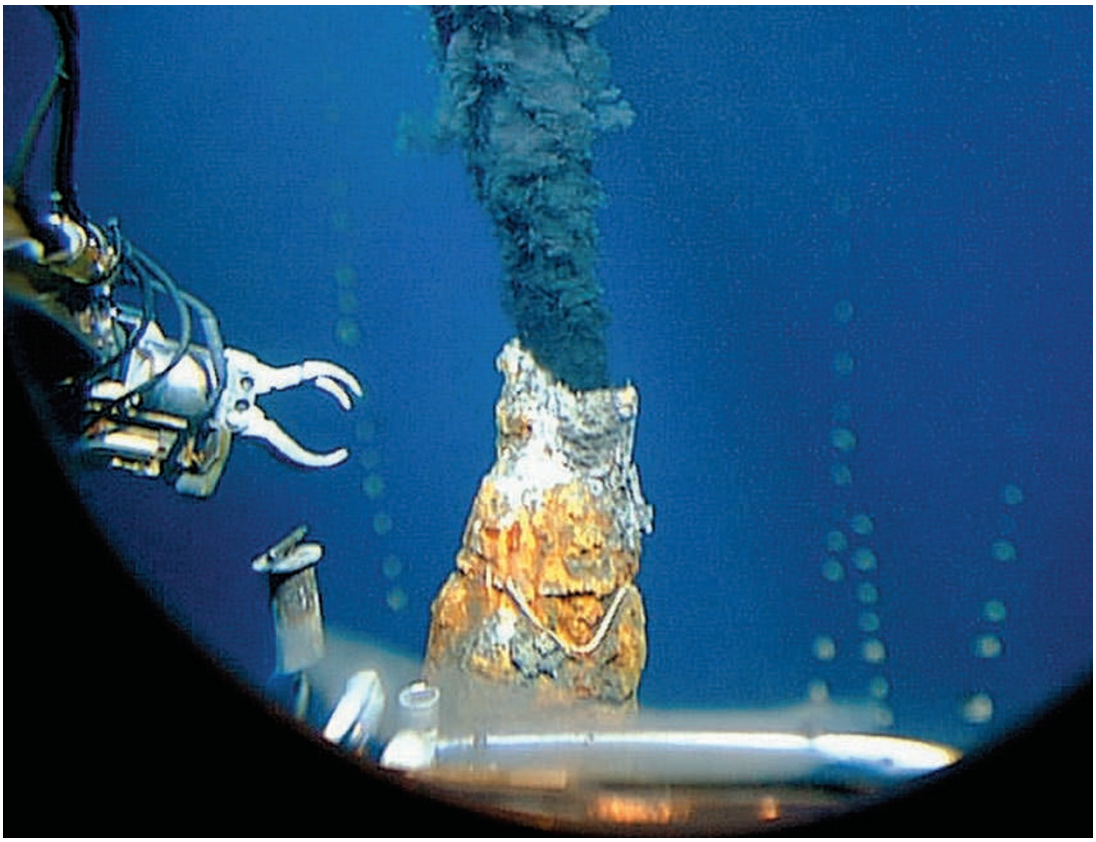
COMMENT



Deep-sea vents are underwater hot springs, home to unique life forms and metal-rich minerals.

P. HICKEY/WHOI

Tighten regulations on deep-sea mining

Extracting minerals from sea-floor vents should not go ahead without a coherent conservation framework, argues **Cindy Lee Van Dover**.

Deposits of gold ore found along the Salmon River in the northwestern United States during the 1860s attracted explorers to the hot mineral springs of the Yellowstone Basin. Soon after, speculators moved in intending to fence and claim the land containing the hot springs. Instead, by 1872, the Yellowstone geyser basin was set aside as the world's first national park. Remarkably, policy-makers in Washington DC, whose only knowledge of Yellowstone was based on photographs, paintings and stories, swiftly saw fit to leave this wilderness pristine for future generations.

In the late 1970s, geologists discovered analogous, mineral-rich hot springs in volcanically active areas of the floor of the Pacific Ocean[1] (see map). These deep-sea hydrothermal vents support bacteria that use chemicals in the vent fluids to generate cellular energy. The bacteria feed luxuriant communities of beautiful and strange invertebrates in an otherwise barren seascape. Scientists studying vents have gained insights into the cooling of Earth's interior, ocean chemistry and the extremes at which life can exist on Earth and potentially elsewhere in the Universe. Some national governments, such as those of Canada, Portugal, Mexico and the United States, have introduced marine parks to protect vent fields of particular scientific interest within 200 nautical miles of their ▶

coastlines. But most vents are found in international waters, where there is little environmental oversight of deep-sea habitats, or in the territorial seas of countries with nascent or non-existent conservation policies that apply to deep-sea hydrothermal vents.

With commodity prices on the rise, mining of mineral deposits at deep-sea vents looks set to begin in the next few years. As a scientist who has studied hydrothermal vents almost since their discovery, and as one passionate about the exquisite organisms that thrive there, I would prefer that sea-floor hot springs remain pristine — deep-sea Yellowstones — untouched by mining. But I recognize that the scientific values I assign to hydrothermal vents must be weighed against other values, including economic ones.

With mining likely to be inevitable, scientists need to promote conservation at every level — from international governance agencies to individual mining companies. To that end I am working with Nautilus Minerals, a deep-sea mining company headquartered in Toronto, Canada, undertaking research that informs its environmental management strategies. In return I am able to tackle research questions that would otherwise be out of reach owing to high costs of field sampling in the deep sea. Some may consider such an alliance a Faustian pact. I disagree.

DEEP HISTORY

Proposals were made in the 1980s to extract mineral ores from hydrothermal vents off the coast of Oregon. But questions about technical and economic feasibility held up sea-floor mining for more than two decades. During this interval, advances in undersea technology — scientific and industrial — have yielded increasing access to the deep sea.

At first it was scientists — American and French — who dominated deep-sea exploration and research, ranging the ocean depths in their manned submersibles *Alvin* and *Nautile*. Next, the oil and gas industry pushed into deeper and deeper waters, facilitated by advances in offshore capabilities, and sometimes highlighting new risks and regulatory limitations, as seen in the Deepwater Horizon oil spill. Today many nations — including China, with its *Jiaolong* submersible that made its maiden dive to the bottom of the South China Sea in 2010 — operate state-of-the-art deep-sea submersibles for scientific research.

"Deposits of copper-, zinc-, silver- and gold-rich ores have been identified at deep-sea vents."

So the technology for seabed mining has matured, and the metals are definitely there: deposits of copper-, zinc-, silver- and gold-rich ores have been identified at deep-sea vents in regions with moderate seas and close to onshore mining infrastructure[2]. At least two mining companies (Bluewater Metals of Sydney, Australia, and Nautilus Minerals) are pushing ahead with mining exploration in territorial waters of island nations in the southwest Pacific Ocean. Both companies undertook exploration expeditions late last year — Nautilus Minerals in the waters of Papua New Guinea and Bluewater Metals in Solomon Islands waters.

Last month, Nautilus Minerals was granted a 20-year mining lease by the government of Papua New Guinea for mineral extraction at a site known as Solwara 1 in the Manus Basin. The company plans to commence open-cut mining of Solwara 1 within the next few years, removing mineral ores (and organisms) to an estimated depth of 20–30 metres over an area equivalent to about 10 football fields. And in July 2011, the International Seabed Authority (ISA), which has jurisdiction over mineral resources in international waters, will review the first lease applications for exploration of sea-floor deposits on mid-ocean ridges. The China Ocean Mineral Resources Research and Development Association submitted an application last May for exploration of the Southwest Indian ridge, and in late December, Russia submitted an application for exploration work on the Mid-Atlantic Ridge. Mineral exploitation will not be limited to territorial waters.

National and international policies for conservation have not kept pace with mineral exploration and plans for extraction. Papua New Guinea's national environment agency, for example, has not yet set aside sea-floor vent ecosystems for conservation in any systematic manner that might protect biodiversity from the effects of mining.

Policies regulating human activities in the deep sea can be arbitrary and inconsistent. As a case in point, the Food and Agriculture Organization of the United Nations lists hydrothermal vents as vulnerable marine ecosystems to be protected from regulated fishing. As a result, seamounts in the South Pacific are protected against bottom fishing. But mineral extraction, which has the potential to destroy the very same habitat, is not prohibited.

In territorial waters, standard-setting develops in an ad-hoc manner. For example, Nautilus Minerals is working in partnership with scientists to establish effective environmental guidelines and collect baseline data[3]. In some cases, the sampling and analysis have been more robust than those undertaken on academic research expeditions. Once mining begins, scientists may participate in monitoring and testing strategies for assessing and mitigating the impacts of mining.

As part of its mitigation plans, Nautilus Minerals has set aside a temporary reserve area of similar size and character to Solwara 1 to serve as a possible source for natural repopulation of the mine site. Under the terms of its permit from the government of Papua New Guinea, Nautilus Minerals is obliged to meet commitments for impact mitigation and restoration, and responsible mine closure.

In international waters, there are gaps — some say chasms — with regard to regulation, governance and conservation of special habitats in the deep sea, whether they are hydrothermal vents, cold seeps or deep-water coral reefs[4]. Instead of leaving it to chance or to the goodwill of a few companies, conservation policies should become an integral part of international seabed regulation — before the ISA grants the first exploration and mining licences. This 15-year-old agency is also responsible for establishing environmental regulations to protect the marine environment from harmful effects that might arise during resource extraction. Some have suggested that lodging leasing and environmental responsibilities in the same agency is akin to setting the wolf to guard the sheep. There can be environmental oversight at the ISA through its Legal and Technical Council, which serves as an independent advisory body, and nations with strong conservation interests can and should ensure that the actions of the ISA take into account conservation objectives.

As one of the first steps, the International Marine Minerals Society (IMMS) presented a Code for Environmental Management of Marine Mining (go.nature.com/mte4gq) to the ISA in April 2010. According to the ISA, the code, which was an initiative of Nautilus Minerals, is "likely to serve as a model for legally binding legislation on marine mining".

The IMMS code offers wide-ranging environmental policies for the management of commercial mining activities. Yet it falls short of providing a comprehensive conservation policy that would systematically protect natural diversity, and ecosystem structure, function and resilience, while enabling rational use. The California Marine Life Protection Act is an example of one such effort to engage stakeholders, scientists, resource managers and members of the public in increasing the coherence and effectiveness of the state's marine management through the design of Marine Protected Areas[5].

Also last year, multiple stakeholders, with the support of the ISA, the Census of Marine Life and other agencies, developed guidelines for networks of reserves for chemosynthetic ecosystems, including deep-sea hydrothermal vents[6]. These, or similar guidelines, need to be turned into regulations within the ISA or another competent body. Until these are in place, wholesale mining of hydrothermal vents is premature.

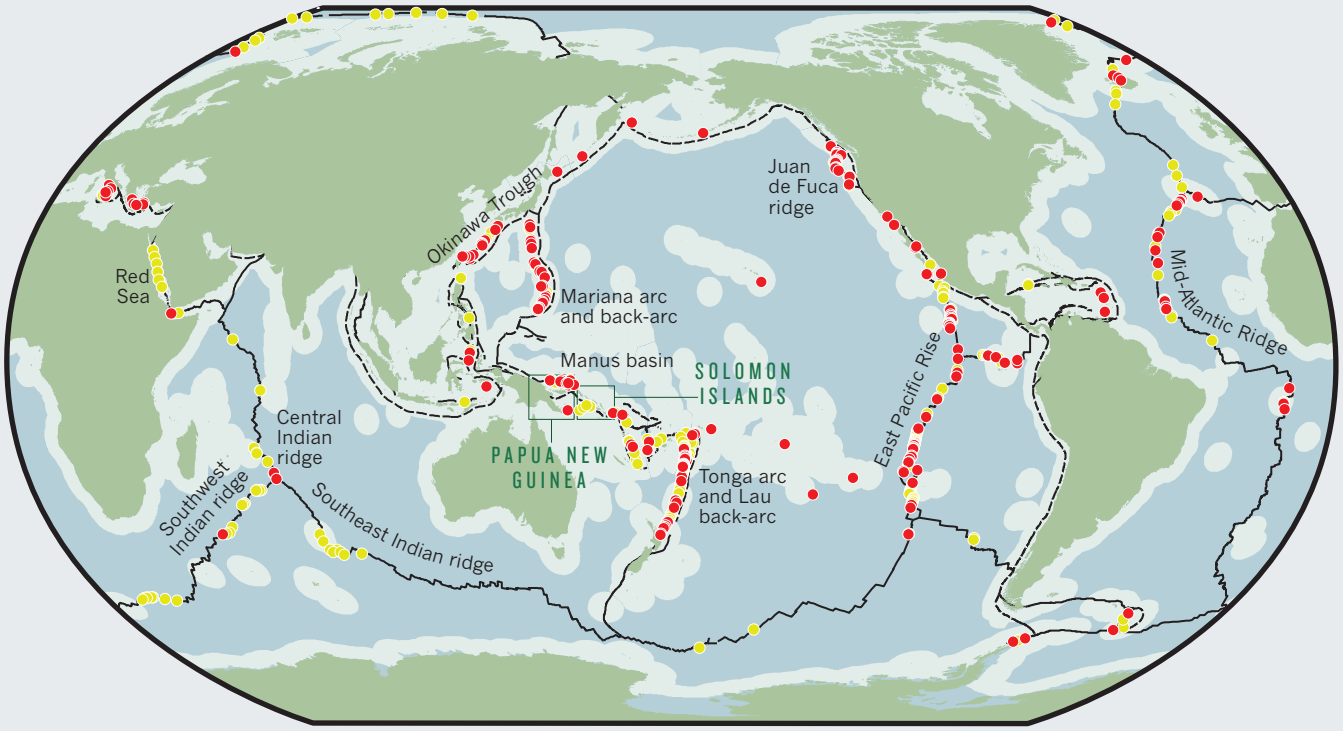
UNFINISHED BUSINESS

There are three scientific reasons for deferring wholesale commercial mining until proper conservation plans are enacted. First, there is much more to learn about hydrothermal vent systems. After three decades of work, researchers continue to find new vent sites in remote locations and new species, adaptations, behaviours and microhabitats, even in well-known settings.

GLOBAL DISTRIBUTION OF HYDROTHERMAL VENT FIELDS

Most deep-sea vents are in volcanically active areas. Many are found in international waters, or in seas belonging to countries that are still developing deep-sea conservation policies.

● Active ● Unconfirmed — Ridge -- Trench ☐ Exclusive economic zones ☐ International waters



S. BEAULIEU; K. JOYCE; S. A. SOULE; WHOI (2010)

Second, there is no strategy in place to assess the cumulative impacts of mining. Mining one vent field may be comparable to a volcanic eruption or other natural process that wipes out vent communities. Active hydrothermal vents are subject to frequent disturbance, including collapse of black smoker chimneys and microearthquake activity. The ability of a vent community to recover from such events may depend on their frequency as well as their scale. Moreover, scientists do not yet understand how vent systems repopulate, or anything about the complex dynamics of neighbouring communities. The effect of continuous and cumulative mining operations may be very different from that of a single event.

Third, we still don't know how best to mitigate mining activities or to restore habitats in the deep sea. Efforts by mining companies (such as setting aside a reserve area) during and after extraction could conceivably alleviate scientific concerns about cumulative effects. But which measures will work, and be affordable, won't be known until the mining is complete or until experimental studies are done.

At this point, I believe a scientific panel would review the current knowledge base and mining plans for Solwara 1 favourably — with the advice that no further mining be initiated until ecologists understand how quickly the mined vent ecosystem recovers and whether the restoration strategies used by the mining company facilitated recovery.

Marine research demands patience; expeditions are long and costly, and scientific answers slow in coming. However, we cannot be patient about effective policies to protect the sea floor. There is an urgent need to establish conservation guidelines before mining begins in international waters, and to place these guidelines in functioning governance and regulatory frameworks. Mining codes alone are not enough.

In states where seabed exploration is already under way, government agencies should act now to comply with global conservation targets, such as those adopted by the Convention on Biological Diversity. The convention has established scientific criteria to identify ocean areas that require enhanced protection, including hydrothermal vents. It has called for a global network of comprehensive, representative and effectively managed protected areas by 2012 and suggests that at least 10% of each of the world's ecological regions be conserved. There is thus an international agreement to protect seabed vent ecosystems.

It is easy to see what would have been lost had Yellowstone been turned over to miners instead of park rangers. Kilometres of overlying water make it harder to see what would be lost in the deep sea. There are creatures of extraordinary beauty down there, exquisitely adapted to their environment. Humans may choose to threaten these habitats for economic or strategic advantage, and to feed lifestyles that depend on relentless demand for minerals and other resources. But we should make these choices on the basis of an understanding of what we may lose as well as what we may gain. ■

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The author declares competing financial interests: details accompany this article online at go.nature.com/b3ydzy.

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