ready completed its rather brief lifetime, while the other three promise to be among the major facilities that will provide the astronomical discoveries expected during the 1980's.

The Very Large Array (VLA) is the name given to the multielement, aperture-synthesis antenna array built by the National Radio Astronomy Observatory (NRAO), with $78 million in funds from the National Science Foundation. Completed early in 1981, this telescope consists of 27 movable antennas, each 25 meters in diameter, capable of working together to provide a spatial resolution at wavelengths of 21 centimeters, 6 centimeters, 2 centimeters, and 1.3 centimeters, comparable to that of the best optical telescopes. David Heeschen, former director of the NRAO, describes the series of political, financial, and technological hurdles that had to be surmounted over a 10-year period to bring this dream to reality, covering the gamut from on-site salvage archeology to a nationwide search for used railroad rails to the decisions that led to the use of a daring new approach for the waveguides needed to provide the critical electrical linkage of the separate antennas. The VLA represented the major capital project in the NSF astronomy budget during the 1970's, and so far no new initiative of this magnitude has developed as a successor.

The second chapter in this monograph deals with the Multiple Mirror Telescope (MMT) built at Mount Hopkins (near Tucson) by the University of Arizona and the Smithsonian Astrophysical Observatory. A substantially more modest undertaking than the others described in this book, the MMT is a test-bed for new approaches that will be required for the much larger optical telescopes being planned for the late 1980's and beyond. A conventional large telescope mirror of ceramic material becomes too heavy and difficult to maintain in precise optical figure for diameters much greater than that of the 6-meter telescope in the U.S.S.R., now the world's largest. The MMT achieves a much more compact design by combining the images from six mirrors, each of 1.8-meter diameter, to produce the light-gathering power of a single mirror of 4.5-meter diameter. As described by its director, Jacques Beckers, and ten other authors, this telescope introduces many innovations in mechanical as well as optical design, including an altazimuth mount and a rotating building instead of the more conventional dome. The greatest challenge has been to maintain the optical alignment; an elaborate laser system has now been abandoned in favor of an approach that uses the stellar images themselves. The more difficult task of also obtaining phase alignment has so far been successful for only two mirrors at a time, but work continues on this problem.

Unlike the other instruments described here, the Space Telescope (ST) has not yet been built. Designed for shuttle launch in 1985, the ST is a nearly billion-dollar project that represents NASA's single largest space science effort in the 1980's. The telescope, of 2.4-meter aperture, will achieve its primary advantage by escaping the limitations of the terrestrial atmosphere on resolution, permitting it to realize the 0.1 arc second resolving power of the optics. Smaller star images will yield a higher signal-to-noise ratio for faint sources, thus permitting as much as a 50-fold increase in sensitivity relative to ground-based telescopes. Project scientist C. R. O'Dell discusses the checkered history, and the great potential, of this instrument. It is almost an article of faith for astronomers today to rally around the ST, but one must note that there remain many problems to solve, particularly with the fine-guidance system, before the telescope can be called a success.

Riccardo Giacconi and seven colleagues from the Harvard-Smithsonian Center for Astrophysics describe, in the final chapter, the Einstein x-ray observatory, launched in 1978 as the culmination of a decade of planning that included several smaller x-ray satellites. The distinguishing characteristic of Einstein (officially called HEAO-B by NASA) was the use of grazing-incidence optics to create a true telescope with imaging capability, as opposed to the wide-field detectors flown previously. During its 2½-year lifetime, this telescope provided our first pictures of the x-ray universe, a unique window on high-energy process es in space. Giacconi and colleagues trace the history of x-ray astronomy, in which they have played a leading role from the beginning. They also discuss the next generation x-ray instrument, AXAF (Advanced X-Ray Astrophysics Facility), a proposed billion-dollar program anticipated for the late 1980's, but rapidly receding into the future as cuts in the NASA science budget become ever heavier. Perhaps it is a sign of the times that Giacconi, after two decades of advocacy for x-ray astronomy, has changed fields to become director of the Space Telescope Science Institute.

One common element of the four chapters is that protracted political battles had to be fought—often over and over again—to make each of the facilities a reality. This book should shatter the illusion, if anyone still holds it, that modern astronomy is an academic, ivory-tower pursuit, carried on independent of the high competition and bureaucratic tangles that characterize "big science" in the United States today. A major new instrument requires at least a decade of intense effort, half of it expended before official approval to begin is ever granted. All of this is worthwhile if the end result is the successful development of major new capabilities, but it becomes a tragic misuse of our best scientific and administrative talent if the result is repeated deferment and ultimate cancellation, which seems to be the recent pattern under shrinking federal science budgets. Anyone contemplating beginning a major new science facility should read this book and think hard before making such a commitment.

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Planetary Geology

The Surface of Mars. MICHAEL H. CARR. Yale University Press, New Haven, Conn., 1981. xii, 232 pp., illus. $45. Yale Planetary Exploration Series.

Unlike some earlier books published to coincide with peak popular interest as a spacecraft arrived at the planet in question (hence guaranteeing overnight obsolescence), this book comes at the end of the Viking program, after its author, as the leader of the Viking Orbiter Imaging Team, has devoted several years to absorbing the meaning of Viking, Mariner, and ground-based data about Mars. The book is an excellent and evenhanded survey of the current state of research about Mars.

Writers who try to summarize the knowledge of a whole planet run the risk of producing a few terrific chapters on their own specialty, only to lapse into superficiality on other subjects. Michael Carr has done a remarkably good job of overcoming this problem. He has capitalized on his close work with Viking colleagues in various disciplines, and he has also made a rewarding effort to review a broad range of pre-Viking and post-Viking literature. This enables him not only to discuss recent prominent theories on subjects such as the source of the channels, variations in past Martian climate, or the interpretation of crater counts but also to show how these theories evolved and to weigh pros and cons as necessary.

The book is comprehensive and profusely illustrated. Contrary to the title, there is discussion not only of the surface of the planet but of the atmosphere and satellites as well. Topics include the outgassing history, volcanoes, tectonics, gravity data, the forms and history of the channels, and the distribution of volatiles. There is a special chapter on the search for life, reprinted from a 1979 summary by Harold P. Klein, who headed the Viking biology team.

Carr not only reviews, he synthesizes, and his conclusions are in the mainstream of current thinking. Carr's Mars has cratered plains formed nearly 4 billion years ago when Mars may have had a thicker atmosphere. Some dendritic channels nearly that old are probably runoff channels caused by water flow. Tharsis volcanism was already under way 3 billion years ago, when some large outflow channels may have formed. The Tharsis lava plains, many canyon systems, and some of the complex fretted channels, caused by mass wasting of earlier channels, may date back to 1 to 2 billion years. The huge volcanoes, Olympus Mons and its companions, were probably active within the last 1 billion years, and the stratified sediments of the polar regions have windblown surfaces as young as a few hundred million years. Permafrost is everywhere. Throughout the book crater counts and other numerical data are provided to support the geological interpretations.

I object somewhat to the unwieldy format (about 12 by 12 inches), given that only about 21 of some 184 illustrations take full advantage of page width and only a lunar photo bleeds to three edges of the page. Figure 10.6 of chaos and channels is upside down, and p. 197 refers to 1877 as the year when "Antoniadi first reported seeing canals"; it was really Schiaparelli who noted them then (as correctly stated on p. 2), and they were sketched even earlier.

A final quibble: Why is it that just because a spacecraft lands with one leg on a rock its photographs are reproduced forevermore with crooked horizons? If Ansel Adams got one of *his* tripod legs on a rock, he'd crop the picture to get a straight horizon. As we try to describe planets as real places to the public, understandable, rather than cockeyed, views of planetary landscapes are important. So I wish that the cover photo and figure 11.8 had horizontal horizons. It's hard enough to hold a 12 by 12 inch tome straight without crooked horizons!

As exploration of our cosmic environment falters owing to federal-funding reversion to 19th-century technology (coal, oil, and guns), this book stands as a useful memorial to the first golden age of Martian exploration, and it is a masterly summary of questions that will surely be probed by future explorers.

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The Oceans

The Sea Floor. An Introduction to Marine Geology. E. SEIBOLD and W. H. BERGER. Springer-Verlag, New York, 1982. viii, 288 pp., illus. Paper, $20.

Marine Geology. JAMES P. KENNETT. Prentice-Hall, Englewood Cliffs, N.J., 1982. xvi, 814 pp., illus. $34.95.

These two complementary books are a welcome addition to a field lacking such texts for over 20 years. Although both books treat aspects of crustal structure and geophysical methodology, the treatments serve mainly as a structural framework for the major focus: the impact of plate tectonics on the circulation of the oceans and on world climate. The evidence of this impact lies in the sediments of the sea floor, but the ultimate payoff lies in interpretations of changing ocean circulation over the last 200 million years as the ocean basins evolved toward their present shapes. Both books concentrate on the Mesozoic and Cenozoic record (rather than on the Paleozoic history, which is stressed in Schopf's recent *Paleoceanography*, or the modern ocean, which is the focus of Gross's *Oceanography*, a third edition of which has just appeared). The authors are all well-known generalists with diverse research experience.

The Seibold-Berger book is intended as a brief overview of the field and would most usefully serve the academic community as a first-level checklist for teachers just creating undergraduate or graduate courses. It is also intended to reach those without formal training in the field. Although I find it difficult to envisage this wider readership's being drawn to a basically academic-style text, the writing makes some concessions to a wide audience by generally moving quickly to the major messages without lingering over details and methodology. But the illustrations are wholly from academic sources, with no allowance made for an audience accustomed to the glossy pictorial style of the new science magazines.

The book grew out of an earlier edition in German by Seibold, with updating and expansion by Berger. The newer sections are in general roughly attached to the older, with the seams showing. The older portions of the text treat the major findings in plate tectonics with admirable balance and historical sensitivity, and the figures from the classic papers are well chosen. Some of the older parts (those on sediment origin and dispersal, for instance) appear not to have been brought up to date at all. Updated or newly written sections convey much of the excitement generated during the last decade by the rapidly expanding knowledge of sea-floor history. The science presented is for the most part solid, except for minor eruptions of personal overenthusiasm (for example, the rather doubtful "global meltwater spike" hypothesized by Berger for the last deglaciation). Scientific errors are relatively rare (an example of such an error is a misidentified continental slope on p. 37), but mechanical mistakes are more numerous—perhaps two dozen typos including several *ist*'s slipping through from the German version. All in all, this is an enthusiastic but hastily done effort for a somewhat uncertain audience.

Kennett's book was heralded by a remarkable advertising flier ("When . . . it's a book by James Kennett, you're confident"). Kennett apparently is a legend at Prentice-Hall because of having met all 19 chapter deadlines. Perhaps intending a reward, Prentice-Hall created the Kennett-confidence persona, leaving others in the field to ponder uneasily what alliteration might grace their own names.

The book is a major success. The scope is broad, the depth substantial, the writing and figures clear, and the price surprisingly reasonable for so full an effort. The references are even current well into 1981. Teachers will find this an excellent and useful textbook with, if anything, more detail than they need. The first quarter of the book establishes basic concepts in the diverse subjects of geophysical methodology, time and stratigraphy, plate tectonics theory, crustal composition, and oceanic circulation. Kennett next discusses continental margin types and sea level history, moves to the deep sea to focus on the open ocean record, and finishes with an extensive