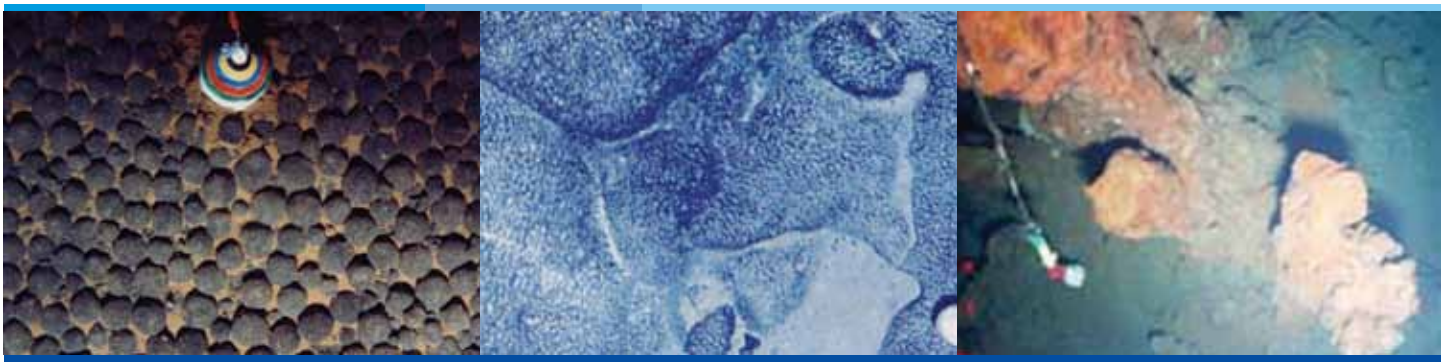
SPC
Secretariat of the Pacific Community

Applied Geoscience and Technology Division (SOPAC)

SPC-EU EDF10 Deep Sea Minerals (DSM) Project



Information Brochure 3
Marine Minerals

Most Pacific Island Countries have large ocean space compared to their smaller land masses. Under the ambit of the United Nations Convention on the Law of Sea (UNCLOS), most of these island countries have significant ocean space that are legally recognised to come under the direct control of individual countries. Ocean and seabed resources including minerals that occur on the seafloor within national waters belong to each country and are managed and governed under national law.

Marine Minerals

Marine minerals encompass minerals that occur on shallow and deep ocean environments including nearshore and continental shelf areas as well as deeper ocean seamounts, mid-ocean ridges and ocean basins.

The most common mineral types that occur on the nearshore environment are sand and gravel deposits that are increasingly becoming a common source of construction materials. For smaller Pacific Island Countries with limited onland resources, sand and gravel extraction in shallow nearshore and lagoon areas (Figures 1A & 1B) provides a better alternative to inland and beach mining.

Figure 1. Marine mineral extraction in nearshore environment: (A) & (B) sand and gravel mining; (C) recent offshore diamond mining in Namibia, southern Africa (Schneider, 2010)[1].

[1] Schneider G. 2010. Exploration of New Mineral Resources in Namibia. Presentation for the 2010 ACP Mining

In addition, valuable mineral deposits (e.g. diamond, gold and rutile) that have accumulated during sedimentary processes (placer deposits) also occur in the nearshore and continental shelf areas. These minerals are largely derived from onland mineral deposits that were transported into the marine environment by rivers and accumulated over a long period of time. Mining of nearshore diamond is currently active in southern Africa (Figure 1C). Placer minerals are naturally heavier and resistant to weathering processes.

Marine minerals that occur in the deeper parts of the ocean are referred to as Deep Sea Minerals.

Deep Sea Minerals

Deep sea minerals are deposited on the surface or sub-surface of the deep seafloor by natural processes. There are different types of deep sea mineral deposits that occur on the seafloor such as iron and manganese in nodular and encrustation forms, massive sulphides, phosphates and metalliferous sediments. The three major deposits that can potentially be developed in the future are: (1) Seafloor Massive Sulphides (SMS), (2) Manganese Nodules (MN) and (3) Cobalt-rich Crusts (CRC).

SMS deposits are formed by active hydrothermal vents that occur in mid-ocean ridges and back-arc and fore-arc basins (Figure 2). A hydrothermal vent is defined as a crack in the earth's surface from which superheated (i.e. very high temperature) water comes out. SMS deposits are found in water depths ranging from 1,500 – 5,000 metres. Nodules are predominantly found in ocean basins at 4,000 – 6,000 metres deep (Figure 2). Cobalt-rich Crust generally occurs on seamounts and around flanks of volcanic islands at about 400 – 4,000 metres deep (Figure 2).

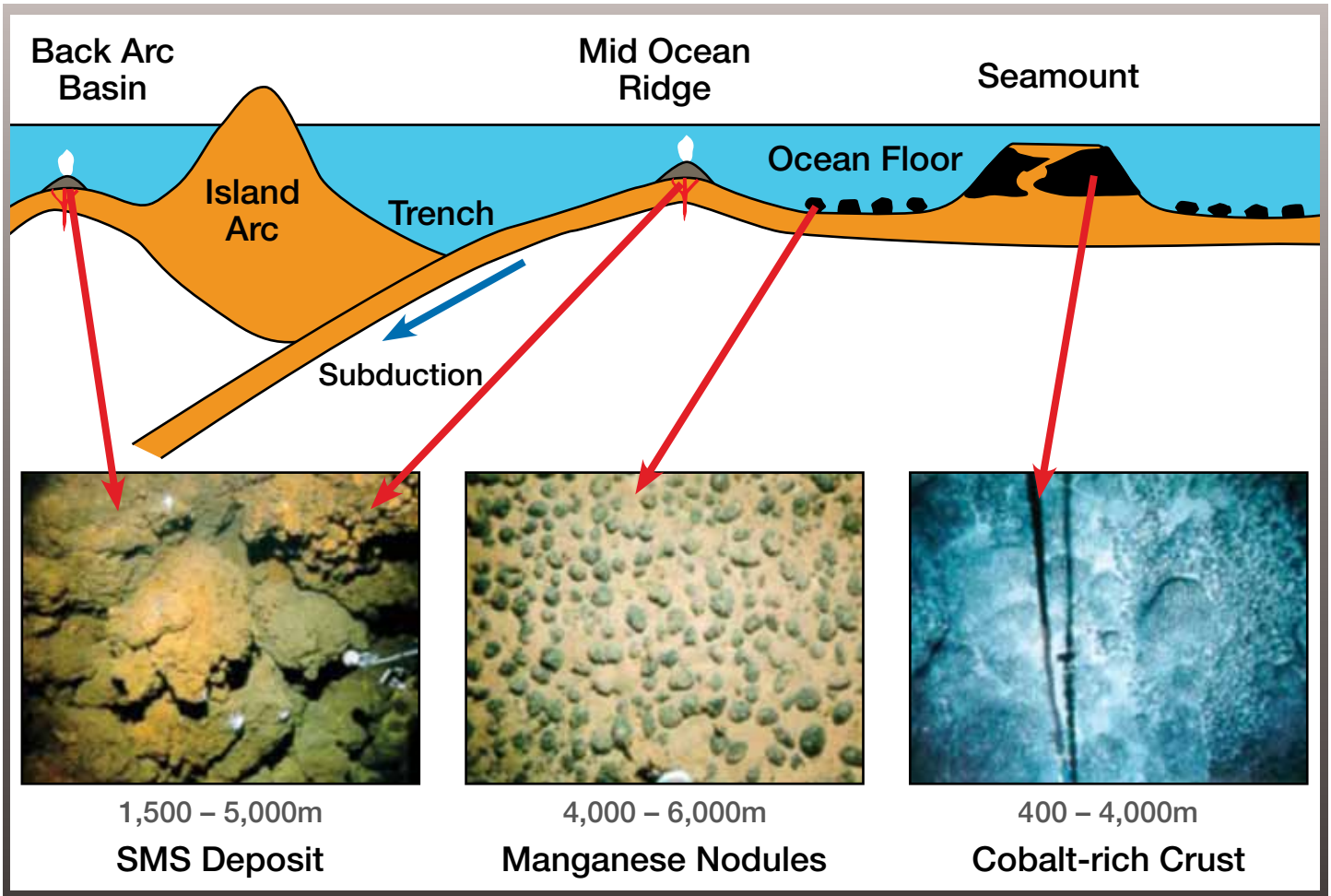


Figure 2. A map of the seafloor showing different geological environment in which Manganese Nodules, Cobalt-rich Crust and Seafloor Massive Sulphides occur.

These seabed mineral deposits are composed predominantly of metals and the target metallic minerals for each deposit type are as follows: SMS deposits – Copper, Gold, Silver, Zinc and Lead; Manganese Nodules – Nickel, Copper and Cobalt; and Cobalt-rich Crust – Cobalt, Nickel and Platinum.

Seafloor Massive Sulphides

Seafloor massive sulphide deposits are modern equivalents of the much older volcanogenic massive sulphide (VMS) ore deposits that are found onland. Ground water that infiltrates the cracks in the earth's crust gets heated from the underlying heat source (the magma) and returns to the surface through the vent (Figure 3A).

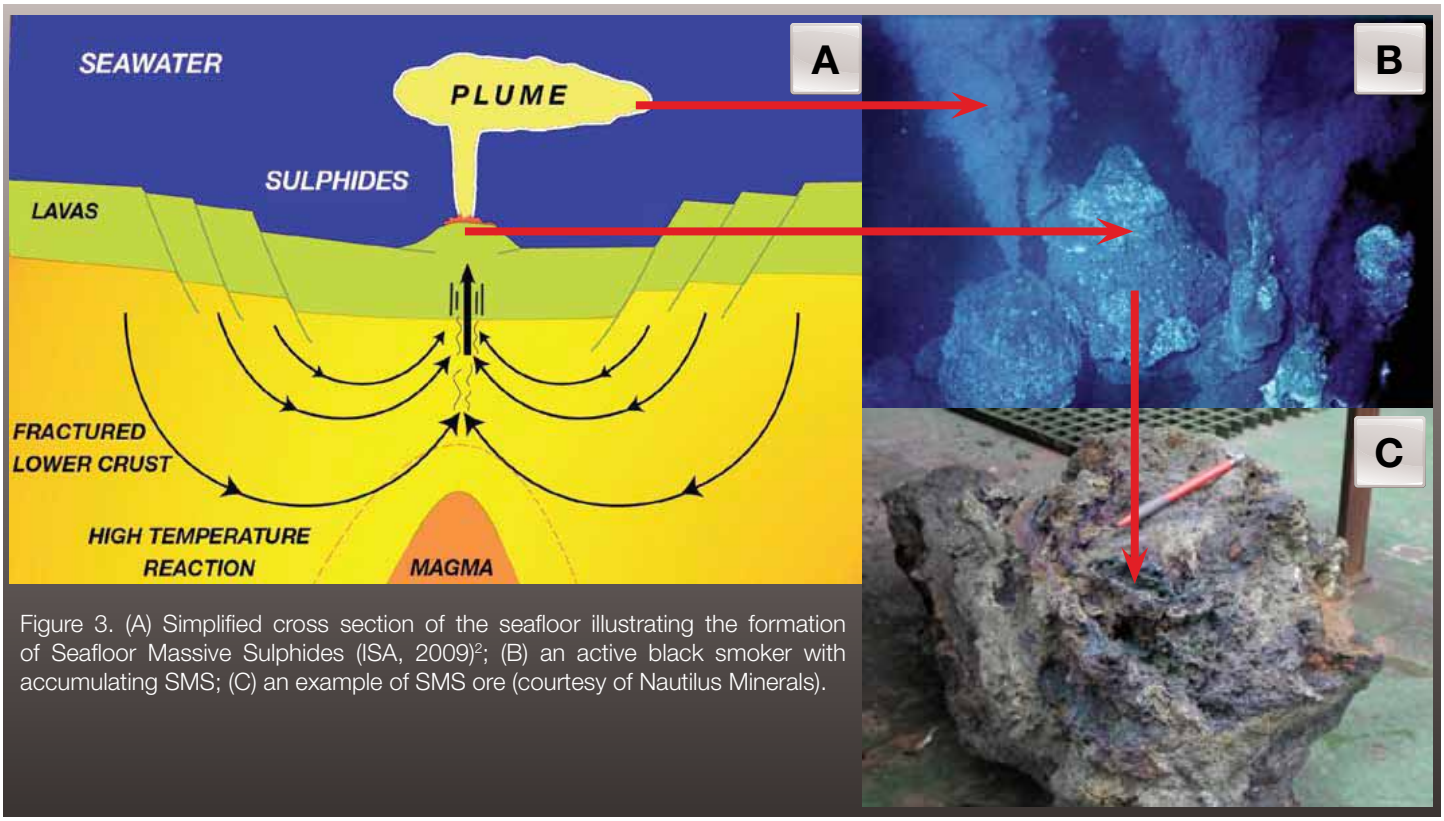


Figure 3. (A) Simplified cross section of the seafloor illustrating the formation of Seafloor Massive Sulphides (ISA, 2009)[2]; (B) an active black smoker with accumulating SMS; (C) an example of SMS ore (courtesy of Nautilus Minerals).

SMS deposits form directly on the ocean floor where superheated water carrying metals from deep in the earth, mixes with cold seawater at the bottom of the ocean, depositing minerals that are rich in metals (Figures 3A & 3B). Active seabed hydrothermal vents that give out mineral-rich black waters are also known as "black smokers" (Figure 3B). In some instances, the vents are no longer active leaving cold, inactive SMS deposits on the seafloor. SMS ores (Figure 3C) are rich in minerals, including chalcopyrite (copper), gold, silver, galena (lead) and sphalerite (zinc) that accumulate at and just below the seafloor.

Manganese Nodules

Manganese nodules are rock materials that occur on the seafloor and are characterised with circular layers (concentric bands) and largely composed of manganese and iron around a core (Figure 4C). They have a wide distribution on the seafloor and whilst their composition is dominated by manganese and iron oxides they also have minor amounts of other minerals. The core can be a rock fragment, a shell or a shark tooth.

Figure 4. Manganese nodules in different forms: (A) nodular; (B) encrustation, and (C) cross section of a nodule showing circular banding formation around a central core.

[2] International Seabed Authority. 2009. Factsheet on Polymetallic Sulphides.

Manganese nodules occur predominantly in spherical nodular form (Figure 4A) and occasionally they are also found in encrustation forms encasing hill slopes and rocky surfaces (Figure 4B). The longest side (diameter) of nodules are usually measured between 1 to 5 centimetres.

Several processes are involved in the formation of manganese nodules. Included in these processes are: (i) metals coming out of solution (precipitation) from seawater (hydrogenetic), (ii) the changing of manganese-iron-rich sediment on the seafloor to form manganese nodules (diagenetic), and (iii) metals derived from very hot water on the seafloor (hydrothermal). These processes may operate at the same time or they may follow one another during the formation of a nodule. Their growth rate is very slow, only a few millimetres over a million year.

Cobalt-rich Crust

Cobalt-rich Crusts are formed when minerals have precipitated out of the cold surrounding seawater and attached onto the clean rock surface of seamounts (Figures 5A & 5B). Crusts do not form in areas where sediment covers the rock surface. Cobalt-rich crusts are found on the flanks of volcanic islands, ridges, and flanks and summits of seamounts (Figure 5A) throughout the world's oceans. Due to the elevated concentration of cobalt in crust, it is called Cobalt-rich Crust.

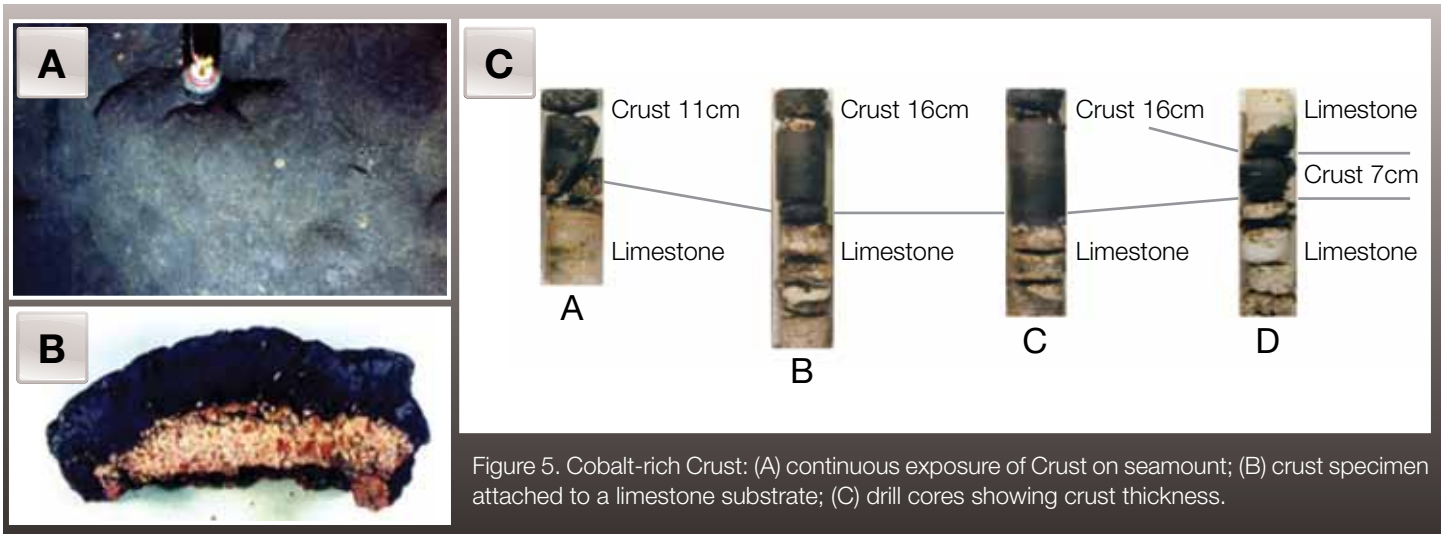


Figure 5. Cobalt-rich Crust: (A) continuous exposure of Crust on seamount; (B) crust specimen attached to a limestone substrate; (C) drill cores showing crust thickness.

Crust bearing seamounts can be huge, some as large as mountain ranges on continents. Only a few of the estimated 30,000 seamounts that occur in the Pacific, where the richest deposits are found, have been mapped and sampled in detail. Crusts generally form at the rate of 1-6 millimetres per million years. Drilling of selected crust bearing seamounts confirms variable crust thickness (Figure 5C) and aids resource estimation.

Summary of Deep Sea Minerals

A summary of the characteristics of the three major marine mineral deposits are tabulated below:

Element	Manganese Nodules	Cobalt-rich Crusts	Seafloor Massive Sulphides
Occurrence	Deep ocean basins	Summit and slope of seamounts as well as flanks of volcanic islands	Mid-ocean ridges, and fore-arc and back-arc basins
Form	Nodular and encrustations	Thin encrustation on the rock surface	Massive sulphide and oxide deposits on the seafloor and seabed sub-surface
Depth (m)	4,000 – 6,000	400 – 4,000	1,500 – 5,000
Major Minerals	Manganese, Iron	Manganese, Iron	Copper, Lead, Zinc
Minor Minerals	Nickel, Copper, Cobalt	Nickel, Cobalt, Platinum	Gold, Silver