

**THE ROLE OF MARINE SCIENTIFIC RESEARCH IN THE IDENTIFICATION  
OF SEAFLOOR MASSIVE SULFIDE DEPOSITS**

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Seafloor massive sulfide deposits (SMS) precipitate where hot metalliferous fluids associated with submarine volcanic activity vent at the seafloor and mix with cold seawater. They occur mostly within two contrasted tectonic settings, (1) mid-ocean spreading axes and nearby seamounts at divergent plate margins or mid-ocean “seafloor spreading zones” situated mainly in “The Area” overseen by the International Seabed Authority (ISA) and (2) submarine volcanic arcs and backarc basins associated with convergent plate margins or “subduction zones”, mainly within the exclusive economic zones (EEZ) and territorial waters of independent Nations as established by the United Nations Convention on the Law of the Sea (UNCLOS). The typical manifestations are spire or pipe-like “chimneys” rising from the seabed, mounds of collapsed chimneys, and sub-seafloor mineralisation only revealed by drilling.

The SMS depositional process is inefficient, and at actively-forming sites plumes of buoyant fluid laden with mineral particles (“smoke”) rise into the seawater column, providing enlarged targets for detection with instruments measuring seawater turbidity. Since they are no longer associated with unique chemosynthetic faunas, sites that have ceased activity and possibly become covered by pelagic sediments are more highly desirable from the environmental viewpoint, but technologies to find them are in their infancy. As a consequence of contrasted magmatic and tectonic affinities, SMS deposits associated with subduction zones tend to be richer, especially in copper and gold, than those in mid-ocean spreading zones, although there is a less common category of the latter, where the substrate is faulted lower crustal ultramafic rocks rather than recently erupted basaltic lavas, that are also rich in copper and gold.

Over 100 SMS occurrences and around 200 other hydrothermal vent sites (submarine hot-springs) have been found in the world’s oceans since the original 1978-79 chimney discoveries in the Galapagos Rift and the East Pacific Rise spreading zones. Until recently, all have been an outcome of Marine Scientific Research (MSR), mostly via academic programs directed at fundamental scientific understandings of geological and

biological processes but in some cases within well-funded governmental programs combining research with systematic exploration for strategic mineral resources. Passage in 2010 of the ISA “*Regulations on prospecting and exploration for polymetallic sulphides in the Area*” will encourage further activity of the latter kind, but it is questionable whether private enterprise companies requiring security of tenure from the onset of operations will be attracted away from National waters where mining laws are the same as operate on land (and indeed where the tenor of valuable metals in SMS deposits tends to be higher).

Low-cost expeditions with small vessels and cheap detection and sampling equipment are quite appropriate to first-pass exploration of relatively protected waters up to 2000m deep in National EEZs and territorial waters. For deeper mid-ocean surveys in The Area larger vessels capable of deploying TV-guided grabs, manned submersibles, remotely operated vehicles (ROVs), and autonomous underwater vehicles (AUVs) are the norm, and of course this higher technology is also suitable for more advanced commercial exploration of EEZ and territorial waters. Major advances in high resolution mapping and imaging of seabed topography, and in accurate positioning of deeply submerged ROVs and AUVs and towed equipment have greatly facilitated systematic sea floor exploration.

MSR indicates that individual SMS deposits are typically small. Clusters in close proximity may in some regions yield aggregated resources sufficient to warrant commercial mining, or geological factors may increase the likelihood of substantial sub-seafloor mineral deposition that expands the resource to one with economic potential. Commercial exploration *ab initio* for SMS deposits is a high-risk venture, and indeed high-cost even disregarding ISA requirements in The Area (or within the waters of any nation inclined to adapt equivalent regulations) for environmental baseline and other work to be conducted at each prospective site *before* it is established whether or not it belongs to the 99% or so of exploration “failures” typical of the minerals industry. Neither private enterprise companies, nor one imagines any financially-constrained government authority, would invite near-certain bankruptcy under such conditions.

Past SMS discoveries have arisen as by-products of some basic scientific interest in geoscience or biology. As the sciences advance there may be less emphasis on finding new “natural laboratories” and more on increasingly sophisticated studies of well-known, well characterised sites. Fewer mechanisms now exist for funding multidisciplinary MSR expeditions of an exploratory nature. Hence, there should be no anticipation of an ever-expanding inventory of new SMS sites in the oceans unless commercial enterprises and government agencies are better encouraged to assume the exploration mantle.

Consider the successful CSIRO-led MSR and resultant industry activity in the territorial Bismarck Sea of Papua New Guinea. Negotiations (commenced in 1980, just after the first “black smoker” discoveries at the East Pacific Rise) between CSIRO (a wide-ranging Australian Government research authority) and the PNG Government’s Geological Survey established the basis for collaboration that led to a 1986-2002 cruise program in PNG territorial waters also involving academics and institutes from many countries. The program was directed at finding and investigating an actively-forming

modern analogue of ancient “massive sulfide” ore bodies exploited on land for many centuries, in a continental margin submarine volcanic setting more relevant to these latter than mid-ocean spreading ridges, as a “natural laboratory” for developing improved exploration strategies and techniques applicable to ancient geological sequences on land.. Naturally the PNG authorities saw potential benefits also in terms of future mineral resources in their waters. Industry sponsors of the CSIRO research were more concerned with application of newly-gained understandings to land-based mineral exploration strategies than with potential mining on the ocean floor.

In 1991 the first discovery of actively forming SMS chimneys was made in the eastern Manus Basin of the Bismarck Sea, and this was extensively surveyed and sampled in 1993, after which on-shore research revealed exceptionally high contents of copper, zinc, gold and silver relative to previously known SMS occurrences. Widespread media publicity followed, and unbeknown to the researchers a group of investors formed a company (now Nautilus Minerals Inc, subject of the accompanying presentation by Mr M Johnston) which applied to the PNG Government for exploration tenements covering this and a subsequent, even richer discovery publicised by CSIRO in 1996. Following legal acceptance that the PNG Mining Act applied to its territorial waters, licenses were issued in 1997 prior to which Nautilus advised CSIRO of its actions and a collaboration agreement was negotiated. A critical aspect of this was that CSIRO’s first responsibility, in the event of any further discovery, was to confidentially advise the PNG Government. Nautilus was then to be informed, again confidentially, if the discovery lay within its tenements. The collaboration continued through to 2004 and has included contracted research on specific topics.

With mining around the corner, it is worth summarising the ingredients of success. They include a positive and encouraging attitude by the PNG government, ideal technical conditions – protected waters and indications of rich “ores”, security of tenements and clear requirements for eventual approval of mining, absence of excessive financial demands on Nautilus recognising its nascent status, and collaboration all around within a carefully-negotiated legal context. I hope this presentation will help lead to similar successes in The Area and other National jurisdictions.

Other opportunities exist for future MSR contributions related to discovery and exploitation of seafloor polymetallic sulfide resources. These include developing strategies and techniques to locate inactive and potentially concealed deposits, and better understanding the factors that govern the size and grade of deposits including presence of sub-seafloor extensions. Such research is best undertaken by comparing and contrasting numerous deposits, and requires close collaboration between MSR organisations and the private enterprise or government-sponsored seafloor explorers. Investigating the potential occurrence of modern analogies of other ancient ore body categories, such as sediment-hosted base metals, is another avenue for future consideration.