SEG 100 Conference: Celebrating a Century of Discovery

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Game Changers in the Exploration of Submarine Hydrothermal Systems

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The discovery of black smokers, and especially their link to chemosynthetic life, was one of the most compelling scientific advances of the last century. Its impact on the model of volcanogenic massive sulfide (VMS) deposits is expressed in a quote from the 100th Anniversary Volume: “... the extraordinary intensity of marine research that followed the discovery of [black smokers] rapidly built our understanding of seafloor mineralization to such an extent that ore deposition in the submarine environment is now arguably one of the most clearly understood of all mineralizing systems ...” (Skinner, 2005). The origins of VMS deposits at seafloor hydrothermal vents and the connection to plate tectonic theory were already established concepts decades before the first images of black smokers appeared. In the early 1900s, research centered around the link to submarine volcanism − a relationship that is obvious today, but its acceptance was hard won at the time. The current model for VMS deposits was introduced in the 1950s, and unequivocal evidence of metal deposition directly associated with seafloor volcanism was uncovered at mid-ocean ridges in the 1960s. When black smokers were eventually found, critical aspects of the model were validated by sampling of actively venting hydrothermal solutions, including the details of water-rock reactions and the behaviour of different end-member fluids. However, the sheer numbers of black smokers and the scale of the global metal flux were unexpected. In a blur of discovery beginning in the late 1970s, more than 700 sites of submarine hydrothermal activity were located throughout the world's oceans, and new sites are still being found every year. The rush to explore the deep sea provided unparalleled opportunity to observe processes that could only have been supposed from the study of fossil deposits and many that would never have been predicted from our early understanding of black smokers.

Among the “game changers” in the exploration of submarine hydrothermal systems was the new partnership between ore deposit geologists and marine scientists who were already investigating the biology, chemistry, and physical oceanography of deep-sea vents. The powerful interdisciplinary research that followed had a direct impact on the changing VMS model, in particular aspects related to marine geodesy and geodynamics, oceanic heat flow, the diversity of submarine magmatic-hydrothermal systems, especially in subduction zones, the dynamics of melt and fluid flow in submarine volcanoes, the associated volcanic geochemistry, and the role of macro- and microfauna at hydrothermal vents, including the limits to life in ore-forming systems. These advances were all made possible by increasingly sophisticated technology for ocean exploration, such as satellite altimetry and navigation, marine gravity and magnetics, high-resolution seismic reflection and refraction, deep-sea drilling, underwater robotics, and autonomous vehicles. These tools enabled unprecedented documentation of submarine hydrothermal activity in the most remote regions of the oceans, revealing the complex geological make-up of different settings for mineralization and building the foundation for new concepts in marine metallogeny.