

Chapter 2

Continental Margins in the Global Context

Abstract As highly significant features of major order at the lands–oceans edge, continental margins play an exceptional role in the Earth system. They are relevant for understanding the continental drift and the birth of oceans, the endogenous and exogenous processes that regulate the planet evolution, the present and past climatic and oceanographic changes, and the carbon cycle and biogeochemistry of the Earth. On this basis, the importance of those features at a global scale is discussed. This chapter also provides the basic definitions needed for understanding the concept of continental margins.

Keywords Continental margins • Continents-oceans boundary • Source-to-Sink • Sedimentary cycle • Sea-floor spreading • Ocean circulation

Continental margins are complex physiographic, geological and biological environments in the transition zone between continents and oceans. The concept of continental margin is closely related to the definition of the boundary between continental and oceanic realms. Although the determination of such a boundary seems an easy matter, complexity soon arises. The shoreline (or “edge of the land,” Bascom 1980) is the line of demarcation between the water and the exposed beach (Komar 1976). However, this line simply represents an “instantaneous” position since it changes at a very short—seconds—(waves), daily (tides), yearly (seasonal) and decades (short climatic cycles) scales if the human view point is considered, but also at a geological scale encompassing thousands or millions of years (different orders of sea-level fluctuations, isostasy and tectonism).

Under these considerations it becomes evident that at a large timescale—as is usually the time-frame involved in paleoenvironmental/paleoclimatic reconstructions—a transition zone exists between continents and oceans where the sea–land border has shifted, and the soil and subsoil at each side of the border can share characteristics of both of them, as a consequence of several major facts. (1) Flooding by marine waters of inland regions close to the seashore in recent times of the Earth history (Holocene sea-level transgression) with consequent draping of older continental features by marine sediments, so giving origin to the

presently emerged “coastal plains.” (2) Exposure of the present seafloor to subaerial conditions during the pre-Holocene sea-level retreat, with consequent development of continental conditions (and hence deposition of terrigenous sediments transported by fluvial, eolian, glacial or any other continental process, and even soils’ development) on the present continental shelf. (3) Delivery of terrigenous sediments offshore by marine-related processes, particularly during sea-level retreats, toward deeper, never-exposed sea bottoms of the continental slope and beyond. These considerations have already been explained in more detail by Duxbury (1971) among others. (4) Influence of tectonic and/or isostatic factors that added complexity to the changing position of the shoreline; in this sense, some authors (e.g., Kennett 1982) define continental margins as exclusively related to endogenous factors associated to the Earth deep structure, by saying that they mark the transition between oceanic (dense) and continental (light) crusts (zone of deepening of the Mohorovicic discontinuity) balanced by isostasy.

Therefore, an extremely complex transitional region develops between the “pure” continental and ocean realms, and this region is the “continental margin” (Fig. 2.1), which comprises coastal plains, shelf, slope and rise (Kennett 1982) (Fig. 2.2). Continental margins are considered second-order morphological features

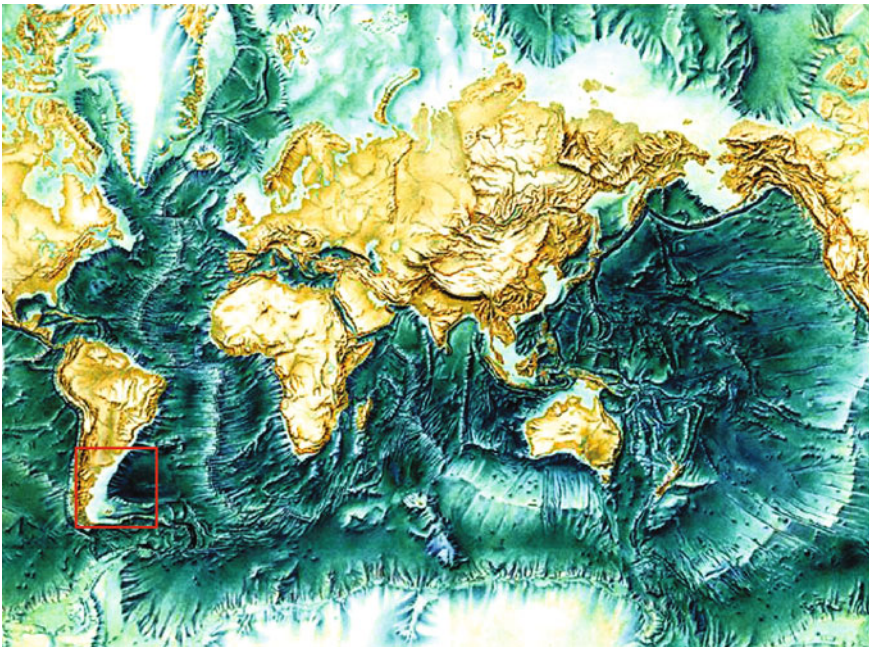


Fig. 2.1 Global map with details of the ocean floor features. The region of the Argentina Continental Margin is indicated by the red square. Observe the “lighter” colors around the continents, indicating the shallowest environments (shelf and part of the slope) in the continental margins. Compare the extension of the Argentine margin respect to others continental margins

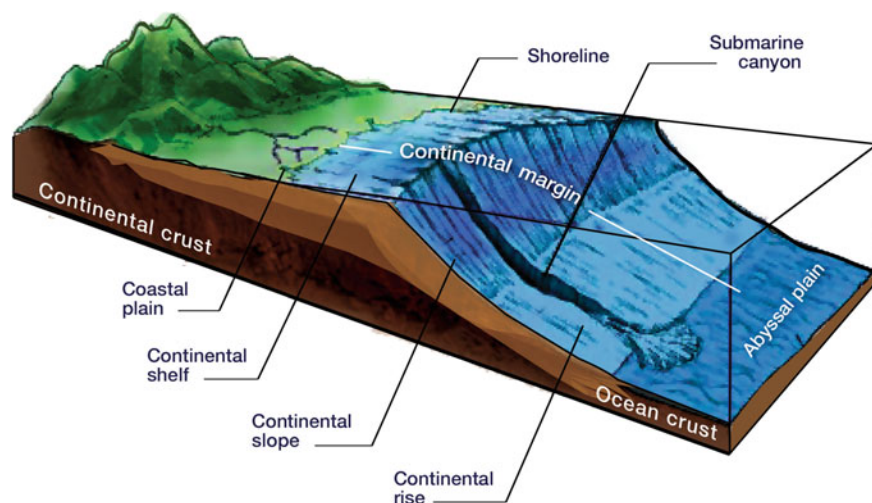


Fig. 2.2 Schematic section of a typical passive margin with its component environments

of the Earth's crust, below first-order features represented by continents and oceans (Heezen and Menard 1966). Continental margins comprise a significant percentage of the world ocean, although there are discrepancies among different authors (e.g., 11% according to COMARGE 2010 and Menot et al. 2010; 15% according to DeMaster 2002; 20% according to Hartnett et al. 1998). Despite these differences, continental margins are of outstanding significance in global sedimentary, biological and geochemical processes, as they store 90% of the total amount of sediments (mostly terrigenous) produced on the Earth surface (McCave 2002) and account for the 25% of the total ocean primary production and more than 90% of all organic carbon burial (Hartnett et al. 1998), and 32% of the biogenic silica deposition in the world ocean (DeMaster 2002).

The term “margin” (sometimes associated to the adjective “continental”) is being used since as early as the last part of the 19th century closely related to the evolution of the concept of continental drift and seafloor spreading. Already in 1885, Suess described different types of margins, and these ideas were later incorporated into the Wegener's continental drift theory (in Bond and Kominz 1988). Authors like Johnson (1919), Shepard (1948) and Bourcart (1952) were pioneers in setting the present concepts of continental margins (in Seibold and Berger 1982). Mitchell and Reading (1969) first introduced the term “passive margin” to refer to the earlier concept of “Atlantic-type” margin that had been previously applied to different regions of the world other than the eastern America's region. Since then, the concepts regarding continental margins rapidly evolved into its present application considering the complex set of endogenous and exogenous processes involved in its construction and development.

As the “links” between continents and oceans, either considering endogenous or exogenous processes (or both combined), continental margins are important

components in the Earth history as they are relevant in the Source-to-Sink system (Margins 2000) and represent a dynamic link among lithosphere, hydrosphere, atmosphere and biosphere (Nitttrouer et al. 2007); hence, they contain the records of many large-, medium-, and low-scale processes involved in the planet evolution, such as

- The continental drift and the birth of oceans
- The geological history of Earth
- The climatic and oceanographic changes that occurred during a large part of the planet evolution (e.g., Wefer et al. 2002)
- The global carbon cycle (Wollast 2002)
- The biogeochemistry, carbon and nutrient fluxes in marine ecosystems (Liu et al. 2010).

Furthermore, continental margins behave as multiple “filters” for sediments being transported from the continent to the sea along the entire sedimentary cycle (Source-to-Sink system). Curray (1975) clearly illustrates this fact (Fig. 2.3) when states that the different environments of the margins (coast, shelf, slope, submarine canyons, rise) are individual features that partially retain terrigenous sediments supplied by rivers, wind, glaciers, volcanic eruptions, coastal and deep currents, etc. Those sediments travel across different environments in a constant search of its final place of deposition. None of the environments is a perfect trap, as they retain only part of the sediments, whereas other materials bypass their boundaries and are transported toward the next (deeper) environment, where again they can be trapped or not, and so on. Recycling of previously deposited sediments as well as locally produced chemical and biogenic materials add new components to the entire sedimentary cycle. The end of the cycle is in the deepest basins where sediments are definitively settled. After that, they suffer several transformations (diagenesis, compaction, consolidation, etc.) and finally they are transformed in sedimentites before entering into the rocks cycle.

Exogenous processes dominating continental margins are mainly associated to the circulation of marine waters, which intervene in the seafloor patterns of sediment transport and distribution, morphosedimentary features, marine biology and geochemistry (Kennett 1982). Marine water circulation depends originally on the solar radiation hitting the planet surface and influencing atmospheric circulation, which drives the wind system that in turn affects the sea surface by “pushing” the water upper levels (e.g., Neumann and Pierson 1966). As these “original” currents travel through different climatic zones and regions of changing water temperatures—and hence the capacity to dissolve salts changes, as well as other physical–chemical properties—different parts of the water masses begun to “float” or “sink” according to density differences. More complexity is incorporated by different degrees of precipitation and evaporation. In this way a distinct vertical stratification develops in the water masses. Sinking waters are then affected by the seafloor morphology when they touch the bottom and can therefore circulate in directions different to the surface waters, particularly if the Coriolis effect is also considered. As a result, thermohaline

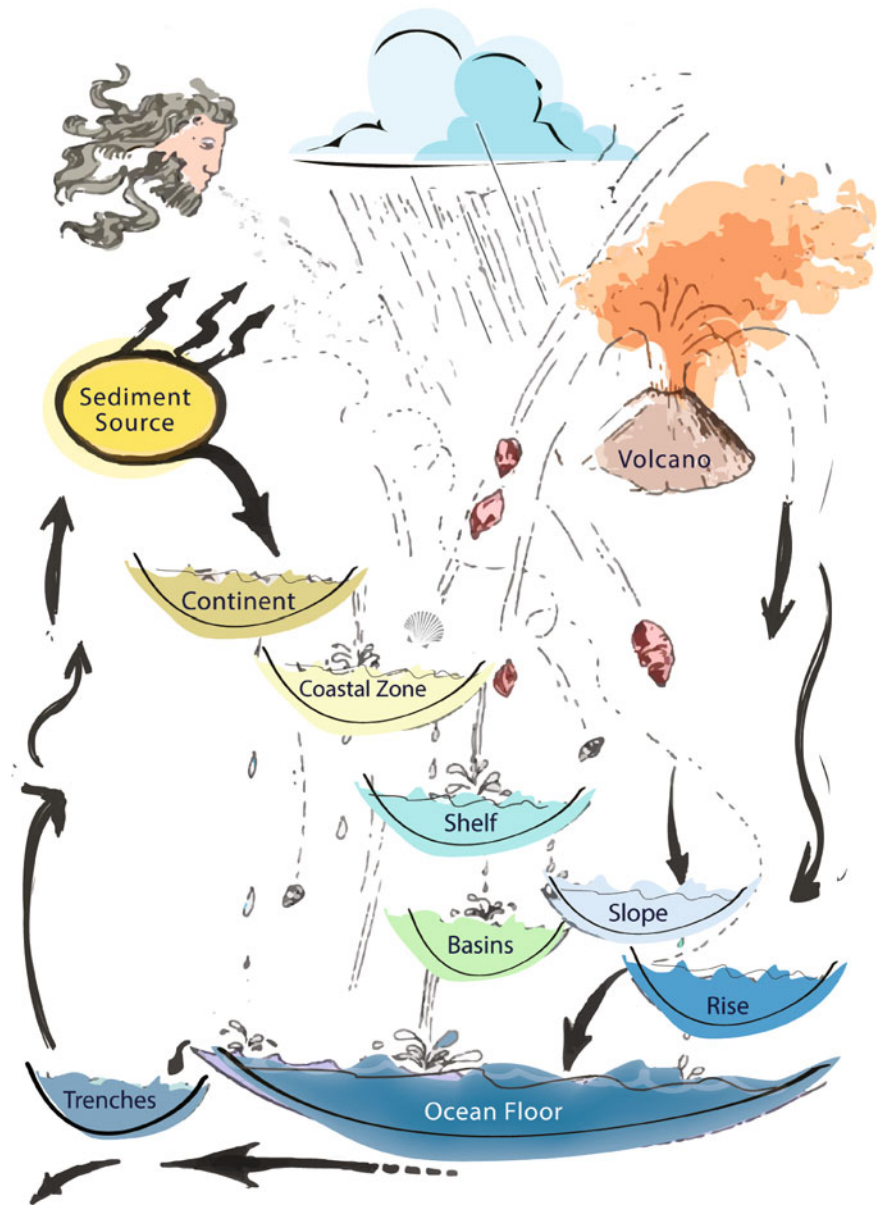


Fig. 2.3 Schematic diagram of the Source-to-Sink system (modified after Curray 1975)

circulation is organized, which basically forms around the world the “Ocean Conveyor Belt” or, as it is nowadays preferred, “Ocean Meridional Overturning Circulation” (e.g., Schmittner et al. 2007) (Fig. 2.4), in which each level of the superposed water masses may run in different directions and at different velocities.

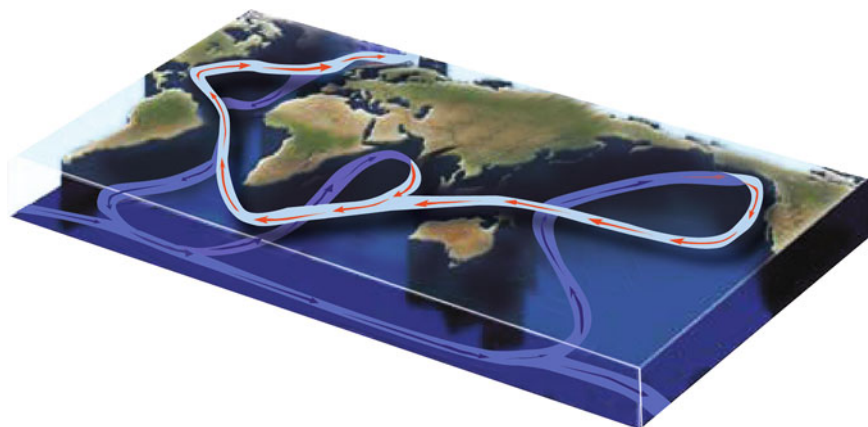


Fig. 2.4 Basic scheme of the main branches of the Ocean Meridional Overturning Circulation

“Local” (regional) factors intervene and create complexity in the entire system, in which high-energy interfaces between adjacent water masses develop and influence the bottom sediments, impacting the seafloor at the edge of continental margins with complex erosive and depositional processes.

In short, it is evident that continental margins are highly complex features that combine continental and marine influence, in which some of the most significant processes affecting the Earth surface occur. In this context, the Argentina Continental Margin occupies one of the most important sectors of the world’s margins (Fig. 2.1) as a result of its particular oceanographic setting, as described in the following chapters.

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