IS THERE A CONTINENT HIDDEN BELOW THE ARABIAN SEA?

Zealandia has caught the imagination of geoscientific world and reams of paper and netspace has been dedicated to announcing arrival of this new 'continent' on the block. Geoscientists have been working hard and long to identify the signatures that could mark a sunken landmass as a continent. They are now quite confident of their interpretation, based on different geological and geophysical parameters, that Zealandia is indeed a continent.

This appreciably vast landmass, which is now hidden under the Pacific Ocean, fulfills all the criteria required of a continent. The first criterion is the continent needs to be taller than its surrounding region. This parameter is based on the thickness and density of the oceanic and continental crust. The principle of isostasy states the dense material has smaller roots and the less dense has deeper roots. Secondly, it should have different kinds of rocks ranging from igneous to metamorphic to sedimentarycutting across timelines from the oldest to the youngest (oceanic crust predominantly has only igneous (basaltic) rocks). The third criterion makes it mandatory for the continent to have a thicker crust than the oceanic. Lastly, the continental plate boundaries need to be quite distinct and well defined. The micro-continents, normally fail on this last count. They do not have distinct geological boundaries.

Apart from the fact that there will be rejigging of the relevant subject syllabi, does the existence of Zealandia mean anything substantial? Does it have any economic importance? Or is this announcementan excuse to mug up the name of yet another continent? It will also entail redrawing of all the geological and geophysical maps prepared till date. Though there is no official body to declare a mass of land to be a continent, or not, like the one that exists for planets, the constant refrain for upgrading nomenclature of crustal entities will soon bring in this kind of a geological organization. Pluto's downgrading from a planet to microplanet was effected by an astronomical agency.

With respect to the new physiological and morphological changes in the earth's existing map, it must be said that it will not be just an academic exercise. This will not be a hollow ordeal carried out to make the existing maps more attractive and color coded. It has wide geological, geophysical and economic significance. It will also shed a light on the deformative processes that

change the crustal configuration leading to demarcating zones of disaster causing mechanisms like volcanoes and earthquakes, or processes that spawn oil and natural gas resources. The existence of the current world civilization is intricately related to both, the natural disasters, and resources. Hence, these kinds of studies are very important, whose import may not be felt instantly.

Zealandia is a stretch of landmass lying between the Pacific and Australian plates. The name Zealandia was first proposed by Luyendykin 1995 containing a mass of almost 5 m km^2 tucked under the deep waters of Pacific Ocean. The acknowledgment of this alleged new continent will force the geoscientific community to look at the dynamics prevailing in this region, and elsewhere in the world, differently and innovatively. Earlier, this continent was 'inferred' to be many different things by many different geoscientists,just so that the reconstruction of continents could be a smooth and seamless affair. But, from now on, the way in which the tectonic plates will be looked at will differ considerably.

Some of the geological formations that were identified in west Antarctica were seen to be present in Zealandia. These two were fused together in some point of time. But these formations were not found in east Antarctica and Australia.

To explain this similarity, probably erroneous scenarios were projected by the geoscientists. The plate tectonic dynamics were invoked to explain the thinning of Zealandia crust which may have seemed valid then, but now will be highly contentious. Scientists will have to overhaul their take on the dynamics of this region. The processes that were supposed to have existed here, may not be operative the way they were imagined earlier. This vast landmass lies almost completely submerged under the oceanic realm,whichwas lacerated from its parent body, and is still unfragmented. This is an enigma that needs better explanation.The search for this clarification will open up a new window through which to view the world.

Does anything of this sort exist near our own country? Do we have a continent hidden beneath the Indian Ocean? The Indian sub-continental landmass is engulfed on three sides by large volume of briny water that has kept hidden some of the complex geology of the area. The Bay of Bengal receives vast amounts of eroded material from the Himalayan terrain. The same is true of the Arabian Sea. It, too, receives eroded material from the Himalayas, but not to the extent that

the Bay of Bengal gets. The Arabian Sea, however, is more exciting and diverse off the Bombay – Cochin coastline. The western Ghat dynamics are tied to the western continental margin of India. In fact, the migratory path of Indian subcontinent is traced through the tell-tale signs left behind in the form of ridges and basins like the Ninetyeast ridge, Laccadive ridge, Laxmiridge to name just a few. The elevations and depressions mapped in the Indian Ocean, through various geophysical and geochemical means,are related to plate tectonic dynamics of the region.

The western continental margin of India is studied vigorously for its natural resources potential. The economic benefits that can accrue, have been cashed on by many private and government agencies, by harnessing the commercial value of hydrocarbon deposits.

But let us begin from the start. The western continental margin of India has undergone episodic deformation due to tectonic activity. This has been going on right from the time of its formation till date. The deformations caused by the moving landmasses, thinning crust, buoyant magma and other attendant processes has given rise to a complex geometry of elevations and depressions in the Indian Ocean, more specifically in the area adjoining the western continental margin of India.

The western continental margin of India came into being because of the break-up of Indian subcontinent, initially from Madagascar, and later from Seychelles. During this pulling apart of rigid plates,in the timeframe spanning from ~80 to 60 million years ago, a number of structural features were newly carved out. This has given rise to diverse structures in the Sea spanning from Bombay to Goa to Cochin.

Beyond and below these places are situated the Lakshadweep islands that seem to be a continuous chain extending to the Maldives group of islands.Though these set of islands seem to be continuous, they exhibit different physical and geochemical characteristics from one place to another. One of the curios features of the Lakshadweep block of landmass is that it is thicker than the surrounding crust. This has led the savants to attribute the origin of Lakshadweep islands to hotspot activity or due to thinning of the continental crust. The debate has been going on for very long.

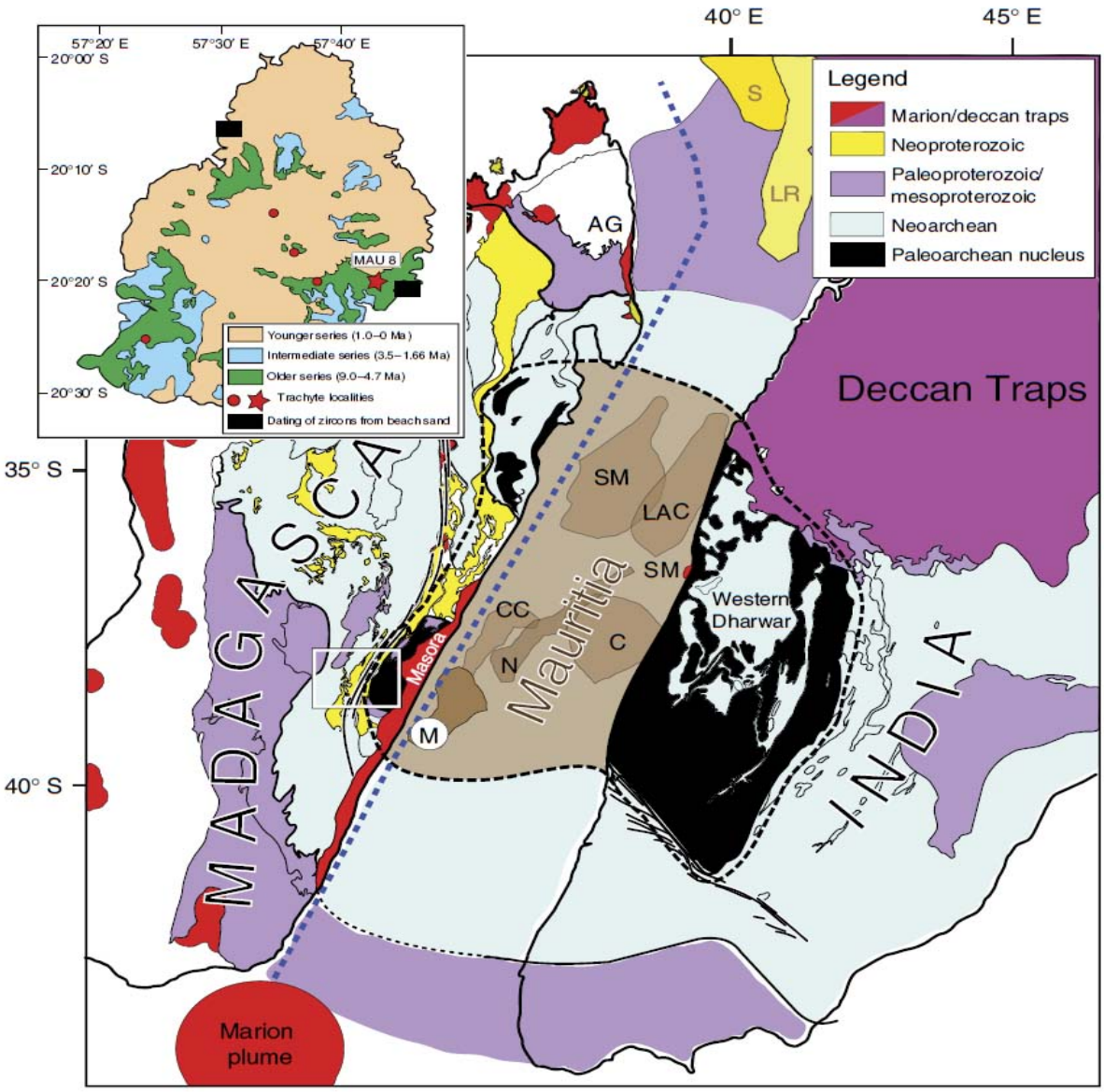
A team of geoscientists from Indian Institute of Geomagnetism, Navi Mumbai, set about to find an answer to this long standing problem. They looked closely at the accumulated data over the

yearswith a fresh and novel perspective. They applied advanced statistical and mathematical toolsby developing new techniques that had the potential to scour out latent information from this treasure trove of data. Through their innovative approach, they found Lakshadweep ridge,lying north of 8.5^{o}N, is continental in nature. They also noticed most of the NE-SW trending geostructuresare related to this ridge. These structures had formed due to reactivation of the earlier existing faults when the Indian plate moved over the Reunion plume.

They also inferred the Lakshadweep region was a part of Dharwar group of formations, which later rifted away with Madagascar from India.

This idea has now found support from other independent investigations which have provided direct evidences. They have found basaltic flows and rocks (Deccan basalts) are directly sitting on the basement formations of these islands. Another major study on Zircons of Archaean age (oldest elements found on earth), which were found in rocks formed from hotspot magma, has indicated the presence of very old continental crust beneath the Mauritius Island. This is one discovery that can add one more continent, apart from Zealandia, to the existing pantheon. Scientists are now confident that there are many different sized pieces of “undiscovered continent” under the Indian Ocean. This new continent has been christened as “Mauritia”. Our own Lakshadweep ridge is a part of this Mauritia.

Zealandia has a young sister in Mauritia.



The above figure (from Ashwal et al, 2017) shows the simplified geology of Madagascar and India prevalent around 90 to 85 million year ago. Mauritius, denoted by ‘M’, has been placed at a likely location just before it broke up. This Mauritia continent contains different entities like Saya de Malha, denoted by SM; Chagos, denoted by C; Cargados-Carajos Banks, denoted by CC; Lakshadweep denoted by LAC; and Nazreth denoted by N.

The blue stippled line indicates the places where the continent was lacerated during the Cretaceous time in the mode of strike-slip faulting containing Analava gabbro, marked AG, of

91.6 million year age; Laxmi Ridge, LR; Seychelles, S; St. Mary rhyolites, SM, all of 91.2 million years of age.

It is estimated that a large lava extrusion event, related to Marion plume, took place between 92 and 84 million years ago.

Article written by Praveen B. Gawali based on the following papers and additional inputs from Dr. Anand S. P.

- Nisha Nair, S.P. Anand, MitaRajaram. 2013. Tectonic framework of Laccadive Ridge in Western Continental Margin of India. 2013. Marine Geology, 346, 79–90.
- Nick Mortimer, Hamish J. Campbell, Andy J. Tulloch, Peter R. King, Vaughan M. Stagpoole, Ray A. Wood, Mark S. Rattenbury, Rupert Sutherland, Chris J. Adams, Julien Collot, and Maria Seton. 2016. Zealandia: Earth's Hidden Continent. GSA Today, v. 27, doi: 10.1130/GSATG321A.1
- Lewis D. Ashwal, Michael Wiedenbeck and Trond H. Torsvik. 2017. Archaean zircons in Miocene oceanic hotspot rocks establish ancient continental crust beneath Mauritius. Nature Communications. DOI: 10.1038/ncomms14086