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Long-term Research Visit (Project No.: 30L-04)

Project title: Scenarios of future volcanic activities based on electromagnetic and other geophysical phenomena. A way to mitigate volcanic disasters.

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DPRI collaborative researcher: Pr Naoto Oshiman Name of visitor
(Affiliation): Jacques Zlotnicki
Period of stay: October 9, 2018 ~ December 2, 2018
Location of stay: Kyoto University, Uji Campus - Disaster Prevention Research Institute (DPRI)
3 days visit at Earthquake Prediction Research Centre (EPRC) at Tokai University 6 days visit of Earthquake Research Institute at Tokyo University

Number of participants in the collaborative research:(provide numbers for DPRI and non-DPRI staff) DPRI: 1
EPRC-Shimizu University: 2 plus one external expert ERI-
Tokyo University: 2 plus one Post-Doc Hokkaido
University: 1

Anticipated impact for research and education

Two targets are simultaneously pursued.
- One is to deliver a "review" article in which electromagnetic methods applied to volcanoes monitoring are analyzed. It will give useful background and guideline for electromagnetic studies on volcanoes.
- Miyake-jima erupted in 2000. At least 1.5 month before, electric signals appeared on both Miyake-jima and on Niijima Islands, although there was not yet any seismicity. The impact of this study is to prove that electric signals may be considered as forerunner indicators of a large eruptive event and maybe of tectonic earthquakes. It could serve as an early warning in the risks mitigation.

Research report

(1) Purpose

The objective is to clarify how electromagnetic (EM) phenomena together with other geophysical observations appear prior a volcanic eruption for evaluating scenarios of future activity (ies). Based on 40 years of Japanese and French experience, we tentatively integrate observations on volcanoes for the last 50 years and more (e.g. Oshima-1968, Soufrière of Guadeloupe-1956).

We also target to analyze electrical signals which have appeared 1.5 month before the July 8, 2000 Miyakejima eruption. This will have a great impact because it means that electrical signals may appear before a volcanic or tectonic seismicity and prior to large dyke propagation. It also could have an impact on the research on electric signals prior to large earthquakes and during seismic swarms, because large tectonic seismicity has developed between Miyakejima and Niijima (~40 km to the NE) Islands during several months.

Results could deserve (1) new methodologies for monitoring volcanoes based on EM techniques, (2) prospective in forerunner electric signals prior to large earthquakes and (3) contribution to a better analysis on on-going volcanic activity and possible eruptive scenarios. Results will contribute to the mitigation of casualties and economical breakdowns.

(2) Summary of research progress

- First, during my stay at Kyoto University-DPRI I was invited to go to Awaji Island where the trace of fault induced by the January 17, 1995 Kobe earthquake (M:7.2) still exists. DPRI has drilled Nojima fault and installed there three boreholes, one being 1800 m deep. Water was periodically injected in the deepest borehole and several devices recorded the electric field both at the ground surface and inside two other boreholes of about 800 m depth. The objective is to study the permeability of the faults system and the recovery period. Signals up several tens of mV were recorded

in relation with the cycles of water injection. This experiment is important because it gives information about the rock permeability and the evolution in time of different parameters (compaction, sealing, weathering...). New experiment will be conducted in mid-December 2018.

- Second, I made a seminar at Uji campus on the 14 years of studies done on Taal volcano in the Philippines. Taal is a very dangerous and explosive volcano. None of the 33 historical eruptions was forecast in time to duly evacuated inhabitants. Our latest studies show that a new large activity could occur and involve the outer northern flank of the volcano at the opposite to common eruptive events starting from the crater. Therefore, a new scenario must be considered as well as the consequences on the evacuation planning and on the economy of the district.
- Third, I collected materials mainly related to electromagnetic studies done on Japanese volcanoes. They are part of the paper in course which title could be 'Review and prospective of electromagnetic methods applied to volcano monitoring'. In this research, DPRI helped me because Kyoto University is in charge to monitor several volcanoes. I was also in contact with Hokkaido, Tokai, and Tokyo universities from where several colleagues sent me articles which will strengthen the paper in course.

During my two months visit at Kyoto University and as proposed in the application, I was able to visit the Earthquake Prediction Research Centre at Shizuoka (Pr Toshiyasu Nagao) during 3 days, and the Earthquake Research Institute at the University of Tokyo (Prs Ueshima and Kanda) for a period of 6 days.

- At EPRC, we mainly focused the work on the progressive appearance of electric signals that EPRC evidenced at the northern tip of Niijima Island in early May 2000, although seismicity was null. On June 26, the seismicity sharply raised below Miyake-jima volcano located about 40 km to the Southeast and quickly migrated toward Niijima Island. From my side, I started to record electromagnetic data on Miyakejima volcano in 1996 in the frame of a Scientific International Program of Cooperation (PICS) led by A. Pr. Yoichi Sasai from ERI. Our own data set show similar observations to those obtained by EPRC. Therefore electrical signals at several independent stations located up to 40 km away have shown a similar behavior 1.5 month before Miyakejima eruption and migration of magma at about 10 km depth from Miyakejima to Niijima Island. Thanks to this short term visit, we emphasized the preliminary research and I could collect most of the data recorded in different places before and during Miyakejima eruption.
- At ERI, the visit covered up two items. One was to give a seminar on Electromagnetic phenomena related to active volcanoes. It was the opportunity for several students to compare with their observations and raise questions. The other subjects were related to (1) the magnetotelluric (MT) tomography of Miyakejima made in 2010 and (2) the static self-potential anomalies observed before and after the 2000 eruption

(3) Summary of research findings

- Review and prospective of electromagnetic methods applied to volcano monitoring

Monitoring active volcanoes by electromagnetic methods depends on the position of the volcano on the Earth (e.g. subduction zone, rift zone), the historical setting, the local geological context as well as the encountered heterogeneities (e.g. crater rim, fault, thermal springs and thermal areas), the metrological environment (e.g. inputs by external waters), and the mean time delay between eruptive events.

In this research, we will consider different mechanisms which participate to the enhancement to electromagnetic signals (e.g. thermomagnetic, piezomagnetic, electrokinetic effects). These signals are strictly dependant on the issues raised above, and their characteristics (time duration, location, amplitude) should be evaluated.

- Forerunner electric signals

On volcanoes, it has already been shown that electric signals may precede or accompany large changes in the activity (Taal, Miyake-jima, La Fournaise volcano). It is probably the first time that electric signals may appear at remote sites long time before an eruptive event and the propagation of a dyke at depth. More detail analysis will probably clarify if the signal emanates from the starting location of the dyke and what could be the displacement rate of this electric signal?

- Self potential anomalies on Miyakejima over 20 years

An hydrothermal system was located below the volcano summit before the 2000 eruption, and we were able to recognize the common pattern of SP anomaly crossing an active volcano, the well-known W shape. Although a caldera

of more than 1 km in diameter was formed during the eruptive phase, the W shape mainly subsisted even the amplitude was reduced. This would mean that the root of the hydrothermal activity has remained and is progressively recharged. This case study is of great interest when we monitor volcanoes over several tens of years.

(4) Publication of research findings

- The article on the 'Review and prospective of electromagnetic methods applied to volcano monitoring' is in course. It requires to analyze many papers and find out the most effective results. This long term study will take several months before to reach a final version.
- The analysis of electric records available on Izu Islands will take time. On each site, several stations have recorded data in different digital formats and several channels need to be analyze at each station. The objective is to process data over one year. Therefore, although we know that these signals have appeared before Miyakejima eruption, it still remain a huge work for processing and analyzing together all the data. A paper might be planned for the end of 2019.