

## CONTINENTAL MARGINS AND MARGINAL SEAS

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### Summary

Extending seaward from most continents are gentle shelves, known as continental shelves, and these reach about 150 m in depth before suddenly and somewhat drastically dropping at the continental break. Just off the break is the steep continental slope which leads to the continental rise and the abyssal plains. The terrace-like features of the gentle continental slope are products of the last glacial when sea levels were lower. Between a continent and an open ocean, a semi-enclosed sea, loosely termed a "marginal sea" is sometimes found, and it can be as large as  $3.5 \times 10^6$  km<sup>2</sup>, as in the case of the South China Sea. Along the Atlantic coastlines are passive margins facing the edges of diverging tectonic plates, while along the Pacific, active margins with earthquake and volcanic activities are found near the edges of the different converging plates.

Waters on the shelves and in the marginal seas are in constant motion, even more than those in the open oceans, and this is mainly on account of the shallower water depths. Understandably, winds have a greater effect on the flow of shallower water, and since tidal currents are also stronger, the end result is that resuspension of bottom sediments is facilitated. In addition, rivers and the eolian input of dust play significant roles not only in the movement of particles but also in the supply of nutrients.

The different environments of the Earth's many continental margins vary drastically. Compared with the relatively uniform environment of the sunlit zones of the open oceans or with the rapidly mixed environments of the atmosphere, the spatial and temporal heterogeneity of the world's coastal zones is indeed somewhat remarkable. As a consequence of this complexity, significant methodological problems arise with respect to the development of a global consensus on the complete roles and functions of

coastal margins in the functioning of the total Earth system. Identifying and quantifying the roles and developing scenarios of potential change in coastal areas of the Earth system under anthropogenic and natural conditions requires a coordinated body of research from dedicated specialists from major international programs. Proof of this is seen in contrasting conditions ranging from fresh water fjords in high latitudes to hypersaline bays in subtropical regions. Added to the complexity, in polar regions, ice rather than river discharges moves fresh water offshore. Eutrophication from excessive nutrient outflow from land now poses a significant threat to some coastal zones, and this has the potential to eventually obstruct activity in some of the world's major fishing grounds.

## 1. Introduction

The coastal zone is one of the Earth's greatest environmental and economic assets with over half of the world's human population currently living within 100 km of a shoreline; that number is expected to increase to 75 per cent by 2025. We just need to look at the US as an example; even though it is such a large country in terms of size, over 80 per cent of the population already lives within 90 km of the coast and still more are coming.

On the ocean side, biogeochemical processes principally occur within the top 200 meters of the sea, which are waters often associated with continental margins. Actually, the continental margins are shallower than 200 m, and they occupy only 7 per cent of the total ocean surface and even less than 0.5 per cent of the ocean volume. Despite their small size, they do play a major role in oceanic biogeochemical cycling. Significantly higher specific rates of organic productivity, for instance, occur in the coastal oceans than in the open oceans (see *The Open Oceans*) owing to a more rapid turnover rate and a higher nutrient supply from upwelling and riverine inputs. Another example is that 8 to 30 times more organic carbon and 4 to 15 times more calcium carbonate per unit area accumulate in the coastal oceans than in the open oceans. In addition, the gas exchange fluxes of carbon and nitrogen in the coastal waters are considerably higher than in the open oceans per unit area. As a result, around 14 per cent of total global ocean production, 80-90 per cent of new production and up to 50 per cent of global ocean denitrification occur in the coastal oceans. The burial sites of 80 per cent of the organic carbon derived both from oceanic processes as well as from terrestrial sources, and in excess of 50 per cent of present day global carbonate deposition, also occur in the coastal oceans. The unburied organic carbon may be respired, or breathed out, onto the shelf, thus forming a potential natural source of atmospheric carbon dioxide. However, how much is actually respired is unknown since much of this carbon is highly inert, or inactive, and only mixes with seawater in a conservative way.

Mankind continually, and to a great extent at that, interrupts the global biogeochemical cycle of carbon, nitrogen and phosphorus. Such interference has led to substantially increased loadings of chemicals from human activities on land and even in the atmosphere. The horizontal fluxes of these elements to the coastal oceans via rivers, groundwaters and even the atmosphere play a strong role in the biogeochemical dynamics, cycling and the metabolism of coastal waters. A potential feedback may result from the anthropogenic eutrophication of continental shelf areas due to increased

nutrient availability, and this also results in reduced oxygen concentration due to increased microbial respiration. Denitrification and methane production are thus increased, and, therefore, so is the release of  $N_2$ ,  $N_2O$  and  $CH_4$ . The eutrophication process accelerates the cycle of organic synthesis and the regeneration of nutrients other than silicate, but calcareous shells and skeletons are preserved. In addition, the damming of major rivers may reduce freshwater output and the buoyancy effect on the shelves, reducing the upwelling and nutrient input. Subsequently, productivity and eutrophication are diminished. These processes, however, cannot yet be accurately quantified.

The flux of carbon from the terrestrial biosphere to the oceans takes place via river transport. The global river discharge of carbon in organic and inorganic forms approximates  $1-1.4 \text{ Gt C yr}^{-1}$ . (One giga ton (Gt) is equal to  $10^9$  metric tons). A substantial portion of this transport (up to  $0.8 \text{ Gt C yr}^{-1}$ ), however, reflects the natural geochemical cycling of carbon and does not affect the global budget of anthropogenic  $CO_2$  perturbation (i.e., disturbance). Furthermore, the anthropogenically-induced river carbon fluxes indicate, to a large extent, increased soil erosion and not a removal of excess atmospheric  $CO_2$ . The above-mentioned discharges of organic matter and nutrients from coastal communities do not have a significant impact on the open oceans, but they can certainly have important effects on the coastal oceans.

For one, the discharge of excess nutrients by rivers may stimulate phytoplankton growth and carbon fixation, but excess organic carbon production due to nutrient input is estimated at only 3 per cent of gross primary productivity. Moreover, much of the unused shelf primary productivity is not available for export or deposition but is decomposed on the shelf instead. On the other hand, dissolved organic carbon (DOC) and particulate organic carbon (POC) inputs from ocean margins to the open ocean interior may be more than one order of magnitude greater than inputs of recently produced organic matter derived from the open surface ocean.

At present, it is not known how much of this excess organic carbon is simply reoxidized and how much is permanently sequestered, or removed, by export to the deep oceans or with sediments on the shelves and shallow seas. In order to determine the contribution of the continental margins and seas to  $CO_2$  sequestration and the horizontal flux of carbon, nitrogen and phosphorus across the ocean-continental margin boundary, the JGOFS/LOICZ Continental Margins Task Team was established.

International cooperation in the continental marginal zones is absolutely necessary as coastal states should have the right to regulate, authorize and conduct marine scientific research in their own exclusive economic zones and on their continental shelves. Marine scientific research in the exclusive economic zones and on the continental shelves can only be conducted with the consent of the coastal states concerned. The Law of the Sea Convention requires that under normal circumstances, coastal states grant their consent for marine scientific research projects conducted by other states or competent international organizations in their exclusive economic zones or on their continental shelves. Accordingly, that research must be carried out in accordance with the Convention and exclusively for peaceful purposes, and in order to increase scientific knowledge of the marine environment for the benefit of all mankind.

On the other hand, states and competent international organizations which intend to undertake marine scientific research in the exclusive economic zones or on the continental shelves of a particular coastal state are obliged to provide that state with a full description of the research, such as the nature and objectives of the projects as well as the method and means to be used. They must do so not less than six months prior to the expected starting date of the marine scientific research project. When undertaking marine scientific research in the exclusive economic zones or on the continental shelves of a coastal state, the bodies concerned must ensure that the coastal state is given the right to participate or be represented in the project if it so desires. The coastal state also has the right to have all data, samples and reports involved in any research.

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### Biographical Sketch

Born in Changhwa, Taiwan, on 22 April 1949, **Prof. Chen-Tung Arthur Chen**, his wife and two

daughters are currently residing in Kaohsiung, where he has been Professor at the Institute of Marine Geology and Chemistry since 1986. After receiving his B.Sc. degree in Chemical Engineering from National Taiwan University in 1970, Prof. Chen was awarded his Ph.D. degree in Chemical Oceanography from the University of Miami in 1977. In the same year, he was appointed Assistant Professor in the College of Marine Sciences of Oregon State University, where he was later promoted to Associate Professor in 1981. He served as Visiting Professor at National Sun Yat-Sen University (NSYSU) in Kaohsiung, Taiwan, and as Chargé de Recherche (CNRS), Université Pierre et Marie Curie in Paris during 1984-1985. During this period, he founded the Institute of Marine Geology at NSYSU, and served as its director until 1989 when he was made Dean of the College of Marine Sciences, a position he held until 1992.

Prof. Chen has sat on numerous international committees, including the Scientific Committee on Oceanic Research and the World Ocean Circulation Experiment. He also served as one of the executives of the Scientific Steering Committee of the Joint Global Ocean Flux Study (JGOFS) between 1992-1995. Just prior to that, he had helped to form the Joint JGOFS / LOICZ Marginal Seas Task Team in 1991, and served as its chairman until 1995. Prof. Chen is at present one of the editors of *Oceanography Journal* and associate editor of *Marine Chemistry*. Besides having more than 150 of his own scientific papers published, Professor Chen was awarded the highly-coveted Biowako Prize for Ecology from Japan in 1997.