



Tracing Fluids in a Subduction Zone: 129I and Halogens in Geothermal Waters from New Zealand

Featured Researcher: Audrey Stewart

This Featured Researcher article focuses on Audrey Stewart, class of 2004, who did her research abroad in New Zealand. Portions of the article are abbreviated excerpts from her senior thesis, which is available in its entirety at <http://jur.rochester.edu>.

What is doing research abroad all about? Doing research abroad is about many different things. From a scientific perspective, doing research in multiple countries allows scientists, like the Professors that I have worked with, to investigate specific questions about the earth as they apply across the globe. When we take such a global view, we can correlate natural processes that happen in different places and gain a “big picture” perspective on how the natural world functions. From my perspective as a student, another important component of doing research abroad is becoming acutely familiar with a different culture and environment. I discovered how to effectively interact with a new culture and not only experienced but carefully studied, analyzed and drew conclusions from a new environment. And, of course, a nice perk of this type of research abroad includes the opportunity to travel for free, with the expenses paid for by a research grant.

How does your project relate to your major?

As an Environmental Science and History double major, the geology field work I did with the Earth and Environmental Sciences department evolved into a senior thesis project. Many environmental scientists are curious about the ways that humans impact the natural world, but we cannot fully understand how society affects the environment without first understanding how the earth functions on its own. My research project gives us more information about how elements cycle on the earth’s surface, which has multiple implications relating to my major and also to broader academic questions. For example, if we understand more about how elements cycle in nature on a global scale, which is an important part of the project I worked on, we can continue to document how human

actions alter those natural cycles and what the affects are. Take global warming and greenhouse gases as an example; they have attracted a lot of attention recently. Although the project I am working on does not measure greenhouse gases directly, many gases, such as methane, are emitted at our sampling sites. If we find out where the geologic material comes from at those sites, something my project investigates, we can potentially learn more about where the associated greenhouse gases come from, too. That information might eventually help geochemists to quantify the flux of gases emitted along subduction zones. This would help to further establish the relationships between natural and anthropogenic greenhouse gas emissions on a global scale, with implications for the future of earth’s climate and, as a result, social or economic policy. I don’t mean to be confusing – I’m not doing climate change research, myself – I’m just trying to show how a small project is connected to larger questions. Limiting ourselves to “majors” and “departments” allows us to specialize, but often causes us to forget how interconnected the different academic subject areas really are.

What or who inspired you to do this project?

My avid love of the outdoors was a major inspiration for doing research abroad. In hopes that I could both gain experience with geology and go on great hikes in beautiful remote areas of the world, I asked several professors in the Earth and Environmental Sciences Department if they needed field assistants for summer research trips. As luck would have it, some did! The field experience involved some serious back-country travel, which was great. Getting to the sampling sites gave me unique views and experiences of the country I never would have otherwise seen. (For example, I got to see mountain-top sheep fields and bubbling mud pits, and meet many sheep farmers.) I was also motivated by several of the professors in the department who have fabulous stories and pictures from their own field-work experiences. My thesis advisor, Professor Udo Fehn, especially encouraged me to become more involved in the research project as a good way to gain

first-hand knowledge of the scientific process. In that way, what started as exciting fieldwork evolved into a senior thesis project.

How can students do research abroad?

Become geology majors! Really. In the past year or two, geology undergraduates at UR have done research in Ireland, Bolivia, New Zealand, the Arctic, and on an ocean-bound cruise ship, and there is a possible trip to Japan coming up. In my case, I traveled to New Zealand for two weeks to collect samples as part of Professor Fehn's multi-year project studying subduction zones in New Zealand and Japan. The research expenses were covered by the Professor's research grant, funded by the National Science Foundation. But, if geology doesn't excite you, fear not; this approach isn't the only way to travel abroad, and it is not always free for undergraduates. Students interested in doing research abroad should realize that there are many available options and that, depending on your academic interests, students can research abroad through various institutions. For example, SIT (the School for International Training) offers field-based study abroad programs during the school year and summer, with emphasis on field research and independent study projects. If you are a student interested in doing research abroad, good first steps include talking to professors in the appropriate departments and counselors in the study abroad office. Our professors are doing some incredibly interesting things, and just might have grant money available for undergraduate research assistants. If not, they can at least point you in the right direction, and the study abroad office can help you identify programs that are already organized to allow students to do research abroad. It is a very rewarding experience, and I encourage anyone who is interested to investigate the opportunities right away!

Research Overview

My research project documents halogen concentrations and iodine isotope ratios from geothermal fluid samples along the forearc region of New Zealand's North Island in order to determine the origins of those fluids. The forearc is the region of a subduction zone between an active volcanic arc and the trench, where one tectonic plate is sinking under another. Determining the origins of geothermal fluids helps to increase scientific understanding of element transport between oceans, the crust and the upper mantle. Previous investigations of subduction zones indicate that some subducted crustal material returns to the surface through fluids in the main volcanic arc (i.e. volcanoes). A limited number of samples from previous studies suggest that fluids along the forearc contain material from the continental marine rocks of the overlying slab, rather than remobilized material from the subducting slab. By providing a more extensive investigation of the East Coast, my project shows that fluids here are most likely derived from old marine sediments in the continental crust, that are released due to folding and faulting of the continental crust along the subduction zone.



Figures 1 and 2: Sample collection locations.

Field Methods

We collected 18 1-L fluid samples, and gas samples where possible, from seeps and springs along the East Coast of New Zealand's North Island over a two-week period in July 2003. The chloride concentrations in the fluids were measured with ion chromatography and the bromine and iodine concentrations in the fluids were measured using Inductively Coupled Plasma Mass Spectrometry at the University of Rochester. We extracted the iodine from portions of our samples, using methods established by Professor Fehn. Iodine extractions were then sent to the PRIME Lab at Purdue University, where iodine isotope ratios were determined using a method known as Accelerated Mass Spectrometry. Gas samples were not analyzed as part of this study but will be incorporated in future studies by the lab group.

Discussion and Conclusion

The halogen concentrations and iodine ratios determined for the East Coast support studies by Fehn and Snyder (2003) and show that iodine in the forearc originates from a different source than iodine in the

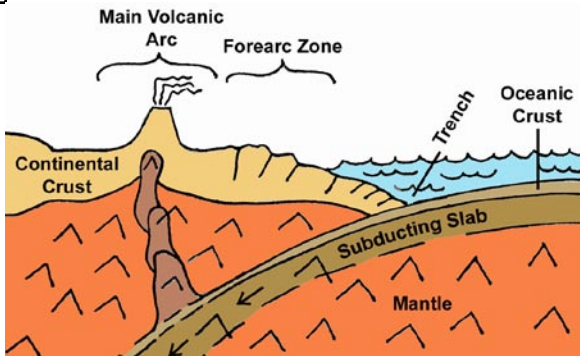


Figure 3: Cross section of a subduction zone.

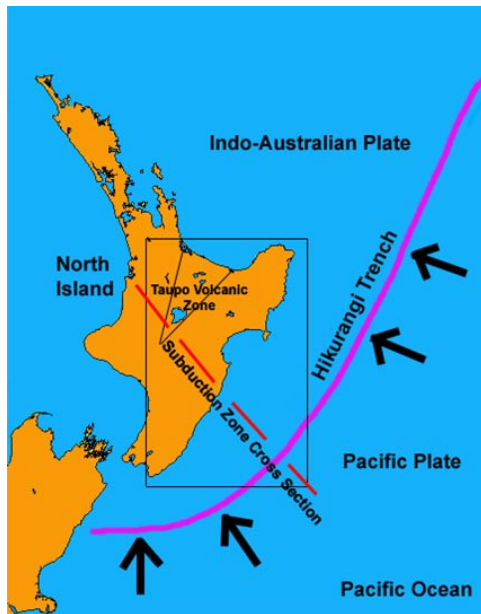


Figure 4: Tectonic sectioning of North Island.

main arc. Calculations from the end-member ratio of the iodine isotope indicate that the minimum age of the fluid is 60 million years, corresponding with earlier age determinations of 70 million years based on a limited number of samples. Both of these clearly differ from ages for the subducting slab, which exceed 110 million years. Iodine concentrations are heavily enriched on the East Coast, close to 100mM (one to two orders of magnitude higher than concentrations in the main volcanic zone), and oil, other liquid hydrocarbons and gas are observed to be closely associated with most seeps. These findings suggest that the likely source of fluids is organic-rich Tertiary and Cretaceous sedimentary marine formations present in the continental crust along the forearc zone. The age calculation is a minimum, and while it does not conclusively rule out the potential for remobilized

elements from the subducting slab, other evidence points to a continental source. This strengthens the findings of Fehn and Snyder (2003). The three sample sites that indicate most similar iodine and halogen behavior are Waipuka, Pouhokia 1, and Waihireri. While Waipuka and Pouhokia are relatively close in geographic location, Waihireri is over 100 km to the north. Roto-o-tahi and Whangara both exhibit potential mixing with older groundwater; given their proximity to the coast the fluids at those seeps may also experience mixing with seawater. It is interesting to note that no trends regarding sample location or type are immediately evident; for example, proximity to coast, hot vs. cold seeps, mud lake vs. individual cones. The lack of distinct trends along the coast indicates that processes leading to the release of geothermal fluids are relatively constant across the length of the forearc.

Numerous factors indicate that geothermal fluids in the forearc zone are derived from continental organic material. The presence of gas and liquid hydrocarbons, the high concentrations of iodine, and the iodine age signal all point towards a continental source.

These findings have several applications. First, the research confirms that remobilized iodine from the subducting slab is present in the main volcanic zone but not in the forearc. This suggests that all iodine recycling from the subducted slab happens at the main volcanic zone, which is useful when calculating certain element budgets in the crust and upper mantle.

In addition, knowing that fluids in the forearc zone have a continental source helps us to understand geologic processes associated with subduction in the forearc zone. Particularly, it suggests that the release of geothermal fluids in a forearc leads to recycling of elements from continental sedimentary rocks of older, marine origin.

The study in this paper is just one component of a larger project, and investigations of several areas which deserve further research are already underway. Analysis of gas samples from New Zealand's forearc are

currently being carried out by Robert Poreda at the University of Rochester Rare Gas Facility. More research of halogens, iodine and gases from other forearc regions, such as the study of Japan planned by Professor Udo Fehn at the University of Rochester, will help to determine whether the processes detected at New Zealand are typical of all subduction zones or unique to New Zealand.

New Zealand: A Microcosm for Studying Subduction Processes

New Zealand is located along the Hikurangi Trench, the plate boundary at which the Pacific Plate is subducting under the Indo-Australian Plate. The island's geology is directly affected by the subduction process occurring at the trench. The North Island spans multiple geologic regions over a relatively short distance and is the first location where iodine and halogens have been measured in both a volcanic arc and its forearc. The main volcanic arc, called Taupo Volcanic Zone, is located ~280 km west of trench. Geothermal power plants operate in this region. The region has been studied extensively in previous works. The forearc region along the East Coast is unusually broad and contains a thick accretionary wedge. Geology primarily composed of marine sedimentary rocks of Tertiary age (1.6-65 million years) overlying Cretaceous basement layer (65-144 million years). Accessible seeps and springs along the forearc are ideal for sampling; previous iodine work there is limited to several sampling sites. At trench, the subducting slab is approximately 98 million years old, subducting rate is 3-6 centimeters per year.