SHELF SEAS

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Summary

Shelf seas exist where the sea floods the continental margin and their areal extent is largely controlled by sea level and tectonic setting. Because of the interplay between a wide spectrum of physical, chemical, thermal, and biologic variables, a plethora of different habitats are present on the shelf. The greatest habitat variability occurs in the nearshore environment where the fluctuations in conditions are most rapid from both

spatial and temporal considerations. Shelf diversity varies along a number of different gradients. The most prominent is latitudinal variation, with much higher diversities at low latitudes as compared to those found at high latitudes. Diversity also is generally lower in nearshore settings because of the greater variability in conditions. Today's shelf biota represents one of the highest diversities seen in Earth history, reflecting the relative isolation of the various continental masses and the presence of a pronounced climatic gradient from the poles to the equator. This contrasts with the Paleozoic and Mesozoic when diversity corresponded much more closely with sea level.

1. Introduction

Shelf seas represent a mosaic of different, vitally important habitats for a broad range of marine organisms. From beaches to the outer reaches of shelf, a broad diversity of marine organisms—reflecting all the known marine phyla—have adapted to the spectrum of conditions that exist within the setting. Furthermore, they are extremely important to humans who, in many places around the globe, exploit the organisms that live in shelf seas primarily for sustenance, but also for other needs. Due to the degree of overharvesting of a range of organisms and also the documented climate change that Earth is currently undergoing, it is critical to understand the nature of the various ecosystems that comprise shelf habitats. In addition, we need to examine, through the use of the fossil record, the nature of past conditions and how the biota responded to these changes.

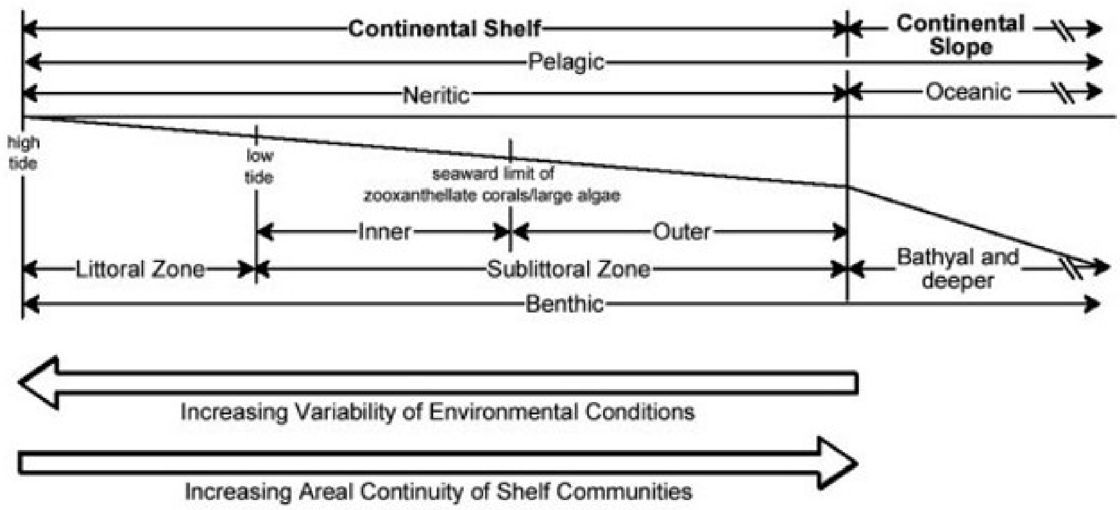

Figure 1. Diagram representing the major physical subdivisions of shelf seas, the variability in environmental conditions, and the areal extent of shelf communities

1.1 Definitions

Marine habitats can be crudely subdivided into two main divisions: open-ocean and shelf seas. Here, the use of the term "shelf seas" will encompass those areas on the outer margins of continents and islands that are flooded by oceans to a depth of approximately 200 m. Although shelf seas include such features as extensive grabens produced in extensional tectonic and back-arc depressions, the former are often extensively filled by terrestrial sediments and the latter are geologically rather ephemeral and rarely preserved in the rock record. Such dominantly nonmarine and short-lived features will not be dealt with herein. Furthermore, the term explicitly excludes marine environments formed in the interiors of continents; these are termed "epicontinental" or "epeiric" seas. In many of today's oceans, these seas fairly closely correspond to the continental shelf–continental slope transition as well as the depth of the photic zone. However, because sea level has fluctuated markedly in the past, the position of shelf seas did not always correspond to this physiographic feature. From a biotic perspective, there is clearly a considerable faunal overlap between these two regions, especially because both nektonic and planktonic elements can readily inhabit and migrate from one of the regions to another. Nevertheless, because of the vast contrast in average depth between these two regions, there are also pronounced differences in faunal constituents, especially when the benthic and deeper pelagic faunas between the two regions are compared. The geological aspects of marine processes are described in detail in ***Coastal and Marine Processes***.

In the most general sense, there are two types of shelf seas that are largely differentiated based on their plate-tectonic setting. The shelf seas present on passive margins are generally very broad with extremely gentle slopes, whereas those on tectonically active margins tend to be very narrow with somewhat higher gradients. As expected, this reflects the amount of tectonic processes, such as earthquake intensity, as well as the physiography of the regions. The lack of tectonic activity along passive margins (i.e., along much of the Atlantic Ocean coast) allows considerable amounts of sediment to be stored relatively close to shore. However, this does not preclude the movement of sediment, often in so-called turbidity currents, to be transported as deep as the abyssal plain. As this sediment accumulates through millions of years, it results in the evolution of a very broad, gently dipping shelf. On active margins (i.e., coasts surrounding much of the Pacific), on the other hand, the residence time of sediment in the nearshore region is much lower. This results from a variety of factors including active subduction of materials and the mass movement of sediments to greater depths in response to tectonic activity (especially seismic events). Hence, in these active environments, sediments cannot build up the broad features typical of passive margin settings. **See** ***Plate Tectonics and Landform Evolution***.

1.2. Controls on Distribution and Size

In addition to the tectonic setting discussed above, the position and the areal extent of shelf seas are governed by three primary variables: sea level, sediment supply, and subsidence. Of these three variables, sea level is arguably the most critical. Not only does its position determine how much of the continental shelves are flooded and hence how large shelf seas are, but it also plays a critical role—through determining where the necessary accommodation space for deposition will be positioned—in controlling where and what types of sediments will accumulate. Due to tectonics, especially the influence of the rate of spreading at mid-ocean ridges, and climate change, dominantly the effects of glaciation, sea level has not been constant through time. During periods of rapid plate tectonics, the mid-ocean ridges increase in volume. This results from the increased extrusion of magma along these features, which results in a larger volume of low-density oceanic crust. In turn, this low-density crust creates larger oceanic ridges that require the displacement of water, and hence sea-level rise, and the flooding of continental shelves. Although the magnitude of sea-level change through this process can be on the order of 500 m, the rate at which sea level varies due to this process is relatively slow. This reflects that this change in mid-ocean-ridge volume is driven by relatively slow-acting, plate-tectonic processes. Glaciation, on the other hand, acts through the storage of water, predominantly in ice caps and sheets. Although water can also be stored in mountain glaciers, the volume of that reservoir is negligible as compared to the far larger oceanic and ice cap/sheet reservoirs. The ultimate reservoir for the water contained in glacial features is the ocean. Therefore, as ice caps and the amount of water that they trapped waxed and waned, the oceanic response was monitored by the fall and rise of sea level, respectively.

The second variable, sediment supply, regulates the size of shelf seas by governing the shoreline position as well as the extent of the shelves that are largely built by sediment accumulation. This is especially well represented on passive margins, where the virtual lack of tectonic activity in combination with the subdued topography create a setting ideal for the deposition of extensive sedimentary units. These sediments forming the shelf can be categorized into two major divisions: siliciclastic and carbonate. Siliciclastic sediments form where the primary source of sediment is the result of the weathering and transport of material from uplifted rocks (spanning the gamut from igneous to metamorphic to sedimentary ones). Carbonates, on the other hand, form through the direct precipitation from seawater, usually aided by biological processes, primarily through the formation of various skeletal elements. In general, shelves dominated by carbonates are found at lower latitudes where warmer conditions promote more growth. **See *Sedimentary Rocks***.

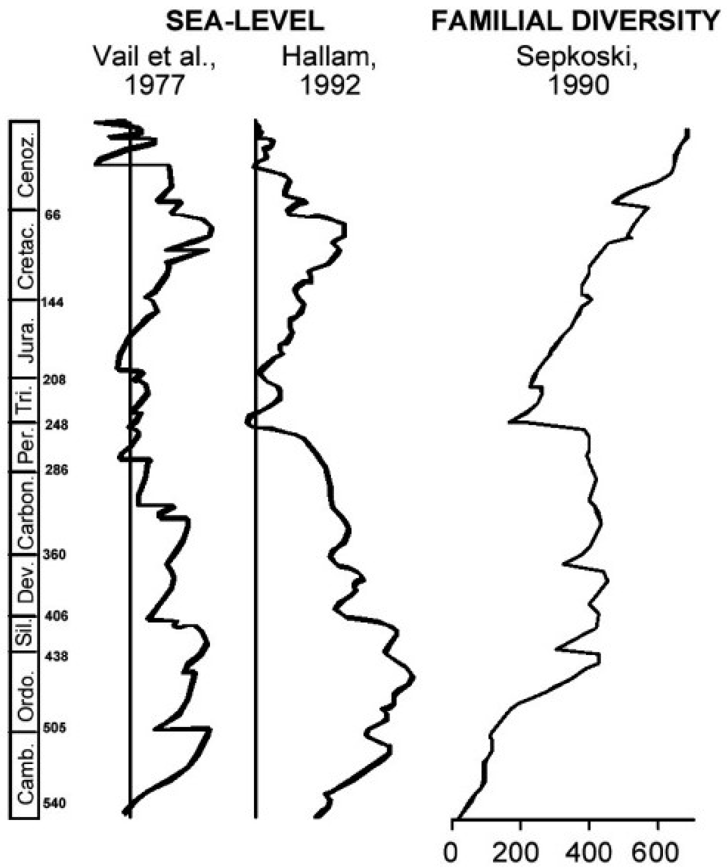

Figure 2. Relationship between sea level and marine familial diversity
Note that during major intervals of rising sea level the two correspond well. However, during lower sea levels (most notably in the Cenozoic), except for when the peak fall is reached, the correlation is very weak, suggesting additional controls on marine diversity.

Largely because accurate measurements of subsidence and especially its variability through Earth history are very difficult, if not impossible, to obtain for continental shelves, in most instances an average subsidence rate is usually employed. Although this is not a completely satisfactory resolution to the problem, when applied in this manner, these estimates produce reasonable results when compared to other lines of evidence. In addition, as compared to the other variables, subsidence, which is largely the result of the isostatic adjustments of the crust, generally occurs at rates much slower than the other two main variables mentioned above. There is, however, a notable exception to this that results from deglaciation. In regions of North America and northern Europe that were previously covered by substantial ice sheets, the continental crust has been and continues to rise at extremely rapid rates. This isostatic rebound results from the removal of the ice load and the crust's response to adjust to the change. It should be noted, however, that not only are the effects of these adjustment relatively localized (though diminished effects may be propagated fairly widely) geographically, but also they are also localized temporally when viewed from geologic perspectives. The latter reflects the fact that the vast majority of Earth history lacked substantial ice sheets and hence the mechanism to produce these types of effects. **See *Quaternary***

History.

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Biographical Sketch

Peter Harries is an Associate Professor of Geology at the University of South Florida. He received his undergraduate degree at Yale University and, after a brief stint at the American Museum of Natural History, did his graduate work at the University of Colorado, Boulder. At the latter institution, he honed his geologic skills on the Cretaceous rocks exposed throughout the west-central portion of North America. He augmented these studies with a Fulbright fellowship to Germany where he compared European repopulation patterns following the Cenomanian–Turonian mass extinction (mid-Cretaceous) to those from the USA. He specializes in the paleobiology, paleoclimatology, and paleoceanography of Cretaceous epicontinental seas as well as in post-mass-extinction repopulations and an extinct group of bivalves known as the inoceramids. Although he has wide-ranging interests in things Cretaceous, he is especially focused on the different dynamics between greenhouse and icehouse worlds.