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Geochemical Advances: Following Prof. Sakai
Preface

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Professor Hitoshi Sakai was a pioneer in stable isotope geochemistry and one of a small group in the world who transformed stable isotope research into a major discipline in the earth sciences. His contributions are enormous and he left a permanent mark, both on the theoretical and analytical sides of stable isotope geochemistry. He published a seminal work in the *Geochemical Journal* in 1968, which theoretically predicted a large isotope fractionation among sulfur species in hydrothermal systems. The idea was intuitive but later confirmed by numerous laboratory studies. This work was very important in the development of stable isotope geochemistry and influenced later studies because his paper illustrated parameters other than temperature, such as the pH and Eh of the hydrothermal solution, that affect sulfur isotope ratios of minerals in nature. This realization opened up a new field of research, sulfur isotope systematics.

Prof. Sakai made significant contributions in many fields across the earth sciences, including economic geology, volcanology, and ocean geochemistry. Among them, his work advanced our understanding of extinct and active hydrothermal systems on land as well on and near the sea floor, including ancient metalliferous hydrothermal activity related to Kuroko-type lead-zinc deposits. Later, he extended his work to laboratory experiments for water-rock interactions. He was among the few analytical chemists who could conduct successful field sampling and discuss his interpretations with geoscientists. He took geological information into consideration during the interpretation of analytical data. Therefore, his conclusions were scientifically sound and readily accepted by geoscientists.

Prof. Sakai completed his PhD thesis in Chemistry at the University of Tokyo in 1958. Shortly after receiving the PhD degree, he went to MacMaster University in Canada to work in H. Thode's laboratory as a postdoctoral research fellow from 1958 to 1960, and then at Yale University from 1960 to 1961. Although stable isotope geochemistry was still in its infancy as a discipline,

it was an exciting period in the history of stable isotope geochemistry. People started to document significant variations in isotope compositions in nature and evaluate the causes for them. Two laboratories at MacMaster University and the University of Chicago were the centers of stable isotope research in the world. At MacMaster, the laboratory led by H. Thode focused on sulfur and carbon isotopes. It attracted many young researchers, including C. E. Rees, H. Roy Krouse and Henry P. Schwarcz. Prof. Sakai became a member of this newly established stable isotope research group, and it was here that he acquired the technical and theoretical knowledge of stable isotope geochemistry.

On his return to Japan in 1962 he was appointed as a faculty member at the Institute for Thermal Spring Research (the former name of the present Institute for Study of the Earth's Interior) of Okayama University, Misasa, and promoted to a Full Professor in 1968. The Institute in Misasa, in a remote area in Japan, did not have sophisticated instruments in 1960s. As a young faculty member in such an environment, it was not an option for him to purchase a commercially available mass spectrometer. He

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Prof. Sakai on board of Research Vessel Hakuho-Maru during the survey of submarine hydrothermal acitivity on the Manus Basin. A photo taken on November 28, 1990, by Toshitaka Gamo of the Ocean Research Institute of the University of Tokyo.

decided to build a mass spectrometer by himself; fortunately, he had the technical skills required to accomplish this extraordinary task. This became the instrument that produced most of the data for his papers published in the 1960s. This anecdote illustrates not only his passion for science but also his strong determination.

He moved to the Ocean Research Institute of the University of Tokyo as Professor in 1983, and on reaching 60, the retirement age of this university, he joined Yamagata University as Professor in 1991, and retired again in 1996. After his move to Tokyo, he set up a new laboratory in the Ocean Research Institute and initiated research on active submarine hydrothermal systems with the same vigour and enthusiasm as he started the laboratory in Misasa. Prof. Sakai boarded many research cruises to examine sea-floor hydrothermal systems near Loihi, Bismark Sea, Manus Basin, and the Okinawa Trough. He also opened the door to a new research field of cold water-rock interaction system along subduction zones. His work included the seepage of gases and water in Nankai Trough and Sagami Trough near Japan. In the gas-rich hydrothermal field in the Okinawa Trough, video images from the submersible showed irregularly-shaped translucent vertical tubes about 10 cm long on the sea floor. Upon looking at the video, he immediately recognized what the tubes consist of and what was happening there. In 1990 he published in the journal Science his discovery of carbon dioxide gas-hydrate formation on the sea floor at a depth of 1330–1550 m. This story highlights his sharp eye to detect unusual phenomena, backed by his broad scientific knowledge and imaginative, flexible mind.

Prof. Sakai produced the next generation of isotope geochemists in Japan. When we were students in the 1970s, Okayama University did not have the privilege to grant a PhD degree. Prof. Sakai, however, gladly accepted us and several others from various universities to conduct our research projects under his supervision. Prof. Sakai truly loved his work. When we first met him, his passion and enthusiasm for research was so apparent that we were immediately convinced where we should conduct our PhD projects. His laboratory was quite different from most others. The first task after arriving in the institute was to design and build our own extraction lines for isotope analysis, starting with a bare stainless steel frame. We all learned how to make furnaces from nickel-chromium wire and clay, how to conduct glass-blowing work to make vacuum lines, and how to test for leaks of gas and electricity. It was not necessarily very cost- and time-effective, but we learned each step from scratch; it is unthinkable now, as we purchase most of our analytical equipment and follow the operation instructions given from commercial companies. It was probably Prof. Sakai's strong belief that students learn through their own trials and errors, although we have lost the opportunity to ask him the answer.

When we were at the institute, we had daily tea breaks. Visitors were not common, but they joined the breaks for discussion. We shared analytical data, plotted rough diagrams on a black board, or showed diagrams of manuscripts that people were working on. Our interpretations often received numerous questions and comments. These occasions taught us how to present and discuss analytical results and write scientific papers. The institute was isolated from urban centers, and everybody lived within a five minute walk from the institute. We worked in the laboratory until late at night most every day, and it was the most productive and fruitful learning period in our lives.

Prof. Sakai was elected as an Honorary Fellow of the Geological Society of America in 1981 for his valuable scientific contributions to earth science. In 1999, he received the Shibata Award of the Geochemical Society of Japan, for his outstanding achievements in geochemistry. Among his many activities in the international scientific community, he served as the president of the International Association of Geochemistry and Cosmochemistry during the period of 1992 to 1996. The 4th International Symposium on Water-Rock Interaction, which Prof. Sakai hosted at Misasa in 1983, is a meeting that every attendee still talks about, with many memorable experiences there.

Prof. Sakai loved traveling throughout the world, from Iceland to the Sinai Peninsula, and New Zealand to Hawaii, for sampling, conference-related field trips, and discussions with people. In the last few years of his life, he was interested in the chemical environment on Mars, related to the possible existence of water and life on other planets. We imagine that he might now be planning his next trip, to Mars to find lines of evidence for his hypotheses.