EPEIRIC SEAS: A CONTINENTAL EXTENSION OF SHELF BIOTAS

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Summary

Although epicontinental or epeiric seaways are virtually absent from Earth today, they are the dominant source for much of our information about marine biodiversity of the past. Furthermore, the sole source for data with which to investigate biodiversity trends older than the late Jurassic are the sediments deposited within the basins located in continental interiors flooded by these seaways at various intervals in the geologic past. The Precambrian record of biodiversity is especially fragmented, and despite the importance of the fossil finds that have been made, a much better record exists in the Phanerozoic due to the rise of skeletonization. The presence of these features in the geologic past is primarily controlled by three factors: sea level, subsidence, and sedimentation. How these three variables interact has determined when and where these seaways are found. Hence, understanding these features is critical to understanding the

temporal and paleobiogeographic biases that control the fossil record and our ability to reconstruct elements of past biodiversity.

1. Overview

1.1. Controls

Epicontinental or epeiric seas represent shallow oceanic bodies resulting from the flooding of continental interiors. They are differentiated from the flooded continental margins of ocean basins—so-called shelf seas—in that they extend into the center of continents. Because maximum sea-level rise during the Phanerozoic has been approximately 400 m higher than that of today (at the beginning of the twenty-first century), these seaways could only flood relatively low-lying areas. Due to the subdued topography generally characteristic of the Paleozoic and Mesozoic, these seaways generally formed broad, shallow features. In addition, their geographic position and temporal distribution is dominantly controlled by two major factors: sea level and continental elevation. During periods when eustatic or global sea level was high, as well as when the general continental elevation was low and augmented by the presence of either intracratonic or foreland basins, these seaways formed important biotic, sedimentologic, paleoceanographic, and paleoclimatic features on Earth's surface.

Epeiric seas are virtually absent from today's world for several reasons. First of all, compared to much of the Phanerozoic, the continental regions in today's world are generally quite elevated, because of the large amount of mountain building that has occurred, as manifest in the Himalayans, the Cordillera of North and South America, and the Alps. Secondly, the pace of the current tectonic activity is fairly slow; therefore, the midocean ridges are not elevated and do not displace water resulting in high eustatic levels. Finally, this diminished sea level is further reduced by the substantial amount of water trapped in the Antarctic and Greenland ice sheets. These three factors conspire to virtually exclude epicontinental seas from modern, as well as much of Cenozoic, Earth. In addition, because we are currently in an interglacial interval chapter ***History of Earth*** for a more detailed discussion of these dynamics), sea level is relatively high, at least compared to its various positions during the past two million years. This indicates that, at least since continental glaciation initiated in the Miocene (and perhaps as early as the Oligocene), sea level has been too low to effectively flood continental interiors. Therefore, despite the detailed geologic record that exists for this interval, it lacks the necessary analogs to understand the various roles these epicontinental seas played in the geologic past.

Despite the virtual absence of epicontinental seaways today, they are of vital importance from geologic perspectives. The vast majority of the geologic information that exists about the various aspects of the marine world, be it related to the fossil or the rock record, is due to the deposits that formed directly as the results of the incursion of these seaways onto continents. Due to subduction, as well as to the fact that many of the ocean basins that exist today formed during the Mesozoic, oceanic regions do not contain, at least from geologic perspectives, old rocks. Currently, the oldest rocks found on the ocean floors are late Jurassic (approximately 180 million years old (Ma)). Due to the preservation of marine rocks deposited from epeiric seas prior to this interval, however, much older rocks exist that can be investigated to decipher earlier events in Earth history. There are, however, limitations associated with these shallow-marine deposits. Because epicontinental seaways are only present under a certain set of conditions, this implies that the quality and preserved quantity of sedimentary rocks and their fossil content critical to investigating past biodiversity of various ages varies substantially. This is an important bias in the geologic record; the record of periods associated with the development of epicontinental seas is considerably more robust than those intervals that lacked those features.

From a historical perspective, epeiric seaway deposits have also played an important role in the development of Geology as a science. Much of the work of the pioneers in the field, ranging from Neils Stensen (latinized to Steno), who developed the basic geologic principles that continue to govern the field in AD 2000, to William Smith, who produced the first geologic map, were based on observations and descriptions of these deposits. Furthermore, because these deposits represent the vast majority of all preserved pre-Jurassic marine strata, much of the data as well as the hypotheses and theories developed concerning the evolution of Earth are derived from them.

1.2. Temporal Distribution

Because of the factors outlined above that control the presence of epeiric seas, these seaways are not found continuously through geologic time. Throughout most of geologic history, eustatic or global sea level has been primarily controlled by the rate of plate tectonics, especially as reflected in the volume of the midocean ridges—the sources of oceanic crust. The presence of ice sheets as well as smaller glacial bodies and their waxing and waning during icehouse intervals has also controlled eustatic sea level. However, most of Earth history is free of large glaciers, and therefore the efficacy of this mechanism is restricted to a relatively limited extent of the geologic record. An exception to this is the Carboniferous–Permian glacial interval. This period is characterized by rapid expansion and contraction of epicontinental seaways as a result of the climatic mediation of sea level. This resulted in the repetitive sedimentary units known as cyclothems that reflect the cyclic changes in sea level caused by the waxing and waning of ice caps during glacial and interglacial periods, respectively. **See *Atmosphere and Climate***.

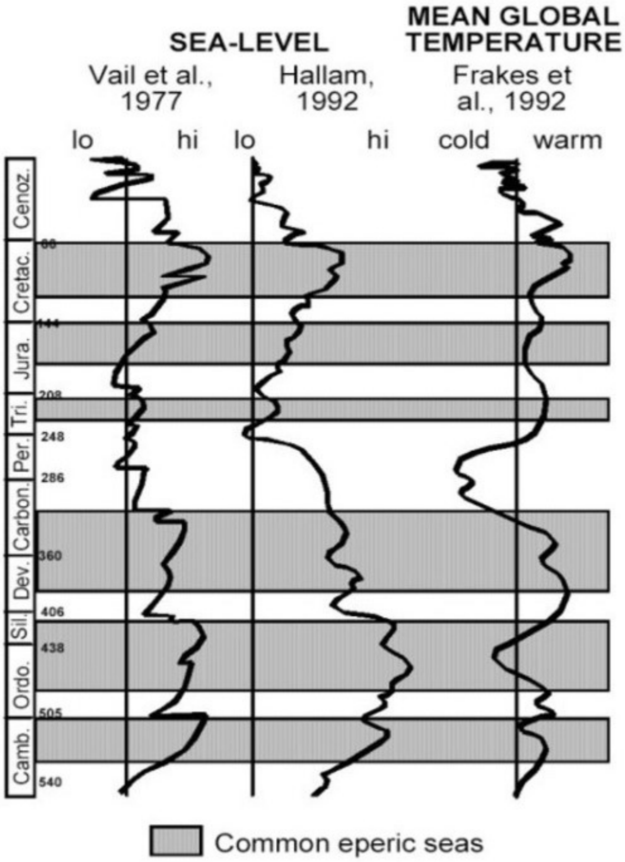

Figure 1. Compilation of Phanerozoic sea level and temperature data Superimposed upon this are the intervals (shaded) when epicontinental seaways were common. The vertical lines on all three plots represent the position of today's conditions.

The periods where epicontinental seaways were most dominant occurred when the rate of plate tectonics, and hence the rate of sea-floor spreading, was rapid. This resulted in an increased volume of the midocean ridges that, in turn, altered the shape of the ocean basins. The effects of this change were to displace seawater that then flooded relatively low-lying areas. This mechanism for eustatic sea-level changes does not primarily reflect an increased volume of magma being extruded at these sites, but primarily a response to younger crust being hotter and hence less dense than older crust resulting in a larger midocean ridge volume. **See *Plate Tectonics***.

Figure 1 depicts two generalized sea-level curves for the Phanerozoic. The overall trends in the curves are quite similar, although the details are slightly different due to the approaches used to reconstruct past sea level. The dark-lined curve is based on sequence-stratigraphic models that use stratal patterns, determined from seismic stratigraphy primarily through the thick sequences preserved in passive margins, to reconstruct past sea-level positions. Whereas the gray-lined curve represents a sea-level history reconstructed on the basis of paleoshorelines and associated facies changes. Periods of high eustatic sea level include the late Ordovician, the late Silurian to early Devonian, the late Devonian–mid Pennsylvanian, the late Triassic, the middle Jurassic, and the early Cretaceous–late Cretaceous. In all cases, these correspond to intervals when epeiric seaways existed. The extent to which they flooded continental interiors, however, is also heavily influenced by the position, height, and geographic extent of topographic highs (i.e., mountains).

In general, the early and middle Paleozoic (Cambrian through Devonian) highstands resulted in the flooding of huge continental areas and the deposition of thick, widespread carbonate sequences. To a large degree, this reflects four factors: the low continental relief of the interval; the limited amount of exposed and therefore erodible igneous, metamorphic, and sedimentary rock as a direct result of the low relief; the existence of broad intracratonic basins; and the relatively low latitude paleoposition characteristic of most land masses during this interval. All of these features promoted large amounts of biologically mediated carbonate precipitation. Starting in the late Paleozoic and continuing through the Mesozoic, siliciclastic input into epeiric basins has played a more significant role. To a large degree, this reflects the increasing amount of orogenic activity and continental uplift that occurred during these intervals, and hence an increased amount of erosion of these uplifted regions. Although tectonic rates slowed during the Cenozoic, numerous large-scale, continent–continent collisions, such as between Africa and Eurasia and between India and Asia, in combination with mountain-building events along active subductions zones, including the rise of the Rocky Mountains and the continued growth of the Andes, resulted in a substantial increase in continental elevation. This increased topography augmented by the initiation of ice-cap formation by at least the Miocene (and potentially by the Oligocene), excluded epicontinental seas from most regions. There are still some localized regions, such as Hudson Bay, where interior portions of continents are flooded, but these are miniscule as compared to the extensive seaways that covered substantial portions of continental interiors earlier in Earth history. See chapter ***History of Earth***.

1.3. Geographic Distribution

The geographic position and orientation of past epeiric seas is dependent on several factors. The fundamental control is continental topography, which, to a large degree, is determined by tectonic history. Regions of continental collision or volcanic activity associated with subduction zones are mountainous and, therefore, given their increased elevation, not areas where epeiric seaways developed. Furthermore, intervals of geologic time associated with the formation of large supercontinents tend to be associated with mountain building due to the continent–continent collisions that occurred. This factor, compounded by the isolation of the continental interiors from the marine realm and the slowing of plate tectonic activity, also makes widespread epicontinental seas rare features during these plate configurations.

The primary site where these seaways were positioned is controlled by the position of basins. Intracratonic basins—regions of broadly, down-warped continental crust—are the result of continent–continent collisions where some of the stress is accommodated by deforming large portions of continents. Such basins tend to be bordered by gently sloped, uplifted areas, known as arches. These types of basins dominated during the Paleozoic reflecting the broad-scale continent–continent collisions that were involved in the development of Laurasia and Gondwanaland as well as their amalgamation to form Pangaea. The other major type of basin that epicontinental seas fill, although not as broad as intracontinental ones, is foreland basins. These basins form due to isostatic adjustments of the crust as it is loaded during mountain-building events. The weight of the additional crust forces the subsidence of the region adjacent to the orogenic belt. Unlike intracratonic basins, which tend to be quite symmetrical and quite shallow, foreland basins tend to be asymmetrical with the region of most rapid subsidence, and hence the location where the bulk of sediments accumulate closest to the mountain belt. This accumulated sediment also plays a role in continuing to load the crust and, thus, perpetuating the basins' development. Although these basins coexisted with intracratonic ones in the Paleozoic associated with mountain-building events that occurred during the interval, they are a more dominant control on the position and orientation of Mesozoic epeiric seaways.

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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.