sandy shores, rocky and cliffed coasts, coastal wetlands, coral reefs, and cold coasts that are influenced by the presence of ice. Problems unique to specific coastal environments, including several detailed case studies, are described at the end of each chapter. The last chapter (Chapter 8) discusses coastal management, with examples from Bangladesh, Bay of Bengal, and the Mediterranean Sea.

A major problem affecting over ⅔ of the world's sandy coastlines (Chapter 3) is erosion. Global sea level rise is only one of many contributing factors. Other causes include activities, such as dredging, mining, upstream damming, which curtails fluvial deposition, and disruption of longshore sediment transport by construction of piers, jetties, and breakwaters. The contribution of "hard" engineering structures to erosion is documented (in some cases, however, groins have proven successful), and the "soft" option of beach nourishment is evaluated as an alternative strategy. Likely responses of barrier islands and dunes to present and future sea-level rise are also considered.

Cliff failure (Chapter 4) is produced by the interaction of wave attack at the base and water loading changes within the cliff profile. Both of these are affected by human interventions that alter patterns of littoral drift or groundwater flow.

Coastal wetlands (Chapter 5) function both as important sinks of global carbon and as providers of nutrients that sustain the productivity of estuarine and other coastal ecosystems. Coastal wetlands occur in diverse environments, including back barriers, estuaries, river deltas, and along open coasts with abundant sediments and low wave energies. Their survival depends on a delicate balance among sea-level variations, tidal regime, wave climates, and vertical accretion rates. This balance can be upset by natural forces, such as cyclones, neotectonic movements, and also by the clearance of mangroves, salt marshes, reduced sediment inputs due to upstream damming, and water pollution.

Coral reef ecosystems (Chapter 6) have a high gross primary productivity. They show sensitivity to light, water temperatures, changes in tidal levels, and tropical cyclones. Recent episodes of widespread coral bleaching have been attributed to positive sea surface temperature anomalies, partly associated with recent ENSO events, although this temperature-bleaching linkage has been questioned. Additional threats to coral reefs come from blasting, dredging, mining, tourist-related land development, oil pollution, and military activities (*e.g.* the Persian Gulf War; also nuclear testing). Sharp differences of opinion surrounding the robustness or fragility of reef systems may depend on differences in the spatial and temporal scales under consideration. A viewpoint of reef fragility is perhaps more applicable to small-scale biological processes, whereas a view of reef robustness is more appropriate over longer, geological time-scales. However, the geological record may be "too smoothed" to determine the effects of individual events.

High latitude coasts (Chapter 7) are strongly affected by ice, ranging from glaciation, both recent and past, and the presence of permafrost. Because of the rigorous climate, there has been less human impact here than in other coastal environments. Yet pollution and oil spills (*e.g.* the Exxon Valdez oil spill, Alaska) are potential hazards.

Relationships between natural and socio-economic factors (Chapter 8) are illustrated by case studies from contrasting developed and developing regions (*e.g.* the Mediterranean Sea and Bangladesh). In the latter area, the major hazard is the location of large populations on the Meghna River delta, which is especially vulnerable to high storm surges. The Mediterranean Sea is affected by rapid coastal population growth and development. Several response strategies are reviewed.

This book provides a good general overview of the interplay between coastal geomorphology and ecosystems, as well as the role played by increasing levels of human development of the coastal zone. It can therefore serve as an adjunct text in courses on coastal geomorphology, physical geography, and environmental science, as well as provide a biogeophysical framework for coastal managers and planners. Since predictions of global sea-level rise have been scaled down somewhat recently, local ecological and geomorphological effects will dominate. Therefore, the case-studies are useful in illustrating a range of possible responses. Another useful feature of the book is the lengthy reference section (31p). Several minor shortcomings include lack of more recent citations on postglacial crustal adjustments (p. 21–23; e.g. see recent papers by Peltier and Tushingham in Science and the Journal of Geophysical Research); no reference to reports on impacts of climate change in the coastal zone in reports sponsored by the Intergovernment Panel on Climate Change. Also, too much credence is given to Sahagian *et al.,* 1994 paper in Nature (p. 57; see alternate viewpoints expressed in subsequent Letters to Nature), and terms in Tables 6.1 a–c (p.210–211) have not been defined.

Vivien Gornitz
Columbia University
New York, New York

The Prehistory of Sri Lanka: An Ecological Perspective, S.U. Deraniyagala, 1992. Department of Archaeological Survey (Sri Lanka), Memoir, vol. 8 (in two parts, xxvi + 1–366; 367–813). ISBN 955-9159-003.

The book is divided into 7 chapters, 1–5 in part I; 6–7 plus several appendices in part II. The author has attempted to set down the whole work on established geochronological foundations, and he has taken great pains to lay out the "textbook" underpinnings of the geoarchaeology, so that reference to other works on geography, geology and climate are essentially superfluous.

This comprehensive monograph deals with the archaeology of an island country covering more than 25,000 square miles, straddling the meridian 80°E at latitudes 5°55′N to 9°50′N, and occupying a major maritime crossroads in the Indian Ocean. It has a written history in Brahmin literature that goes back more than two millennia, its old name being *Lanka*, which the author uses for brevity. Greeks and Romans called it *Taprobane* and to Arab sailors it was *Serendip.* It is the last name that provides a link with the English language through the expression "serendipity", based on an old folktale about an unexpected discovery in "The Two Princes of Serendip". The Portuguese explorers gave it the name "Zeylan", a corruption of a Sanskrit name and from that came the English name Ceylon.

The basic chronology (Chapter 3) deals with the *Ratnapura Beds*, the principal alluvial complex that contains traces of early humans. It is typically developed in the "Ridge and Valley" country of the southwest in a trellis pattern of radial and circumpherencial (strike) valleys that are dissected into the youngest of a succession of peneplains which characterize the mainly Precambrian landmass. The alluvial gravels have been extensively prospected for gemstones, and the mining operations have "serendipitously" brought to light numerous faunal remains and artefacts. This "Ratnapura Industry" contains hammer stones, and flakes, but no Acheulian-type biface tools. The open-face mine cuts disclose bedrock at 3–30 m overlain by a stratigraphic succession of gem-bearing gravels and sands at the base (up to seven horizons) with a fauna of major mammals, followed by black or blue clay with leaf beds, sands, clays and loams. Ferricretes tend to mark water-table levels. Chronologically, most of these beds appear to be Middle to Upper Pleistocene, but they grade upward into the Holocene as shown by a radiocarbon-dated (7520 ± 150 BP) sample of wood at a depth of 18 m, although this is most likely a product of landsliding. The teeth and bones of the large mammals include varieties of *Elephas, Leo, Rhinoceros, Hexaprotodon* (a hippopotamus with six incisors), *Bos, etc.*; a freshwater snail *Paludomas* is also found, together with a *Tanalia*, a clam. The tooth of a primitive hominid *Homopithecus sinhaleyus* is interesting but not particularly diagnostic.

There can be no question but that these faunas migrated from peninsular India to Sri Lanka during Pleistocene low sea-level stages (p. 610) and there seems a probability of multiple immigrations. The Palk Strait that separates Sri Lanka from India (see p. 484) has an 11 m depth threshold (with small tidal range), so that it was dry land from about 8 kyr BP back to the Eemian interglacial, *ca.* 100 kyr BP, and then cyclically back into the early Quaternary, with isolation phases corresponding to each interglacial. While the author accepts the concept of a certain amount of neotectonic activity, earthquakes being not infrequent, Sri Lanka is basically a rather stable region and there is no evidence that the usual eustatic fluctuations should not be taken as a general guide to Quaternary evolution. The author (p. 431) recognizes the inappropriate nature of the old Günz-Mindel-Riss-Würm labels, in the light of the marine oxygen-isotope chronology; at the present stage of development it is still impossible to transfer the latter to this terrestrial setting.

What makes Sri Lanka a particularly interesting setting for geoarchaeological studies is its almost unique combination of (a) a tropical/monsoonal climate, (b) a mountainous interior, providing niches for continuous biologic survival, and (c) its quasi-continuous physical connection with peninsular India that is filtered by the eustatic fluctuations, being totally isolated during interglacials. The climatic factor is particularly interesting, because modern oceanographic work suggests an on-off switching of the monsoonal air flow, on during interglacials, off during glacials when a more insular convective system took over, with strongly seasonal aridity. (The author, *e.g.* p. 86, seems unaware of these developments.)

The author points out the anomalous relationship suggested by the Ratnapura gravels in the face of sluggish stream velocities at the present day. There are some indications that these basal gravels and sands constitute a condensed accumulation of repeatedly reworked climatogenic facies, a product of seasonal flash-flooding in an otherwise dry climate. In the more complete sections, there is evidence of repeated fine-grained horizons which suggest thalassostatic ("back-up") fluvial hydrology, such as would be expected with each interglacial stage. It should be mentioned that a number of these ideas were developed by the author's father P.E.P. Deraniyagala, who, as former director of the National Museum in Colombo, collected and first described many of the faunas now orientated into their chronostratigraphic slots, often in the pages of an important monograph series, *Spolia Zeylanica.* His unique contributions are freely acknowledged by the son. This reviewer enjoyed some correspondence with Deraniyagala senior and can also acknowledge the role played by Frederick Zeuner in developing ideas about the Quaternary climates of India and Sri Lanka.

What is particularly interesting about some of the basal Ratnapura faunas is their inclusion of dry, savanna-type species, which are found also in the Narbada Valley fluvial sequence of western India and in the Siwaliks of the Himalayan foothills (see p. 75). It was these observations (by Deraniyagala senior) that helped convince this reviewer about the global nature of the Quaternary tropical aridity during the glacial maxima, first seen in Australia, then in Africa and finally in Brazil (Fairbridge, 1972, 1987).

We turn now to Deraniyagala's second most important category, *The Iranamadu and Reddish Brown Earth Formations*—abbreviated to I Fm and RBE Fm. These are widely developed in the northwest, east, and southeast (map 11, p. 35), which corresponds to the so-called "Dry Zone" (900–1400 mm annual rainfall). The I Fm is limited to within 32 km of the sea and is marked by low, flat to undulating terrain, while the RBE Fm reaches up to 300 m and is associated with latosols and "stone lines" such as described from Brazil by Fairbridge and Finkl (1984), and by others from the tropics and subtropics of Africa or Australia. Deraniyagala also regards them to be of colluvial origin (p. 95). Dry valleys in I Fm often are floored by gravels, ferricrete and human artefacts. The surface is often covered by deeply leached, white quartz sands, known as *teri* in India, also well known in Brazil, Australia and parts of tropical Africa.

The bedrock unconformity below the I Fm is either on Precambrian gneiss or on Jurassic and Tertiary sedimentary formations. Its basal component in the northwest is a ubiquitous gravel, well rounded and homogeneous, believed to represent a product of fluvial (flood) transport and coastal reworking. It would be exposed on the west coast to the powerful SW Monsoon, which is absent to the north and east. A northward transport is evident from the fact that in the north the bedrock consists of the soft Jaffna Limestone (Miocene). The gravels are sometimes cemented to an "ironstone", evidence of a former sea-level related groundwater horizon. Karstic dolines in the limestone are often floored by lag gravels with a confusing variety of cultural artefacts (p. 92).

Generally overlying the gravels of I Fm are a series of sandy-clay loams, which are believed to represent deeply weathered near-shore and coastal sands where the feldspars and ferromagnesian silicates of the parent sands (derived from the Precambrian uplands) have been chemically degraded to clays (p. 87). Size analyses suggest that the sands were for the most part redistributed as littoral dunes, but that the eolian cycle was prior to the chemical weathering; otherwise the clay components would have been winnowed out. On the coast today the shore-dunes merge inland into parabolic dunes aligned with the SW monsoon direction and reach up to 30 m elevation. In southern India the *teri* sands reach up to 60 m above MSL, but they would have the wrong facing for monsoon eolianites, reflecting rather successive shore deposits (beachridge complexes in the reviewer's opinion, although these are not mentioned by the author). They are separated by former lagoon deposits. The same successive coastal sand-lagoon facies alternation has become known to North American readers by the studies of Donald Colquhoun and associates on the coastal plain of South Carolina (see their well-dated Holocene record, in Finkl, 1995).

Sri Lanka has a very small tidal range and with its abundant supply of unconsolidated coastal sediments, it is an ideal setting for the development of barrier beaches and parallel lagoons. Indeed the early Dutch colonists there were able to join them into a series of coastal canals that antedated the American system by more than two centuries.

Geologically, a common thread seems to tie all these barrier island or beachridge-lagoon environments together. This is a uniform history conformable to a global forcing, but subject to a specific set of requirements or constraints, *viz.* (a) an essentially stable tectonic setting, in plate tectonics, a mature, extensional, "trailing edge" coast of the "Atlantic type" of Suess (in Fairbridge, 1968, p. 34); (b) an abundant supply of loose, well-weathered clastic particles (mainly quartz), favoring prograding landforms; (c) a mild, sub-tropical to tropical climate. Sri Lanka seems to fit ideally to this prescription, and thus its coast displays many attributes which apply also to the southeastern United States, eastern Brazil, and some parts of Africa and Australia. Even when the prevailing wind is not on-shore, in the warm latitudes there is almost always the powerful diurnal sea-breeze/land-breeze effect which is sufficient to convert the inner part of any beach into a littoral dune (shore-parallel). Only where such winds are enhanced, at least seasonally such as by Sri Lanka's SW Monsoon, do the littoral sands break out and develop long, parabolic tongues. As Deraniyagala points out (p. 91) the frequent frosting of the I Fm sand grains is not immediately diagnostic of eolian genesis and can be confused with pitting by ground water. (The matter can easily be solved by electron microscope examination.)

The very fine-grained sands of I Fm are characterized in places by the distinctive honeycomb structures of termitaria (p. 92). These merit closer study as the author points out; a significant point is that the termites are useful paleoclimate indicators insofar as they require at least a seasonal humidity, and are absent from perennially arid environments.

As might be expected the former lagoon deposits of the I Fm are accompanied in places by rich deposits of lagoon molluscs (p. 93). While formerly mistaken for *in situ* accumulations, they are almost certainly midden deposits. Curiously, these interesting facies do not appear to have received much attention. The former lagoons, on silting up, create marshy settings for dark gray to black *grumusols* (p. 94), which are thus useful potential indicators of former sea levels.

Along the valleys near the coast there are thalassostatic terraces in a 5–10 m range above MSL; they appear to be Eemian, but do not carry any artefacts or fossil indicators. They are constructed of gravels and reddish brown earth soils, which clearly speak for a Pleistocene age. In places the 5–10 m terraces are partly truncated by Holocene terraces (and coral reefs in places) in a 1–3 m range, which the author recognizes as comparable to the mid-Holocene Peron terraces of Western Australia. They have been widely identified around the Indian Ocean (p. 98). A lower-than-present sea level of post-Younger Peron age identified with artefacts and charcoal, radiocarbon-dated at 1880 and 2220 BC (calibrated).

Lagoon shells of aragonite (*Arca, Meretrix*) have been radiocarbon dated at 2820 BP (calibrated 997 BC). Another sample, on similar material, at 17 m elevation above MSL, was 2960 BP (calibrated 1240 BC), but with stone tools in the underlying stratum (a coastal dune), would appear to be transported to a midden site. A third sample, at 4500 BP (calibrated 3310 BC), was associated with stone tools, but was apparently a pre-ceramic midden. Unfortunately the author does not clearly distinguish between Holocene coastal dunes and the earlier *teri* dunes; thermoluminescent dating of the latter gave dates of 22,600 BP and 28,260 BP, which correlate nicely with radiocarbon dating of comparable artefact-bearing sands in southern India (p. 98). An underlying bed gave TL dates at 74,200 and 64,380 BP, located below a paleosol. An eolianite in SE India, overlying the 8 m terrace, contains aragonitic land snails that have been radiocarbon-dated at 21,000 BP and 25,450 BP.

We turn finally to *Cave Deposits*. These have generated "the most reliable information in the form of radiocarbon dates on charcoal from sealed stratigraphic horizons" (p. 107). Numerous dates demonstrate the vigorous presence of the south-Asiatic "Mesolithic" in the range 28,000 to 4000 BC, with clearly defined stratigraphic horizons. The lithic technology of geometric microliths appeared at the earliest date in Sri Lanka (p. 689). The detailed figures and stratigraphy are presented systematically in Appendix I (p. 685–706).

The regional Mesolithic is followed by the "protohistoric" Early Iron Age (*ca.* 900–600 BC), without any evidence of classical Neolithic or Chalcolithic. Deraniyagala (p. 707) attributes this absence to ecological factors, notably the heavy soils and dense rain forests being unconducive to the Neolithic type of farming technology. The advent of the Iron Age changed all this dramatically, iron tools permitting forest clearing and permitting rice paddy cultivation by the Sinhalese and Tamil ethnic groups. With rice came also pottery and the appearance of the horse and domestic cattle.

The more ancient Veddas ("Vaddas" in this volume) maintained their hunter-gatherer economy, inhabiting the eastern and mountainous part of the country to this day. This extremely ancient stock is often regarded as the ancestors of the Australoids; radiogenic dating of early sites in Northern Australia has pushed their immigration dates back to before 50,000 BP. There being no land bridges to cross the "Wallace Line", in this reviewer's opinion, the Vedda migrations began *before* the last interglacial, when repeated eustatic rise of sea level (to +8 m) made many coastal lowlands and low islands untenable. Continued occupation of flooded landscapes being impossible, early humans were forces to evacuate; whether by means of newly designed boats or as "waifs" on accidentally occupied rafts, we cannot say. Deraniyagala favors the boat hypothesis, but in truth there is no evidence one way or the other. The "bottom line" is that the Australoids made the journey—that is, unless one follows the creationist model.

Interestingly, the author believes that the Veddas survival is due to the development of a symbiotic relationship with the new arrivals, bartering forest produce for their iron tools and so on. Stone implements were very quickly supplanted. The youngest date for a Mesolithic survival is 1800 BC.

Sri Lanka is fortunate in having a written history that goes back more than two millennia, with Brahmin scripts that are traced to the Ganges valley centers, *ca.* 250 BC. The earliest port settlement disappears to have been at Matota, a well-protected site a short distance across Palk Strait from southern India. Probably for health reasons, the major center was at Anuradhapura, 50 miles inland, which by 800 BC covered over 10 ha, and within 200 yr extended to more than 50 ha. The island's principal iron and copper deposits were 70 miles east again, on the NE coast, at Seruvila, located in the fertile and well-watered reddish brown earth belt. The paleoclimatologist may speculate perhaps that the introduction of the horse, a savanna-steppe animal by the first millennium BC might suggest increasing cycles of seasonal aridity, especially here on the "dry" north side of the country and remote from the rainforests of the SW monsoon side.

The "Early Historic" period began with evidence of the first writing in Sri Lanka about 600–500 BC with delicate bone points which appear to be the first styli. By the time of Alexander the Great (356–323 BC) considerable maritime trading is evident; his admiral Onescritos reported 35-ton ships undertaking 20-day voyages from the west coast of India, and traders from the Near East or Ionian area (known ? as "Yonas") are believed to have been active since 850 BC, with a special quarter reserved for them at Anuradhapura; at that time West Asian ceramics began to appear. By 250 BC to AD 100, mega-irrigation projects were being undertaken for more extensive rice paddy cultivation, and large-scale public monuments were constructed, identifying Anuradhapura as one of the great cultural centers of the age. Glazed roof-tiles appeared and quantities of coins, Roman and Indian, have been found. The port of Matota underwent a massive expansion.

A "Middle Historic" period, *ca.* 300–1250 AD, saw a profusion of Near Eastern ceramics that was supplemented by Chinese wares in the 9th to 11th centuries. Sri Lanka's major export was probably iron, evidence of its smelting being found as slag in innumerable places. Excessive tree-felling, for charcoal, may have exacerbated an increasing frequency of drought cycles. The author provides maps and detailed radiocarbon dates on the dateable contents of much of this material. From around the citadel of Anuradhapura some 45 dates document the various archeological layers, which start *ca.* 3900 BC, the peak of a Holocene low-latitude pluvial. We note that 3940 BC marks a maximum in the ^{14}C flux measured in tree rings by Stuiver and associates, a "Spörer-type" event of global cooling; it appears to reflect an expansion of the polar high pressure vortex, causing a southward shift of the main southerly jet stream trajectories. This led to increased rainfall and prosperity in the Near East, increased winter snowfall in the Himalayas and thus to an expectable increase in the strength of the SW Monsoon.

Solar radiation, during the early to mid-Holocene, influenced by the Milankovitch effect of the precession cycle, would in the general way have brought warmer summers (thus stronger monsoons) and cooler winters in the northern hemisphere (and thus winter rains in Rajasthan) as shown by Bryson from Singh's pollen data. This broad pattern formed an envelope that was modulated by large secondary fluctuations, the largest of which was 6200 BP (calibrated 4250 BC). Bryson's curve (see p. 157; reproduced in Fairbridge, 1976) is very helpful for picking up the strong monsoonal/semi-arid alternations in Sri Lanka; we can now add the Stuiver and Braziunas ^{14}C flux peaks, with Near Eastern correlations (in sidereal yr, with the ^{14}C yr given as BP): 1870 BC (3400 BP) Babylonian peak (Harappan terminus), 2860 BC (4200 BP) Akkadian peak (Harappan-1 peak), 3640 BC (4800 BP) Memphic peak, 3940 BC (5000 BP) Amratian peak, 4460 BC (5400 BP) Rajasthan peak, 5640 BC (6600 BP) Fayum peak, 6450 BC (7300 BP) Damascene peak, 7050 BC (7900 BP) Jordanian peak, and 7600 BC (8800 BP) Jericho peak.

A comparison between these figures and the newest analysis of Scandinavian neoglacial advances (Karlén *et al.*, p. 49, in Finkl, 1995) shows that cultural crescendos, together with rainfall abundance, in the Near East, Rajasthan and Sri Lanka all correspond to times of glacier advances in Scandinavia, as well as to negative peaks of solar activity (through the proxy of ^{14}C flux from tree-ring analyses).

Emerging from these conclusions is a remarkable contrast between two distinctive climatic forcing functions:

(a) On the scale of Milankovitch cycles ($\sim$20 kyr and up), the variations of insolation, that is the effective solar radiation distributed over the Earth's surface, can lead to global cooling (in the order of 3 to 5 °C), resulting in higher albedo, lower sea-surface temperatures, greater continentality and climatic aridity, together with greatly amplified global wind velocities and expansion of deserts and savanna or steppe lands.

(b) On the scale of 500–1000 yr during interglacial cycles, the forcing is NOT by variance of the Earth-Moon-Sun orbits, but by variance of solar activity itself, *i.e.* absolute radiation. This variable in the Sun's energy emissions that is demonstrated by the ^{14}C flux rate in tree rings, appears to be forced by the changing gravitational torques developed between the planets (especially the Jupiter-Earth-Venus) and the Sun's photosphere (Fairbridge and Sanders, 1987).

These thoughts bring into focus the extraordinarily useful position occupied by Sri Lanka in helping to solve one of the planet Earth's most elusive climatic challenges.

Needless to say, the above discussion is centered on the reviewer's personal interests and opinions, which are very properly to be taken "with a grain of salt". This observation in no way detracts from the fact that Deraniyagala has created a tour-de-force of lasting value. Copies of this work should be in every institute and department of archaeology.

For the future, there is one aspect of the "big picture" that is needed to encompass a general understanding of the geoarcheology of a given country and that is the discipline of geomorphology. This volume ignores it and that is a pity because there are excellent studies on the landforms of Sri Lanka (notably Bremer, 1981). True, this literature is mostly in German which isolates it from the average worker, but some efforts at integration would certainly be worthwhile.

Rhodes W. Fairbridge
Columbia University, and
NASA-Goddard Institute for Space Studies
2880 Broadway
New York, NY 10025, U.S.A.

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