by Gemma Venhuizen

CoCoA: The future ingredient for geoscientific research

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In my essay CoCoA: the future ingredient for geoscientific research I focus on three topics with respect to the future of geoscientific research: ***Co****operation,* ***Co****mmunication and* ***A****djustment.*

Concerning cooperation, I argue that it is important for scientists from different disciplines and countries to work together and I come up with some examples of good cooperation which could serve as possible solutions.

As for communication, I argue that scientists should focus on lay-people more often by disseminating their knowledge. This could be done in four different ways: by Public Awareness of Science, by Public Understanding of Science, by Public Engagement with Science and by Public Participation in Science.

Regarding adjustment, I emphasize the importance of looking at our research topics from different viewpoints – both at a macroscopic and a microscopic level, both through the eyes of our fellow scientists and through the eyes of the lay-public.

In my opinion, interdisciplinarity and cooperation should become keywords in the scientific world and by means of this essay, I hope to stimulate the dialogue between scientists and society.

Picture yourself a big, homemade chocolate cake. Your sister is coming to visit you with her husband and their two kids, and you wanted to surprise them by baking the cake. You've spent hours finding the right ingredients and mixing them in the appropriate amounts and the result is fantastic. It has a nice and spongy cake-layer as a base and on top of it, there is the most delicious cream layer, which is in its turn covered by a dark chocolate mousse As a topping, you've arranged some walnuts in a nice pattern.

'I don't like cake!', exclaims your nephew as soon as he walks in, and he picks all the walnuts out of the cake, ruining the looks by making large holes in the upper layer. 'You know I'm a chocolate addict', sighs your sister, and starts heaving big lumps of the chocolate layer towards her mouth. Immediately, your niece devours the cream layer, leaving only the spongy cake base for your brother-in-law. 'Nice cake', he says. 'A bit plain, maybe, but nice.' Disillusioned, you eat the last few crumbs from the plate – if only they would have tasted the cake as a whole, they would have enjoyed it even more...

Now picture yourself a slightly different cake. The walnuts are replaced by buildings, the chocolate turns out to be a dense vegetation layer. The cream is represented by ground water and the base layer is not that spongy anymore, as it consists of hard rock. In other words: welcome to the earth.

And on this heavily inhabited cake, it's easy to recognize your family members. Your nephew turns out to be a promising civil engineer, your sister is a keen biologist, your niece is studying hydrology and your brother-in-law specializes in geology. All four of them are working with the earth, but they are each so focused on their own job that they're not aware of what is going on in other parts of the world - and that's a pity.

Although science is not just a piece of cake, this example illustrates the way in which many scientists work. They are occupying their own niche, concentrating on their specific research area. Of course, only by doing thorough, in-depth research on a specific topic, it is really possible to unravel complex processes. On the other hand, this high-resolution, small-scale type of research cannot stand on its own. A broader, panoramic view of the scientific field is necessary to understand how all the parts of a system are related.

The geological sciences cover an area in which many different disciplines come together. A lot of cooperation is already going on in the field, but in my opinion, this interdisciplinary approach could be stretched even further. Therefore, I will try to formulate the recipe for future earth scientific research in this paper.

And to be able to do that, I will focus on the most important ingredient: CoCoA – Cooperation, Communication and Adjustment.

Cooperation – or 'four different ways to look at a pingo'

Everyone who has ever done some gardening is aware of the fact that soil isn't just some collection of sand grains – it is the whole of roots, groundwater, animal life and abiotic particles. An ecosystem that could not exist if some of the most important members were missing, because they all depend on each other. Without the water the roots would die, without the roots the soil particles would erode, without the soil the animals would be homeless.

Even on a scale of a few centimeters, it is already visible how intertwined different parts of nature are: geology, biology and hydrology all come together.

Why then, is it that these disciplines are seen so often as separate sciences?

In May 2010, I was selected to participate in a summer school on permafrost, organized by the University of Alaska in Fairbanks (www.iarc.uaf.edu/education_outreach/summer/2010). The special thing about this course was that it was not only developed for earth scientists, but for young scientists from different disciplines: ecology, geomorphology, hydrology, archaeology, meteorology, civil engineering and science communication. Part of the course was a field trip along the Dalton Highway, one of the world's most northernmost highways. Along the road, we saw a few beautiful examples of one of my favorite phenomena within the earth sciences: pingos. With my background in Quaternary geology, I immediately started explaining the development of these pingos (which do in fact form by a subsurface ice lens pushing the soil upwards until a hill develops).

As it turned out, I was not the only one fascinated by pingos. The ecologist pointed out to me that the small secondary mounds we saw on top of these pingos were in fact the result of bird droppings: birds rested on top of the hill (as a look-out) and their droppings provide a nutrient-rich base for the vegetation. The archeologist, overhearing our conversation, told us that human artifacts (like arrow heads) can be found around pingos quite often, because prehistoric men used them as look-outs. And the hydrologist started to explain something about the drainage patterns in the area around the pingo. As a result, each of us got wiser on the pingo-topic, just by looking at the hill from a completely different point of view.

In my opinion, geoscientists should and could use this interdisciplinary approach more often in the future. Like the IUGS already shows us, it is valuable to create a platform where different disciplines within the geosciences can meet. Or, as it says on the website: 'The Union aims to promote development of the Earth sciences through the support of broad-based scientific studies relevant to the entire Earth system; to apply the results of these and other studies to preserving Earth's natural environment, using all natural resources wisely and improving the prosperity of nations and the quality of human life' (www.iarc.uaf.edu/education_outreach/summer/2010).

When it comes to academic research, geologists could look more often past the frontiers of their own research area. This interdisciplinary approach asks for a broader view. Courses, conferences and excursions should not only focus on rocks and faults, but also on the animals and plants that use them as their habitat; on the people that are threatened by geo-hazards; even on the shapes of the clouds that form above a mountain range.

Interdisciplinarity encompasses both cooperation within the exact sciences and cooperation between exact and social sciences. Especially the second type of cooperation deserves more attention. Sure enough, most universities incorporate courses like history of science and philosophy of science in their colloquium, but most students regard them as a necessary evil. Why not incorporate a little bit of history and philosophy in each geology-related course, instead of making separate courses out of them? In that way, students will get used to these subjects, instead of regarding them as the 'odd-ones-out'. Next to history and philosophy, other disciplines could be combined with the earth sciences as well: economy (focusing on the exploration of minerals), archeology (focusing on the relation between geomorphology and the distribution of old settlements, or between petrology and tool making) and maybe even literature (focusing on how landscapes are depicted in novels). Such programs could make young scientists aware of the fact that the spectrum of science is broader than just the part they're studying themselves.

A good example of improving cooperation between sciences was the conference of the International Polar Year held in Oslo in the summer of 2010 (www.iarc.uaf.edu/education_outreach/summer/2010). The great thing about this conference was that it wasn't only about geoscience, but also about biology, management, communication, politics – everything associated with the poles. In my opinion, it would be a good thing if magazines, courses and conferences would have a system-based approach in the future (i.e., focusing on a specific area or ecosystem for example). Another interesting example is the existence of Scientific Journal Publications (www.science-journals.org) and Scientific Journals International (www.scientificjournals.org/index.php). On this website, a whole range of scientific papers is available for free – right now, the field encompasses physical science, medicine and health science, biology and social science. The physics section already contains a few geologic journals (a.o. the *Journal of Geology and Mining Research*) and it would be wonderful if more geoscientific journals would become available for free on this website, to make it easier for scientists from other disciplines (and for journalists, as a matter of fact) to read something about a topic they are not too familiar with.

Cooperation does not necessarily have to be linked to inter-disciplinarity between sciences – there could also be more cooperation between different countries. Once again, the IUGS sets an example by creating a platform for 121 nations. In many field projects, there is a quite good cooperation between different countries already and more than 5000 geoscientists from all over the world attended the 33rd quadrennial IGC in 2008 (ww.34igc.org/sponsorhip-enquiries.php). However, there are also researchers from different countries who all try to solve the same problem separately.

Luckily, a positive trend can be seen already. Especially for young geoscientists, some great international platforms exist: the YES-network (www.networkyes.org/) (Young Earth Scientists), APECS (www.apecs.is/) (Association of Polar Early Career Scientists) and PYRN (Permafrost Young Researchers Network) (www.pyrn.ways.org/). These networks do the literal meaning of the word 'network' justice: they create linkages between different groups of people. By enabling webinars and by sending digital newsletters, they enable contact and knowledge exchange between scientists of different countries in a quick, easy and low-cost manner. Moreover, these networks organize meetings, both for members from developed and developing countries. For example, the YES organizes a big YES Africa conference in 2011, thus enabling contact between African geoscientists and geoscientists from other parts of the world (www.networkyes.org/index.php/meetings/yes_africa_2011).

Last but not least, it would be desirable if scientists could cooperate more with nature itself. Over the last few centuries, we made ourselves part of the landscape. Our highways are meandering like rivers, our industrial installations look like modern volcanoes, pumping smog into the air. Our buildings may be the walnuts on the cake, but our influence stretches further than that. In a way, we are the ones baking the cake and that makes us responsible for the end product.

During the next few decades, our presence will be felt even more, as the number of people inhabiting the planet is increasing. Therefore, the future of geoscience should also be about responsibility, about how we can take care of the earth – to make sure there will be enough cake left for future generations. And closely related to this topic, there is another important keyword: communication.

Communication – or: how to come out of our ivory towers

Remember that piece of garden soil, in which the roots, the particles and the animals all need each other? The same goes for society. Even though we live in an age of ongoing individualism, with the pre-fix 'i' popping up in front of phones, books and pads, we cannot function without each other. We need – among others – bakers, nurses, plumbers, teachers, policemen and scientists to make the human ecosystem work. Most of these groups are occupying a clearly structured niche, in the centre of the ecosystem: they bake bread for anyone who is hungry, they take care of anyone who is ill, they fix the plumbing for anyone whose sink is broken and they teach anyone who is interested. The scientists, however, seem to occupy a niche somewhere on the border of the ecosystem – each discipline dwelling in its own ivory tower, in order to avoid distraction by colleagues from other research areas or by society as a whole.

However, we forgot to make an entrance door in these ivory towers. We only have a small window, very high up, through which we watch society every now and then. We have locked ourselves up, waiting for the knights in shining armor that are called 'journalists' to climb our long, golden hair and hear all about our fascinating research. But unfortunately, science communication is not a fairytale. If we want to make ourselves heard, we have to throw our own rope ladder out of the window and meet up with society in the city center. We have to communicate what we are doing, to transfer our knowledge to the lay-public, instead of performing 'iScience' by only minding our own business.

In my opinion, an appropriate way of doing this would be by means of the 'PAS PUS PES PPS' model (Van der Sanden and Meijman, 2008). According to this model, there are four ways of disseminating scientific knowledge to a lay audience: by means of Public Awareness of Science (PAS), Public Understanding of Science (PUS), Public Engagement with Science (PES) and Public Participation in Science.

The first element of the model, PAS, simply is about making people aware of the existence and basic meaning of the geosciences. That sounds straightforward, but in reality, that is not always easy. Especially in a flat country like the Netherlands, where no mountains or volcanoes can be seen, many people are quite ignorant when it comes to the geosciences. Quite often, they think that geology is the same as archeology, and I have to explain over and over again that I'm not looking for old bones but for old stones. And when I first went to college, my hearing-impaired grandfather mistook 'geology' for 'theology' and asked me all about the Bible.

On the website of the IUGS, it says that one of the goals is 'to strengthen public awareness of geology and advance geological education in the widest sense' (www.iugs.org).

Introducing people to the geosciences could be accomplished in a number of ways, for example by putting signs with geologic background information on sightseeing spots – just to make them aware of the fact that they're looking at a geologic phenomenon.

Often there is a thin line between PAS and the next element: PUS. Public Understanding of Science is about increasing general geologic knowledge, and this can be done in various ways: by publishing popular-scientific books and articles on earth science and by creating exhibitions around geological topics, for example. Often, people think about PUS when they think about science communication and knowledge transfer is very important indeed. The important thing is to find the right way to transmit the knowledge, because hard-core science is not that attractive to lay-people. Even for geologists it is not always tempting to wrestle through scientific literature, as it is often written in passive, objective language. 'Hell is sitting on a hot stone reading your own scientific publications', as Kaj Sand-Jensen put it in his article *How to write consistently boring scienti?c literature*(Sand-Jensen, 2008).

It has not always been like that. A few centuries ago, many scholars were skilled novelists or poets at the same time. Beatrix Potter, author of the famous Peter Rabbit-series, was well known for her studies of fungi; the notebooks of the Swedish botanist Carl von Linné contained both scientific remarks and exciting travel descriptions; Charles Lyell's *Principles of Geology* were not only famous among other scientists (like Charles Darwin), but also among lay-people – in the introduction of the Principles, it is said that 'in prison for blasphemy in 1842, the atheist agitator Charles Southwell asked for a copy along with his accordion and some cigars.'(Secord, 1997)

Why not stretch the strict boundaries of scientific writing a little bit? Why not adopt a lighter, slightly more personal tone in our articles every now and then, just to make them more readable? Why not organize some journalistic writing courses for scientists? Or some geology courses for journalists? The Geological Association of Canada (www.gac.ca/awards/Fortier_journalism_award.php) and the Earth Journalism Network (www.awards.earthjournalism.org/about-competition) already set a good example by handing out awards for earth science journalism and the National Center for Atmospheric Research has organized a Journalism Fellowship to introduce journalists to the earth sciences for three times in a row (www.ncar.ucar.edu/resrel/jfellowship/). At the Columbia University in New York, it is even possible to take a course in earth science journalism. It would be wonderful if more of such courses would exist, but unfortunately, the opposite seems to become true: the Columbia University announces that it will not accept new students for the fall of 2011, due to the current weakness in the job market for environmental journalists (www.ldeo.columbia.edu/edu/eesj/).

Therefore, it might be a good idea to try and reach the public in other ways as well. Public Engagement with Science (PES) is about the emotions which can be invoked by science – and it is closely related to the beauty behind science.

For example, the geological novels that have been written over the last centuries (not in the last place Jules Verne's *Journey to the center of the earth*, about a descent in an Icelandic volcano; Verne, 1864) have served the goal of PES. Verne might not have attributed to Public Understanding of Science, by his far-fetched theories about volcanoes, but at least he managed to stimulate the scientific fascination of his readers.

Of course, engagement with science can be stimulated in more ways than just by means of literature. Last month, an exhibition entitled *Beauty in Science* was opened in the Netherlands, showing pictures from ten scientific disciplines (among which geology) (www.boijmans.nl/en/7/kalender/calendaritem/754/schoonheid-in-de-wetenschap) No signs were present to explain the visible phenomena on the pictures – visitors were left alone with their imagination. And the reactions were overwhelmingly positive.

Last but not least, science communication can take place via Public Participation in Science. By actively taking part in geology (for example by going on a guided excursion), people can experience the landscape. The American Marine Biological Laboratory and the University of Vermont even organize an annual Polar Hands-On Lab, in which journalists can participate in a scientific research project and afterwards write an article about it (www.mbl.edu/sjp/environmental.html).

All these four strategies (subsequently increasing the awareness, the knowledge, the engagement and the participation of the public) are in my opinion valuable and it would be worthwhile to focus on ways how to enhance them in the future.

As an example, we can look back at the International Year of Planet Earth (2007-2009), during which all kinds of activities took place (www.yearofplanetearth.org). The organization of such an event was a perfect example of PAS, the lectures that were given supported the PUS-part, the beautiful exhibitions around the world increased the PES and the many excursions took care of the PPS. What was more, the International Year of Planet Earth was a great example in which cooperation and communication came together: scientists, journalists and lay-people around the world were experiencing the Earth and felt the need to take care of it.

Adjustment – or: 'Replacing iScience by eyeScience'

More than 400 years ago, two inventions were made that lead to great scientific breakthroughs: the microscope and the telescope. The first has become an indispensable tool for biologists, geologists and health scientists alike; the second has been essential in our discovery of the space surrounding our earth.

And together, these two inventions represent the third important factor of CoCoA: adjustment. They make it possible to change our viewpoints, to zoom-in and zoom-out, to make the unseen things visible. Only by looking at things from different angles, it is possible to get a clear picture. Depending on the scale and the viewpoint, different phenomena emerge: some major faults can only be seen from the air, while small frost cracks in a pebble are hardly visible with the naked eye.

In my opinion, this ability to adjust is crucial in science – not only in a literal, but also in a metaphorical way. It is all about scope – it is not the 'iScience', but the 'eyeScience' that matters. We should look more often through the eyes of fellow scientists and of lay-people to analyze our own research. In that way, we can stimulate our 'out-of-the-box thinking' and come to new insights.

In my opinion, all different levels of scientific research are important. I don't adopt the reductionist point of view, which assumes that all science could be reduced to 'fundamental' science (i.e., physics). On the contrary, I think that new insights emerge when you add different sciences. You cannot predict how a river will run by staring at the individual water drops, you cannot know what a cake will taste like if you only try the separate ingredients.

We should break down the ivory towers belonging to the separate sciences, but not leave the building blocks unused. From the debris, a center can emerge – a research center where scientists from different disciplines work together; a visitor center where citizens would not have to pay an entrance fee and where they can communicate with scientists. Where they can experience, learn, admire and take part in science.

The future of geoscience is about developing a unifying language; by providing a recipe to make our planet the most delicious chocolate cake ever. All the layers are tasty, but they taste the best as a whole. Only together, we can bake the most delicious cake.

Tuck in!

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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 breaths 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.
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> "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 gong 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 new 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, 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 is 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 shear 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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by Anne Carter Witt

Treading lightly on shifting ground: The direction and motivation of future geological research

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The future of the geosciences and geological research will involve complex scientific challenges, primarily concerning global and regional environmental issues, in the next 20-30 years. It is quite reasonable to suspect, based on current political and socioeconomic events, that young geoscientists will be faced with and involved in helping to resolve some well defined problems: water and energy security, the effects of anthropogenic climate change, coastal sea level rise and development, and the mitigation of geohazards. It is how we choose to approach these challenges that will define our future. Interdisciplinary applied research, improved modeling and prediction augmented with faster and more sophisticated computing, and a greater role in creating and guiding public policy, will help us achieve our goals of a cleaner and safer earth environment in the next 30 years. In the far future, even grander possibilities for eliminating the risk of certain geohazards and finding sustainable solutions to our energy needs can be envisioned. Looking deeper into the future, the possibilities for geoscience research push the limits of the imagination.

Introduction

> "Any sufficiently advanced technology is indistinguishable from magic." – (Clarke, 1973)

In the 1960s and 1970s, British science fiction author and scientist Arthur C. Clarke proposed three "laws." These adages describe our modern interpretation of advanced technology by future civilizations as seen through the context of our current technological limitations. The third law (above), written as an accompaniment to his 1973 revised collection of essays, 'Profiles of the Future: An inquiry into the limits of the possible', is probably his most well known. There is no reason to suspect that technologies, which we may consider to be impossible or even laughable now, may be a reality in the future. Our lofty goals of predicting the timing of volcanic eruptions and earthquakes, controlling ocean circulation and weather patterns, are all imagined possibilities that modern scientists can only dream about and continue working towards. I see no place in the far future without the help and expertise of various geoscientists; on this planet, or elsewhere in the solar system. However, in order forecast a realistic conjecture of a far future world shaped by advances in the geosciences, it is important to recognize the variables that will affect our more immediate future. One cannot step so far forward, without first looking backwards at where we have been.

The first Geological Survey in the United States was started in 1823 in North Carolina through a legislative order by the North Carolina General Assembly. The sole scientist in charge of the Survey, Denison Olmsted, was instructed to find and map sources of mineral and rock material that would benefit the state monetarily, and elucidate the geological resources of North Carolina for the greater good of the public. His prime objectives were to find material to promote agribusiness and identify precious metals, including gold. The first geological map of the state, completed and delivered to the Department of Agriculture in 1825, was influential in directing the service of other geological surveys to follow. In the nearly 200 years since the completion of this map, little has changed. Many geologists and geoscientists are still heavily involved in the identification and retrieval of natural resources, although the scope of what is now considered "precious" has expanded to include such intrinsic concepts as clean air and water. The notion of what a geoscientist does in the workplace is also expanding and merging with other scientific disciplines. The momentum of the "green economy" has required that recent graduates have knowledge in many disciplines (meteorology, geology, chemistry, biology, etc.) and be able to integrate with other fields of study to solve modern problems. These problems not only present great challenges, but also provide exciting and relevant avenues for new research.

Future Research Trends in the Geosciences

For the past 50 years, geologists have been employed in such endeavors as traditional geologic field mapping, mining and the petroleum industry, and more recently, hydrology and environmental fields. Earth science research has generally focused solely on understanding and visualizing the interaction of the Earth's systems. The effects of anthropogenic forcing have now reached critical levels where natural processes are being disrupted. Human interference in our natural systems can no longer be excluded from geological research. Potential future research trends will involve issues related to the climate, natural resources and geohazards, primarily driven by the needs of an ever increasing global population. Galloway (2010) postulated that future geosciences research, and subsequent funding, will be in three general areas: cross-disciplinary science, modeling and prediction, and scientific communication to society. I would also insert into this list, that we will see an institutional shift from "science for the sake of science" to applied science for the benefit of humanity.

The increased interest in the interdisciplinary nature of science is primarily due to a push within the physical sciences over the past 20 years to promote the concept of the Earth as a system. This concept focuses on the interconnectedness and interaction of the Earth's individual parts (e.g. the biosphere, lithosphere, atmosphere, etc). The emerging concept of "Earth system science" will redefine geoscience research in the 21st century and the tasks we will be asked to accomplish. No longer can the natural sciences function in a vacuum. There will be a fundamental shift away from study within an individual discipline to interdisciplinary sciences, as hiring in government, academic and private industry will require a more diverse workforce. There will also be a need to incorporate and work with our colleagues in the social and economic sciences. By breaking down barriers between the individual disciplines we can improve modeling and prediction on the global scale, within the Earth System.

There will also be more geoscientists working on applied scientific problems to creatively provide applied solutions to global and regional dilemmas. Probably our most pressing challenge will be serving the world's growing energy demands. Our need for fossil fuels certainly will dominate the socioeconomic and political stage in the immediate future, and perhaps into the far future (without a viable and economical energy solution). Demands will also increase on our other natural resources including available fresh water in our river and aquifer systems. The availability of clean, potable water is already a challenge in many developing countries and will continue to require more attention as world population grows. Future research efforts will need to focus on providing long-term water security and more robust modeling of freshwater occurrence, distribution, and sustainability.

The effect of human-interaction and modification of our coastal areas will become a major concern in our immediate future. Near shore systems are particularly vulnerable to changes in local sea level rise further exacerbated by the specter of anthropogenic climate change. Even though the world's coastlines only occupy a small percentage of the world's habitable land, they represent the part of the ocean system that humans actively use and benefit from economically. The continued increase in population in coastal areas will require applied solutions to mitigate potential damage from overuse and protect offshore and near shore ecosystems.

As human populations continue to push to farther corners of the world, they will also encounter greater geologic hazards. More people are living in active seismic zones, nearer to volcanoes, and on steeper slopes in landslide prone areas. Further research into the earth's interior will help provide insight into the mechanisms behind earthquake generation and a more systematic approach to earthquake prediction. Increased instrumentation, qualitative observation and predictive modeling will improve our understanding of the timing of volcanic eruption and improve the modeling of landslide hazards.

Advanced Technology: Improvements in Modeling and Prediction

Many of these global problems will require advances in probabilistic modeling and prediction at various temporal and spatial scales. It is to our benefit that young geoscientists have been primed to approach some of these multi-faceted challenges and are particularly adept at utilizing technology. Never before has a generation had such computing power available, in such near real-time, at any other time in our history. Since the 1960's, science students have been inundated with environmental dogma, learning of the unintended human-induced effects on our ecosystems. More recently, young scientists have matured in a world with the personal computer and the Internet, and are uniquely skilled in comprehending and utilizing this technology. These individuals live in a wired world, interacting together as a global community. While technological innovation has been changing at a blinding pace, our computing ability has also grown exponentially in the past 20 years. Smaller and more mobile data storage and faster processing speeds have made technology more widely available at lower prices. As long as the Internet is available cheaply and without restriction, global datasets can be made accessible for interpretation and application to myriad problems.

A discussion of the future of the geosciences cannot take place without mentioning the advances in GIS technology. It was not long ago that geospatial platforms were only used by specialists toiling away in the production of 2-D maps and CAD drawings. More sophisticated software is allowing for earth visualization in 3-D and 4-D. Mobile hand-held devices such as smart phones, laptop PCs, and even GPS navigation systems in cars, have placed geospatial data in the hands of users who need no special training. Thanks to programs like 'Google Earth,' aerial photography and digital topographic data at varying scales are now available to nearly everyone for interpretation. This seemingly simple program is being utilized by numerous organizations for a variety of uses, from the academic to the mundane.

The availability and inherent usability of 'Google Earth', and other open-source geospatial programs, is one that the scientific community can use as a model for future data dissemination. Various agencies and universities worldwide are collecting massive amounts of physical observational data and storing these away, waiting for a time when these observations can be utilized. The challenge for the geoscience community is to bring datasets from these various disciplines together, in a rational way, rather than have distinct, separate communities working in isolation. Instead, cross-disciplinary work can connect scientists together to create cohesive observation networks for modeling and prediction purposes.

Comprehensive data networks will allow for modeling at ever greater temporal and spatial scales. These datasets should be expandable to the global scale, but must also be able to address and identify patterns for modeling in regional and local areas. While anthropogenic climate change is certainly a global phenomenon, the effects of changes in weather patterns and circulation are being recognized regionally. There also must be significant improvement in accurately modeling the effects of localized but devastating mega-events such as hurricanes, floods or large earthquakes. Temporally, these improved datasets will allow us to model natural systems far into the geologic past, in order to discern patterns that will help predict outcomes far into the future.

At the same time, scientists will need ever larger datasets at greater resolution to produce more realistic and complex models with greater model accuracy. These immense datasets will require expertise that is not usually taught as part of the core earth science curriculum. Complex data visualization, data mining and assimilation, and database management will involve collaboration with our colleagues in statistics, mathematics and computer programming. Since new models are often data driven, new methods of collecting this data will need to be created. Where remote sensing is not realistic or possible, new monitoring systems will be developed and our data array expanded to provide a more realistic framework for complex natural system modeling.

Creating these interdisciplinary networks within the open framework of "cloud computing" will provide easier collaboration and data dissemination by allowing data and maps to be collectively stored on the Internet. This will eliminate the need for static data storage, costly infrastructure, and onsite network management. Once the dataset is made available, various users can then access this data for a variety of means and uses. The advancement of "cloud computing" and GIS-based web mapping will have a profound benefit for developing and emerging countries that may not have the capital to invest in data centers.

Unfortunately, some technological advances may make more traditional geologic endeavors, such as field mapping, obsolete. In the future, these tasks will continue to move out of the field and into the office. Already, smaller field laptops have begun to replace field notebooks and better GPS location devices have significantly improved our mapping techniques. Digital topographic imaging using LIDAR has proven successful for identifying major lineaments and fracture systems. Smaller projects are using mounted high-resolution LiDAR devices to scan and continuously monitor slow moving rockslides and displacement along faults. Continued advances in remote sensing and smaller, hand-held spectrometers for mineral and rock identification will decrease the field time needed for long-term mapping projects. In the immediate future, there will still be a place for having "boots on the ground" to collect samples and complete detailed investigations for individual projects, but field time will be much more efficient and limited.

Communicating Geoscience: Science for the greater good

Communicating complex scientific problems to a variety of audiences will also be a great challenge for geoscientists. Educating the public and decision makers will be necessary to provide popular momentum to fund and support further geoscience research and to encourage young people to enter the field. There will need to be a continuous effort to train geoscientists in effective communication and appropriate ways of interfacing with local communities and stakeholders. Complex geological ideas will need to be described in a way that is scientifically accurate, complete and understandable to diverse populations with a variety of skill levels and little scientific background.

It is also reasonable to suspect that geoscientists, based on our inherent knowledge and experience with environmental issues, will become even more involved in political decisions by helping to create and write public policy. The geoscience community will also have increasing international visibility and will play an important role in reinforcing the capacity of developing countries to mitigate and resolve environmental and natural resource issues. To that end, there will be an ongoing need to hire and collaborate with geoscientists with an expertise in business management, political science, language and communication skills, and even human psychology.

Perhaps one of the greatest society benefits that future geoscientists can provide is the protection of life and property during natural disasters and the improvement of early warning systems. In crisis situations, the geologic community will play a critical role in providing concise geologic information to decision makers for emergency management decisions. This will involve moving beyond the era of the static geohazard map and even beyond real-time forecasting of individual hazards, such as a heavy rain event. A system will need to be put in place that can predict specific dangerous weather patterns, within several hours to days, with sufficient lead time for action by those directly impacted. This will mean being able to identify discrete areas affected by specific hazards before the event unfolds. Individual home owners can be systematically warned of flooding and landslide dangers with specific instructions of what to do. Emergency personnel can be directed, safely, where they will be needed and most efficiently utilized. Whatever level of predictive skills and techniques that we develop, it will be imperative for geoscientists to be able to educate, communicate and motivate the public to understand that the events that are forecasted are real and imminent, so as to limit potential loss of human life.

Geological Imagining: The Far Future of the Geological Sciences

Oddly, there have been very few writers of speculative fiction who have delved into the idea of what geologic exploration and innovation will be like in the future, 100 or even 1000 years from now. This seems strange as there have been geologists sent to the moon, completed research on the international space station and others who are currently working on the Mars missions. There have been a few stories dealing with the mining of raw materials in space, mainly involving asteroids or distant planets. It seems even stranger when one realizes how instrumental the geosciences will be in shaping our future world. Indeed, if one of our goals as a civilization is to move beyond this planet and further into the universe, comparative planetology and planet exploration will be a critical function of the future geoscientist. How is it that the geosciences have been reduced to the background players in stories where we should be leading characters?

Perhaps the reason is because we have not yet made the scientific discoveries that will quantify and solidify what seem like geological imaginings. Some of these are not steps along the road to discovery, but leaps from where we are today. They will require continued long-term research, continual funding availability, and extensive data collection. In the future, geoscientists will make systematic and accurate earthquake and volcanic eruption prediction a reality. Geoscientists will be able to better manage and modify the behavior of the world's oceans, weather patterns and global temperature for our benefit. Long-term and accurate modeling of landslides, tsunamis and other natural hazards will eliminate loss of life and property.

In the far future I am also hopeful that we will be able to move away from nuclear fission and harness nuclear fusion as an alternative energy source. However, our civilization will also require raw materials. Without a viable way to use our mineral resources with optimum efficiently or create them artificially, it is reasonable to assume that we will eventually be forced to look off planet for raw materials. Some have speculated that we will be able to capture and tether an asteroid in high orbit to mine for metals. Further advancement in the fields of nanotechnology and robotics will also help us explore places formerly unavailable to humans: the interior of the earth, the deep ocean, and deep space.

Our goals are lofty, but generally seem to revolve around the control of our fate as a species on this planet. Ultimately the role of geoscientists will be to control and modify our environment to make it more livable, to provide the raw materials and energy to power our civilization, and to make sustainable environs, wherever that may be.

Conclusion

Young geoscientists have a particular stake in the future of the geological sciences and our world. Undoubtedly, unforeseen world events will change the outcomes of any prediction and reshape our influence on the future. We also cannot exclude the influence of political pressure on the outcomes of science by directly guiding funding to particular studies while “starving” others that are of less interest or intrinsic value. The current global economic recession is already stressing sources of funding for the geosciences. In reality, current funding levels will need to be maintained or significantly increased to help meet the realities of our changing world. We will need to be able to effectively communicate these critical issues to our political leaders, decision makers, and private industry.

With all of our technological advances and potential for multi-disciplinary collaboration, I still foresee a need to provide young geoscientists with a strong background in the fundamentals of rudimentary science. One cannot understand the Earth System as a whole without first exploring and understanding how these individually subsystems operate. As a civilization matures, individuals specialize in disciplines in which they excel. Our new world will be made of scientists with specialties in their individual fields, working together with other specialists to bring together ideas and tackle new problems. For young geoscientists, these will be some of the greatest challenges and accomplishments of our generation.

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by Nathan Barber

The future of the geosciences

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"No great discovery was made without making a bold guess" – Isaac Newton

The future of geosciences will be radically different than it was 100, 50, or even 5 years ago. We are on the cusp of new discoveries, techniques, and ideas. Geoscientists are becoming well respected in the science and public communities as new challenges face us. The future of geosciences will involve research into renewable energy and the depleted water resources. The water crisis will also increase the need for medical geology research and will perhaps open up a new industry for this specific title. Geoscientists will be called to help find water on other planets or decipher the historical geology of a planet to see if it is habitable. These planetary geologists will also be used to set up lunar bases or develop local resources. Geoscientists will be educated in many disciplines to fully understand everything they are studying. As much as theory is important, classes in the geosciences will be aimed toward applicability and practical use. Dating techniques will improve so we can understand how fast one animal evolved, or how fast climate change can realistically take place. Geoscientists will be the experts and therefore must be more responsible with scientific evidence and the differences between truth and imagination. Finally, geosciences will depend on all encompassing ethical codes, meticulous documentation in the field, and a better way to present confidence of a given topic.

We know from studying history, that most advances come when someone proposes an original idea. Usually, if these ideas go against a traditional, widely accepted view, they are temporarily ignored, unfairly politicized, or completely dismissed as opinion. In the case of Isaac Newton, his publication of "Principia" was slow to convince other scientists of his discoveries or derivations. This was likely due to the complete change in conventional thinking, as well as the processes involved to conclude his ideas (Lazzari *et al.*, 2000). Alfred Wegener probably suffered the most, when he proposed his theory on continental drift in 1912. His ideas were so ill-received, that the rest of his life was spent trying to convince others of his theory; this was to no avail, as he was not recognized for his groundbreaking theory until approximately 30 years after his death. It was then that paleomagnetism provided the evidence (Frankel, 1987). Pythagoras and Aristotle, among others, each independently predicted the Earth was round, contrary to the prior, popular belief. This idea was continuously thrown by the wayside until finally proven when Ferdinand Magellan (in 1519) circumnavigated the world (Nowell, 1962).

Advancement in science is generally controlled by grandiose ideas that change the way we think. Though some of these ideas inevitably fail, either due to lack of evidence or because of our nature to reject change, we must, at least, consider what new science is available. Although such notions may initially appear outlandish, they may dismiss our entire basis for present scientific thought. As we move into a time when scientific discoveries are becoming more important, we must learn to accept change and push through our natural reaction to new concepts. Specifically in the field of geosciences, we need to move away from conventional ideas, and become increasingly innovative like our scientific greats of the past. I believe this is the track the geological sciences will take for the future. The times of purely discussing ideas are over; for better or for worse we now have to react to them. If research can't be funded, we are now taking things into our own hands (this might mean paying for research out of our own pockets, or even organizing a group to speed up the process and exchange ideas).

The future of the geological sciences must, and will, focus on renewable energy and Earth's water resources. This will include creating safer and more environmentally friendly ways to do the same thing we did perhaps 20 years ago. This will also open up the less talked about sub-discipline of geosciences, medical geology. We are beginning to learn what is causing us to grow unhealthy and why. Just ask the rural peoples of India who suffer from disfiguring diseases and cancer because of high concentrations of Fluoride in their water (Pearce, 2006). With the increased interest in water science, planetary geology will also be of increased importance. We already found water in the poles of the moon. Can it be extracted? And if it can, will we be able to set up a lunar base there? Geoscientists now need to be educated in multiple sub-disciplines, as opposed to just one. In the past, being proficient in one subject was sufficient for a lifetime of research; today a second PHD might be necessary. In the case of geoscience education, additional classes will be taught on applied subjects. Theory is important only if it is balanced with applicability to the real world.

To understand our future, we must more accurately understand our past. Accurate dating techniques will be important to really know how fast extinction occurred or how fast sea level can rise. As a scientist, we will inevitably be given more responsibility to solve the Earth's problems. As a consequence, this will demand an incredibly detailed code of ethics and will change the way we document findings. It will be necessary to document every single aspect of research to prove a finding in order to keep politics and tradition from veiling the truth. Finally, we will learn to be humble with our findings. Arrogance has burned ideas in the past and will continue to do unless replaced with fact.

The Rise of Water and The Fall of Fossil Fuels

It is no secret that we are changing from a fossil fuel dependent world, to a planet that is thinking more and more about its future and sustainability – most importantly about its water. National Geographic released a special issue in April, 2010 entitled "Water: Our Thirsty World". The magazine features eight articles relating to the scarcity of fresh water and the challenges many face to simply find clean water. Though some water, in the form of vapor, does leave Earth, we generally have the same amount of water we did a million years ago. Unfortunately, much of this water is unsafe to drink or economically not recoverable. Geoscientists must develop affordable ways to process saline water, clean up polluted water, or drill for uncontaminated groundwater. Fortunately, groundwater extraction is already a common practice and is utilized heavily around the world. The downside of this technique is the decreased quantity and quality the deeper one drills. Can this water be artificially recharged back into Earth's soil in an economical way? Can we balance discharge from a producing well with imported water from desalination plants and not demand too much from each source? Can vast areas of polluted land be cleaned in a fair amount of time and in a cost efficient manner? Will this once polluted landscape now be able to sustain a population dependent on water again? These questions among others will be the topic of decades to come as our population booms and our clean water quantity busts.

Similarly, it is pertinent that our fossil fuel reliance be phased out, in terms of necessity for economy and life. During my senior year at The Pennsylvania State University, I completed an internship at the Department of Environmental Protection, taking water samples at various streams that are recovering from "yellow boy". As I toured coal mines and hiked past old high walls, I realized how much we once depended on coal, and more importantly, how little we have left. Popular coal-producing seams such as the Kittaning and Freeport throughout Pennsylvania are all but mined out other than thin seams or "stumps" from room and pillar mining in the 1800's. Though Pennsylvania still has about 76 billion tons of coal left, much of it is unrecoverable (Edmunds, 2002). The same fate now rests with oil. At some point oil will run out and by then we absolutely must have an alternative to it. Though we are making headway utilizing wind, solar, and hydro/geothermal power, these ideas need refined and set in motion. Fresh water retrieval and research into renewable energy will be at the forefront of future geosciences research.

Medical Geology; Prescribing Million Year Old Remedies

As mentioned earlier, water quality is a growing concern and will be for years to come. Though we are finding new ways to improve it, what effects does poor water quality have on the health of humans? The U.S. Environmental Protection Agency is at the forefront of understanding what certain natural elements and minerals can do to one's health. They currently research health effects on air pollution, certain heavy metals and pesticides, and alternative ways to live a pollution/chemical free life. Private environmental agencies and organizations will continue to increase in number as the environment's connection to health becomes more pronounced. Research from such organizations has already shown that volcanic ash, bentonite, is good for your intestines. Alkaline water is shown to be better for your body than neutral water. Also certain types of the mineral asbestos are extremely damaging to one's body. As we study more minerals and find out how they are formed, the same emphasis and excitement should be placed on researching how they can benefit or harm the human body. In the near future geoscientists will be working with hospitals and in clinical research arenas as medical geology becomes gradually more important.

The Search for Other Habitable Planets

At the time of writing this paper, the Kepler mission has discovered 15 confirmed planets (NASA, 2011). We know this number will continue to rise (though probably slowly as discoveries are confirmed and rejected). Missions such as this will continue to receive more funding and attention. In November of 2009, a similar story broke out into the news when NASA intentionally crashed the LCROSS (satellite) into the moon. Significant amounts of water were found exciting many people on the real possibility of creating a lunar base. Though some of these sounds more like science fiction than actual science, planetary geologists and other scientists alike must continue to explore and speculate on ideas of this nature. This forward thinking has reaped benefits in the past, and will do the same in the future. Geoscientists will soon be working with architects on where to place a base on the moon and what resources will be needed as well as where. Once on the moon or a foreign celestial body, geological resources will be necessary and planetary geologists will be the first on the call. In the meantime, planetary geologists will be sought after to help in determining the geological past of certain planets and if populating the moon or another planet is a possibility.

Cross Discipline Education

In the early 1900's, scientists were just beginning to learn that one subject would soon be insufficient in making new discoveries or developing a new theory. This was evident when Albert Einstein tried to develop his law of space-time warpage. Trying first to develop this theory, he simplified one equation after another until the theory was less applicable to the reason he was trying to formulate it (which was to explain the perihelion shift in Mercury's orbit). He needed four-dimensional geometry, a subject he knew little about. With the help of David Hilbert, a well known mathematician, he learned the necessary math skills the hard way and finally created an equation that worked in any situation (as well as explain Mercury's orbit) (Thorne, 1994). This is a basic lesson for aspiring geoscientists. Because the basic laws of chemistry, mathematics, physics, and geology have already been discovered, one will be hard-pressed to find a line of work in just one subject. We need to know a lot about a lot and little about nothing. To do meaningful research, knowing a multitude about a given subject will not only help in basic understanding, but it will also allow the pursuit of other areas of interest along the same path. Geoscientists will begin defining their specialty in their bachelor degree programs as opposed to waiting until graduate school

Applied Science for the Sake of Applied Science

Because of the urgency to solve Earth's environmental problems, more applied classes will be taught in high schools and universities. Though theory is, the emphasis should be placed on application. I have taken a few classes in my undergraduate curriculum that were based solely on theory. I do admit that I did not prefer applied sciences, rather theory, but these classes ignored all practical use. Such classes need to have an applicability side, as well as a counterpart lab activity. I was very fortunate to have the opportunity to go to Penn State University where a majority of the classes in the geosciences included theory, applicability, and labs together in one class. Other educational institutions don't have this. To spark curiosity in a student, we must show them what some theory actually means or how an equation can actually make something work. Time is precious and we must educate students more efficiently to keep their interest beyond the college years – to go out and discover, build, or invent something useful. Science, for the sake of science, has its place. However a much greater portion of education must be placed on applicability.

Accuracy, Precision, and Truth

Climate Change has been a popular topic for a number of years because of our excessive use of fossil fuels and the politics that surround it. Unfortunately, topics such as this get politicized on a number of fronts, thus turning people against them for the wrong reasons. It is for such that more accuracy and precision will benefit how we look at a new idea. Geoscientists need to continue to find more accurate ways to decipher dates as well as rates of change in the geologic past. As our precision improves, we can truly get to the bottom of ideas such as climate change and sea level rise, based on similar events in the past. This will not only improve our understanding of geologic events, but it will also help us solidify what could happen and how fast, in the future. Geochronologists will have a great amount of pressure on their shoulders because of debated topics such as climate change. The closer we get to dating past events or periods, the greater our understanding of biologic evolution will become. Was the Cambrian explosion really as quick as its name implies? As our future geoscientists discover more precise ways to date geologically significant fossils, periods, etc…, the public will inch closer to accepting these dates as truth. Once this does happen, politics can be dropped from scientific theories, and progress can be made.

Responsibility

Geoscientists will inevitably be faced with a much greater responsibility and pressure than they did in the past. This will include a responsibility to only publish facts, solve some of the world's greatest problems, and only spend money on research that is beneficial to mankind. Unfortunately in today's society, an idea will get scrutinized terribly even if it is merely an idea or piece of one's imagination. The public, casual scientific readers, and the media only want to hear theories that conform to their own beliefs, or ideas that "sound" reasonable. For this reason, the more we publish what is someone's imagination or idea, the less attractive it will be as a scientific article. Secondly, we will be faced with fixing all of Earth's environmental problems. From climate change, to the clean water crisis, these are topics that will be, and are, forced upon us (for the good). We will also be forced to fix them in an unreasonable amount of time, given the ways we collect data, process data, and wait for a hypothesis to be repeated several times. This aspect of responsibility will be the toughest, however with the many geological societies throughout the world, collaboration can make this work. Finally, we will have to be frugal with our funding and research spending. If something can be done near home without going to the beautiful island of Bora Bora, then so be it. Many scientific topics are becoming extremely important, and we need to be responsible with where we are putting the money.

Ethics, Documentation, and Overconfidence

We usually brush aside such boring topics as ethics and documentation. The first is a topic that many young geoscientists don't really care about, while the second is something that most scientists hate doing. Overconfidence is, however, something we all know about and something we are all guilty of doing. In every branch of science, whether it is chemistry, physics, or geology, we need to employ very precise ethical codes. I realize that many organizations or agencies already have these, but they need to be exact in terms of supporting evidence for a claim, or a basis for what is being hypothesized. Without going into specific examples, a number of "scientific" articles have been published that are completely false or made false to prove a point. Only sound scientific evidence should get out to the public, especially with a public that is so two-sided on many ideas. Ethics coincides with documentation. When we collect data in the field, we must document who, what, where, why, and when it happened. This not only will help out the researcher, but it will also provide sound evidence for data if questioned later. Geoscientists must learn to write everything down, even when it seems pointless.

Overconfidence is a grey area that needs to be addressed. In some cases overconfidence has kept ideas alive that end up being monumental. But for most of the cases, overconfidence blinds the possibility of another idea being correct as well. When we write an article, or develop an idea, we must learn to be critical of ourselves and tell the audience how confident we are in an idea. At the very least, add a sentence that reflects the validity of our research and other possible conclusions.

Conclusion

The future of geosciences will be radically different than it was 100, 50, or even 5 years ago. We are on the cusp of new discoveries, techniques, and ideas. Geoscientists are becoming well respected in the science and public communities as new challenges face us. The future of geosciences will involve research into renewable energy and the depleted water resources. The water crisis will also increase the need for medical geology research and will perhaps open up a new industry for this specific title. Geoscientists will be called to help find water on other planets or decipher the historical geology of a planet to see if it is habitable. These planetary geologists will also be used to set up lunar bases or develop local resources. Geoscientists will be educated in many disciplines to fully understand everything they are studying. As much as theory is important, classes in the geosciences will be aimed toward applicability and practical use. Dating techniques will improve so we can understand how fast one animal evolved, or how fast climate change can realistically take place. Geoscientists will be the experts and therefore must be more responsible with scientific evidence and the differences between truth and imagination. Finally, geosciences will depend on all encompassing ethical codes, meticulous documentation in the field, and a better way to present confidence of a given topic.

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