in just a few short years is astounding. They will only get better as more satellites are launched and more field data are collected.

It appears then that the way forward does lie in technology. We can look at and under every rock on Earth, but until we tweak the methodology of doing so, we will just be the players in a game we don't fully understand. Funding should fall into the laps of those researching cheap, innovative ways to achieve practical efficiency, which I suppose goes without saying. Geoslicing, peeling, and QuakeSim are just two examples of these advances in the active tectonics community, but there are numerous examples from all sects of geoscience in the last decade alone. Money helps, but it seems the most important factor has been the collaborative efforts of different disciplines. Perhaps, as geoscience moves forward into the 21st century, members should consider higher degrees of specialization and a high amount of collaboration to combat time and money constraints.

All of this, of course, is easier said than done. It seems that in large part, the amount of funding depends on how happy the public is with the current product- a Catch 22 of the science world. Abrupt,

eye opening events like a devastating earthquake could see the scale tip either direction; in Christchurch and New Zealand's case, the sheer amount of damage makes it hard to believe there will be an excess of money in any science program for years. Especially if people start rallying for more tide gauges to measure earthquake potential.

Earthquakes have been a plague on humanity since the first erected bit of infrastructure - last decade alone saw well over half a million people die as the result of quakes. As the world population surges towards 7 billion, more and more people are inevitably congregating near active margins and faults, with some even preferentially gathering near faults as sources of spring water. The world demands a penicillin-type moment from geologists. There needs to be a cure, or at least a medicine, better than the one currently provided. We're moving in that direction with new technology and advances in computing power, but it can never be fast enough. Just ask the crew of the Apollo 15 that worked to finally prove a 450 year old theory only 40 years ago.

The same message will ring true for all branches of the geosciences in the coming years. Every basic need of every human on the planet revolves around some aspect of geosciences, and they will look to us for answers. Clean water and energy will be the task of the geoengineers and geologists across the globe. Seismologists, volcanologists, and climatologists will continue to refine their methods in the face of rising populations, risks, and sea levels. Astrology fan clubs will continue to speculate on long-studied phenomena while InSAR satellites whirl around them making actual useful measurements. It will either be the geoscientist's greatest hour, or humanity's darkest. It's an uphill battle and we're often on the public's scarp slope. But there's every reason to believe that we can meet all the challenges we face.

Another quake in Christchurch and the coffee mug hits the deck again. You'd think by now I'd have put it some place safer than the edge of the table, or at least come up with an innovative way to fasten it down. Ah, scotch tape. There's my geoengineering for the day.

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