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What are volcanic passive margins? A discussion based on seismic and field examples

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Volcanic or magma-rich passive margins are continental margins whose underlying rift basins, developed during the stretching and thinning phases that affected the continental crust before breakup, are totally or predominantly filled by volcanic and volcanic-derived rocks. The type of magma is usually fissural tholeiitic basalts, eventually bi-modal basaltic-rhyolitic. This is in strong contrast with the definition of sedimentary or magma-poor passive margins, whose rift basins are predominantly filled with sedimentary rocks. As the name states, magma-poor margins may display a certain amount of magmatism, but which is clearly secondary with respect to the dominant sedimentary nature of the syn-rift filling. These are two end-members in the classification of passive margins, and as such, transitional members represented by passive margins displaying characteristics of both extremes are recognizable. The significant difference in the nature of the syn-rift strata gives rise to strikingly different seismic facies in seismic sections that cross the entire width of passive margins, allowing a relatively easy visual distinction between the end-members, as well as of the transitional members. Typical growth volcanic strata dip seawards and fill grabens controlled by landward dipping listric faults, giving rise to the well known laterally accreted wedges of seaward-dipping reflectors (SDR). The amount of magmatism in volcanic margins is so high that it impacts a large area surrounding the continental margin, thus, also easing the recognition of this end-member through the analysis of the neighboring surface geology. Volcanic margins are characterized by Large Igneous Provinces (LIPs) that present pre-rift (lava deltas, tabular lava flows, trap-stage), syn-rift (seaward-dipping growth strata, extrusive centers, SDR-stage) and post-rift (volcanos, punctual lava flows) magmatism. Breakup of the continental crust takes place at the climax of the SDR-stage. Volcanism is strongly and gradually diminished over the separated continental crust while it continues in the newly formed spreading ridge feeding the laterally growing (also as SDR) tabular oceanic crust.

According to the soft-point model of plate breakup developed by Laurent Geoffroy (2005), volcanic passive margins are mantle plume related. They are generated in continental crust positioned above or in the near vicinities of the magma-invaded lithosphere. The large volumes of melted mantle intrude the upper mantle and the crust, erupting onto the surface creating the LIPs. If a mega-continent is impinged by several mantle plumes and later broken apart as a result of their activity, volcanic margins will develop in the vicinities of the plumes (soft points) and magma-poor margins will develop in the connecting areas far from the plumes (hard points). Litosphere becomes so weakened by the thermal anomaly that it breakups much more quickly (volcanic margins) than in the hard areas (magma-poor margins). Transitional margins, with characteristics of both end-members, develop when the soft points approach the hard points.

In the South Atlantic Ocean, the Pelotas Basin is a typical volcanic passive margin while the Santos, Campos and Espírito Santo Basins are examples of magma-poor passive margins. The Sergipe-Alagoas, Potiguar and Ceará Basins are examples of margins displaying characteristics of both sedimentary and volcanic margins.