Modern and Ancient Continental Shelf Anoxia

R. V. Tyson and T. H. Pearson (eds.), 1991. The Geological Society, London, 470 p., $125.

Drs. R. V. Tyson and T. H. Pearson convened a symposium on modern and ancient shelf anoxia in May, 1989 under the aegis of the Gological Society Marine Studies Group. This volume is the product of that meeting. The meeting was multidisciplinary including geologists, biologists and chemists.

The examination and interpretation of anoxic sedimentary environments is of significance in our understanding of the interplay of organic production, water circulation and sediment accumulation. When the flux of degradable organic material exceeds the oxygen supply, then anoxia and the exclusion of macrobenthos removes the more common bioturbation effects preserving primary depositional structures. It has also been postulated that the anoxic environment permits preservation of a larger proportion of the incoming organic matter. Studies in a variety of modern environments has tended to argue against that hypothesis although certainly the role of sulfate reducing bacteria versus aerobic bacterial processes is a major factor in the ultimate sedimentary product.

Within the broad spectrum of anoxic environments, shelf anoxia is a special case. One complicating factor for the stratigrapher is that the anoxic condition in several shelf environments discussed in these papers is temporary and ephemeral. Thus a primary question is what artifacts of these periods of low or zero oxygen will remain in the sedimentary record? As the convenors point out in their opening review, the modern effects impact fisheries and with the overprinting of anthropogenic effects produce some complex questions for the marine biologist. They also aver that much of the hydrocarbon-rich sedimentary resources were laid down and developed in organic-rich and oxygen-depleted depositional environments. As noted earlier, the sometimes higher organic content of such sediments reflects the common association of high productivity regions (upwelling regions) with oxygen-deficient depositional environments. Even if degradation and removal rates are similar for all depositional environments, certainly the net input under high production areas will be larger.

Major factors influencing oxygen-deficiency in shelf regions are the higher biological production in margins as compared to open ocean, the short fall path in margins compared to open oceans and resulting higher sediment input rates, higher sediment accumulation rates and thus thicker mass accumulation and higher burial rates for carbon. Bioturbation is also operating at higher rates, and fluctuations in depositional regime are larger and faster.

The editors also introduce a suggested standard terminology for such environments in which the environmental facies are termed oxic, dysoxic (with subdivisions), suboxic and anoxic with respective bottom water oxygen contents of >2.0 ml/L, 0.2–2.0 ml/L, O–0.2 ml/L and <0.0 ml/L (increasing dissolved H_2S). Biofacies terms for these are respectively aerobic, dysaerobic, quasi-anaerobic and anaerobic at the same oxygen boundaries. Physiological regimes would be Normoxic, Hypoxic (no matching term for Suboxic) and anoxic respectively.

The volume is subdivided into modern shelf anoxia studies, and ancient shelf anoxia studies. The papers in the two sections number 11 and 16 respectively and space does not permit review of each paper. The modern studies examine the northern Gulf Of Mexico shelf associated with or adjacent to the Mississippi River discharge (papers by Boesch and Rabalais; Rabalais, Turner, Wiseman and Boesch; Harper, McKinney, Nance and Salzer)) which discuss effects on benthos, recovery of communities and general oceanographic characteristics of the environment. This area may well be one in which the anoxia has an anthropogenic source as noted in the paper by Rabalais and others. Contrasts with other areas are noted. The effects are of the order of 4–5 months in duration in the delta front area.

A paper by Van der Zwaan and Jorissen compares the effects in the northern Adriatic, Orinoco-Paria shelf and the Mississippi locale. All are influenced by high river discharges and pollution effects. The authors utilize benthic foraminifera as indicators.

Malone reviews conditions in a large estuary, Chesapeake Bay. He notes that annual cycles of nutrient supply, phytoplankton production and oxygen depletion are uncoupled in the Bay but that phytoplankton biomass is directly related to seasonal variability in river nutrient input and this biogenic biomass supply then affects the oxygen depletion.

Justic; Faganeli, Pezdic, Ogorelec, Herndl and Deolenec; and Stachowitsch present a set of 3 papers that discuss the northern Adriatic Sea shelf anoxia. These papers discuss physicaloceanographicconditions,effects of stratification, interstitial water biogeochemistry and response of benthos to changing oxygen content in this interesting area and note the strong anthropogenic effects on river nutrient discharges. The influence of seasonal water stratification and rates of depletion/recharge is primary with the impact of anthropogenic effects superimposed.

The last 3 papers in the section deal with the more broadly recognized areas of anoxia associated with strong oxygen minima in classic margin upwelling areas. Arntz, Tarazona, Gallardo, Flore and Slazwedel; and

0883-1351/93/0008-0307/$3.00

Emeis, Whelan and Tarafa describe characteristics of the Chile-Peru margin with emphasis on benthos and sedimentary and geochemical characteristics of the underlying shelf and slope sediments. Bailey reviews shelf anoxia on the Benguela Shelf associated with that well known upwelling margin. The coupling or decoupling of the oxygen minima with shelf anoxia are discussed and ENSO effects noted. The role of primary productivity and multi-year circulation effects are documented in the respective areas.

The larger ancient shelf anoxia papers look at the black shales of long geologic interest. Most of the classic locales are represented including the North American Midcontinent Pennsylvanian black shales (Heckel), and Late Permian formations (shales and limestone) of East Greenland (Piasecke and Hallam). Wignall and Hallam discuss the Jurassic black shales of Britain, and the Jurassic Posidonia Shale of Germany is described from several localities by Littke, Baker, Leythaeuser and Rullkotter for northern Germany; Prauss, Ligouis and Luterbacher discuss the facies of that formation in southern Germany; and Brumsack discusses inorganic geochemical aspects of the formation and the paleoenvironmental consequences of such variations.

Hudson and Martill review the Jurassic Lower Oxford Clay of central England; Oschmann examines the Kimmeridgian Jurassic shelf environments of western Europe; Doyle and Whitham report on the late Jurassic–early Cretaceous Nordenmskjold Formation of the east coast of the Antarctic Peninsula; Breheret discusses glauconitization episodes in mid-Cretaceous anoxic events in the French Vocontian Basin; Koutsoukos, Mello, and De Azambuja Filho examine paleoenvironmental characteristics of mid-Cretaceous anoxic dysoxic paleoenvironments in the Sergipe Basin of northeastern Brazil, and Veto and Hetenyi report on the fate of carbon and reduced sulfur in dysoxic-anoxic facie of Oligocene facies in the Central Parathethys of the Carpathians.

In more general studies Rhoads, Mulsow, Gutschick, Baldwin and Stolz reexamine the characteristics of the dysaerobic zone and possible magnetic attributes of diagenetic changes in that facies; Savrda and Bottjer review and update their models of oxygen-related marine biofacies; Cuomo and Bartholomew examine pelletal black shale fabrics as indicators of biogenic fluxes; and Baird and Brett examine submarine erosion on an anoxic seafloor with its resulting stratinomic, environmental and chronologic significance.

All of these studies bring to bear an impressive array of physical, chemical, biological and geological methods and modern analogs on the stratigraphic problems of black shales. The studies are all focussed on the dynamics of the systems and the interaction of supply, sea level position and diagenetic rates on the establishment of particular low oxygen or oxygen-deficient environments. The approaches range from paleoecologic to paleooceanographic and from geochemical to sequence stratigraphic analysis. All represent state-of-the-art examinations of a multi-faceted spectrum of environments.

Given the stated concentration on shelf environments (more correctly continental margin environments), the convenors have brought together an impressive set of papers spanning a number of disciplines, geographic and temporal examples, and processes. The papers are well edited and well referenced which is a benefit to the reader who wants to delve more deeply into the various subjects.

I must also make the all too common complaint that the book is expensive at $125 U.S. However, since all reference texts are in the same price range these days what can one say beyond the comment that this is a valuable reference for all interested in the black shales and the oxygen-deficient regime.

I add the note that the volume is also available through the American Association of Petroleum Geologists Bookstore.

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