By contrast, !Kung low fertility poses an enigma. The !Kung have the same age-specific *pattern* of marital fertility as other populations lacking the use of contraception but much lower *levels*. In terms of Coale's "Hutterite" indices, their 0.40 index of marital fertility is very low indeed. Howell implicates the mean age at menarche (the !Kung have the latest observed in human populations) and long intervals between births in this low fertility. Sterility from venereal disease, which some cohorts contracted from outsiders, also plays a part. To explain these patterns, Howell turns her attention to the controversial Frisch critical-fatness model, which postulates that women mature reproductively when they accumulate body fat to levels critical for menarche and then for stable reproductive ability. Although the !Kung eat balanced nutrients, they consume relatively few calories. They are remarkably lean. When Howell converts stature measures to estimates of individual women's levels of body fat, the results suggest that the Frisch model, if valid, could be implicated in !Kung low fertility. Not only would maturing !Kung women approach menarche and stable reproductive ability late because of low deposition of body fat, their body fat would drop below critical levels for stable reproductive ability while they lactate, thus extending birth intervals. Moreover, critical fat levels thus could serve to regulate this hunter-gatherer population homeostatically should it outstrip the Kalahari desert's capacity for feeding it. The hypothesis is too intriguing for Howell to set it aside easily. On the other hand, the data in this section of the book will not convince Frisch's critics, and Howell is careful not to embrace the explanation. In the final analysis she leaves !Kung low fertility explored but unexplained.

Howell's forthright exposition adds to the credibility of the study. She confronts fairly the difficulties and probable pitfalls of analytically bounding groups such as the Dobe, many of whom have joined other !Kung settlements or have taken up livelihoods at new Bantu cattle-posts. After exploring the genetic implications of !Kung demography, she is willing to acknowledge that the results are inconclusive.

If the study falls short anywhere, it is in its lack of comparative ethnographic perspective rather than in its demography. Howell eschews comparing !Kung with other hunter-gatherers, for whom demographic data are largely unreliable. But had she done so she would have recognized how prevalent among them are women's enjoyment of sexual liaisons and women's reluctance to bear and raise children who will tie them down. Correspondingly she might have focused more attention than she does on !Kung infanticide and on cultural explanations of why !Kung fertility is so low.

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## An Updating in Petrology

**The Evolution of the Igneous Rocks.** Fiftieth Anniversary Perspectives. H. S. YODER, Jr., Ed. Princeton University Press, Princeton, N.J., 1979. xii, 588 pp., illus. Cloth, $35; paper, $15.

The science of igneous petrology is founded on astute observation of rocks, guided by the rigorous principles and data of physical chemistry. Almost all the latter have been developed since 1900, and the one man who stands out in their development is the late N. L. Bowen of the Carnegie Institution of Washington. His 1913 experimental phase equilibrium diagram of the plagioclase feldspars stands without major revision today, and his powerful theoretical analyses brought a good many matters to completion. His invited lectures at Princeton in 1927 formed the basis of an elegant treatise (1928) whose pointedly Darwinian "evolution" in the title reflected Bowen's lifelong emphasis on fractional crystallization as a clue to the diversity of igneous rocks. The book is still treasured for its masterly integration of experiment and observation, its exquisite prose, and its driving intensity. It is the work of a young scientist who was to see nearly three decades more of discovery, culminating in a spectacular resolution of the granite problem with O. F. Tuttle in which it was proved that granite magma could easily be produced by the partial melting of sedimentary rocks.

The present volume is a sort of Bowen Redux, written by 18 strong men, one to a chapter. The ground rules imposed by the editor required limitation to the broad subject matter of the original chapters, with only moderate allowance for verbal inflation despite the explosion of both field and experimental knowledge since 1928. The result has a unity of purpose imposed by Bowen and a unity of tone far above that of a typical festschrift.

There are many things in the book that Bowen would have liked, among them an extension of theory that enhances the quantitative application of phase equilibria to natural rocks and melts. Investigations at controlled oxygen fugacity have clarified the role of oxygen in magma evolution. Studies at high pressure with and without $H_2O$ and $CO_2$ have illuminated the origins and source regions of magma and have provided the groundwork for understanding the degassing of the earth to form the atmosphere and hydrosphere. Kinetic studies of crystallization rates have permitted cooling histories to be calculated for terrestrial and lunar volcanic glasses. Detailed field evidence and new theory have clarified the process of crystal sorting as a mechanism of fractional crystallization. Isotope and trace element studies are being used effectively to detect contamination of magmas by crustal rocks or by other magmas. The studies that Tuttle and Bowen pioneered with granitic rocks have been extended to the economically interesting alkaline rocks. The feldspar-free lavas, given short shrift by Bowen, have been extensively explored in laboratory analog systems. Most striking, knowledge of the earth's interior and of plate tectonics has provided a global framework for the consideration of magmatic processes. Bowen's own able attempts to frame such a setting suggest that he would have greatly appreciated this revolution. The new chapters contain information and ideas not previously published in journals.

If such a book can have a conclusion, it is probably that Bowen's identification of fractional crystallization as a ruling process causing diversity in igneous rocks was correct but that the myriad processes between the generation of magma at depth and eventual crystallization of the *n*th batch of liquid make fractional crystallization alone too simplistic a model. Nevertheless, Bowen's insights are celebrated in every chapter. Even when wrong, he was edifying, and he was seldom wrong without good reason.

Bowen's book served for half a century as a blueprint for research, practically a super-proposal. Can its latter-day counterpart hope to serve such a function? Probably so. For example, silicate liquid immiscibility, discounted by Bowen, has now been convincingly demonstrated in lunar and terrestrial rocks and in the laboratory, and yet a strong case for its operation on a significant scale in nature is difficult to make. And perhaps the most challenging subject for new research will be the structure and thermodynamic mixing properties of silicate melts, for it is surprisingly true that no silicate liquidus diagram has yet been successfully predicted ab initio from calorimetrically derived thermodynamic data. In order for magmas to serve as probes into the interior of Earth and other planets, or as guidelines for condensation sequences in the early solar system, such calculations would be most helpful. A chapter by Burnham makes great progress in the matter, not starting from calorimetry but using one phase diagram, with a minimum set of assumptions, to solve a sequence of other phase diagrams. Perhaps this is the beginning of wisdom. At least it has the elegance of Bowen's approach and something of its humor.

Historians of science should have a good time with this book and with Bowen. Having the master's book brought up to date by his able followers is in itself a rare experiment, particularly when preceded by such an explosion of discovery. That such a format could even be contemplated is impressive testimony to the prophetic integrity of the original. That it should succeed is a modest triumph of common purpose and good sense.

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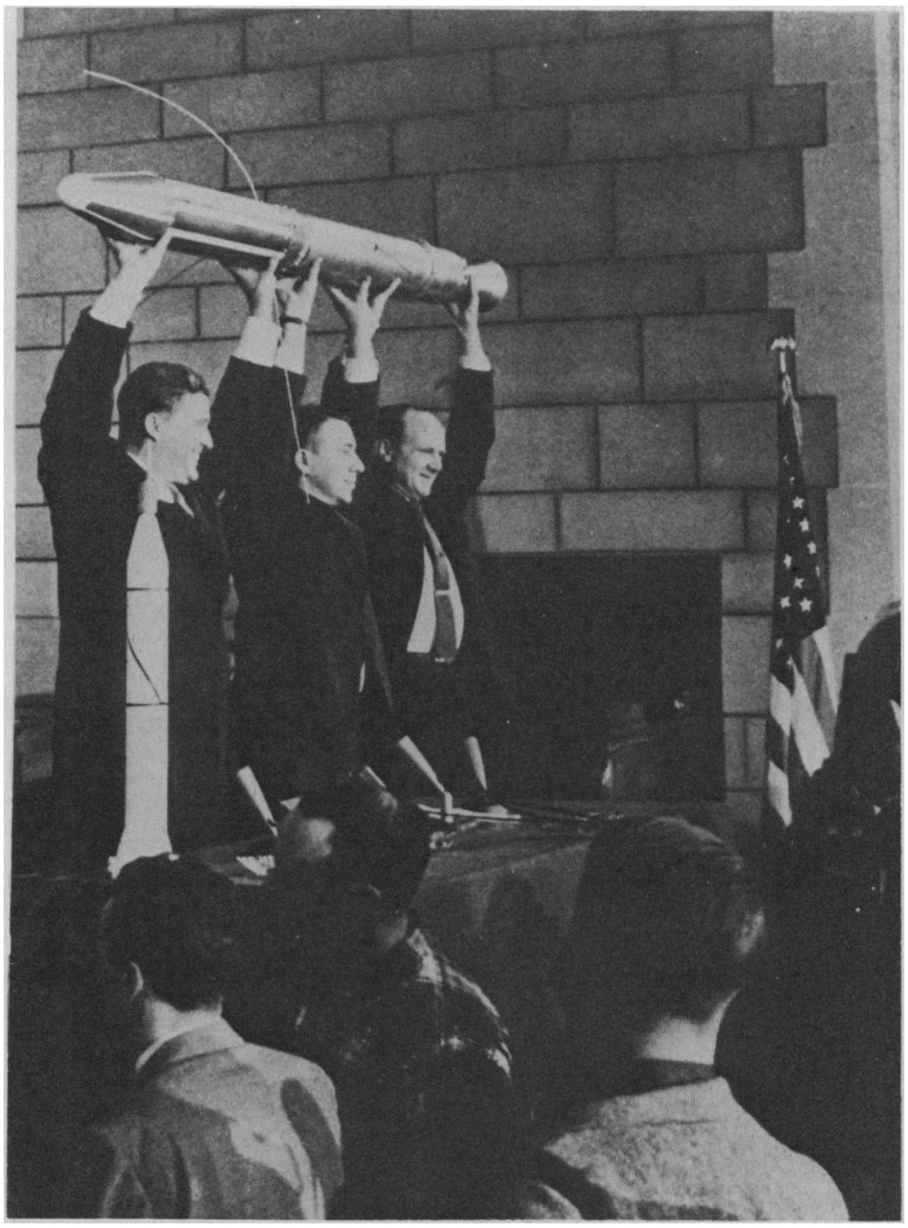
## Space Research

**Solar System Plasma Physics.** E. N. PARKER, CHARLES F. KENNEL, and LOUIS J. LANZEROTTI, Eds. North-Holland, Amsterdam, 1979 (U.S. distributor, Elsevier, New York). In three volumes, illus. Vol. 1, Solar and Solar Wind Plasma Physics. x, 344 pp. + index. \$73.25. Vol. 2, Magnetospheres. x, 402 pp. + index. \$66.75. Vol. 3, Solar System Plasma Processes. x, 378 pp. + index. \$66.75. The set, \$186.25.

These three volumes are a fitting commemoration for the 20th anniversary of space research. In most previous works of this genre on space research, the authors have stayed safely away from the forefront of research. The result is that the books are five to ten years out of date and neither exude the excitement of basic research nor yield material useful for graduate students, teachers, or researchers in peripheral fields. The chapters in these three volumes avoid this pitfall. The authors seem to have pushed deeply into their topics and, in most cases, have identified the crucial and exciting questions currently occupying theorists and experimentalists alike.

In some sense these volumes mark the transition of solar system plasma physics from the era of exploration, exemplified by the Explorer I spacecraft, into one of understanding and application. By application I do not necessarily mean the type summarized in the section entitled Technological Impact of Solar System Plasma Physics (although the brief expositions there are quite interesting), but the possibility for the application of the results of solar system plasma physics research in astrophysics and in experimental and theoretical plasma physics.

In the near space region of the earth, which includes the ionosphere, magnetosphere, and interplanetary medium, detailed study of cosmic-scale plasma physical systems can be made. These regions are remarkably rich in physical processes and span the vast ranges of parameter space. Some regions of the ionosphere are so quiescent that the largest perturbations present, other than the odd passage of a whistler or other electromagnetic wave, are thermal fluctuations in the medium. In fact, as is pointed out in the chapter on the ionospheric plasma, the detection of thermal fluctuations via the incoherent-scatter radar method and the explanation of the scattered spectrum was a triumph of engineering on the



"W. Von Braun, J. A. Van Allen, and W. H. Pickering triumphantly holding aloft a model of Explorer I on the occasion of the first announcement of its discoveries." The saturation of the simple Geiger counter carried on board the spacecraft, launched in January 1978, "attributed correctly to the presence of high fluxes of particles trapped in the earth's magnetic field, provided the catalyst for the following two productive decades of scientifically-instrumented spacecraft studying of solar system plasmas." [From *Solar System Plasma Physics*]