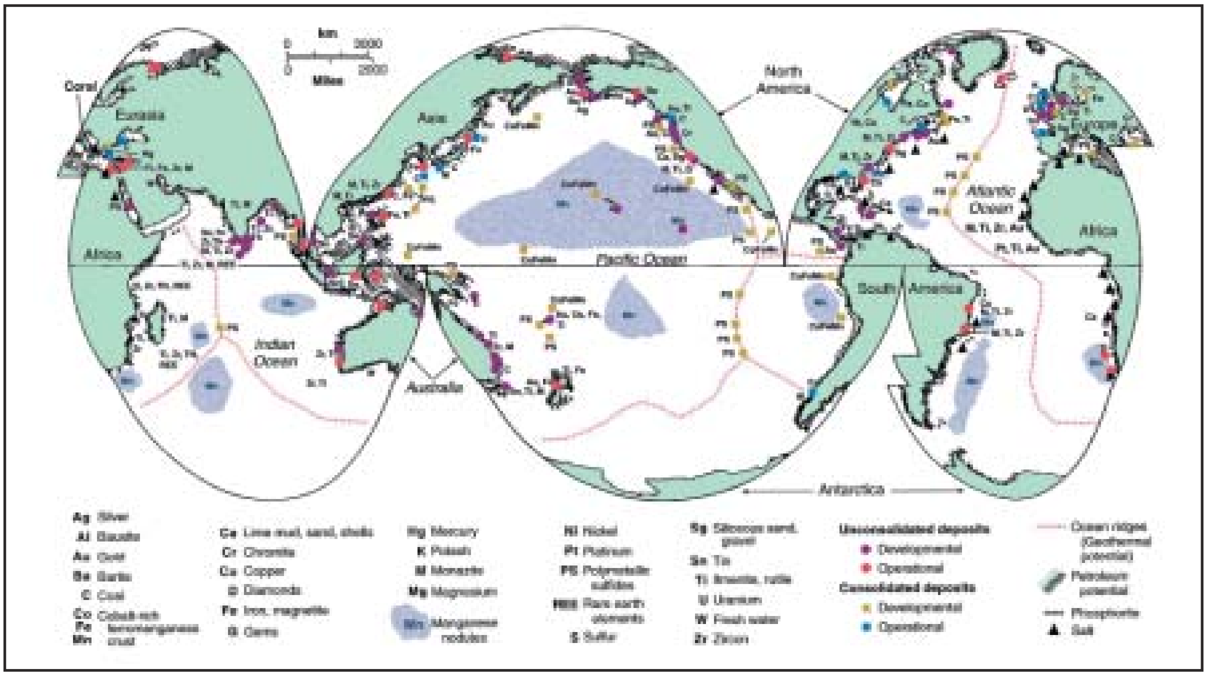
Marine Mineral Resources

- Polymetallic Nodules
- Cobalt-Rich Crusts
- Polymetallic Massive Sulphides

The recovery of minerals from the seabed and our knowledge of new sources of marine minerals have developed rapidly during recent decades, yielding significant economic returns and promising potentially valuable additions to the world's resource base. Commercial exploitation of solid marine minerals has so far been limited to deposits originating from mechanical and chemical erosion of rocks on continents and transported to the ocean primarily by rivers. These are found in relatively shallow offshore areas of the territorial sea and the 200-nautical-mile exclusive economic zone. The newly discovered resources, some of them richer than any land-based deposits, derive partly from land sources and partly from natural processes within and beneath the oceans, often in the deep seas beyond the limits of national jurisdiction.

Minerals derived by mechanical erosion from continental rocks are concentrated in placer deposits, which are sorted by water motion (waves, tides, currents) according to the varying density (mass per unit of volume) of the constituent minerals. These minerals contain heavy metallic elements (barium, chromium, gold, iron, rare earth elements, tin, thorium, tungsten, zirconium) and nonmetals (diamonds, lime, siliceous sand, gravel). Of the metals, gold is mined intermittently offshore from Alaska dependent on price (producing as recently as the 1990s) and tin continues to be mined at sites off Thailand, Myanmar and Indonesia. Of the nonmetals, a viable diamond-mining industry exists off Namibia and the adjacent coast of South Africa (in water depths to 200 metres, distance to about 100 kilometres), with recovery of 570,000 carats reported for 2001 by the principal producer (De Beers Marine). Sand and gravel are being mined from beaches and shallow offshore accumulations at many sites around the world for construction material (concrete) and beach restoration; these are the marine materials with the highest annual production value.

Of the non-solid minerals beneath the sea – fossil fuels derived from the decay and compression of land vegetation in areas that have since sunken below sea level – natural gas and petroleum are being exploited in shallow and deep water in national areas off the coasts of Africa, the Americas, Asia and Europe, with production valued at $100 billion annually. This compares to production of solid marine minerals totaling about $2 billion a year. Among the most promising of new fuel sources are methyl hydrates, a mixture of natural gas and water compressed into a solid by the cold and high pressures of the deep ocean floor in undersea basins of the continental margins. If recovery techniques can be perfected, estimated reserves could satisfy the energy needs of the world for centuries.



Global distribution of marine mineral resources known at this early stage of ocean exploration. {P. Rona, SCIENCE 299:673 (2003)}. Reprinted (abstracted excerpted) with permission from the American Association for the Advancement of Sciences.

The continuous input of materials dissolved by chemical weathering from continental rocks and transported into the ocean by rivers is considered adequate to meet future economic needs of several mineral types. One of these resources is phosphorite, which precipitates in the form of nodules and layers where seawater wells up from the deep ocean at continental shelves within the belt of the trade winds (30 degrees of latitude north and south of the equator). Phosphorite is used as an agricultural fertilizer by adjacent coastal states. Land supply of phosphorite originally deposited beneath ancient seas fulfills present needs.

Two metallic mineral resources of the deep seafloor incorporate dissolved metals from both continental and deep ocean sources. One of these consists of the golf-to-tennisball-size polymetallic nodules (nickel, cobalt, iron and manganese in varying concentrations). These nodules precipitate from seawater over millions of years on sediment that forms the surface of the vast abyssal plains underlying the deep ocean (water depth 4 to 5 kilometres). The most promising of these deposits in terms of nodule and metal concentration (combined nickel and copper at least 2 percent of weight) occurs in the Clarion-Clipperton Fracture Zone of the eastern equatorial Pacific Ocean between Hawaii and Central America, an area that has been allocated by the International Seabed Authority for exploration by several pioneer investors; another prospective area, similarly allocated, lies in the Indian Ocean.

Cobalt-rich ferromanganese crusts are the second of the two metallic mineral resources that incorporate metals from both land and sea sources. These precipitate from seawater as thin layers (up to 25 centimetres thick) on volcanic rocks of seamounts and submerged volcanic mountain ranges at water depths between 400 and 4,000 metres. The richest of these crusts lie within and beyond the exclusive economic zones of the island nations of the western Pacific. It is estimated that one seabed mine site could provide up to 25 percent of the annual global market for cobalt (used to make corrosion-resistant, light, strong metal alloys, and paints), contingent on the development of mining and refining technology.

Cut of a "chimney" IFREMER

"Smoker" IFREMER

Polymetallic massive sulphides are types of minerals discovered in the oceans in 1979 that were previously known only from deposits that have been mined on land since pre-classical times for copper, iron, zinc, silver and gold. Massive sulphides are deposited around seafloor hot springs (the most impressive are the black smokers) that are heated by magma (molten rock) upwelling beneath a submerged volcanic mountain range. This range, extending through all the ocean basins of the world, emerges in places as volcanic island chains. The magma cools, solidifies and creates areas of new seafloor that move like opposing conveyor belts at a rate of centimetres per year on either side of the submerged mountain range, in the process of seafloor spreading. As cold, heavy seawater descends several kilometres through the volcanic rocks that underlie the seafloor, the water is heated by the magma. It then expands and buoyantly rises, dissolving metals present in small quantities in the volcanic rocks, precipitating others from the surrounding seawater and concentrating the metals (copper, iron, zinc, silver and gold) as massive sulphide deposits beneath and on the seafloor (water depth 1 to 4 kilometres). With only about 5 percent of the seabed having been systematically explored, about 100 such sites have already been found along the submerged volcanic mountain range in deep basins of all the world's oceans and associated with volcanic island chains that border the western margin of the Pacific Ocean. The seafloor massive sulphide deposits are valuable as analogs guiding economic geologists as they seek out and mine ancient massive sulphides that were formed on the seafloor by similar processes and subsequently uplifted onto land. A site actively forming on the floor of the Bismarck Sea within the exclusive economic zone of Papua New Guinea was leased in 1997 from that Government by an Australian mining company and is under development for mining.

hot springs ecosystem

In addition to concentrating metals, the seafloor hot springs provide the chemicals used by microbes to generate energy at the base of a food chain that supports an ecosystem of newly discovered animal species living amidst the mineral deposits. This ecosystem has scientific and commercial value in terms of its role in sustaining biodiversity, elucidating the early evolution of life, and producing novel organic compounds useful in industrial and pharmaceutical applications. The coincidence of non-living and living resources poses the challenge to develop a regime that allows sustainable development of both resources while protecting the ecosystems.

The International Seabed Authority is engaged in the tasks of organizing and promoting the development of deep-sea mining in areas beyond national jurisdiction, and protecting the marine environment from any adverse effects. The function of controlling this potentially valuable industry was assigned to the Authority by the 1982 United Nations Convention on the Law of the Sea, now in force for 141 countries (end of 2002). The Authority has begun by adopting (in 2000) regulations covering prospecting and exploration for polymetallic nodules in the international area, which apply to all private and public entities under contract with the Authority. It is now working on a similar set of regulations for polymetallic sulphides and cobalt-rich crusts.