

## SECTION - B

### Popular and Review Notes

# Seamounts – Their Formation, Mineral Deposits, Biodiversity and Atmospheric Oxygen

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Imagine that you are onboard a pleasure cruise, standing on the deck and enjoying the calm blue sea. As the breeze soothes your body and soul you hear a rumbling sound and suddenly you are astonished to see a small island emerging from the sea right in front of your eyes. The cruise liner rocks and rolls and the passengers are bewildered and frightened to find hot rocks popping up and exploding and to hear the sizzling sound of hot lava as it contacts the warm sea water and steam rising in the vicinity. In October 1987 such a scenario occurred when an undersea volcano in the south-central Pacific Ocean erupted directly beneath a California-based research vessel. The eruption resulted in large bubbles of steam and gas that burst under the hull of the ship and shook the ship. Welcome to the world of underwater volcanic explosions and formation of seamounts and islands.

Of the several morphologic and tectonic features that characterise the floor of the seas and oceans around us, seamounts are fascinating. Seamounts are volcanic edifices located on the seafloor and are a few tens of metres to more than a kilometre in height. Based on the definition of the International Hydrographic Organisation (Intergovernmental Oceanographic Commission), a seamount is “a discrete (or group of) large isolated elevation(s), greater than 1000 m in relief above the sea floor, characteristically of conical form.” In certain instances, a seamount may break through the seawater and form islands, the best example being that of Hawaii, Bermuda, Azores etc. While at times the summit of a seamount or that of a sunken island gets flattened due to erosion and attain a flat top. This results in a ‘guyot’ (or Table mount) while ‘atolls’ form if a sunken seamount is covered by coral reefs. ‘Knolls’ have smaller elevations and a rounded profile than a

seamount. But generically, any conical or steep volcanic feature is referred to as a seamount and these may or may not be presently volcanically active.

For a number of reasons seamounts are of scientific interest. Seamounts serve as ‘windows’ to the earth’s mantle and help to understand the magmatic processes and products. The rocks of a seamount represent non-contamination with the crustal material and hence may indicate the composition of the mantle and core. Since a seamount is formed at areas of crustal weaknesses this could favour the formation of mineral deposits. Additionally, the ecosystem near a seamount is unique and helps in the dispersal and conservation of organisms.

This article expounds on (i) the production and distribution of seamounts in the world oceans (ii) the role of seamounts in the formation of mineral deposits and (iii) the influence of seamounts in the spatial variation of organisms.

### Distribution and Development

The actual number of seamounts in the world oceans is unknown. In the Pacific Ocean, seamounts are in thousands, in the Atlantic Ocean in hundreds while those in the Indian Ocean are intermediate. Seamounts can be mapped either by using satellite altimetry method or by ground truthing i.e., by undertaking oceanographic expeditions. During such expeditions, the technique used to locate the seamounts is mainly by sonar devices (multibeam mapping). Once a seamount is located than dredging (for rocks), CTD (Conductivity-Temperature-Salinity) measurements, and sampling for organisms are carried out. Besides these, Remotely Operated Vehicles (ROV), Autonomous Underwater



Vehicles (AUV) and Submersibles may also be deployed to examine a seamount in detail. As drilling through a seamount is an expensive and time consuming task, only a few have been drilled. Yet, drill samples are needed to understand the lithological zonations, if any.

Wilson (1963) proposed that the long chains of seamounts (Hawaiian-Emperor) may have formed as the tectonic plates move over a stationary 'hot spot' (a region ~2900 km below the oceanic crust where magma is produced), then the plates get 'punctured' and subsequently the hot ascending magma accumulate to form a seamount. But the concept of a hot spot has been challenged and also it is difficult to explain the formation of non-hot spot seamounts. Seamounts may develop from plumes to form near-axis seamounts (i.e., on the sides of active mid-ocean ridges, MOR, which are underwater mountain chains), off-ridge but related to plume and off-axis seamounts not formed by plumes. In the last case, several other mechanisms have been suggested namely, convective rolls, localised mantle flow, diffuse regional mantle upwelling and migration of volatiles from the low velocity zone of the asthenosphere.

The fact that there are thousands of seamounts indicates that volcanic activity on the sea floor has been wide spread since the geologic past and continues to be so. Lisitzin (1996) assumed that the maximum age of seamounts is 150 million years i.e., the Jurassic-Cretaceous period, the time when seamount production was initiated and their production peaked. He calculated that in 100 years only 0.05 seamounts would form. Based on an average height (1.5 km) he opined that about 50 million tons of basaltic magma is annually generated to form seamounts in the world oceans. Yet, this value is hundreds of times lower than the magma produced at MOR and constitutes ~10 % of MOR production rates. It is estimated that less than 400 seamounts have been sampled and of these hardly 25 % have been sampled in detail. Seamounts occur either as single entity, in clusters or in linear chains.

In short, the emplacement of seamounts depends on physico-chemical conditions, rate of ascension of the magma, environ of the magmatic melt, amongst others. Seamounts host a variety of rocks ranging from hyaloclastites, pillow basalts, alkali basalts and serpentinites. These petrological variations suggest the presence of multiple melting domains in the mantle.

### **Formation of Mineral Deposits**

In several regions the seafloor is profusely cracked and fissured and these are congenial for the dense sea water to percolate into the earth's interior. In regions where magma ascends, the cold sea water gets heated, thermally expands, becomes lighter and starts to rise. This heated sea water during its travel reacts with the rocks of the ocean crust and dissolves the metals in them to give rise to hydrothermal solutions. In course of time this hydrothermal solution (up to 400° C) concentrates the metals and deposits these as polymetallic sulphides, on and below the sea floor. The remaining metal-laden solution gets discharged through chimneys and vents as a 'black smoker.' Although hydrothermal activities are common along the MOR but sites of seamounts too are favourable for the formation of hydrothermal deposits as the oceanic crust around the seamounts tends to be weak. Generally, the hydrothermal deposits are sulphides of copper, zinc, lead, iron, etc. while silicates such as talc, barite, opal, chalcedony, nontronite and various native minerals (aluminium, gold, nickel, silver, etc.) are not uncommon. Besides these massive deposits, the sediments around the seamount would be enriched in several oxides, oxyhydroxides and silicates. In recent years emphasis is placed on the exploration and exploitation of cobalt that occur in ferromanganese crusts from seamounts.

### **Seamounts and Biodiversity**

Since the last four decades, marine biologists too have shown interest to study the seamounts as these are sometimes referred to 'oases' of prolific productivity (biodiversity) and biomass. Furthermore, the facts that (i) a high level of endemism is associated with seamount



ecosystems (ii) elevated biomass, unexpected biogeographic affinities, and/or altered species diversity compared to surrounding habitats and (iii) deep sea fishing trawlers has been shown to be highly destructive to seamount ecosystems; makes it imperative to understand the coupling between seamounts and biodiversity.

Seamounts possess an independent habitat with marked endemism and also sustain important ecological communities. In the 1960-70's, intensive studies and exploration of biological resources on seamounts were initiated by the erstwhile USSR in the world oceans. This was particularly undertaken to establish new deep sea fishing grounds. Subsequently, other countries not only developed fisheries on seamounts but also detailed the biodiversity around the seamounts. From a biological view point, to-date, less than 4 % of the seamounts have been investigated.

Since the HMS CHALLENGER expedition of 1872, a review of seamount biota and biogeography reported a total of 597 invertebrate species recorded from seamounts worldwide. Most reports, based on a single taxonomic group, were extremely limited. For instance, only five seamounts of the estimated more than 30,000 seamounts in the world's oceans accounted for 72 % of the species recorded and only 15 % of the species were considered potential seamount endemics.

The distribution pattern of biological communities that have little overlap at even a few kilometres apart is consistent with Johannesson's hypothesis that many taxa adapted to seamount conditions limit their dispersal to maintain their populations. This is because of the generally small size of seamounts, the considerable distance between them and their unique oceanographic environment. Circulation cells near the seamounts facilitate recruitment of biological species within relatively close proximity.

The highly localised distribution of many seamount species has a great significance for their conservation. Seamount communities are extremely vulnerable to the impacts of fishing; their limited fixed habitat, the extreme longevity of many

species of the order of 100 years and more and the apparent limited recruitment between seamounts. These factors add to the uncertainty of recovery from trawling, which sweeps away the benthic epifauna community. The global status of seamount benthic communities is unknown; however, the restricted distribution of many benthic seamount species greatly increases the threat of extinction and may require that conservation and protection of seamount communities be undertaken on a local scale.

In 2002, the United Nations General Assembly impressed upon its associated agencies and research institutions to "consider urgently ways to integrate and improve on a scientific basis the management of risk to marine biodiversity of seamounts and certain other underwater features within the framework of the United Nations Convention on the Law of the Sea."

### **Seamounts and Atmospheric Oxygen**

It is an enigma as to when and how did Mother Earth get the oxygen that we breathe. Prof. L. R. Kump (Penn State University) and his group reported that prior to 2.5 billion years ago, the Earth's atmosphere lacked oxygen. Interestingly, biomarkers in rocks 200 million years older than that period show oxygen-producing cyanobacteria released oxygen at the same levels as today. The oxygen produced then, had to oxidise the soils and form red beds but such occurrences were negligible during the Archaean. The ancient Earth should have had an oxygen atmosphere but something was converting, reducing, the oxygen and removing it from the atmosphere. Prof. Kump suggested that submarine volcanoes, producing a reducing mixture of gases and lavas, effectively removed oxygen from the atmosphere and this was bound to minerals.

Profs. Kump and M. E. Barley (University of Western Australia) examined the geologic record from the Archaean and the Palaeoproterozoic for evidences of volcanoes. They found that during the Archaean there were hardly any terrestrial volcanoes in contrast to a high population of submarine ones. The Palaeo-Proterozoic witnessed abundant terrestrial volcanic activity in



tandem with submarine events. Subaerial volcanoes increased after 2.5 billion years ago and did not remove oxygen from the air. A co-existence of these two types of volcanoes but dominated by terrestrial ones, permitted oxygen to exist in the air. The researchers, after studying the ratio of submarine to subaerial volcanoes vis-à-vis the geologic time, opined that because submarine volcanoes erupt at lower temperatures than terrestrial volcanoes, they are more reducing. They inferred that as long as the reducing ability of the submarine volcanoes was larger than the amounts of oxygen created, the atmosphere had no oxygen. When terrestrial volcanoes began to dominate, oxygen levels increased.

The above extract from the 3<sup>rd</sup> Sep. 2007 issue of Science Daily, underscores the important role of underwater volcanic eruptions and their influence in controlling the oxygen level in the atmosphere during the past.

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### CONCLUSION

There are several unanswered aspects concerning the seamounts some of which are: the link between morphology of and volcanism at seamounts, controlling factors for the ascension of magma from different depth to produce seamounts of varying heights, recovery of heterogeneous rocks from certain seamounts, seamounts as representative of the gradual evolution of the mantle with time, congeniality of a seamount site for hydrothermal activity and the role of seamounts in biodiversity. To a marine scientist the discovery of a new seamount or newer details from a known seamount is always welcome.