Book Reviews

The Imprint of Upwelling

Coastal Upwelling. Its Sediment Record. ERWIN SUESS and JÖRN THIEDE, Eds. Plenum, New York, 1983. In two volumes. Part A, Responses of the Sedimentary Regime to Present Coastal Upwelling. xvi, 604 pp., illus. $85. Part B, Sedimentary Records of Ancient Coastal Upwelling. xvi, 610 pp., illus. $85. NATO Conference Series IV, vol. 10. From an Institute, Vilamoura, Portugal, Sept. 1981.

When one is attempting to understand first-order features of the physics and chemistry of the ocean, it is convenient to think of the sea as a two-layer system consisting of a shallow-water body and a deep-water body, the two strata being separated by the thermocline. The thermocline forms a barrier to the exchange of properties between the two water bodies, which has the effect of locking up nutrients at depth, where they are unavailable for photosynthetic production. The thermocline barrier breaks down along the coast, for various reasons, some having to do with offshore movement of surface waters (the classic upwelling drive) and some with the interactions of ocean currents and coastal bottom topography (turbulence and mixing). The point is that much of the action in terms of mixing, eddy generation, photosynthesis, and nutrient regeneration is concentrated along the margins. Margin processes therefore play a disproportionately large role in governing the physics and chemistry of the ocean: with some exaggeration one might say that the biochemistry of the ocean is governed by coastal processes, especially sedimentation, which pulls nutrients and carbon out of the system, and that the pelagic offshore sediments act more as a monitor of the system than as a control.

Awareness of the importance of upwelling for the geologic record has been at a rather moderate level until very recently. The physical processes associated with upwelling and the effects on ocean productivity were first brought to the attention of a wide geologic audience in 1939 in a well-known symposium the proceedings of which were published as *Recent Marine Sediments*, edited by P. D. Trask. Trask drew attention to the high content of organic matter (4 to 8 percent) in sediments deposited in regions of upwelling. Other authors described the upwelling process in some detail, and yet others described organic-rich sediments off California, in the Baltic Sea, and in Norwegian fjords. Curiously, the connection between the physics, chemistry, and sedimentation of upwelling was never clearly established in that symposium. Instead, the focus was on "stagnation" as a cause for organic-rich sediments. "Stagnation," that is, lack of oxygen, was seen as a result of stable stratification rather than as a dynamic balance between oxygen supply and oxygen demand.

Perhaps because of this lack of integration of physical oceanography and sedimentology, upwelling remained a non-issue with geologists. In the *Treatise of Marine Ecology and Paleoecology*, edited by J. W. Hedgpeth and H. S. Ladd (1957), for example, upwelling is only mentioned twice in connection with sediments (by Brongersma-Sanders in her paper on mass mortality). M. N. Bramlette, in his classic study of the Monterey Formation published in 1946, suggested that the most important factor in producing the high accumulation rates for diatoms "was the drifting of this micro-plankton by currents from the open ocean into areas of deeper water and into cul-de-sacs along the coast." He also suggested that the leaching of volcanic ash provided an important local source for much of the silica precipitated by the diatoms.

Geologists had to become oceanographers in order to fully integrate marine physics, chemistry, and biology into their sedimentologic models. Milestones in this development were *The Sea off Southern California* by K. O. Emery (1960) and a symposium whose proceedings (*Marine Geology of the Gulf of California*) were edited by Tj. H. van Andel and G. G. Shor (1964). The Gulf of California studies showed that laminated sediments can occur in open-ocean environments, below an oxygen minimum, and that all the silica deposited in these sediments could be accounted for by upwelling processes. The gulf emerged as a trap into which silica-rich waters enter at depth and silica-poor waters—stripped by algae—leave at the surface. The picture of a trap, I think, is crucial to the understanding of the relationship between upwelling and sedimentation. Both Calvert and Brongersma-Sanders deserve much credit for clearly formulating the concept at an early stage. E. Seibold in the 1960's initiated a research program in Kiel around the idea that upwelling and downwelling in shelf seas are crucial to sedimentation patterns now and in the past. Incidentally, Suess and Thiede were, respectively, post-doc and student of Seibold's.

The volume under review is in the tradition of that edited by Trask and of the *Treatise* but with much more advanced integration of physics, chemistry, biology, and sedimentology. The complex of subjects that Suess and Thiede wished to address in the work includes the spatial and temporal control of upwelling centers, the imprint of upwelling in the sediment, the relationship between productivity and burial of organic carbon, the role of oxygen minimum layer in the production of geochemical signals within the sediment, and the recovery of upwelling signals from the record. The first volume focuses on matching present upwelling conditions to the sediment imprint, the second on the geologic past. About one-third of the work consists of review papers. The remainder of the papers address specific questions in specific geographic areas. Though they are specialized, the papers on specific topics tend to be of broad interest, for their particular findings are set in a large context. The following eclectic summaries may indicate the scope of the treatise.

In the lead paper of the first volume, R. L. Smith describes the complexities of the upwelling phenomenon, the variability of upwelling in time and space, and the different types of flows involved in it. He stresses the importance of the subsurface poleward flow, which acts as a broom, sweeping particles and nutrients back toward the region of upwelling. Satellite images show just how far the influence of upwelling reaches into the open ocean. Not all upwelling will have the same effect on productivity (and hence sedimentation). It depends very much on the type of source water, which is a matter of well depth, water mass evolution, and oceanic fractionation processes (Codispoti, Dugdale). Fractionation processes are non-linear; that is, at threshold values the system changes behavior. For example, denitrification sets in when free oxygen disappears, removing substantial amounts of available nitrogen from source waters.

To make sediment, particles have to

sink to the sea floor, singly or in aggregates. Just how this happens and what is coming down is being investigated by means of sediment trapping. The system acts as a trap not only for nutrients and carbon, but also for dust and mud introduced from land: terrigenous matter is filtered out and deposited in feces. The geochemistry of sediments produced by coastal upwelling has a peculiar character: such sediments are rich in diatom silica, planktonic organic material, and phosphorite (Calvert and Price). The odd observation that phosphorites tend to be concentrated at the upper and lower boundaries of the O_2 minimum off Peru may be related to bioturbation. Where bioturbation is absent, incipient phosphorite concretions may be readily buried. The relationship between the rates of accumulation of organic matter and certain heavy metals may hold the clue to distinguishing between open ocean sapropels and truly euxinic ones (Brumsack). The nature of the preserved organic matter similarly may hold clues to the depositional environment. The interactions of metals and organic matter during early diagenesis may bear importantly both on metal enrichment and on organic-matter preservation (Ittekkot and Degens).

G. N. Baturin leads off the second volume with a brief overview of the geochemistry of upwelling sediments. This is followed by an extensive review of the sedimentation of organic matter in upwelling regimes (Summerhayes). Massive, short-period production may be more important in providing organic accumulation than is steady-state high productivity. Other papers concentrate on the sedimentary signature of specific areas. Fütterer searches for upwelling clues in sediment properties other than chemistry and paleontology; he finds present-day conditions off northwest Africa not conducive to the preservation of such clues. Trace fossils may indicate the intensity of upwelling (Wetzel).

The historical part of the work starts one-third of the way into the second volume. There are four papers on Holocene changes, five on Pleistocene variations, and seven on pre-Pleistocene episodes. The Holocene data show, not surprisingly, that upwelling intensity varies. Increases in productivity can be dated rather exactly in places and correlated with climatic events (cool, dry periods in the case of California). Off Peru, the occurrence of hiatuses in Wisconsin to Holocene sediments tends to interfere with stratigraphic-climatic interpretations. The Pleistocene records in general confirm that coastal upwelling tends to be more intense during glacial intervals than during interglacial ones (Müller *et al.*, for example).

The Deep Sea Drilling Project is represented by two multiauthored papers, one showing increased productivity of the Benguela Current at the beginning of the Pliocene, the other presenting downcore carbon analyses from off northwest Africa and elsewhere. Onshore upwelling-related sediments are explored in the remaining 100 pages of the volume. The most comprehensive of the pre-Pleistocene papers is one on Paleozoic upwelling (Parrish *et al.*) featuring the striking global reconstructions of Ziegler's group at Chicago.

In summary, the book delivers what it promises: a collection of useful papers setting forth our current understanding of the subject. Part A is the stronger volume, for old hands are more concentrated among its authors and the rules of interpretation are better defined. In part B, about half of the material is of regional rather than general interest. Also, there is an air of rather painful groping in a confusing stratigraphic record. Those bold enough to try to reconstruct the history of still poorly understood phenomena clearly pay a price. In showing where we are, the book lays the groundwork for where we need to go: toward a greater integration of oceanography into the geologic record (as distinct from present-day sedimentation) and toward an effort to tackle such global issues as primary production, isotopes, extinctions, and the evolution of the atmosphere, as H. Tappan urged 16 years ago. The task is immense; it will be a while until a treatise with similar scope and comparable advancement will be presented.

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The Physics of Stars

Solar and Stellar Magnetic Fields. Origins and Coronal Effects. J. O. STENFLO, Ed. Reidel, Boston, 1983 (distributor, Kluwer Boston, Hingham, Mass.). x, 564 pp., illus. $67.50; paper, $32.50. International Astronomical Union Symposium no. 102. From a symposium, Zurich, Aug. 1982.

The study of stars was once the central topic of astrophysics. However, the advent of large telescopes with efficient detectors plus the ability to observe non-optical radiation have made the present time the golden age of extragalactic astrophysics. Now these same advances are being applied to stars, with the result that a renaissance of stellar research is under way and this field is one of the most rapidly growing in astrophysics.

The present volume is a good indication of current research on the physics of stars, specifically on activity that is thought to be caused by magnetic fields generated within stars. The book is the proceedings of a symposium that was cosponsored by no fewer than six commissions of the International Astronomical Union. Such broad sponsorship indicates the wide interest in the subject. The organizing committee of the symposium chose to limit oral presentations to 17 invited reviews, 36 papers selected from submitted abstracts, and five summaries. An additional 56 papers were presented as posters. The book follows this organization by including all of the oral presentations save one. Poster papers are listed by title and author only. The result is the first IAU symposium volume that includes only half of the contributions. One hopes this is not the start of a new trend. The value of the book would have been greatly enhanced if at least the abstracts of the other papers had been included. The papers that are included fairly represent the symposium as a whole with one major exception: only five papers on solar observations, of the some 29 such papers presented at the symposium, are included. Thus the reader seeking recent observational results about the sun will not find much of interest in this volume. On the other hand, the book is a good collection of papers on recent stellar observational results and the theory and modeling of magnetic processes on both the sun and other stars.

The major theme of the book is magnetic activity on stars and its effects on their atmospheres. The emphasis is on combining results from the sun and stars not too different from the sun to obtain a better understanding of the basic physics than observations of either alone could provide. In the first section (Magnetic Fields in Stellar Photospheres) we learn that the difficult observations of magnetic fields on sunlike stars are advancing rapidly. The remarkably intermittent spatial character of the photospheric magnetic field seems to be reasonably well understood according to theoretical and modeling results presented here. This happy state is probably a temporary one that will be shattered once space-borne observations of the sun's magnetic field with the Solar Optical Telescope allow us to actually resolve the magnetic structures.