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# OUT OF OUR DEPTH

Mining the Ocean Floor in Papua New Guinea



MiningWatch Canada  
Mines Alerte

**CELCoR**

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**Author:** Helen Rosenbaum (PhD)

**Researcher:** Anne Nolan

**Editors:** Natalie Lowrey, Christina Hill (Oxfam Australia) and Catherine Coumans (PhD) (Mining Watch Canada)

**Expert contributions:**

Alex Rogers, Professor, Department of Zoology, University of Oxford;  
Scientific Director of the International Programme on State of the Ocean

Jeff Kinch, Principal, PNG National Fisheries College, New Ireland Province, PNG

Stuart Kirsch, Associate Professor, Department of Anthropology, The University of Michigan

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MiningWatch Canada  
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**Design, layout and illustrations:** Natalie Lowrey

**[www.deepseaminingoutofourdepth.org](http://www.deepseaminingoutofourdepth.org)**

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## List of Abbreviations

|               |   |
|---------------|---|
| <b>CSIRO</b>  | Commonwealth Science and Industry Research Organisation |
| <b>DEC</b>    | Department of Environment and Conservation              |
| <b>DSM</b>    | Deep Sea Mining   |
| <b>EEZ</b>    | Exclusive Economic Zone                                 |
| <b>EIA</b>    | Environmental Impact Assessment                         |
| <b>EIS</b>    | Environmental Impact Statement                          |
| <b>EMP</b>    | Environmental Management Plan                           |
| <b>ISA</b>    | International Seabed Authority                          |
| <b>PNG</b>    | Papua New Guinea  |
| <b>SMS</b>    | Sea-floor Massive Sulphides                             |
| <b>SPC</b>    | Secretariat of the Pacific Community                    |
| <b>UNCLOS</b> | United Nations Convention on the Law of the Sea         |

# EXECUTIVE SUMMARY

## Background

Canadian mining company Nautilus Minerals Inc. (Nautilus) is set to embark on the unprecedented extraction of metals from the sea floor. The mining project, known as the Solwara 1 project, will extract gold and copper from the floor of the Bismarck Sea in Papua New Guinea. It is the first of a potentially large number of deep sea mining projects within the Pacific Region, including others in the Solwara area.

Nautilus is headquartered in Toronto, Canada, has regional operational offices in Brisbane, Australia and representation in Port Moresby, PNG and Nuku'alofa, Tonga. The company's main geographic focus is the territorial waters and Exclusive Economic Zone of Papua New Guinea. Nautilus has been exploring the territorial waters of Papua New Guinea since 1997. It has been granted more than 158,000 km<sup>2</sup> of tenements and a further 366,000 km<sup>2</sup> are under application in the territorial waters and Exclusive Economic Zones of Papua New Guinea, Tonga, the Solomon Islands, Fiji and New Zealand. If granted, these will enable Nautilus to explore a total area of 524,000 km<sup>2</sup>. With over 250 deep sea massive sulphide deposits identified worldwide, mining companies are waiting to see how Nautilus fares before taking the plunge themselves.

The focus of deep sea mining is the deposits laid down over thousands of years around underwater hot springs, or hydrothermal vents. Known as Seafloor Massive Sulphides, these deposits occur at depths of 1-2 kilometres and can range in mass from several thousand to 100 million tonnes.

Hydrothermal vents occur in volcanically and tectonically active areas - along ridge lines or associated with island arcs or with seamounts. The ecosystems at hydrothermal vents are produced by the rare combination of superheated highly mineralised vent fluids, cold seawater and microbes capable of using chemicals as an energy source and a basis for making organic nutrients. As a result, vent ecosystems are rich in carbon dioxide, hydrogen sulphide, organic carbon compounds, methane, hydrogen and ammonium. They provide habitat for thriving

communities of organisms. In recent years, they have been found to host over 500 species previously unknown to science. There is evidence to suggest that deep sea hydrothermal vents may be where life first evolved on earth.

Vent fauna are highly endemic (not found elsewhere) because of the special adaptations required to live in an environment associated with high temperatures, extreme pressures and the presence of toxic chemicals.

## Deep Sea Mining in the Bismarck Sea

Nautilus is the first company worldwide to commercially explore the sea floor for high grade massive sulphide deposits. In January 2011, Nautilus was granted a 20 year mining lease by the Government of Papua New Guinea for the development of the Solwara 1 deposit.

The Solwara 1 massive sulphide deposit lies in the eastern Manus Basin on the floor of the Bismarck Sea at approximately 1,600 metres depth. The site is bordered on the north by the island of New Ireland and to the south by the island of New Britain, and is 50 kilometres north of the town of Rabaul in East New Britain Province.

Nautilus plans to start processing ore in 2012, producing about 80,000 tonnes of copper and 150,000-200,000 ounces of gold per year over the estimated 2.5 year life of the mine. At current prices the project will generate around \$US275 million in gold and \$US783 million in copper.

## Environmental and Social Impacts

This is the world's first commercial deep sea mining operation. Thus, there is a high level of uncertainty about the risks posed by deep sea mining to marine environments and to communities. What is certain is that impacts will be associated with each step of the mining process. This paper provides an overview of major impacts and critically assesses the adequacy of the data, assumptions and predictions

found in Nautilus's 2008 Environmental Impact Statement.

Although approved by the Government of Papua New Guinea, the Environmental Impact Statement fails to provide adequate analysis and modelling of the environmental impacts of the operation. Similarly no studies or projections have been made by either Nautilus or the Government of Papua New Guinea with regard to the potential social, cultural and economic effects of the Solwara 1 project.

**The Government of Papua New Guinea has granted a 20 year licence for Solwara 1 based on a flawed Environmental Impact Statement and a superficial understanding of social and economic impacts. It may be concluded that in the case of Solwara 1, Papua New Guinea's environmental approvals process has failed to protect the health of the marine environment, the livelihoods and well-being of coastal communities, and fisheries of national and regional economic importance.**

Nautilus is currently developing an Environmental Management Plan for Solwara 1. A major focus of the Environmental Management Plan must be to fill the gaps in the Environmental Impact Statement: that is to assess the nature and scale of the full range of risks. Only once these gaps have been filled, can appropriate mitigation strategies be developed.

Mine production is scheduled to start as soon as 2012. It is imperative that the Environmental Management Plan including the intended mitigation strategies, undergoes a process of public and expert scrutiny prior to the start-up of mining. If necessary, mining operations should be delayed to ensure that independently validated mitigation strategies addressing the full range of significant risks are in place before mining commences.

Similarly, social and economic impact studies must be conducted before Solwara 1 begins. These would determine impacts of the mine on:

- marine ecosystems and fisheries resources of local, national and regional economic importance
- local society and culture; and
- human health including the bioaccumulation of metals and other toxicants - including dietary intake studies for

communities eating fish caught in the Bismarck Sea, the monitoring of metals associated with the Solwara 1 deposit and an assessment of which communities are likely to be exposed to dietary contamination (which relates to market sales of seafood as well as proximity of communities to points of pollution).

Nautilus cannot be considered to have achieved a social licence to operate until these environmental and socio-economic information gaps are closed and independently endorsed mitigation strategies are developed. In addition, due to the lack of good governance and accountability demonstrated to date, independent monitoring by a team of experts and civil society representatives should continue throughout the life of Solwara 1 and any subsequent Solwara projects.

The benefits of the Solwara 1 project to the national economy and local communities appear to be limited compared to high level of risk that will be borne. A small number of jobs will be created (a maximum of 140 of which many may be filled by expatriate workers), a modest level of taxes, duties and royalty will be paid to the Government Papua New Guinea, and a small community development fund will be established. The Government Papua New Guinea has retained an option to take up to a 30% stake in the Solwara 1 project as a joint venture partner. Whilst this may secure an extra revenue stream, this arrangement would result in a gross conflict of interest that would compromise the Government Papua New Guinea's capacity to regulate the mining activity.

## Cumulative Impacts and the Need for Regulatory Frameworks

Sea floor volcanic systems and deep sea ecosystems are still under-researched and not well understood. As a result it is not possible to predict the impacts of any individual deep sea mining project, let alone the cumulative impacts of the many potential deep sea mining projects proposed for the Bismarck Sea and throughout the Pacific.

This is particularly of concern in national waters where governments do not have environmental regulatory systems specific to deep sea mining, or



the capacity to enforce regulations and conduct independent monitoring. In international waters, no authority is empowered to ensure the protection and conservation of the biological resources of the seabed.

The development of regulatory frameworks for deep sea mining in national and international waters is a priority before the deep sea meets with the 'gold rush' that is set to ensue. Furthermore, the cumulative effects of extensive mining of the seabed must be considered as each individual project seeks approval.

First steps in this direction have been taken by the Secretariat of the Pacific Community with its recently initiated project "Deep Sea Minerals in the Pacific Islands Region: a Legal and Fiscal Framework for Sustainable Resource Management". The first stakeholder workshop for the Secretariat of the

Pacific Community project was held in June 2011, but no invitations were extended to representatives of Papuan New Guinean civil society. This does not auger well in regard to the Secretariat of the Pacific Community's stated concern that deep sea mining should be sustainably managed so as to bring tangible benefits to Pacific Island Countries and their people. It can be hoped that in the future, the Secretariat of the Pacific Community will rectify this omission and also align the work of the project with the findings of the International Earth System Expert Workshop on Ocean Stresses and Impacts. These experts have recommended the establishment of a global body empowered to ensure compliance with United Nations Convention on the Law of the Sea and the precautionary principle – allowing activities to proceed only if they can be proven not to harm the ocean singly or in combination with other activities.

# 1. INTRODUCTION

Canadian mining company Nautilus Minerals Inc. (Nautilus) is set to embark on the unprecedented extraction of metals from the sea floor. The mining project, known as Solwara 1, will extract gold and copper from the floor of the Bismarck Sea in Papua New Guinea. It is the first of a potentially large number of deep sea mining projects within the Pacific Region.

Deep Sea Mining (DSM) involves the extraction of metals such as iron, manganese, copper, zinc, lead, nickel, cadmium, silver, platinum and gold from the seafloor. Interest in deep sea mining began in the mid-1960s with the publication of a book by J.L. Mero entitled “The Mineral Resources of The Sea”, which suggested that there was a near-limitless supply of certain metals contained in manganese nodules, potato-sized lumps of compressed sediment on the seafloor at depths of 5,000 meters or more.<sup>2</sup>

Early attempts at deep sea mining ended in failure as a result of the collapse of world metal prices.<sup>3</sup> Between 1974 and 1982, more than US\$1 billion was spent by private companies and governments on manganese nodule investigations. However, none of these endeavours resulted in commercial success, due to overestimates of the potential resource, high extraction costs, political intervention and collapsing metal prices.<sup>4</sup> The ratification of the United Nations Convention on the Law of the Sea (UNCLOS) in 1994 further tempered mining interests.<sup>5</sup>

However, the past decade has seen high demand and soaring prices for gold and copper as well as for metals such as nickel, cobalt and tellurium which are used in computers, batteries, mobile phones and various military applications. With advances in sea bed mining technology, the exploitation of these resources is now economically viable.<sup>6,7</sup>

The International Seabed Authority (ISA) is responsible for management of mineral resources in international waters. While the ISA has received several applications for sea bed mining, the first commercial projects are likely to occur in areas of national juris-

isdiction - on continental shelves and in Economic Exclusion Zones (EEZ). However, no regulatory frameworks exist to protect the biological resources of either national or international waters (see sections 5 and 8).

In January 2011, Nautilus was granted a 20 year mining lease by the Government of Papua New Guinea for deep sea mining in the Bismarck Sea.



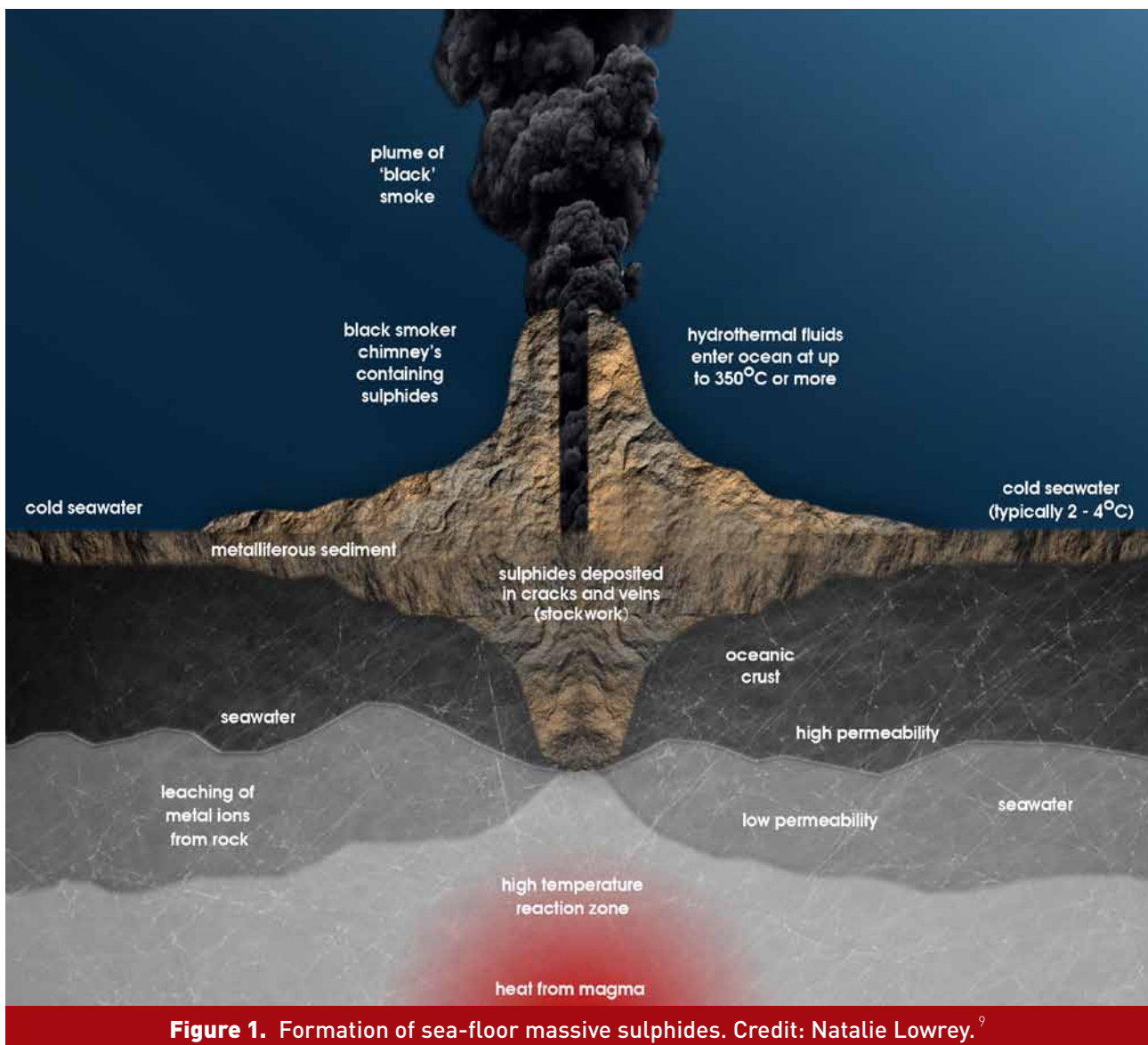
## 2. DEEP SEA MINERAL RESOURCES

### 2.1 The Formation of Seabed Mineral Resources at Hydrothermal Vents

Deep sea hydrothermal vents are volcanic hot springs that occur on the sea-floor at depths of 1-6 kilometres. Around these vents, cold oxygen-rich seawater is forced down through the porous sea bed by very high pressures (see Figure 1). In chambers under the seabed (called sub-surface aquifers) “hot rocks” or magma beneath the earth’s crust heat the water to around 400°C. The heat and high pressure chemically modifies the seawater such that it becomes acidic, low in oxygen and highly concen-

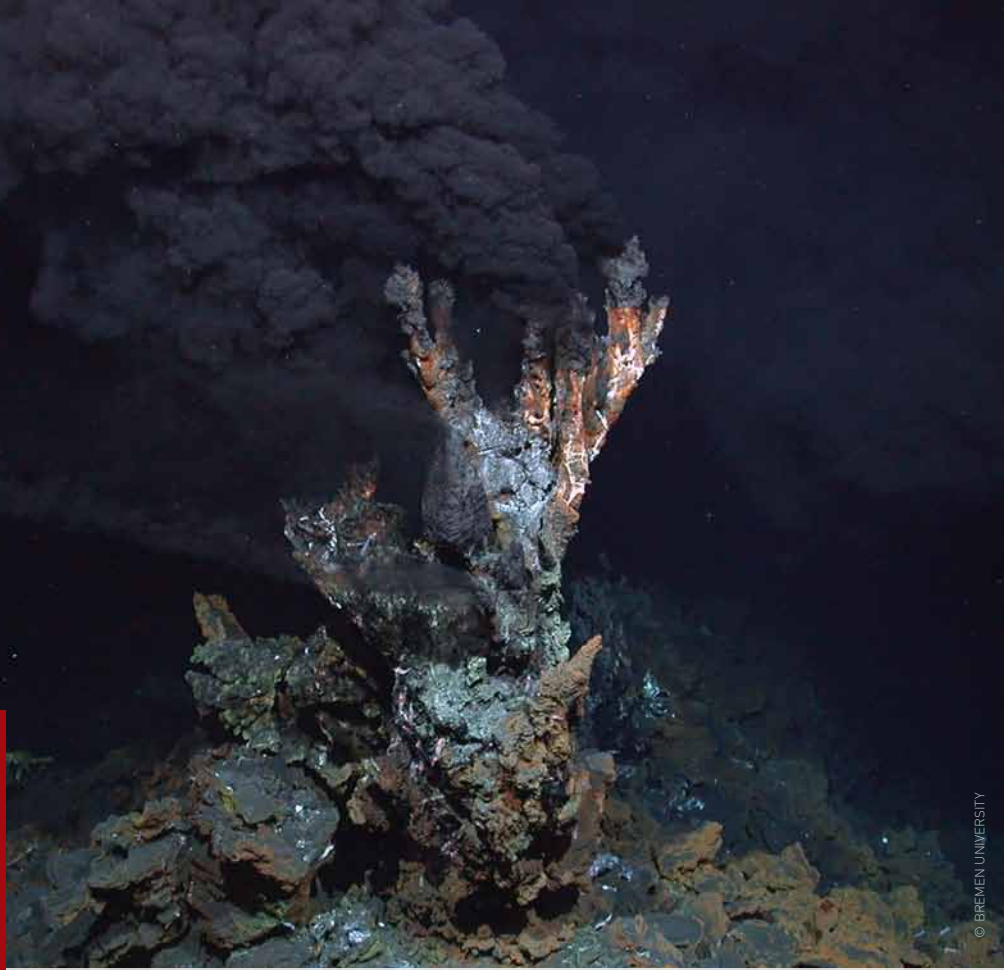
trated in metals dissolved from the surrounding rocks – most of which are in the form of sulphides.<sup>8</sup>

The metal rich, superheated water (or vent fluid) becomes buoyant and rushes up through the seabed forming the hydrothermal vents and mixes with cold water from the ocean bottom. This causes the minerals in the vent fluid to crystallise, forming massive sulphide deposits. Some of these form below the seabed in the cracks and crevices of the vents, while above the seabed, uniquely sculptured, chimney-like towers are created. Vent fluid continues to gush out of their hollow centres, depositing

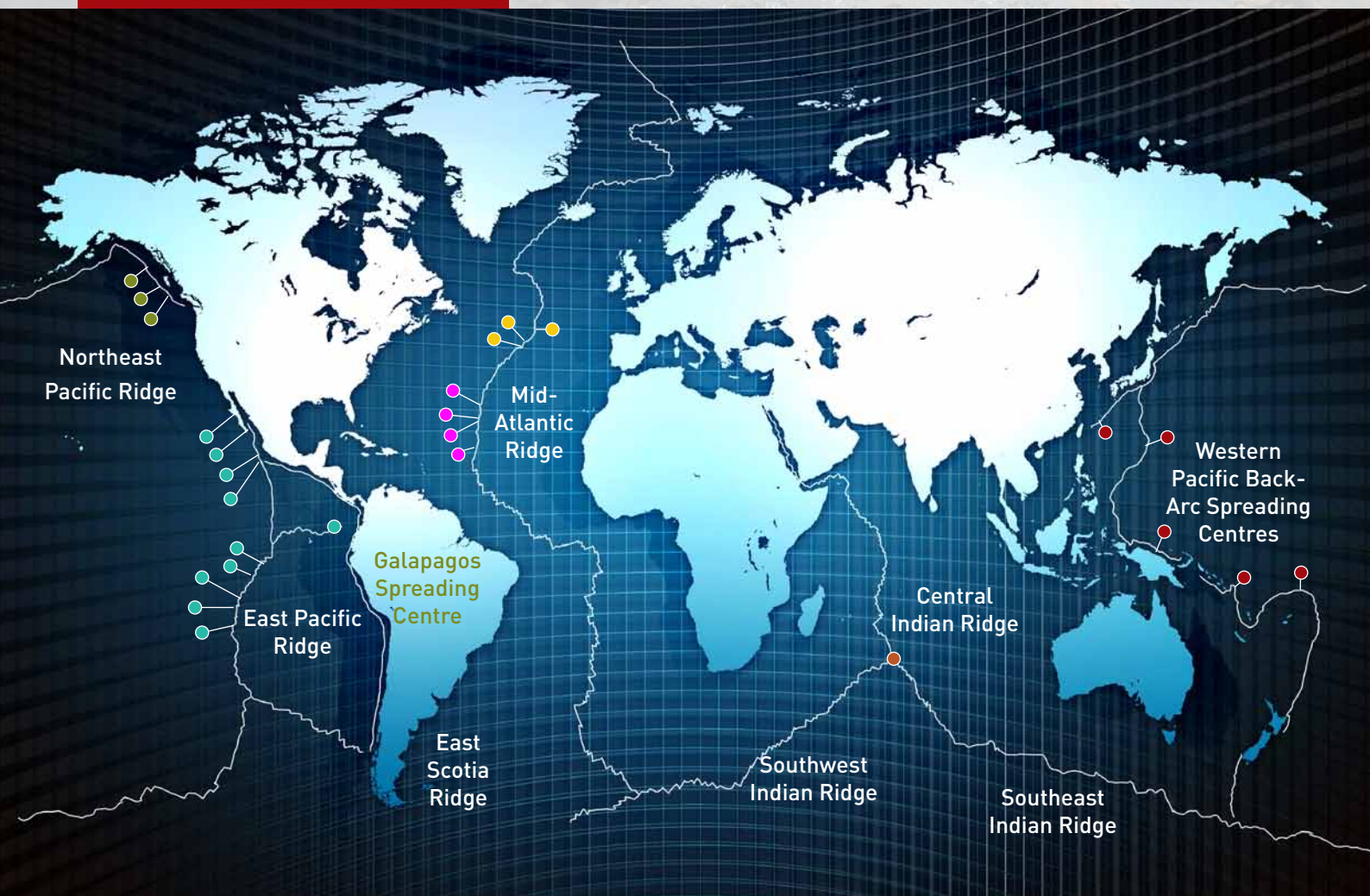


**Figure 1.** Formation of sea-floor massive sulphides. Credit: Natalie Lowrey.<sup>9</sup>

“Black Smoker” - active hydrothermal vents emitting sulphide. Credit: MARUM Forschungszentrum Ozeanrand, Universität Bremen.<sup>10</sup>



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**Figure 2.** Location of hydrothermal systems and polymetallic sulphide deposits. Credit: Natalie Lowrey.<sup>11</sup>

metal sulphide particles on and around the towers: many of them growing to tens of metres tall.

First discovered in the 1970s, these towering high temperature vents were called “black smokers” because the clouds of metal sulphides they discharge resemble black smoke billowing from factory chimneys.<sup>12</sup>

Over thousands of years, the metal sulphide particles settling around the vents can develop into huge mounds. These are known as Sea-floor Massive Sulphides (SMS), and can range in mass from several thousand to 100 million tonnes.<sup>13</sup> It has been suggested that the SMS deposits at Nautilus’s Solwara 1 site in the Bismarck Sea are over 5,000 years old.<sup>14</sup>

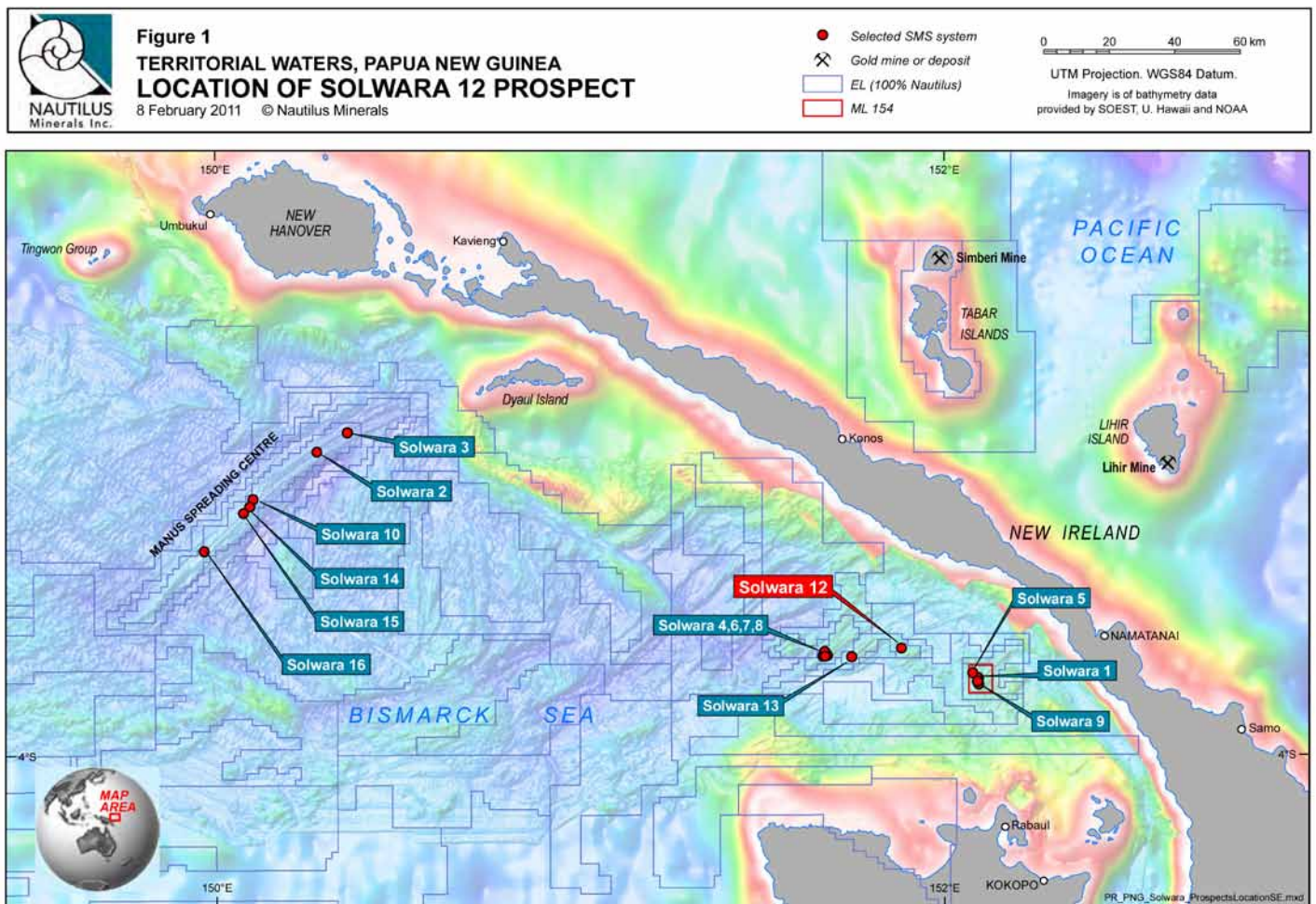
## 2.2 The Location of Sea-floor Massive Sulphides

Hydrothermal vents occur along underwater fault lines and volcanically active chains of mountain

ranges. The *Mid Ocean Ridge* is an 84,000 kilometre chain of volcanic mountains that extends throughout the world’s oceans. Most of the known SMS deposits have been located along particular sections or rises of the Mid Ocean Ridge - at the East Pacific Rise, South-East Pacific Rise and North-East Pacific Rise. Several deposits are also known at the Mid-Atlantic Ridge but only one has so far been located in the Indian Ocean.<sup>15</sup>

In the mid-1980s, sulphide deposits were also discovered in the south-western Pacific. Further deposits have been found in the Lau Basin and North Fiji Basin east of Australia, and the Okinawa Trough southwest of Japan.<sup>16</sup> The location of SMS deposits on the sea floor is shown in Figure 2.

In 1991, extensive sulphide deposits were found to be associated with *felsic volcanism* - the most explosive type of volcanic activity - in the Manus and Woodlark Basins in PNG and to the north of New Caledonia. It is this activity in the Manus Basin and



**Figure 3.** Location of Nautilus Minerals Solwara 1 Project and other Solwara Prospects. Credit: Nautilus Inc.<sup>17</sup>

in the Bismarck Sea that created the Solwara deposits.

Today, more than 250 deep sea massive sulphide deposits have been identified worldwide.

**Only 5 % of the earth's oceanic ridges have been surveyed in any detail. Sea-floor volcanic systems and deep sea ecosystems are still under-researched and not well understood.<sup>18</sup> As a result it is not possible to predict the impacts of any individual deep sea mining project, let alone the cumulative impacts of the many potential deep sea mining projects proposed for the Bismarck Sea and throughout the Pacific.<sup>19</sup>**

### 2.3 Mineral Deposits in the Manus Basin

The Manus Basin SMS deposits are located on the floor of the Bismarck Sea at approximately 1,600 metres depth. They are bordered on the north by the island of New Ireland and to the south by the island of New Britain [see Figure 3 on the previous page], and are 50 kilometres north of the town of Rabaul (in East New Britain Province).

The Solwara 1 project is located in the Eastern Manus Basin and was first discovered by the Australian Commonwealth Science and Industry Research Organisation (CSIRO) in 1996, while another deposit, Solwara 4 was discovered in 1991. Extensive research campaigns between 1993 and 1997 formed the knowledge base for later more intensive commercial development activities.<sup>20</sup>

Nautilus has been exploring the Solwara 1 area since it was first granted an Exploration Licence in November 1997. The Solwara 1 deposit is on the north-west shoulder of the active North Su submarine volcano. It stands about 200 metres above the surrounding sea-floor and stretches about 2 kilometres in diameter. Samples taken during scientific cruises by the CSIRO and Nautilus indicate very high grades of copper, gold, and silver.

The Manus Basin hosts some 40,000 hydrothermal vents over 0.25 metres in height.<sup>21</sup> They are thought to support one of the rarest and most unique ecological communities known to science.<sup>22</sup>



### 3. THE UNIQUE ECOLOGY OF HYDROTHERMAL VENTS

The ecosystems at hydrothermal vents are produced by the rare combination of superheated highly mineralised vent fluids, cold sea water and microbes capable of using chemicals as an energy source and a basis for making organic nutrients. As a result, vent ecosystems are rich in carbon dioxide, hydrogen sulphide, organic carbon compounds, methane, hydrogen, and ammonium. They provide habitat for thriving, abundant, ever changing communities of organisms (Van Dover, 2004<sup>23</sup>). In recent years, such ecosystems have been found to host over 500 species previously unknown to science that are thought to occur only at these vents (Desbruyeres et al., 2006<sup>24</sup>). Some scientists suggest that deep sea hydrothermal vents may be where life first evolved on earth.<sup>25</sup>

All other known life forms depend directly or indirectly on sunlight. In contrast, vent fauna live with no sunlight and in extreme conditions of tremendous pressure (up to 600 atmospheres), very high

temperatures (highest recorded at 403°C) and high acidity (with the pH of vent waters as low as 2.8).<sup>26</sup>

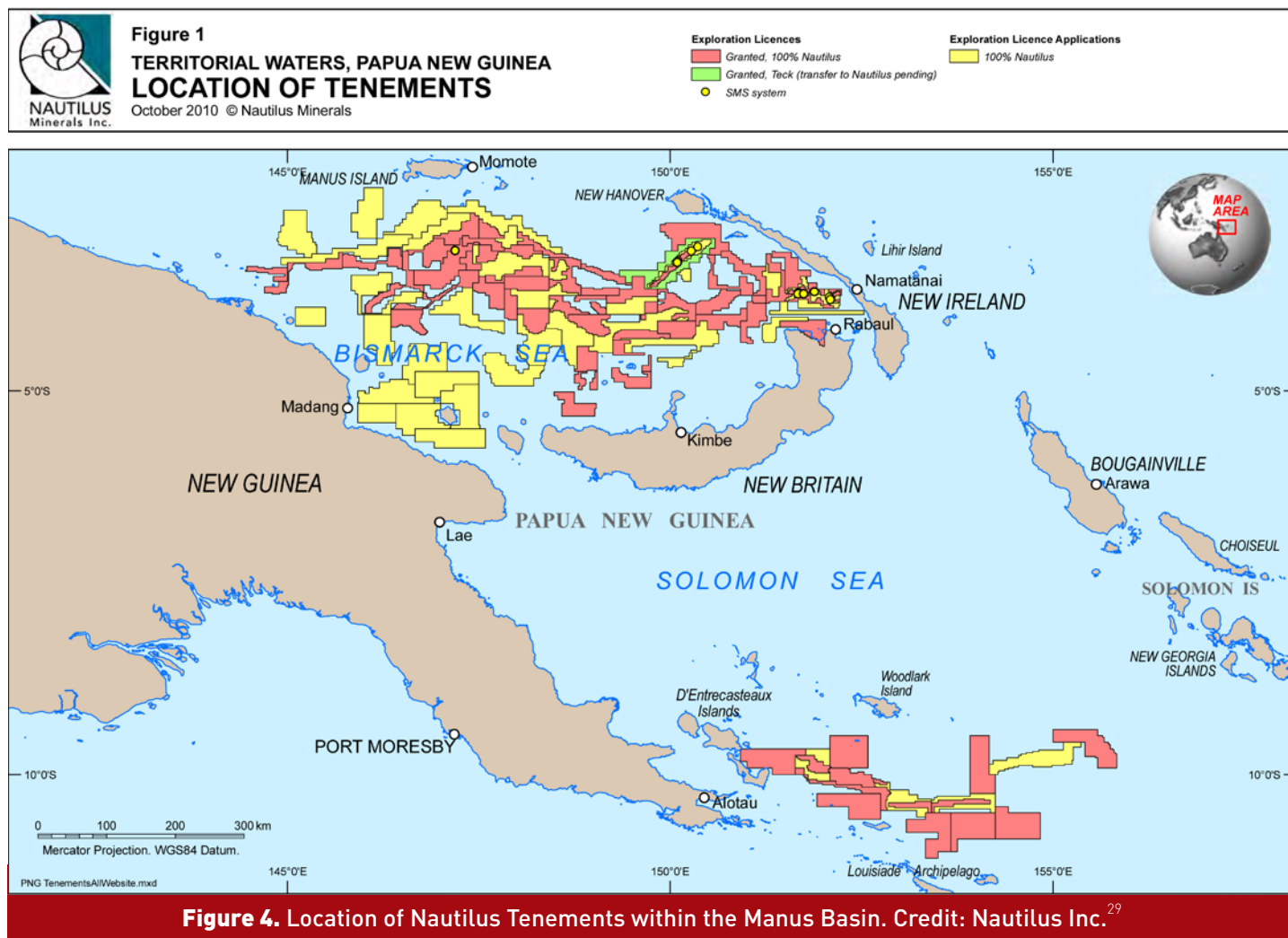
Instead of relying on sunlight, bacteria at the hydrothermal vents use chemical nutrients as an energy source in a process called chemosynthesis. Bacteria are found living under and on the surface of vents, suspended in vent water and on and inside vent animals such as tubeworms, mussels, clams, snails, shrimps and crabs.

Organisms such as the blind Atlantic vent shrimp *Rimacaris*, worms and polychaetes feed directly on the chemosynthetic bacteria, while larger organisms such as vent crabs and fishes depend on these and other vent organisms as food sources.<sup>27</sup> There also may be relationships between vent fauna and marine species with which we are more familiar as human food sources. Thus, it is possible that the disruption of vent ecosystems due to mining will have wider impacts on marine ecosystems.



East Pacific Vent at 9degN, 2,600meters on Tube Worm Pillar. Vent fish, giant tubeworms and crabs that prey on the worms, International Team to Honor 30th Anniversary of *Deep Sea Vent Discovery in Galápagos*. Credit: Stephen Low Production.<sup>27</sup>

## 4. NAUTILUS MINERALS INC.



Nautilus was originally an Australian managed private company. It was listed on the Toronto Stock Exchange in 2006 and the London Stock Exchange in 2007. Nautilus is headquartered in Toronto, Canada, has regional operational offices in Brisbane, Australia and representation in Port Moresby, PNG and Nuku'alofa, Tonga.<sup>30</sup> The Company's main geographic focus is the territorial waters and Economic Exclusion Zone of Papua New Guinea.

Nautilus is the first company worldwide to commercially explore the sea-floor for high grade SMS deposits. The production system it intends to use is based on technologies adapted from offshore oil and gas industries.

At 30 September 2010, the major shareholders of Nautilus were<sup>31</sup> Gazmetall<sup>32</sup> with 21.0%; Anglo

American<sup>33</sup> with 11.1%; and Teck Resources<sup>34</sup> with 6.8% of shareholdings.

### 4.1 The Scope of Nautilus' Exploration

Nautilus has been exploring the territorial waters of Papua New Guinea since 1997. It has been granted more than 158,000 km<sup>2</sup> of tenements and a further 366,000 km<sup>2</sup> are under application in the territorial waters and Exclusive Economic Zones of Papua New Guinea, Tonga, Solomon Islands, Fiji and New Zealand.<sup>35</sup> If granted, these will enable Nautilus to explore a total area of 524,000 km<sup>2</sup>.

Within PNG, Nautilus has been granted 51 exploration licences in the Bismarck and Solomon Seas, covering 108,000 km<sup>2</sup>. It has applied for a further

37 exploration licences that would cover another 89,000 km<sup>2</sup>.<sup>36</sup>

Since 2006, Nautilus has used the term 'Solwara' (which means salt water in PNG's national language, *Tok Pisin*) to refer to its PNG exploration projects. In addition to the Solwara 1 project, Nautilus owns 11 other prospects within the Bismarck Sea (Solwara 1-12). In February 2011, Nautilus reported it would be likely to develop a second mining project at the Solwara 12 prospect just 25 kilometres north-west of Solwara 1. Exploration at Solwara 12 identified mineralisation at five drill sites at approximately 1900 metres below sea-level and extending to a maximum depth of 35 metres below the sea-floor. Thus, it is likely that Nautilus will mine several Solwara deposits.

## 4.2 The Financial Position of Nautilus

Despite the significant expense of sea-floor exploration, Nautilus is debt free and has significant financial reserves<sup>37</sup> - US\$185 million in cash and cash equivalents held on deposit with major banks as at 30 June 2010.<sup>38, 39</sup>

Nautilus has enjoyed a major advantage in being the first company to secure exploration rights over a vast area of sea-floor [see Figure 4.]. A key part of its financial strategy has been to attract major mining companies as investors and partners. This provides Nautilus with access to technical capability, as well as significant financial resources. At the same time Nautilus promotes itself as retaining the flexibility and entrepreneurial ingenuity of a smaller company.<sup>40</sup> It could also be speculated that this strategy benefits major mining companies by allowing them to participate in a high risk venture without suffering significant financial or reputational cost should things go wrong.

The case Nautilus puts to potential investors is that land based sources of minerals for which there is high demand are exhausted, and sea floor mining offers high returns for low prospecting effort and investment (the Solwara 1 project is expected to generate over US\$1 billion per annum). Additionally, it argues that the concentrations of copper and gold that exist at Solwara 1 are many times higher than land-based mines, and deep sea mining offers the ability to move and reuse the capital equipment

once mining at one site is completed.<sup>41, 42</sup> Possibly, the inaccessibility of the mine site to landowners and other stakeholders and the lack of the public visibility of the environmental damage caused, would be viewed as additional advantages by Nautilus and its investors.

Nautilus' economic confidence is indicated by the contracts it has awarded in relation to its Solwara 1 project. These include<sup>43</sup>:

- December 2007 - approximately GBP33 million pounds to the company Soil Machine Dynamics to design and build two sea-floor mining tools;
- April 2008 - US\$116 million contract to Technip USA Inc to provide engineering procurements and construction management for the Riser and Lifting System;
- May 2008 – contract with Canyon Offshore Inc. to provide the vessel, Remote Operated Vehicle and drilling equipment for the exploration and environmental programs;
- June 2008 - contract with North Sea Shipping Holding to provide the specialist Mining Support Vessel ; and
- October 2010 - commenced a drilling program which sub-contracted the TS-Marine Group of Companies.

## 4.3 The Status of the Solwara 1 Project

The Solwara 1 project will extract gold and copper ore from SMS deposits at a depth of 1,200 – 1,600 metres. The project will be mined as five areas covering 11 hectares (0.11 km<sup>2</sup>) of sea-floor. The operation's life is about 30 months at an extraction rate of 5,900 tonnes per day.

The deposits have a stated resource of 2.2 million tonnes of ore. The ore is estimated to include 870,000 tonnes with copper grades of 6.8% and 0.19 oz/tonne of gold.<sup>44</sup> This deposit contains an average copper grade more than ten times higher than a typical land-based copper mine, as well as a significant quantities of high grade gold.<sup>45</sup>

Nautilus plans to process ore at an annual rate of more than 1.3 million tonnes, producing about 80,000 tonnes of copper and 150,000-200,000 ounces of gold per year over the estimated 2.5 year life of the mine. At current prices the project will generate annually around US\$275 million in gold (at US\$ 1,374/ounce) and US\$783 million in copper (at US\$ 9,788/tonne)<sup>46</sup> – approximately US\$2.5 billion in total.

According to the Nautilus 2010 Annual Report, the company plans to complete engineering in 2010, build the necessary equipment in 2011, integrate this equipment into the vessel and commission the operations to produce its first ore in 2012.<sup>47</sup>

In January 2011, Nautilus was granted a 20 year mining lease by the Government of Papua New Guinea for the Solwara 1 project. The Government of PNG has retained an option to take up to a 30% stake in the Solwara 1 project as a joint venture partner.<sup>48</sup>

**This represents a conflict of interest that would compromise the Government of PNG's capacity to regulate the mining activity. A similar situation prevailed in regard to the Ok Tedi mine in the Western Province of PNG with disastrous consequences for the communities and ecosystems of the Ok Tedi and Fly Rivers, in addition to impacts being felt as far away as the Torres Strait in Australian waters.**<sup>49</sup>

#### 4.4 The Mining Process

The mining process will consist of the following steps (as depicted in Figure 5)<sup>50</sup>:

- Removal of unconsolidated sediment and hard rock from the areas to be mined - approximately 130,000 tonnes of unconsolidated sediment and 115,000 tonnes of rock will be dumped on sea-floor outside of the mining area;
- Levelling of vent chimneys and cutting of a mining bench with the sea-floor mining tool;
- Open-cut mining and pumping of the ore slurry via the Riser and Lift System to the Mining Support Vessel at the surface. The Riser and Lift System

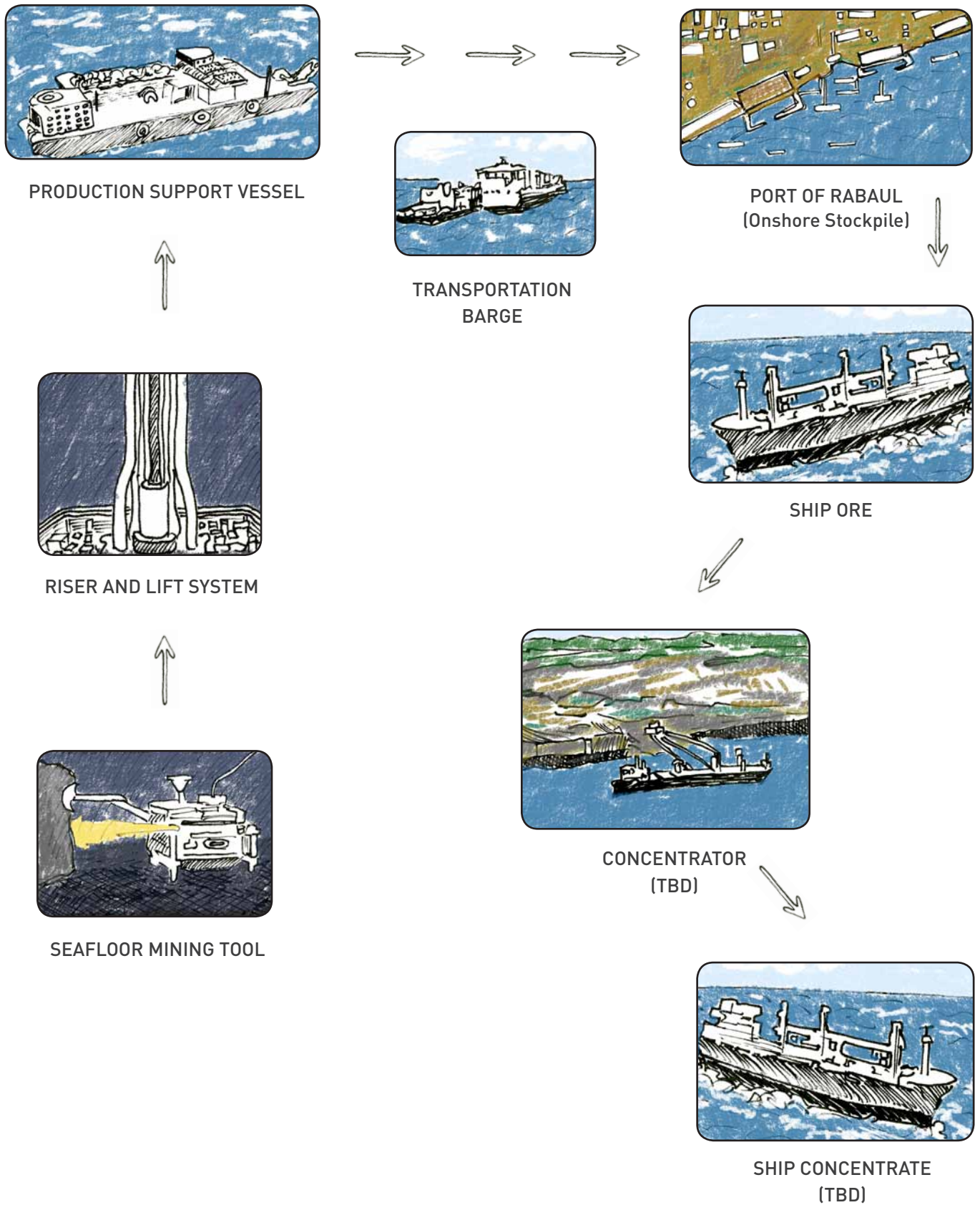
comprises a pipe attached to the sea-floor mining tool. A pump attached to the bottom of the Riser and Lift System will pump the slurry to the surface. The pump will be hydraulically powered by return water from the surface;

- Separating the ore from the slurry (dewatering) on the Mining Support Vessel and its transfer to a shuttle. The dewatering system consists of screens, centrifuges, hydrocyclones and disk filters. Water separated during the dewatering process will be pumped back to the sea-floor and used to drive the Riser and Lift System pump; and
- Transport of the dewatered ore to temporary storage facilities at the Port of Rabaul, from where it will be shipped to overseas processing facilities. The ore is likely to be processed by Bass Metals Ltd. on the west coast of Tasmania. Nautilus and Bass Metals have signed a Letter of Intent whereby the suitability of Bass Metal's Hellyer mill and supporting infrastructure to process and transport the ore will be determined.

Environmental impacts are associated with each stage of the mining process – as described in Sections 5 and 6.



Figure 5. Deep Sea Mining Process. Credit: Natalie Lowrey.



# 5. ENVIRONMENTAL MANAGEMENT OF SOLWARA 1

## 5.1 The Environmental Approvals Process

The PNG Department of Environment and Conservation (DEC) administers the Environment Act 2000, which forms the legal framework for the environmental regulation of the Solwara 1 Project. The Environmental Approval Process for the Solwara 1 Project is summarised below.<sup>51</sup>

Phase one of the Solwara 1 Project was deemed to be a Level 3 activity under the Environment Act for which an Environmental Impact Statement (EIS) is required.<sup>52</sup> In October 2006, DEC issued Nautilus with a “Notice To Undertake Environmental Impact Assessment” under Section 50 of the Environment Act.

This required Nautilus to submit an Environmental Inception Report which identified the potential environmental and social issues associated with the Project, described the scope of the EIS to address these issues, initiated the formal process of stakeholder consultation, and enabled DEC to review the proposed EIS scope and redress any shortcomings.

The EIS was submitted to DEC in October 2008. The *Guideline for Conduct of Environmental Impact Assessment and Preparation of Environmental Impact Statement* outlines the process and content expected by the Government of PNG. Standard procedure would have mandated the Director of Environment to review the EIS, undertake public consultation and receive submissions on the EIS. The Director of Environment would then make a recommendation regarding approval of the EIS to the DEC Environment Council, which advises the Minister in regard to the final decision.

The extent to which the environmental approvals process was followed and the degree of rigour applied is questionable. As described below, there are significant gaps in the EIS approved by the Government of PNG.

**It may be concluded that in the case of Solwara 1, PNG’s environmental approvals process has**

**failed to protect the health of the marine environment, the livelihoods and well-being of coastal communities, and fisheries of national and regional economic importance (described in section 7). Should the Government of PNG decide to take up its 30% shareholding option, it is likely that regulation of the mine will further fail the communities and environment of the Bismarck Sea.**

### Key elements of the approvals process were:

- The process commenced when Nautilus registered their intent in October 2006
- In February 2007 Nautilus submitted the Environmental Inception Report which was approved by DEC in May 2007, enabling the EIS to commence
- In October 2008 Nautilus submitted their EIS to DEC
- In April 2009, the Mining Warden’s hearing for the Solwara 1 mining lease (MLA154) was held
- In December 2009, DEC issues the final Environmental Permit for development of the Solwara 1 Project for a term of 25 years
- January 2011 Nautilus was granted a 20 year mining lease for the Solwara 1 project.

## 5.2 Inadequate Risk Analysis

There is a high level of uncertainty about the impacts of deep sea mining and the risks it poses to marine environments and to communities. This is because:

- the technologies and systems underpinning the mining process are new;
- there is limited knowledge about the biodiversity and ecosystems of the deep ocean in general;
- there is limited knowledge about the biodiversity and dynamics of hydrothermal vent systems in particular;

- there is no knowledge about the capacity of vent systems to re-establish after mining - with regard to hydrothermal properties or biological communities;
- there is generally limited knowledge about currents at various levels of the ocean; and
- the cumulative effects of mining hydrothermal vents are unknown.<sup>53</sup>

The EIS prepared by Nautilus for Solwara 1 acknowledges that “The extent of the impacts to vents and other seafloor habitats directly mined will inevitably be severe at the site scale (i.e., the area of mining)”.<sup>54</sup> The EIS rates the overall ecological impacts as “moderate”, assuming that the environmental management measures implemented are successful.<sup>55</sup> However, these mitigation measures have never been tested and are unlikely to be entirely successful. Thus, the level of overall ecological impacts should be expected to be higher (Steiner, 2009 p22).

In order to manage the risks associated with mining Solwara 1, all of the likely significant environmental impacts associated with it must be identified and assessed. However, such an analysis is yet to be undertaken. Although approved by the Government of PNG, the Solwara 1 EIS provides a limited and superficial description of the environmental risks. Indeed, the rigorous independent review of the EIS by Professor Richard Steiner (of the University of Alaska Marine Advisory Program) found the EIS to be too general to consider specific likely impacts.<sup>56</sup>

Despite this deficiency, the number and the potential scale of the risks that Nautilus has identified are sufficient to condemn the project as unsustainable. When combined with the significant likely environmental and socio-economic impacts yet to be assessed (as described in sections 6 and 7), the conclusion must be drawn that Solwara 1 poses unacceptable risks to communities and the environment. This is particularly so in the light of a recent report by an international panel of experts concluding that the combination of stresses on the world’s oceans are likely to lead to mass extinctions unless negative impacts are curtailed.<sup>57</sup> The regional scale, the many different types of impacts and the cumulative nature of the impacts of DSM, mean that ex-

treme caution must be exercised in regard to this new mode of mining.

### 5.3 The Environmental Management Plan

Nautilus is currently developing the Solwara 1 EMP. Its purpose will be to mitigate the impacts identified in the Solwara 1 EIS. However, as discussed below the impacts identified in the EIS represent only a small proportion of the likely significant negative effects. A major focus of the EMP must therefore be to fill the gaps in the EIS: that is to assess the potential nature and scale of the full range of risks. Once all the risks have been analysed, appropriate mitigation strategies can be developed.

**Mine production is scheduled to start as soon as 2012. It is imperative that the Environmental Management Plan, including all intended mitigation strategies, undergoes a process of public and expert scrutiny prior to the start up of mining. If necessary, mining operations should be delayed to ensure that independently validated mitigation strategies addressing the full range of significant risks are in place before mining commences. Without strategies endorsed by communities and independent experts Nautilus will have no social licence to operate.**

The PNG Environment Act 2000 enables the establishment of a Public Enquiry Committee and an Independent Technical Consultative Group to review the EIS. This did not occur prior to the approval of the EIS. Such a process is now essential to ensure effective environmental management. In addition, due to the lack of good governance and accountability demonstrated to date, independent monitoring by a team of experts and civil society representatives should continue throughout the life of Solwara 1 and any subsequent Solwara projects.

The world witnessed too clearly the economic, social and ecological calamity caused by the lack of risk management that underpinned the Gulf of Mexico oil spill in 2010. The production technology Nautilus plans to use is adapted from the deep sea oil and gas industries. It would be foolish to not learn the hard won lessons of the BP oil spill and properly assess whether the likelihood and consequences of major failures are within levels acceptable to communities and the environment.<sup>58</sup>

## 6. ENVIRONMENTAL IMPACTS OF SOLWARA 1

According to the EIS, the mining of Solwara 1 will destroy:

- an area of 11 hectares of SMS mounds
- tens of thousands of active and inactive vent chimneys
- species associated with these vents – many of which have not yet been identified or studied
- the seafloor to a maximum depth of 220 meters below the existing seafloor
- benthic (sea-floor) species in the 11 hectare mining site.

This section provides an overview of the potential major impacts of mining Solwara 1 identified in the scientific literature and by Nautilus.<sup>1</sup> It provides a critical assessment of the adequacy of the data, assumptions and predictions found in Nautilus's 2008 EIS and draws on the independent review of the EIS to assist in this regard.<sup>59</sup>

### 6.1 The Physical Destruction of Hydrothermal Vents

During the mining of Solwara 1, 11 hectares of SMS deposits, all associated organisms and tens of thousands of active and inactive vent chimneys will be destroyed to a depth of up to 220 metres below the existing seafloor, leaving a smooth hard final surface.<sup>60</sup>

It is expected that this will disrupt venting frequency, vent location, and the flow of water through the sea floor in and around the mined areas. The short and long-term consequences of these impacts are unknown. However they will certainly affect the marine species living in and on the vents and those that live just above the seafloor (the bathypelagic species), with a high likelihood of impacts on more familiar species that inhabit the mid and upper ocean (mesopelagic and epipelagic species respectively).

The full characterisation of ecological communities is a prerequisite to understanding likely impacts. While Nautilus has undertaken some studies of the bottom dwelling organisms at the Solwara 1 site, no systematic studies of the other species and ecological communities likely to be impacted have been undertaken. In fact, at the time of submission of the EIS, ecological baseline studies into species composition and distribution had not been completed and only very limited sampling for sediment biota had been conducted. Thus, as Nautilus admits, it will not be possible to know the full range of species the project will render extinct (EIS Section 7-35-40). Indeed, many species will be eliminated from the mine site even before they have been identified or described.

Nautilus anticipates rapid regrowth of mineral chimneys after mining. However, it cannot be assumed that habitats will return to anything like pre-mine conditions (Van Dover, 2010<sup>61</sup>). If “plumbing” to the site is damaged, chimney recovery will not occur.<sup>62</sup>

Nautilus hopes that after an area is mined, recolonisation will begin in a way that mimics recovery at vent systems that have been disturbed by one-off natural events. It hopes that after a transition period of 1 to 3 years, fauna characteristic of active sulphide mounds will return and reorganise to a condition of biomass and diversity that resembles pre-mining ecosystems. However, deep sea animal populations are thought to have little resilience to vent disruptions as their growth is limited by lack of food supply and low water temperatures.<sup>63</sup> Furthermore, the inactive hard sulphide sediments exhibit slow growth rates and it may take decades to return to pre-mining conditions, if at all. In that time it is conceivable that might have been done to inter-linked ecosystems and food webs.

Nautilus advises that recolonisation could result from parent stock it plans to relocate to refuge sites in the Solwara 1 area and also from the unmined area of South Su, a little over 2 kilometres south-east of Solwara 1. This is an untested and passive approach to rehabilitation, which would not be ac-

ceptable at land based mines in developed economies such as Canada and Australia. Furthermore, Nautilus acknowledges that there is significant variation between the species found at South Su and Solwara 1, thus making rehabilitation of the original ecosystem an unlikely prospect.

In truth, no information exists about the capacity of hydrothermal vent systems to re-establish following widespread vent field destruction. As emphasised by Professor Van Dover, no one can predict the effects of scraping away 5000 years of mineral deposits across a whole vent field.<sup>64</sup>

Given this reality, Nautilus needs more than *wishful thinking* to mitigate the impacts of its operation. A comprehensive management plan is required prior to the commencement of mining, incorporating completed baseline studies linked to a systematic monitoring program and a pro-active approach to restoration ecology.

## 6.2 Sediment Plumes

Sediment plumes are clouds of sediment particles spread in water by prevailing currents.

- During the mining of Solwara 1 it is expected that plumes will be created by:
- The removal and dumping on the seabed of sediment (130,000 tonnes) and rock (115,000 tonnes) from the mining area - Nautilus expects a sediment plume to extend for up to 1 kilometre from the dump site, covering an area of about 2.3 km<sup>2</sup> with sediment;<sup>65</sup>
- The cutting and drilling of ore by the seafloor mining tool and its movement along the seafloor; and
- The discharge of the polluted water removed from the ore slurry. Also known as the *dewatering flow*, this toxic, muddy water will have extremely high concentrations of suspended solids (6,000

mg/L) and contain heavy metals such as arsenic, copper manganese, zinc, cadmium, nickel and lead leached from the crushed ore.<sup>66</sup> The dewatering flow will be discharged at a rate of 0.3 m<sup>3</sup>/second and is expected to generate plumes up to 175 meters wide, the impacts of which are likely to be felt 10 kilometres from the discharge site.<sup>67</sup>

Sediment plumes pose an environmental risk due to their physical as well as chemical properties. Physically, sediment particles settling out of the plumes are likely to smother entire seabed ecological communities and also clog hydrothermal vents, cutting off the food supply and effectively starving vent communities. If this were to occur in South Su, which Nautilus hopes will seed the recolonisation of Solwara 1 (see Section 6.1), there would be little chance of ecological rehabilitation.

Closer to the ocean surface where light penetrates, turbidity resulting from sediment plumes will reduce photosynthesis, thereby impacting on marine food webs. In deeper zones, where many species are dependent on bioluminescence, increased turbidity may also interfere with functions such as catching prey, defence against predators and communication with others of the same species (Nautilus EIS 9-15).

The sediment plumes will introduce nutrient rich deep water into surface waters, with the possibility of increased algal growth, including harmful algal blooms that can adversely affect shallow-water ecosystems. Increased algal growth may also reduce oxygen concentrations in deeper water and negatively affect pelagic (open ocean) ecosystems with “knock-on effects” for commercially valuable species.<sup>68</sup>

Additionally, sediment particles could adhere to plankton reducing their ability to float. Entire food chains that depend on plankton as primary producers could be potentially affected (Ahnert and Borowski, 2002).

Sediment plumes will also expose marine food chains to heavy metals. A range of metals can be

taken up directly from the ingestion of sediments by some species of fish. For other species metals may be taken up from the water column over gill membranes, while in still other cases the most common route for metal uptake is via the food chain. Where concentrations are high enough, acute toxicity can occur, leading to death. More subtle effects such as cell damage, mutations and reproductive failure are detected at lower levels of pollution.

Species such as octopus, squids and cuttlefish readily accumulate heavy metals through their diet of fish, molluscs and crustaceans. Higher up the food chain, species such as tuna, dolphins and humans are vulnerable to heavy metal poisoning through their consumption of these and other contaminated seafoods.

Despite acknowledging the possibility of bioaccumulation of heavy metals in marine food chains, Nautilus is yet to sufficiently model the heavy metals associated with the Solwara plumes, to describe their likely chemical forms, their concentrations through the water column and the ways in which different marine species will be exposed to them.

Toxicity testing of a comprehensive range of species likely to be exposed to the plumes including those associated with the Solwara 1 hydrothermal vents is required. Very limited toxicity testing has been conducted on organisms in the projected impact zone of the sediment plume. The results of these limited tests indicate that the mineralised sediments are highly toxic (Nautilus EIS 9-15; Steiner, 2009 p17), suggesting that plumes carrying sediment particles would have a significant impact. Nautilus is yet to consider toxic effects on organisms in the marine food chain. Significantly, the diet of people living in nearby coastal communities relies heavily on seafood.

**In order to guarantee the health of coastal communities it is essential that Nautilus undertake studies on the potential dietary intake of heavy metals associated with Solwara 1 (see Section 7). In addition, baseline studies of metal concentrations in sediment, the water column and seafood are required prior to the commencement of mining, so as to enable the rigorous monitoring of mine derived metals.**

### 6.3 Operational and Infrastructure-Related Hazards

There are risks inherent in the operational activities of the mine and the presence of mining equipment and associated support and transport vessels. In general, the EIS fails to provide adequate analysis and modelling of these and little is known about their potential impacts (Steiner, 2009). These risks include:

- The discharge of the dewatering flow 25-50 metres above the seabed. Nautilus has not addressed the impact of elevated temperatures or toxicity of the dewatering flow, which may be experienced by deep sea organisms for up to 10 kilometres from its point of discharge.
- Constant light and noise deep under water and on the ocean's surface. Noise will be generated by the seafloor mining tool and, surface support vessels. Despite the lack of modelling, the Nautilus EIS dismisses the likelihood of significant physiological effects on marine mammals unless they are immediately adjacent to the vessel. Nautilus's casual attitude towards potential impacts is also indicated by its failure to collect data on current pre-mining levels of ambient noise and light (Steiner 2009, p15).
- Stationary light from the support vessels could affect the behaviour of seabirds, whales, dolphins and sea turtles. Nautilus has not adequately considered the potential impacts of a constant presence of the illuminated mining support vessel on fauna including the critically endangered Beck's petrel bird which is thought to forage in that area. On the sea floor, the mining tool's cutter head will introduce light where it would not naturally occur.
- Pollution of near-shore waters off East New Britain due to potential contamination by invasive species introduced via the 1.44 million m<sup>3</sup> of ballast water that will be discharged by bulk ore carriers;

potential fuel spills during the refuelling of the mining support vessel at sea; and the leaching of acid, copper and zinc from ore stockpiles at port of Rabaul into Simpson Harbour. Nautilus has argued against the likelihood of risks to coastal communities and has therefore not studied these (EIS Section 1-5). In addition, no attempt has been made to characterise near shore ecosystems that would be affected by such events. The adequate engineering of ore stockpiles is critical to prevent leaching and run-off into coastal waters. This is especially important given the high rainfalls characteristic of East New Britain.

- Potential accidents, equipment malfunctions and extreme weather conditions that could result in spillage of ore, fuel or other hazardous substances on the sea floor, in the water column or surface or on land (Steiner 2009, p23). Many of these risks have been poorly considered by the EIS and shipping risks have not been considered at all. This is extremely negligent given that 3-9 shuttle barges per week are expected to travel from Solwara 1 to Rabaul, each laden with 6,000 tonnes of ore, fuel, and other hazardous materials. Similarly 3-6 bulk ore carriers are expected to export 25,000 tonnes of ore each from Rabaul per month. This will increase vessel traffic in and out of the port of Rabaul by 25-50%, with an associated increase in the level of accident risk (Steiner 2009, p15). It must also be noted that these shipping and operational activities will occur in the context of tropical weather conditions and high local levels of seismic activity.



East Pacific Vent at 9degN, 2,600meters on Tube Worm Pillar. Giant tubeworms being preyed on by vent crabs and fish, *International Team to Honor 30th Anniversary of Deep Sea Vent Discovery in Galápagos*. Credit: Stephen Low Productions.<sup>69</sup>



## 7. SOCIO-ECONOMIC ASPECTS

### 7.1 Lack of Social and Economic Impact Assessments

The onshore and offshore components of the Solwara Project will be in the provinces of East New Britain (in the Rabaul Urban local government area) and New Ireland (under the Kavieng Urban local level government). The discussion above indicates that communities in both provinces will face a range of significant risks related to the project.

However, just as the EIS fails to adequately assess many of the project's environmental impacts, it also falls short in its consideration of social impacts. To date no studies have been made by either Nautilus or the Government of PNG with regard to the potential social, cultural and economic effects of the operation.

For surrounding coastal communities, the Bismarck Sea underpins local culture and provides food and economic livelihoods. Typically in PNG coastal communities, subsistence fishing provides nutrition for families, with surplus sold at local markets contributing to material family needs and the cash economy. The pattern and nature of subsistence fishing around the Bismarck Sea and the effects of the Solwara 1 project on this and family livelihoods are yet to be determined. The impacts described in Section 6 imply that the Solwara 1 project has the potential to erode the long term economic base of local communities.

In New Ireland Province generally, various fisheries and marine resources are harvested for subsistence, small and larger scale commercial uses. Coral reef finfish are a major source of protein for most coastal communities, while beche-de-mer is sold to supplement household incomes. A relatively new deep water fishery is also developing (due to gear limitations, depths to 250 metres are currently fished but deeper water may be accessed, as local fishing equipment improves). In some communities, coral finfish are either sold for cash or bartered for food crop items within communities. Fish are also sold to hotels, restaurants, and fish and chip shops in Kavieng

town, as well as wholesale fish buyers and exporters. In addition, New Ireland has highly productive tuna fishing grounds that provide opportunities for the province to act as a base for large-scale commercial tuna developments.<sup>70</sup> However, all of these activities and their associated economic contributions are now potentially at risk.

There are likely to be strong spiritual connections between local communities and the marine environment. No analysis has been conducted of the possible effects of the Solwara 1 project on traditions related to the marine environment or on the fabric of society in general.

Throughout PNG, communities are experiencing what has been described as a clash between traditional values and new "western" values, frequently resulting in apathy amongst young people, a high rate of drug and alcohol abuse, sexual promiscuity leading to sexually transmitted diseases (including an alarming rate of HIV AIDS), and violence against women and children.<sup>71</sup>

Typically, resource extraction projects exacerbate these problems. Nautilus and the Government of PNG must work with local governments and communities to develop strategies to ensure that Solwara 1 does not escalate the social problems island communities already face.

The acknowledgment in the EIS (Section 10-1) of the likelihood of conflicts arising over the distribution of benefits and in-migration of people looking for work can be barely considered a start: more substantive analysis is required.

National fisheries will also be affected by the Solwara 1 mine. PNG's domestic tuna fishing industry is concentrated in the Bismarck Sea and along the northwest coast of PNG. The 500 metre exclusion zone around the project will reduce the area available to the domestic tuna fishery. The exposure of the marine food chain to mine derived heavy metals and other toxicants (as described in Section 6), as well as other impacts on the pelagic ecosystem, is also a threat to the fishery's viability.





Children playing in Kavieng, PNG.  
Credit: Jessie Boylan/MPI.

Weather and currents will make it difficult to predict and contain pollution generated by the mine. Jerome Tioti from Papua New Guinea's National Fisheries Authority argues that "vast areas could be polluted and with tuna being a highly migratory species, contamination of the stock could have dire consequences for the entire region, far overstretching the immediate impact zone of the mine".<sup>72</sup> Furthermore, according to Mr. Tioti, tuna fisheries of the Western and Central Pacific Ocean supply about 60% of the world's total raw tuna with 30% of that coming from PNG waters.<sup>73</sup> Thus contamination of tuna in PNG or in the western and central Pacific Ocean will create a shortfall in the tuna available for human consumption globally.

Without an analysis of the potential impacts on fisheries resources, the granting of a 20 year mining lease to Solwara 1 appears to be extremely premature.

**The lack of social and economic impact studies means that the Government of PNG has approved an unprecedented mining operation with only the most superficial understanding of the consequences for the people of New Ireland and East New Britain and for fisheries of importance to PNG and the Pacific region. This seriously questions whether the Government of PNG has fulfilled its duty of care to its own citizens, as well as to its neighbours.**

## 7.2 Health Impacts

Seafood forms a significant component of the diet of people living in the villages and towns in the vicinity of the Bismarck Sea. Traditional foods are likely to encompass a range of shellfish, fish, seaweeds and sea mammals. Organs such as the liver and hepatopancreas in shellfish that concentrate heavy metals and other toxicants are likely to be consumed.

**It is essential that prior to the commencement of mining, research is conducted to confirm the seafood component of islander diets, the baseline levels of heavy metals associated with the Solwara 1 project and which communities are likely to be exposed to dietary contamination.<sup>74</sup> This will then provide the basis for a comprehensive monitoring program to determine whether Sol-**

**wara 1 derived metals are causing human health and ecological impacts.**

Specifically such a monitoring program should include:

*Dietary intake studies for communities eating seafood from the Bismarck Sea:*

- Recording the full range of seafood consumed by islanders and the organs and tissues that are eaten;
- Recording their weekly intake of different seafoods and seasonal variations in consumption;
- Investigating the cumulative effects of consuming several metals via seafood and also of combining heavy metal intake with practices such as smoking and other health-related conditions that may be common in the area; and
- Determining maximum acceptable concentrations of heavy metals relevant to the high rate of seafood consumption. Health guidelines for safe concentrations based on average amounts of seafood for average Australian populations would have little relevance to determining the risk to islanders. It will be important to determine relevant maximum acceptable concentrations of heavy metals for the average islander as well as for specific vulnerable populations such as pregnant women and children. A risk assessment could then be undertaken using a risk quotient approach (Connell and Lam, 2004<sup>75</sup>).

*The monitoring of metals associated with the Solwara 1 deposit:*

- Determining the concentrations of these metals in the full range of seafood consumed by islanders and in the full range of tissues that are commonly consumed
- Determining the territorial range of species consumed by islanders that may be contaminated
- Determining the spatial and temporal

distribution and concentrations of all forms of the metals i.e. in sediment, dissolved, and suspended particulate form. Particular attention should be paid to monitoring the biologically available fraction

- Monitoring the spatial characteristics of plumes and establishing the extent of associated toxic zones where concentrations of metals could be expected to cause toxicological impacts.
- Monitoring the territorial range of species

These significant gaps in information must be closed in order to assess the exposure of communities in the vicinity of the Bismarck Sea to heavy metals and to determine the nature and extent of risks to human health from the contamination of seafood by Solwara 1.

### 7.3 Benefits?

Nautilus and the Government of PNG argue that Solwara 1 will bring widespread benefits to PNG. The Nautilus EIS states the project will generate about 140 jobs and that where skills are not available within PNG, expatriates will be employed until such time as PNG citizens have been suitably trained. Thus at a maximum, 140 PNG nationals may be eventually employed.

The Project will generate revenues in excess of US\$1 billion. However total tax, duties and royalty payments to the Government of PNG are estimated at only US\$40.8 million over the life of the project. This appears in large part to be due to an exemption from paying company tax on the basis of costs incurred. Similarly the community development fund to be established by Nautilus to support local health and education projects represents a very small proportion of revenues. Nautilus will contribute two kina for every tonne of ore mined, providing only around PGK5.8 million over the life of the mine.

The Government of PNG has reserved the right to a 30% joint venture partnership in the Solwara 1 project. While it may secure a greater revenue stream for the Government, this arrangement would rep-

resent a gross conflict of interest that would compromise the PNG Government's capacity to regulate the mining activity (as described in Section 5). Furthermore experience demonstrates that the lack of good governance and accountability means that revenues accrued by the Government of Papua New Guinea may not necessarily translate into benefits for citizens.

Overall, it would appear that the direct economic benefits of the Solwara 1 project to the economy of Papua New Guinea and to local communities are small compared to level of risk that will be borne.

## 8. THE CUMULATIVE IMPACTS OF DEEP SEA MINING AND THE NEED FOR REGULATORY FRAMEWORKS



East Pacific Vent at 9degN, 2,600meters on Tube Worm Pillar. Giant tubeworms being preyed on by vent crabs and fish, *International Team to Honor 30th Anniversary of Deep Sea Vent Discovery in Galápagos*. Credit: Stephen Low Productions.<sup>76</sup>

With the licensing of Solwara 1, exploitation of the deep sea is becoming a reality. The shift in prospecting and exploration to EEZs means it is the responsibility of individual nations to issue mining licenses and to define environmental safeguards.

This is of concern when nations are dealing with a new industry associated with a high level of uncertainty and risk, where governments do not have environmental regulatory infrastructure and expertise specific to DSM or the capacity to enforce regulations and conduct independent monitoring.

Nautilus has secured or is in the process of applying for the exploration rights to 534,000 km<sup>2</sup> of the sea floor in PNG, Tonga, the Solomon Islands, Fiji and New Zealand. Other companies are also in the race to explore for deep sea mineral deposits. Neptune Minerals<sup>77</sup> is exploring the Kermadec sea mounts off the coast of northern New Zealand for copper,

silver, zinc, lead and gold.<sup>78</sup> It is poised to start off-shore extraction in the next five years.

The Metal Mining Agency of Japan has begun a 5 year feasibility study for mining a large sulphide deposit in the Okinawa Trough. On 4 April 2011, South Korea launched its deepwater exploration of minerals in the seabed off Tonga.<sup>79</sup> Meanwhile in Arnhem Land in northern Australia, Aboriginal Traditional Owners in March 2011 rejected applications by Groote Resources and called on the company to abandon its DSM exploration tenements in the region.<sup>80</sup>

In July last year, the Chinese Government filed the first application to the ISA for deep sea mining in international waters. Seeking to mine cobalt, nickel, copper, silver and gold in the Indian Ocean, the application, was due to be heard at an ISA meeting in April 2011.<sup>81</sup>

With over 250 deep SMS deposits identified worldwide,<sup>82</sup> mining companies are waiting to see how Nautilus and Neptune fare before taking the plunge themselves. If they are successful, a tsunami of interest in deep sea mining is likely to explode.

The cumulative effects of extensive mining of the seabed must be considered as each individual project seeks approval. The geographic footprint of each individual seabed mining operation is likely to be large. The interactions between currents, weather and seismic events (associated with volcanically active hot springs) will mean that the spread of pollution and impacts cannot be contained nor readily predicted. The high level of uncertainty and risk associated with individual projects will accumulate and compound in unknown ways as deep sea mining activity increases.

Of particular relevance are the words of Dr. Alex Rogers, co-author of the 2011 State of the Oceans Report, “As we considered the cumulative effect of what humankind does to the ocean, the implications became far worse than we had individually realized. This is a very serious situation demanding unequivocal action at every level. We are looking at consequences for humankind that will impact in our lifetime, and worse, our children’s and generations beyond that.”<sup>83</sup>

Currently no mechanisms exist by which to appropriately regulate and manage the impacts of individual projects let alone multiple deep sea mines. The ISA, an intergovernmental body based in Jamaica, was established by the UNCLOS to organise and control all mineral-related activities in the international seabed beyond the limits of national jurisdiction, an area comprising 64% the world’s oceans.

The ISA began assigning leases for deep sea mining in international waters in April 2011, requiring EIS and best practices for lease applicants. It has entered into eight 15 year contracts for exploration for polymetallic nodules in international waters. Each area is limited to 150,000 km<sup>2</sup> of which half is to be relinquished to the Authority after eight years. Each contractor is required to report once a year on its activities in its assigned area.

However, the ISA has no jurisdiction over biological resources and a gap exists with regard to the conser-

vation of the seabed in international waters. While UNCLOS establishes a comprehensive legal framework to regulate the use and resources of all ocean space, including providing for the protection and preservation of the marine environment, no agency has been charged with overseeing this responsibility.

The development of regulatory frameworks for DSM in national and international waters is a priority before the deep sea meets with the ‘gold rush’ that is set to ensue. The need to strengthen protection of the 64% of the ocean that lies beyond the zones of national jurisdiction is a key finding of the International Earth System Expert Workshop on Ocean Stresses and Impacts.<sup>84</sup> This workshop recommended the establishment of a global body empowered to ensure compliance with UNCLOS and the precautionary principle – allowing activities to proceed only if they can be proven not to harm the ocean singly or in combination with other activities.

In recognition of the need for regional regulatory frameworks, the SPC has initiated a project entitled “Deep Sea Minerals in the Pacific Islands Region: a Legal and Fiscal framework for Sustainable Resource Management”. A meeting was convened by the SPC in June 2011 to inform stakeholders about the project and to stimulate discussion about DSM and agree on a way forward. No invitations were extended to representatives of PNG civil society – who will experience the first DSM project in the region. This does not auger well in regard to the SPC’s stated concern that DSM should be sustainably managed so as to bring tangible benefits to Pacific Island Countries and their people. It can be hoped that in the future, the SPC will rectify this omission and also align the work of the project with the findings of the International Earth System Expert Workshop on Ocean Stresses and Impacts.

## 9. CONCLUSIONS

There is a high level of uncertainty about the impacts of DSM and the risks it poses to marine environments and communities. These uncertainties arise due to the lack of knowledge and experience about the technologies and processes underpinning the mining system, the biodiversity and ecosystems of the deep ocean and particularly of hydrothermal vent systems including their capacity to re-establish after mining, currents at various levels of the ocean and the cumulative effects of DSM.

What is certain is that many impacts will be associated with each step of the mining process. This paper provides an overview of major impacts and critically assesses the adequacy of the data, assumptions and predictions found in Nautilus' 2008 EIS. It can be concluded that the Government of Papua New Guinea and Nautilus have not fulfilled their duties of care to safeguard the well being and livelihoods of local communities, and fisheries of national and regional economic importance. The EIS approved by the Government of Papua New Guinea fails to provide adequate analysis and modelling of the environmental impacts of the Solwara 1 project. Similarly no studies or projections have been made by either Nautilus or the Government of Papua New Guinea with regard to the potential social, cultural and economic effects of Solwara 1.

Professor Richard Steiner states in his independent review of Nautilus Solwara 1 EIS, "it is likely that the project would result in severe, prolonged, and perhaps region-wide impacts to a globally rare and poorly understood biological community, and it is clear that the EIS does not adequately assess many of these impacts. ... species would likely become extinct due to the mining project, even without having yet been identified or described. This alone constitutes an unacceptable risk. ... Further, the benefits to local people or the economy of PNG seem disproportionately low compared to the scale and risk of the project."

It is imperative that the gaps in information about environmental and social impacts be filled and miti-

gation strategies developed before mining begins at Solwara 1.

A major focus of the EMP, which is currently in development, must be to assess the nature and scale of the full range of risks so that appropriate mitigation strategies can be developed. The EMP including the intended mitigation strategies, must undergo a process of public and expert scrutiny prior to the commencement of mining. If necessary, mining operations should be delayed to ensure that independently validated mitigation strategies addressing the full range of significant risks are in place before mining commences. The PNG Environment Act 2000 enables the establishment of a Public Enquiry Committee and an Independent Technical Consultative Group to review the EIS. Given these processes were not used to ensure an adequate EIS, they could now be adapted to validate the EMP.

Similarly, before mining at Solwara 1 begins social and economic impact studies must be conducted and appropriate mitigation measures developed and independently validated. These studies would determine impacts of the mine on:

- fisheries resources of local, national and regional economic importance;
- local society and culture; and
- human health including the bioaccumulation of metals and other toxicants - this would require dietary intake studies for communities eating fish caught in the Bismarck Sea, the monitoring of metals associated with the Solwara 1 deposit and an assessment of which communities are likely to be exposed to dietary contamination (which relates to market sales of seafood as well as proximity of communities to points of pollution).

**Nautilus cannot be considered to have achieved a social licence to operate until the information gaps on environmental and socio-economic impacts are filled and independently endorsed miti-**

**gation strategies are developed. In addition, due to the lack of good governance and accountability demonstrated to date, independent monitoring by a team of experts and civil society representatives should continue throughout the life of Solwara 1 and any subsequent Solwara projects.**

Due to the high level of uncertainty associated with DSM, it is not possible to predict the impacts of any individual DSM project, let alone the cumulative impacts of the many potential DSM projects proposed for the Bismarck Sea and throughout the Pacific.

This is particularly of concern in national waters where governments do not have environmental regulatory systems specific to DSM, or the capacity to enforce regulations and conduct independent monitoring. In international waters, no authority is empowered to ensure the protection and conservation of the biological resources of the seabed.

The development of regulatory frameworks for DSM in national and international waters is a priority. Furthermore, the cumulative effects of extensive mining of the seabed must be considered as each individual project seeks approval.

The SPC has made a start towards a Pacific regional regulatory approach. We encourage the SPC to now actively engage with civil society in the Pacific so as to realise its stated concern that DSM should be sustainably managed so as to bring tangible benefits to Pacific Island Countries and their people. We also hope the SPC will align its work with the recommendations of the International Earth System Expert Workshop on Ocean Stresses and Impacts. These includes establishing a global body empowered to ensure compliance with UNCLOS and to apply the precautionary principle – allowing activities to proceed only if they can be proven not to harm the ocean singly or in combination with other activities.

## Endnotes

### Executive Summary

1. Alviniconcha sp. (Hydrothermal vent snail) Suiyo Seamount, Tokyo Hydrothermal Vent. This snail inhabits deep-sea hydrothermal vents and harbors chemoautotrophic symbionts in its gills. This individual is probably a new species. Photo credit: Yoshihiro FUJIWARA/JAMSTEC [http://comlmaps.org/ge\\_layers/a-decade-of-discovery](http://comlmaps.org/ge_layers/a-decade-of-discovery)

### 1. Introduction

2. <http://www.independent.co.uk/environment/nature/deepsea-mining-adds-to-fears-of-marine-pollution-2016292.html>
3. Glasby, G P. 'Lessons Learned from Deep-Sea Mining.' *Science Magazine* 28 July 2000: 551-53.
4. [http://www.interridge.org/files/interridge/Going\\_for\\_Gold\\_pdf\\_final.pdf](http://www.interridge.org/files/interridge/Going_for_Gold_pdf_final.pdf)
5. Halfar, J and Fujita R., *Precautionary Management of deep sea mining* [http://eyeonmining.files.wordpress.com/2009/07/736\\_deepseamining.pdf](http://eyeonmining.files.wordpress.com/2009/07/736_deepseamining.pdf) accessed 4 January, 2011.
6. <http://www.rsc.org/chemistryworld/Issues/2007/January/TreasuresDeep.asp>
7. <http://www.moneyweek.com/investments/commodities/the-dawn-of-deep-sea-mining-50216.aspx>

### 2. Deep Sea Mineral Resources

8. Sulphide minerals contain sulphide (S<sup>2-</sup>). Many metals important to the mining industry are in the form of sulphides eg: silver sulphide, lead sulphide, iron sulphide.
9. Figure 1. Illustration based on Baker, Maria and Christopher German. 2008. 'Going for Gold!: Who will win the race to exploit ores from the deep?', *Ocean Challenge*, Vol 16 No 1. Nov, pg.11.
10. Black smoker image, © MARUM\_Forschungszentrum Ozeanrander, Universitat Bremen <https://picasaweb.google.com/109421560750700623225/BlackSmoker>
11. Figure 2. illustration based on Herzig et al. Proceedings, 'Minerals other than polymetallic nodules of the international seabed area', Kingston, Jamaica, *International Seabed Authority*, 2000, pg. 109-161.
12. American Museum of Natural History Expeditions. [http://www.amnh.org/nationalcenter/expeditions/blacksmokers/black\\_smokers.html](http://www.amnh.org/nationalcenter/expeditions/blacksmokers/black_smokers.html)
13. <http://www.isa.org.jm/files/documents/EN/Brochures/ENG8.pdf>
14. Professor Cindy Lee Van Dover, *Catalyst* TV Program 9 June, 2011, *Australian Broadcasting Corporation*.
15. <http://www.isa.org.jm/files/documents/EN/Brochures/ENG8.pdf>
16. <http://www.isa.org.jm/files/documents/EN/Brochures/ENG8.pdf>
17. Figure 3. <http://www.nautilusminerals.com/i/pdf/LocationOfProspects11Feb2011.pdf>
18. <http://www.isa.org.jm/files/documents/EN/Brochures/ENG8.pdf>
19. Sections 4.2 and 9 outline many of the other mining operations proposed.
20. <http://www.dsmedialtd.com/Downloads/H2Ops%20Vol4%20Issue%205%20e-edition.pdf>.
21. <http://www.cares.nautilusminerals.com/Assets/Documents/Main%20Document%20Text.pdf> pg. 7-30.
22. Steiner, R., 2009, Independent Review of the Environmental Impact Statement for the proposed Nautilus Minerals Solwara 1 Seabed Mining Project, Papua New Guinea Conducted for the *Bismarck-Solomon Seas Indigenous Peoples Council*. Madang, Papua New Guinea.

### 3. The Unique Ecology of Hydrothermal Vents

23. Van Dover, C., 2004, 'The biological environment of polymetallic sulphide deposits, the potential impact of exploration and mining on this environment, and data required to establish environmental baselines in exploration areas', *International Seabed Authority*.
24. Desbruyères, D., Segonzac, M., and Bright, M. 2006. 'Handbook of the deep sea hydrothermal vent fauna'. Linz, Austria: Denisia, *Volume 18; Land Oberosterreich, Biologiezentrum der Oberosterreichische Landesmuseen*.
25. Halfar, J and Fujita R. 'Precautionary Management of deep sea mining', [http://eyeonmining.files.wordpress.com/2009/07/736\\_deepseamining.pdf](http://eyeonmining.files.wordpress.com/2009/07/736_deepseamining.pdf)
26. <http://dgukenvis.nic.in/artmar1.htm>
27. <http://www.bren.ucsb.edu/research/documents/VentsThesis.pdf>
28. [http://www.noc.soton.ac.uk/chess/event/galapagos\\_event.php](http://www.noc.soton.ac.uk/chess/event/galapagos_event.php)



#### 4. Nautilus Minerals Inc.

29. [http://www.nautilusminerals.com/i/pdf/PNG\\_TenementsAllWebsiteNov10.pdf](http://www.nautilusminerals.com/i/pdf/PNG_TenementsAllWebsiteNov10.pdf)
30. <http://www.nautilusminerals.com/s/Contact-Us.asp>
31. <http://www.nautilusminerals.com/i/pdf/FactSheet-Dec2010.pdf>
32. Gazmetall is a subsidiary of the Metalloinvest Group, one of Russia's largest iron ore producers. Metalloinvest Group owns several integrated steel operations and one of the largest and fastest growing mining and metallurgical holdings in Russia.
33. Teck Resources ("Teck") is a diversified mining and metals company, headquartered in Vancouver, Canada, <http://www.teckcominco.com>
34. Anglo American is one of the world's largest mining and natural resource groups, with its headquarters in London, United Kingdom, <http://www.angloamerican.com/>
35. <http://www.nautilusminerals.com/s/Tenements.asp>
36. <http://cares.nautilusminerals.com/Assets/Documents/Main%20Document%20Text.pdf> pg 1-3
37. [http://www.nautilusminerals.com/i/pdf/PNG\\_TenementsAllWebsiteNov10.pdf](http://www.nautilusminerals.com/i/pdf/PNG_TenementsAllWebsiteNov10.pdf)
38. [http://www.nautilusminerals.com/s/Media-NewsReleases.asp?ReportID=413671&\\_Type=News-Releases&\\_Title=Nautilus-Minerals-Announces-Financial-Results-for-Q2-2010](http://www.nautilusminerals.com/s/Media-NewsReleases.asp?ReportID=413671&_Type=News-Releases&_Title=Nautilus-Minerals-Announces-Financial-Results-for-Q2-2010)
39. Information on Nautilus' banks could not be identified during the course of this research.
40. <http://www.brr.com.au/event/37439/nautilus-minerals-presentation-at-sydney-mining-club-mr-david-heydon-ceo>
41. <http://www.nautilusminerals.com/s/Investors-StockInfo.asp>
42. <http://cares.nautilusminerals.com/Assets/Documents/Main%20Document%20Text.pdf> pg 1-3.
43. <http://www.nautilusminerals.com/s/Media-NewsReleases.asp?DateRange=2005/01/01...2006/12/31>
44. <http://www.nautilusminerals.com/s/Media-NewsReleases.asp?ReportID=437932>
45. [http://cis.who.edu/science/interridge/dsm/abstracts/Smith\\_Samantha\\_Nautilus\\_WHOI\\_April2009\\_rev.doc](http://cis.who.edu/science/interridge/dsm/abstracts/Smith_Samantha_Nautilus_WHOI_April2009_rev.doc)
46. <http://www.basemetals.com/>
47. <http://www.nautilusminerals.com/i/pdf/2009AR.pdf>
48. [http://www.nautilusminerals.com/s/Media-NewsReleases.asp?ReportID=437932&\\_Type=News-Releases&\\_Title=Nautilus-Granted-Mining-Lease](http://www.nautilusminerals.com/s/Media-NewsReleases.asp?ReportID=437932&_Type=News-Releases&_Title=Nautilus-Granted-Mining-Lease)
49. Barry Bolton, ed. 2009. *The Fly River, Papua New Guinea: Environmental studies in an impacted tropical river system*. New York: Elsevier. *Developments in Earth & Environmental Sciences* 9; Rosenbaum, H. 2005, *Potential Impacts of OK Tedi Mine Derived Sediment in the Gulf of Papua and Torres Strait*, The Mineral Policy Institute, Sydney, Australia; Rosenbaum, H. and Krockenberger, M. 1993, *Report on the Impacts of the Ok Tedi Mine in Papua New Guinea* ACF, Melbourne, Australia.
50. Nautilus EIS Chapter 5, September 2008, <http://www.cares.nautilusminerals.com/Assets/Documents/Main%20Document%20Text.pdf>

#### 5. Environmental Management of Solwara 1

51. Outlined also in Figure 3.1 of the Nautilus EIS, September 2008,: <http://cares.nautilusminerals.com/Assets/Documents/EIS%20Figs%20and%20Plates%20Chapter%201-6.pdf>
52. Activities that – (a) involve matters of national importance; or (b) may result in serious environmental harm, may be prescribed as level 3 activities. <http://faolex.fao.org/docs/texts/png70607.doc>
53. <http://www.bren.ucsb.edu/research/documents/VentsThesis.pdf>
54. <http://www.cares.nautilusminerals.com/Assets/Documents/Main%20Document%20Text.pdf> pg 9-25.
55. <http://www.cares.nautilusminerals.com/Assets/Documents/Main%20Document%20Text.pdf> pg 9-26.
56. Steiner, R., 2009, *Independent Review of the Environmental Impact Statement for the proposed Nautilus Minerals Solwara 1 Seabed Mining Project, Papua New Guinea Conducted for the Bismarck-Solomon Seas Indigenous Peoples Council*. Madang, Papua New Guinea.
57. <http://www.iucn.org/?7695/Multiple-ocean-stresses-threaten-globally-significant-marine-extinction>
58. Risk Analyst, Professor Emeritus Robert Bea, Department of Civil & Environmental Engineering, University of California Berkeley. Personal Communication 23 June, 2011

#### 6. Environmental Impacts of Solwara 1

59. Due to the expense and difficulty of deep sea expeditions, there is little independent scientific data. Ecological research relating to Solwara 1 has either been commissioned or supported by Nautilus. It is beyond the scope of this briefing paper

to assess whether this has influenced the information available.

60. Steiner, R., 2009, Independent Review of the Environmental Impact Statement for the proposed Nautilus Minerals Solwara 1 Seabed Mining Project, Papua New Guinea Conducted for the *Bismarck-Solomon Seas Indigenous Peoples Council*. Madang, Papua New Guinea.

61. Van Dover, C., 2010, Mining seafloor massive sulphides and biodiversity: what is at risk, *ICES Journal of Marine Science*, <http://icesjms.oxfordjournals.org/content/early/2010/06/29/icesjms.fsq086.full#ref-42>

62. Dr. Alex Rogers, co-author of the 2011 *State of the Oceans Report*, personal communication 3 September, 2011.

63. <http://www.guardian.co.uk/environment/2010/oct/21/papua-new-guinea-mine>

64. Professor Cindy Lee Van Dover, *Catalyst Program*, 9 June, 2011, Australian Broadcasting Commission.

65. <http://www.cares.nautilusminerals.com/Assets/Documents/Main DocumentText.pdf>, pg. 1666.

66. <http://www.cares.nautilusminerals.com/Assets/Documents/Main%20Document%20Text.pdf> pg. 9-6; It should be noted that in Canada, the home country of Nautilus, mines are not permitted to dispose of more than 15 mg/L suspended solids per month into the water that contains fish. Thus it can be expected that the dewatering flow will be very toxic to marine life. (Coumans, Catherine. 2002. 'Canadian Legislation on Submarine Tailings Disposal.' *Submarine Tailings Disposal Toolkit*. MiningWatch Canada and Project Underground. <http://www.miningwatch.ca/en/submarine-tailings-disposal-toolkit/>)

67. <http://www.cares.nautilusminerals.com/Assets/Documents/Main%20Document%20Text.pdf> pg. 9-3.

68. Dr. Alex Rogers, co-author of the 2011 *State of the Oceans Report*, personal communication 3 September, 2011.

69. [http://www.noc.soton.ac.uk/chess/event/galapagos\\_event.php](http://www.noc.soton.ac.uk/chess/event/galapagos_event.php)

## 7. Environmental Impacts of Solwara 1

70. National Fisheries Authority and Coastal Fisheries Management and Development Project, 2007 A review of Fisheries and Marine Resources in New Ireland Province, Papua New Guinea. [Kavieng].

71. Rosenbaum, H. 2008. 'Some Musings on Lessons Learned from PNG.' *New Community Quarterly* 6(1):16. Borderlands, Melbourne, Victoria.

72. *Institute for Security Studies*, 19 December 2008: 'Considering The Future Environmental Impacts Of Marine Mining' <http://www.iss.co.za/pgcontent?UID=22599>

73. *Mines and Communities*, 24-11-2008; <http://www.minesandcommunities.org/article.php?a=8930>

74. The exposure of communities to dietary contamination would relate to the spread of market sales of contaminated seafood as well as proximity of communities to points of pollution.

75. Connell, D and Lam, P, 2004 'Assessment of Risks to Human Health and the Indopacific Dolphin Due to Contaminants in Hong Kong Waters'. *Interact 2004 Conference* Gold Coast, Queensland Australia 4-8 July, 2004.

## 8. The Cumulative Impacts of Deep Sea Mining and the Need for Regulatory Frameworks

76. [http://www.noc.soton.ac.uk/chess/event/galapagos\\_event.php](http://www.noc.soton.ac.uk/chess/event/galapagos_event.php)

77. Neptune Minerals is a UK-registered public company founded in 1999 to explore, develop and commercialise seafloor massive sulphide deposits. Neptune's operations office is based in Sydney, Australia. It has been granted exploration licences totalling more than 261,146 km<sup>2</sup> in the territorial waters of New Zealand, Papua New Guinea, the Federated States of Micronesia and Vanuatu. Neptune has exploration applications covering 350,780 km<sup>2</sup> pending in the territorial waters of New Zealand, Japan, Commonwealth of Northern Mariana Islands, Palau and Italy. <http://www.neptuneminerals.com/Neptune-Minerals-corporate-overview.html>

78. <http://www.rsc.org/chemistryworld/Issues/2007/January/TreasuresDeep.asp>

79. [http://www.koreatimes.com.kr/www/news/biz/2011/04/123\\_84771.html](http://www.koreatimes.com.kr/www/news/biz/2011/04/123_84771.html)

80. 'Top End TOs reject mining applications', *National Indigenous Radio Service*, <http://tiny.cc/tllk6>; 'Owners block Groote', *Sydney Morning Herald*, <http://tiny.cc/aw2eb>

81. <http://www.independent.co.uk/environment/nature/deepsea-mining-adds-to-fears-of-marine-pollution-2016292.html>

82. M.D Hannington et al., 'A global database of seafloor hydrothermal systems' *Geological Survey of Canada*, Open File 4598, 1CD-ROM, Ottawa 2004.

83. <http://www.iucn.org/?7695/Multiple-ocean-stresses-threaten-globally-significant-marine-extinction>

84. Rogers, A.D. & Laffoley, D.d'A. 2011. 'International Earth system expert workshop on ocean stresses and impacts. Summary report', *IPSO Oxford*.

# OUT OF OUR DEPTH

Mining the Ocean Floor in Papua New Guinea



“ it is likely that the project would result in severe, prolonged, and perhaps region-wide impacts to a globally rare and poorly understood biological community, and it is clear that the EIS does not adequately assess many of these impacts. ... species would likely become extinct due to the mining project, even without having yet been identified or described. This alone constitutes an unacceptable risk. ... Further, the benefits to local people or the economy of PNG seem disproportionately low compared to the scale and risk of the project.

*Professor Richard Steiner in his independent review of Nautilus Solwara 1 Environmental Impact Statement, the first of a potentially large number of deep sea mining projects within the Pacific Region*

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