Understanding the processes of the multiple subduction plate boundary around Japan

Dr Hitomi Nakamura
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Dr Hitomi Nakamura uses knowledge from studying slab fluids in magma formation and applies it to study spring waters formed from a similar process. In this interview, she discusses what is special about the Japanese plate system and why such fluids are important.

Let’s start at the beginning so that everyone can understand about more about what you do. What’s your research background? And how did you get into your chosen field?

I am a volcanologist/petrologist/geochemist. My PhD thesis concerns Quaternary magmatism in Central Japan where the multiple plates meet and interact, which led me to realize the importance of fluid, particularly salty aqueous fluid derived from the subducting plates, to magma genesis. My research activity includes field works, rock/water sampling, laboratory works (e.g., chemical and isotope analyses utilizing ‘clean room’ and mass spectrometer), and data analysis using computers. Now I am involved in a project on magmatism in Kamchatka, where again fluids play an important role, collaborating with Dr Tatiana Churikova in fvs FEB RAE. Based on these studies and my background, I have also started to study a new target ‘spring water’. Many spring waters are upwelling in Japan, some of which seem to have the same origin with the deep-seated fluid triggering magma generation.

Many people are familiar with tectonic plates, but what is special about the subducting plates found on the islands of Japan?

A lot of your focus is centred around ‘slab fluids’. What are slab fluids, and what important role do they play at plate boundaries?

The reason why we have plate boundaries and subduction is probably due to liquid water on this planet, which weakens the rock strength. Therefore, how water interacts with rocks in subduction zones is related to the uniqueness of this planet. Another unique feature of Earth is the presence of the continents, which is thought to be produced also via water-rock interactions. Slab fluid is such water derived from subducting slabs. Slab fluids are not pure water, but a brine containing abundant metals, as a result of water-slab material interactions at high pressure and temperature. In many arcs, slab fluids are upwelling beneath volcanic regions and produce magmas and possibly one deposits, in which they can be trapped as ‘fluid inclusions’. Recent studies suggest that slab fluids are also upwelling in non-volcanic regions, especially through faults in the fore-arc region.

What makes the Japanese subduction zone so special is the fact that the oceanic plate is the largest on Earth, giving the greatest subduction power in the world.

CAPTURING THE SLAB-DERIVED FLUIDS IN SPRING WATER

Slab fluids are impure water solutions found at subduction zones at plate boundaries. They have generally been derived to produce magma formation. Dr Nakamura and her colleagues have used their knowledge and applied it to similar principles that occur for the heating of spring water in Japan.

Tectonic Tales

As many people are aware, unlike other planetary bodies in our solar system, the Earth is made up of multitude of massive rock slabs which move over each other known as Tectonic plates. Tectonic plates interact with each other at plate boundaries and most commonly occur in two ways. The first, where the plate is constructive and the plates move away from each other. And second, where the plates move toward each other where one plate becomes submerged under the other. This article is concerned with the latter upon which they occur between an oceanic plate and a continental plate boundary where it concerned with making geological structure such as mountain building (like Himalaya). Analysis of the Japanese islands, the tectonic activity is constrained with subduction plate boundaries. So what is next for your research?

Since I have just started to study spring waters, there are many things to do at the moment. In particular, I will continue to search for deep-seated brines that correspond to slab fluids along the entire Japanese islands, first mapping their distribution. The detailed compositions of the brines will tell us both their origin (from which we may infer the physical-chemical condition of the subducted plates) and ascent processes (from which tectonic stress applied from the four colliding plates along the Japanese islands).
Slab fluids? Hot Springs? What’s occurring under the surface?

As we are concerning ourselves with not only the geological environment but also the slab fluids that these environments produce, you may be wondering what slab fluids are and why they are relevant.

To put it simply, a slab fluid is water that is derived from a subducting plate. Slab fluids are the water that get submersed with the plate during the submersion process (there is always so water lubrication present). However, it is unlike the water that we are accustomed to in everyday living, but an impure water form with a high salinity and many earth elements (REEs) concentration—essentially if you mixed ‘hard water’ with salt water, it would loosely represent the composition of slab fluids. The reason for the impure fluid is due to the intense heat and pressure it is subjected to during the submersion. Slab fluids then travel upwards, generally through aquifer rocks and can produce magmas or ores.

When slab fluids ascend from the plate beneath the non-volcanic region, upwelling velocity and total time to reach the surface seem to be fast and short where they have no interaction with magmas on the way. This can be observed as it is observed by a special type of earthquake, called ‘non-volcanic tremor’. Such deep-seated tremors could have ascended to a rather shallow depth without being significantly modified until it meets the aquifer water/meteoric water. On the other hand, the meteoric water in the aquifer receives gas components (e.g., CO2 and helium) degassed from the cooled brine. This combination of liquids is what forms the spring waters in regions and faults between the rocks cause the springs to physically form by upwelling from the aquifers.

There is a higher spring water abundance around Japan because there are two oceanic plates being subducted, causing the amount of slab fluid at the boundary to be doubled, resulting in a larger quantity of spring water produced. The Arima Springs is one such area of spring water accumulation where this is physically shown.

How to determine the composition of slab fluids to give an accurate representation?

Because Slab fluids have a high amount of rare earth elements (REEs) it means that the ions in solution behave uniquely and coherently and are sensitive to changes in temperature, pH, ionic (oxygen) environment and TCO2 (CO2 environment). This sensitivity can provide key information on the process at shallow levels where these variables may significantly change. In spite of such usefulness of REEs, the analysis of spring waters is not trivial. Partly due to the variations and due to mixing of meteoric waters, the concentrations of REEs in the spring waters are variable, being very low (a ppb level) on average, which requires an analytical method with a very high sensitivity and a wide dynamic range, such as Inductively Coupled Plasma—Mass Spectrometry (ICP-MS). High salinity and other dissolved metals and elements interfere the REE analysis (even more so with a high-sensitivity method like ICP-MS), but procedures have been developed by the group to cope with the difficulties so that cataloguing of compositions is possible.