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Geological Approaches to Coral Reef Ecology, edited by Richard B. Aronson. Ecological Studies Series, vol. 192, xxi + 439 p., 108 black-and-white illustrations; Springer, New York, 2007, USD 129.00, ISBN 978-0387335384

This book is edited by Richard Aronson, a renowned coral-reef ecologist, and includes a preface and 12 chapters organized into 4 parts. The editor has brought together as contributors 19 well-known coral-reef workers, including both biologists and geoscientists. At the end of the book there is a comprehensive index of over 650 items.

The Preface by the editor begins with the observation that the condition of coral reefs worldwide is declining (e.g., Pandolfi et al., 2003), and that the geosciences, with their larger spatial and temporal view, may provide additional insights to modern biological studies of reef ecology. The study of fossil reefs is especially crucial as it allows a view of reefs before human impacts. Temporal patterns observed in reefs in the fossil record may also help to make predictions about the near future. The fossil examples presented in the book go as far back as the late Pleistocene. The older fossil record of coral reefs, which goes back to the Ordovician (some 450 m.y.) is not covered here. Following the first comprehensive work of Fagerstrom (1987), this topic was treated in great detail in three monographs published not too long ago (Wood, 1999; Stanley, 2001; Kiessling et al., 2002).

Part I of the book, entitled Coral Reefs in Context, begins with a chapter by Rachel Wood on the changing fate of coral reefs and lessons from the deep past. This chapter puts the following chapters in perspective, although it does not really explore the deep past. After a discussion of the problems inherent in the study of fossil reefs, e.g., stratigraphic-temporal resolution, loss of soft-bodied organisms, taphonomy in general, or the ecology of extinct taxa, she concentrates on the end Permian–Early Triassic time window of extinction. Subsequently, a brief overview of coral and reef evolution is given for the Caribbean Cenozoic. In this context, I was surprised to read in the introduction and later in the chapter that the community structure of Caribbean reefs supposedly has been very stable since the late Pleistocene and that ecological changes recently observed in modern reefs were unprecedented in the geological history of reefs, according to the author. Regarding the former, it is quite clear among Pleistocene reef workers that there are similarities between modern and Pleistocene reefs; however, there are also fundamental differences in coral community structure, as seen in southern Florida, for example (see Chapter 9 of this volume by Precht and Miller); or remember Heinz Lowenstam's famous joke regarding modern reefs as models for fossil reefs: The present is the key to the Pleistocene—perhaps. As for the latter, it is a fact that (1) changes observed in a few decades cannot be resolved stratigraphically in the fossil record, and (2) that there were several times of complete reef community extinction in the fossil record. From the fossil record in the Caribbean, Wood concludes that living reefs in the same area have very low resilience to further anthropogenic disturbance. Subsequent predictions of change and destruction can be made regarding the loss of herbivores and higher predators, changing storm patterns and land use, sea-level rise, rises in carbon dioxide and temperature, and change in seawater chemistry, namely the decline in ocean alkalinity. The last item potentially diminishes the ability of reef corals to secrete their calcium carbonate skeleton (see Chapter 12 of this volume by Kleypas). Finally, the author discusses the potential gain of knowledge from the study of reefs growing in extreme conditions and nonreef habitats, which potentially may act as refuges during time of decline or extinction.

Part II covers the detection of critical events, and the five chapters deal with the taphonomy of coral assemblages, biotic turnover events, crown-of-thorn sea star outbreaks, the influence of terrigenous run-off on reefs, and bleaching events as recorded in coral skeletons.

Chapter 2, by Benjamin Greenstein, treats the taphonomy of reef corals with examples from the modern and Pleistocene reefs of Florida and the Bahamas (San Salvador). The author discusses topics such as taphonomic bias, fidelity of death assemblages, and the comparison of life, death, and fossil coral assemblages. Greenstein concludes that, based on disparity between studies, especially regarding fidelity, further research in this field is necessary in order to provide a temporal context for the recent changes in reefs, to test for a shifting baseline, and to determine what makes a pristine coral reef (i.e., before human impact).

In Chapter 3, Richard Aronson and Stephen Ellner analyze biotic turnover events observed in shelf reefs of southern Belize, where branched *Acropora*-dominated reefs were replaced by foliaceous *Agaricia* reefs in the mid-1980s. In a number of pushcores taken over 375 km^2, the authors detected additional anomalous layers of *Agaricia*, which indicate biotic turnover events during the past 3,000 years. Using probabilistic models,

Aronson and Ellner show that the recent event was unprecedented during the past 3,000 years and that the previous turnover events only had very local significance.

Lyndon DeVantier and Terence Done (Chapter 4) investigated scar patterns on coral heads in order to identify former outbreaks of the crown-of-thorn sea star *Acanthaster* in the Great Barrier Reef. Distinctive circular feeding scars in a number of study sites can be related to outbreaks during the 1980s, 1960–1970s, and prior to 1960. In summary, frequency and geographic range of *Acanthaster* outbreaks have increased in the 20th century, according to the authors. Causes for outbreaks include relaxation of predation pressure on sea stars, and enhancement of larval survivorship through coastal runoff, reduced salinity, and increased food supply through nutrient input. I noted there is a repetition of an entire passage from subchapter 4.11 (p. 116, paragraph 3) in the summary (p. 118, paragraph 2).

In Chapter 5, Kenneth Deslarzes and Alexis Lugo-Fernández discuss the influence of terrigenous runoff on the remote coral reefs of the Flower Garden Banks in the Gulf of Mexico. The authors report detailed information on environmental factors, such as sea surface temperatures (SST), salinity, light, chlorophyll *a* concentration, and nutrients, and they show results from X-radiography and fluorescence of coral skeletons. The remote Flower Garden Banks are in much better shape compared to Caribbean reef sites in general. Observed fluorescence patterns in coral skeletons indicate the influence of river discharge combined with Louisiana-Texas shelf circulation and cross-shelf water transport. The time span investigated covers the 1980s and 1990s.

Robert Halley and Harold Hudson explore the fidelity of annual growth increments in the massive coral *Montastraea* and the timing of recent coral bleaching in southern Florida in Chapter 6. By analyzing growth bands, stress bands, and fluorescence in coral skeletons from the northern Florida Keys, the authors can demonstrate that severe bleaching events were rare prior to 1980. Apparently, unprecedented environmental stress (runoff in combination with proximity to shore) only began in the late 20th century in this area.

Part III is entitled Patterns of Reef Development and Their Implications and explores fossil reefs. The three chapters are concerned with the development of late Quaternary reefs and patterns and ecological shifts in Pleistocene reefs of the Caribbean.

Chapter 7, by Ian Macintyre, is entitled "Demise, Regeneration, and Survival of Some Western Atlantic Reefs During the Holocene Transgression," and it summarizes the development of reefs since the Last Glacial Maximum (LGM). Examples include relict reefs on shelf edges and outer slopes, and shelf reefs, which this author investigated. The development of reefs is largely discussed in the context of control by sea-level rise and the reef–sea-level relationships which Neumann and Macintyre (1985) termed keep-up, catch-up, and give-up. A number of studies on the topic by other authors, including other models and controlling factors of reef growth, are not mentioned. These topics include, for example, the importance of antecedent topography, cyclones and sediment redeposition, or exposure to waves and currents. Recent literature also shows that shelf reefs of the western Atlantic are clearly older than 7,000 years as mentioned by Macintyre (e.g., Hubbard et al., 2005).

Chapter 8, by John Pandolfi and Jeremy Jackson, covers broad-scale and long-term patterns in Pleistocene reef communities from San Andrés, Curaçao, and Barbados. In particular they discuss the influence of differential recruitment and larval dispersal on diversity and community structure, biotic interactions, and the role of disturbance on community structure. They found high degrees of variance in community structure at small spatial and temporal scales, a reduction in variance at intermediate scales, and intermediate variance at large temporal scales, indicating interactions of ecological processes.

In the extensive Chapter 9 (75 pages), Precht and Miller discuss ecological shifts along the late Quaternary Florida Reef Tract. In the introduction to the chapter, the authors acknowledge that there are fundamental differences between the modern and the late Pleistocene reefs of the area, in that the major Atlantic breakwater species, *Acropora palmata*, is absent in the marine isotope stage (MIS) 5e reefs. The section that follows discusses possible well-known causes of *Acropora* mortality, such as temperature, inimical water, disease, and storms. The next part covers the Quaternary history of reef building in southern Florida. The authors discuss how higher sea levels during MIS 5e could have been responsible for the transport of inimical bank water to the reef tract, which hampered *A. palmata* development. Both the larger lagoonal area and the lack of a breakwater formed by emergent islands (like today's Florida Keys) were important factors in the Quaternary. In the discussion of the various models for the MIS 5e reefs, bank barrier reefs described by Multer et al. (2002) are omitted, and Precht and Miller reject what they call the ramp hypothesis of Multer et al. (2002) for reasons not entirely clear to me. I would like to draw the reader's attention to the cross section on Figure 9.8, which clearly shows the ramp-type morphology (Fig. 9.8 is redrawn based on the original fig. 7 in Multer et al., 2002). In this context it should also be stressed that the wedge-shaped morphology of the post-MIS 5e reefs in Figure 9.8 is solely based on Multer et al. (2002). Apparently, Precht and Miller misinterpreted the use of steep ramp; ramps may well contain steep elements, however, and they may also contain reefs as well as barriers (e.g., Burchette and Wright, 1992). The existence of a *Montastraea*-dominated, discontinuous reef belt (the modern Keys) does not contradict a ramp morphology. A problem in this particular context might be that—unlike the other chapters, which are in large part based on the authors' own research—Precht and Miller have no publication record on the Pleistocene Key Largo Formation (at least according to the cited literature). The last part of the chapter covers the present status of the Florida reefs, its future, and possible implications for reef management based on such threats as decreasing water quality, climate change, overfishing, and coral diseases.

Coral Reefs and Global Change is the title of Part IV. The three chapters of this section discuss responses of reefs to climatic events and climate change.

Chapter 10, by Bernhard Riegl, explores the impact of the El Niño Southern Oscillation (ENSO) and tropical cyclones

on modern reefs in the Caribbean, southern Africa, and the Arabian-Persian Gulf. Meteorology, the history of the ENSO phenomenon, and tropical cyclones are described in detail. Whereas ENSO and high SSTs may cause loss of photosymbiotic dinoflagellates (zooxanthellae) in reef corals (bleaching), cyclones are major causes of physical damage. Regarding ENSO, the author concludes that even though the phenomenon is very well understood, it remains unclear whether or not the recurrence or severity of ENSO will increase in the near future. Hurricane and typhoon frequency may or may not increase, but storm intensity will probably increase in the next decades, according to Riegl.

Gerard Wellington and Peter Glynn also investigate the ENSO phenomenon in Chapter 11. After an introduction and a discussion of ENSO-related disturbances of coral reefs, including bleaching events, there is comprehensive documentation of the history of ENSO events. The authors next discuss factors that may have caused recent increased SSTs, with the increase of atmospheric carbon dioxide being a major potential factor. Geomorphological, ecological, skeletal, and geochemical ENSO markers on coral reefs are described and evaluated in the next section. The final part of the chapter covers reef and coral recovery from warming events and the possible future of reefs in a warming world. The authors conclude that temperature increases will likely lead to an increase in ENSO frequency and intensity.

Finally, Joan Kleypas (Chapter 12) evaluates constraints on the prediction of coral reef response to climate change. She discusses late Quaternary variation in atmospheric carbon dioxide, SSTs, warming, and ENSO, including models for future developments and cases from the geologic past. The main part of the chapter covers seawater chemistry, i.e., the decrease in carbonate alkalinity due to more and more carbon dioxide production, and the potential loss of the ability of reef corals to secrete their calcium carbonate (aragonite) skeletons. Problems with the model include the fact that, with rising temperature, calcium carbonate saturation increases, possibly outweighing the alkalinity decrease. In this context, it is also of interest that there is a discussion on how corals could have lost their ability to form skeletons repeatedly during their evolution (e.g., Stanley, 2003). Recently, Fine and Tchernov (2007) showed in laboratory experiments that modern scleractinians can lose their skeleton in low-alkalinity seawater, survive, and build new skeletons when the alkalinity increases.

In summary, the new book by Richard Aronson represents a very good summary of current directions in reef ecology research, based on geological or historic approaches, including modern techniques and, for the most part, state-of-the-art knowledge. The book also includes a number of studies that make it quite clear that coral reefs are not only in decline, but that the decline is to a large part caused by human disturbance, and that we need to take actions to decelerate this process. I can highly recommend this book to both reef scientists and students of reef systems, either with a biological and a geoscientific background. As a geoscientist, I would have liked to see more examples from the fossil record and the deep past, i.e., Part III of the book, which includes the fossil reef studies, could have had more chapters in my opinion. Possible topics could have been earlier reef and coral extinction events, which in turn could have been compared to the current decline of corals and reefs. Part IV of the book is too long in my opinion, and there are some repetitions, especially with regard to the discussion of the ENSO phenomenon. As a final comment, the selection of chapters is a little biased toward the Caribbean, especially southern Florida, and more examples from the Indo-Pacific realm would have been interesting as well.

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