



P-343

## Passive Continental Margin Around East Coast India

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### Introduction:

The definition of the **continent-ocean boundary** at passive continental margins has proved to be an elusive task. Multichannel long offset seismic reflection profiles on many passive margins have revealed the presence of remarkable suites of arcuate reflectors, dipping seaward to form a wedge-shaped structure. Their general characteristics and velocity structure suggest that they may be largely volcanic in nature, but there is no agreed upon model for their origin. Nevertheless it is generally thought that they lie at or close to the boundary between continent and ocean, and as such they are extremely important structural markers that may yield important evidence concerning the structure and evolution of passive margins.

A **passive margin** is the transition between oceanic and continental crust which is not an active plate margin. It is constructed by sedimentation above an ancient rift, now marked by transitional crust. Continental rifting creates new ocean basins. Eventually the continental rift forms a mid-oceanic ridge and the locus of extension moves away from the continent-ocean boundary. The transition between the continental and oceanic crust that was originally created by rifting is known as a passive margin

### Volcanic passive margins (VPM):

Volcanic passive margins (VPM) and Non-volcanic passive margins are the two forms of transitional crust that lie beneath passive continental margins that occur on Earth as the result of the formation of ocean basins via continental rifting. Initiation of igneous processes associated with volcanic passive margins occurs before and/or during the rifting process depending on the cause of rifting. There are two accepted models for VPM formation: hotspots/mantle

plumes and slab pull. Both result in large, quick lava flows over a relatively short period of geologic time (i.e. a couple of million years). VPM's progress further as cooling and subsidence begins as the margins give way to formation of normal oceanic crust from the widening rifts

Despite the differences in origin and formation, most VPMs share the same characteristics:

- 4 to 7 km thick basaltic and frequently silicic sub aerial flows; dike swarms and sills running parallel to continent-facing normal faults
- 10 to 15 km thick bodies in the lower crust (HVLC) show high seismic P-Wave velocities, between 7.1 and 7.8 km/s which lie under the transitional crust (crust between continental crust and oceanic crust)
- Seaward Dipping Reflector (SDR) series: Inner SDR's overlay transitional continental crust. They are composed of varying mixtures of subaerial volcanic flows, volcanoclastic and non-volcanic sediments which range from 50-150 km wide and are 5-10 km thick. Outer SDR's overlay transitional oceanic crust are composed of submarine basaltic flows which range from 3 to 9 km thick

### Global Distribution of Passive Margins

The distribution of known volcanic margins is shown on the graphic to the right. Many of the margins have not been thoroughly investigated and more passive margins are identified as volcanic from time to time.

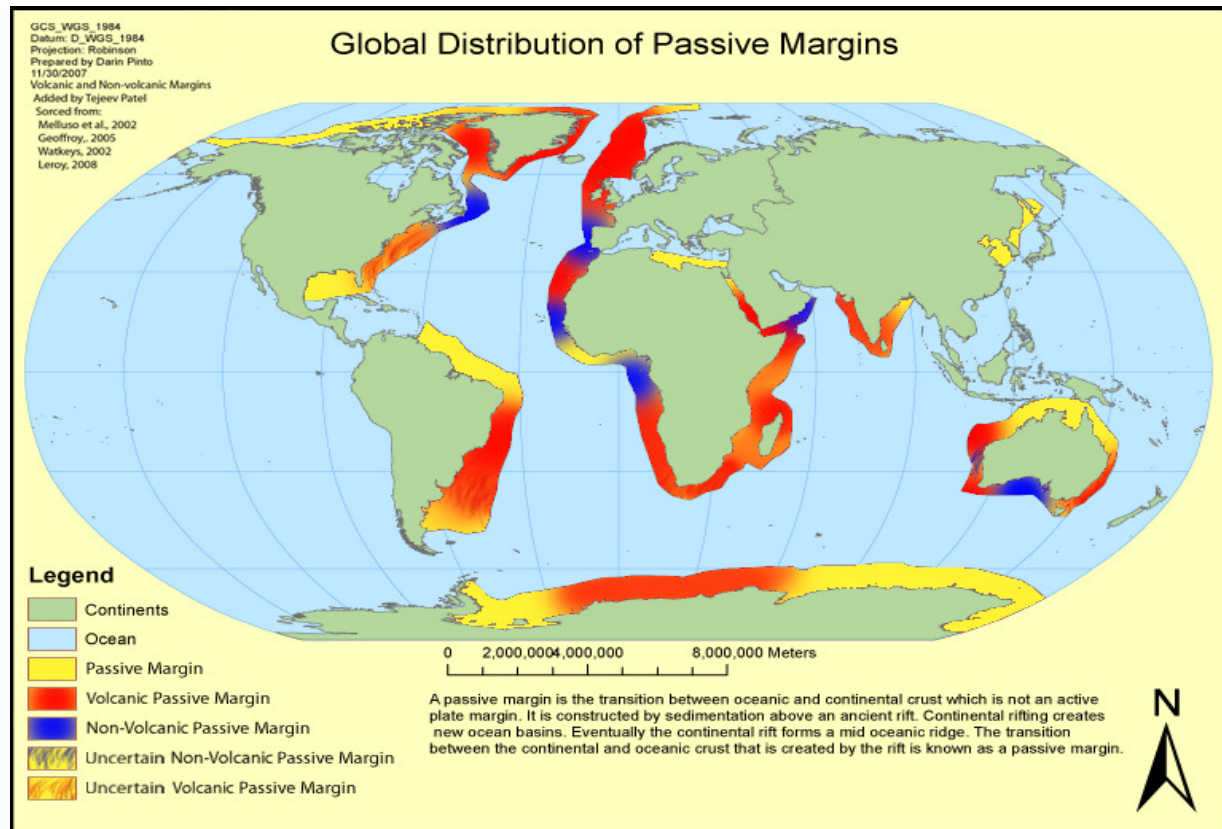


Fig.1: Map showing the distribution of Earth's passive margins with known volcanic and non-volcanic margins distinguished. The margins are marked with color masks where the darkest blues and reds are non-volcanic and volcanic passive margins, respectively.

### Active vs. Passive Margins

This refers to whether a crustal boundary between tracts oceanic and continental crusts is boundaries of plates or not. Active margins are found on the leading edge of a continent where subduction occurs. These are often marked by uplift and volcanic mountain belts on the continental plate, and by island-arc chains

(Andaman island arc) on the oceanic plate. Less often there is a strike-slip fault, as is defining the southern coastline of W. Africa. Most of the eastern Indian Ocean and nearly all of the Pacific Ocean margin are examples of active margins.. Active subsidence, sedimentation, growth faulting, pore fluid formation and migration are all very active processes on passive margins. Passive margins are only passive in that they are not active plate boundaries.



## Bathymetry of Typical Passive Continental Margin

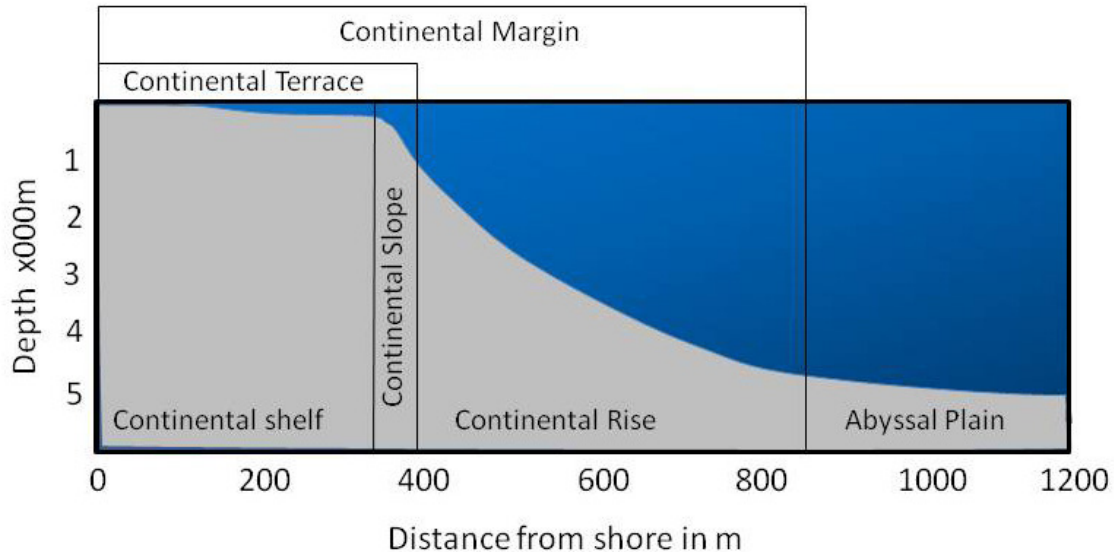


Fig.2: Bathymetric profile across a typical passive margin where vertical scale is greatly exaggerated relative to the horizontal scale.

Passive margins consist of both onshore coastal plain and offshore continental shelf-slope-rise triads. Coastal plains are often dominated by fluvial processes, while the continental shelf is dominated by deltaic and longshore current processes. The great rivers (Brahmaputra, Ganga, Mahanadi, Krishna-Godavari Amazon, Congo, Nile, Yellow, Yangtze, and Mackenzie rivers) drain across passive margins. Extensive estuaries are common on mature passive margins. Although there are many kinds of passive margins, the morphologies of most passive margins are remarkably similar. Typically they consist of a continental shelf, continental slope, continental rise, and abyssal plain. The morphological expression of these features is largely defined by the underlying transitional crust and the sedimentation above it.

Passive margins defined by a large fluvial sediment budget and those dominated by coral and other biogenous processes generally have a similar morphology. In addition, the shelf break seems to mark the maximum Neogene lowstand, defined by the glacial maxima. The outer continental shelf and slope may be cut by great submarine canyons, which mark the offshore continuation of rivers.

At high latitudes and during glaciations, the nearshore morphology of passive margins may reflect glacial processes, such as the fjords of Norway and Greenland.

### Rifted Passive Margin

The main features of passive margins lie underneath the external characters. Beneath passive margins the transition between the continental and oceanic crust is a broad transition known as transitional crust. The subsided continental crust is marked by normal faults that dip seaward. The faulted crust transitions into oceanic crust and may be deeply buried due to thermal subsidence and the mass of sediment that collects above it. The lithosphere beneath passive margins is known as transitional lithosphere. The lithosphere thins seaward as it transitions seaward to oceanic crust. Different kinds of transitional crust form, depending on how fast rifting occurs and how hot the underlying mantle was at the time of rifting

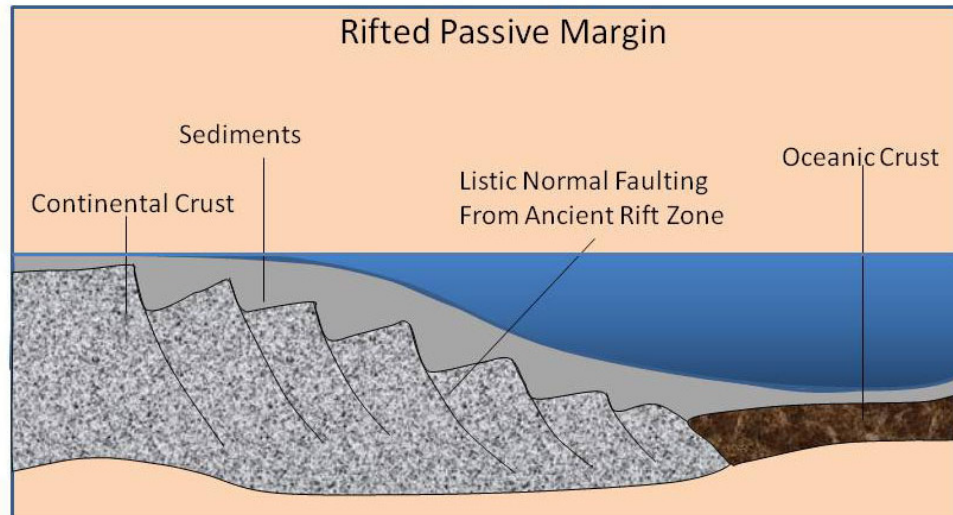


Fig.3: Transitional crust composed of stretched and faulted continental crust where vertical scale is greatly exaggerated relative to horizontal scale.

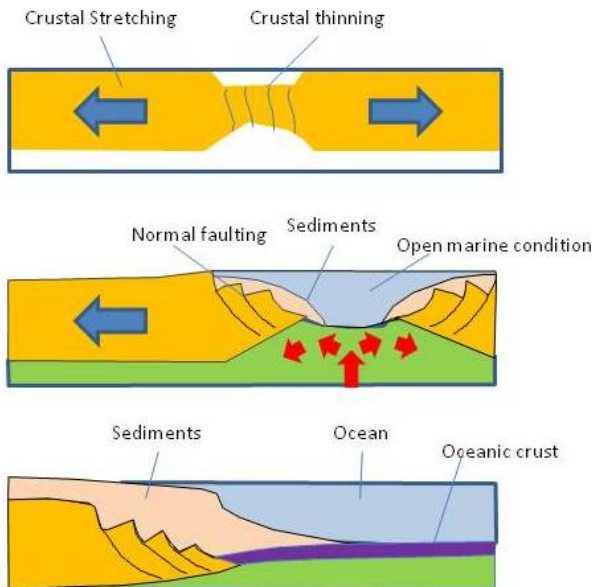


Fig.4: There are three main stages in the formation of passive margin

Volcanic passive margins represent one endmember transitional crust type; the other endmember (amagmatic) type is the rifted passive margin. Volcanic passive margins they also are marked by numerous dykes and igneous intrusions within the subsided continental crust. There are typically a lot of dykes formed perpendicular to the seaward-dipping lava flows and sills. Igneous intrusions within the crust cause lava flows along the top the subsided continental crust and form seaward-dipping reflectors.

1. In the first stage a continental rift is established due to stretching and thinning of the crust and lithosphere by plate movement. This is the beginning of the continental crust subsidence. Drainage is generally away from the rift at this stage.
2. The second stage leads to the formation of an oceanic basin, similar to the modern Red Sea. The subsiding continental crust undergoes normal faulting as transitional marine conditions are established. Areas with restricted sea water circulation coupled with arid climate create evaporite deposits. Salt has low density so this later may migrate upwards as salt domes. Crust and lithosphere stretching and thinning are still taking place in this stage. Volcanic passive margins also have igneous intrusions and dykes during this stage.



## Passive Continental Margin Around East Coast India



- The last stage in formation happens only when crustal stretching ceases and the transitional crust and lithosphere subsides as a result of cooling and thickening (thermal subsidence). Drainage starts flowing towards the passive margin causing sediment to accumulate over it.

### Present Study:

The recently acquired long offset seismic data by GXT along Eastern Coast of India has shown occurrence of seaward dipping reflectors in the strike lines. The location map is shown in Figure -6.

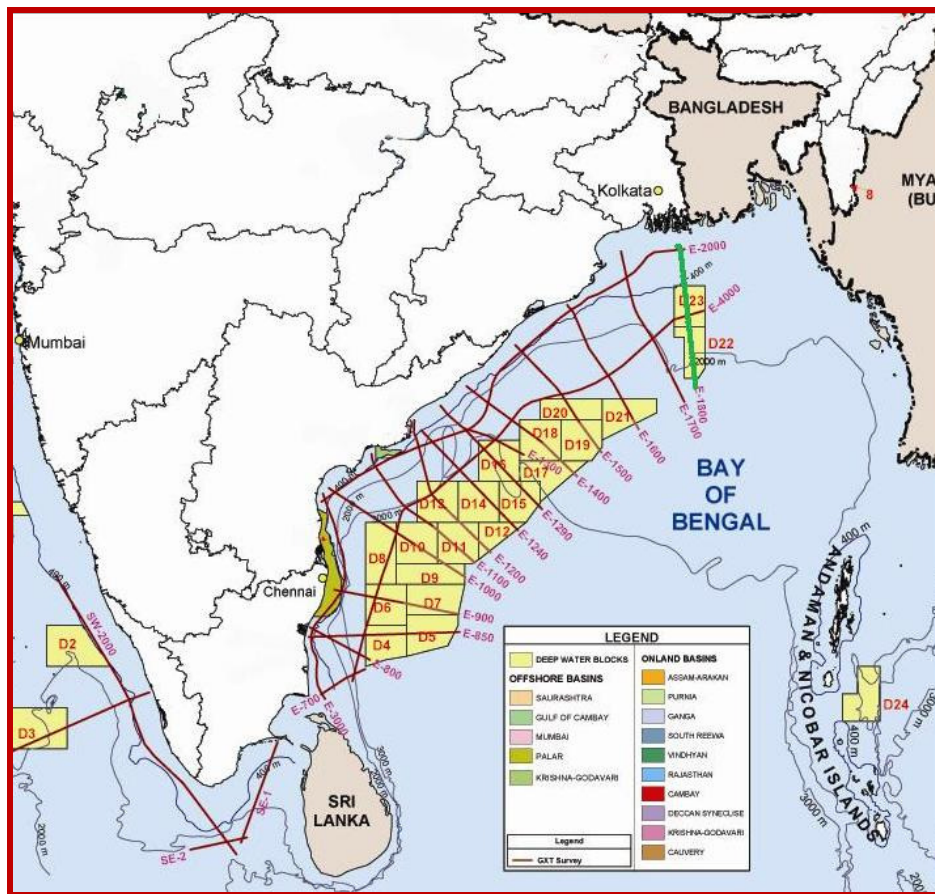


Fig.5: The Seismic line E-1800 (green line) which has shown prominent seaward dipping reflectors near Mahanadi delta.



## Passive Continental Margin Around East Coast India

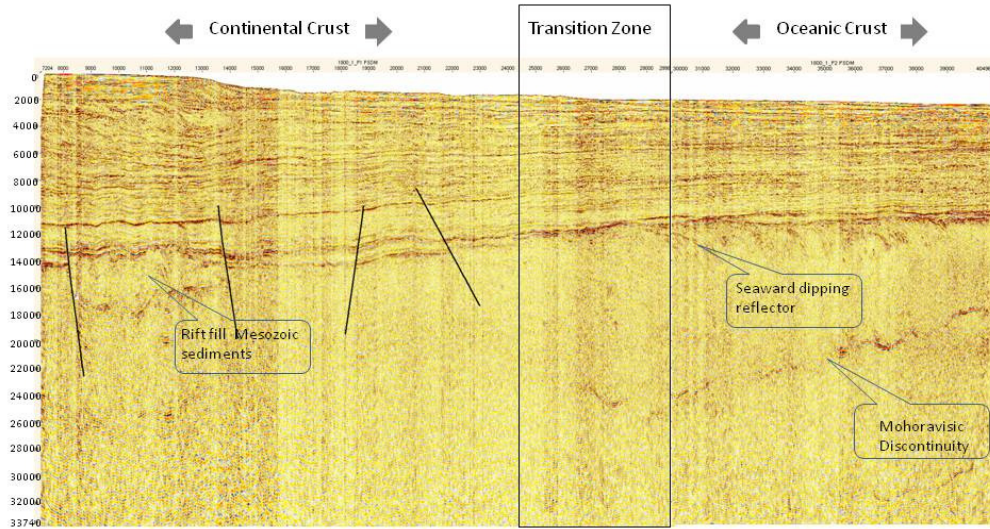


Fig.6: Seismic Line E 1800 along Indian East Coast showing Seaward Dipping Reflectors (SDR)

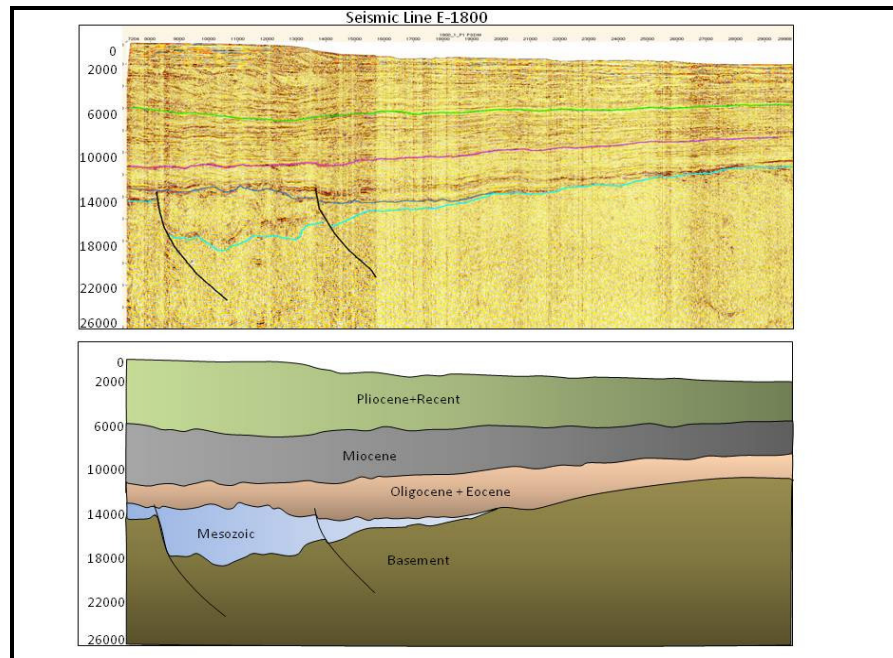


Fig.7: Seismic Section depicting Transition zone between Continental Crust & Oceanic Crust



## Passive Continental Margin Around East Coast India



Extrusion of lava took place in the surface as the plates move apart. As the plates move further more layers are extruded followed by subsidence of layers due to accumulation of heavier Fe<sup>++</sup> & Mg<sup>++</sup> rich quickly chilled lava put an overburden weight especially around extrusion point causing the layers to “dip”, This phenomenon is shown above in different stages of rift formation clearly depicted in accompanied seismic section where the reflectors are increasingly dipping seaward.

The accommodation space created this way has given entry to the basin fill sediments to get deposited. These sediments often having high TOC % and VRo values and are kitchen to hydrocarbon trapped in updip seals as in the case of several discoveries in offshore Cretaceous basins of Indian east coasts in and around NEC, Mahanadi and KG deltas.

### Economic Significance

Passive margins are important reservoirs of many minerals including oil and gas, Basins associated with collision zones and subduction zones are where most of the remaining giant oil fields are found. Passive margins are petroleum storehouses because these are associated with favorable conditions for accumulation and maturation of organic matter. Early continental rifting conditions led to the development of anoxic basins, large sediment and organic flux, and the preservation of organic matter that led to oil and gas deposits. Crude oil will form from these deposits. These are the localities in which petroleum resources are most profitable and productive. Productive fields are found in passive margins around the globe, including the Gulf of Mexico, western Scandinavia, Western Australia, Cambay Basin, India and the East Coast Extended Basin presently under discussion.

### Conclusion:

The transition between oceanic and continental crust i.e. a passive margin is not an active plate margin and is originally

created by rifting. However, mantle plumes result in large, quick lava flows over a short period of about a couple of million years. While cooling and subsidence begin as the passive margins give way to formation of normal oceanic crust from the widening rifts, magmatic plume activities cause seaward dipping reflectors and may be used to demarcate continental and oceanic crust margin.

Presently the seismic data is confined to Exclusive Economic Zone (EEZ) where only on limited seismic profile SRD can be visible, which may be in deeper part in other area and extended beyond the EEZ. With more and more data available for studies, a robust geological model can be built up to demarcate continental and ocean basin margin along East coast of India. Detailed geological studies of additional fresh 2D or 3D seismics, with the help of Seaward dipping reflectors, would likely to reveal some more passive margins as well as suitable locales of hydrocarbons in the basin fill sediments ( Fig. 7).

### References

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