The two volumes complement each other and are necessary reference works for anyone considering the use of remote sensing techniques in environmental work. Both contain references following each paper, and Johnson's symposium includes an extensive, selective bibliography. The rhetoric, as in most symposia, is varied, and some papers seem wordy. One is particularly difficult to read, having "fog" indices (Robert Gunning, *The Technique of Clear Writing*, McGraw-Hill, 1952) ranging from 17 to 22.

Studies of environmental problems through remote sensing methods may well create a trend toward a more geographic view of ecological problems and away from plot studies. Remote sensing will be invaluable, especially when the investigators realize that knowledge of the significance of the phenomena in question on the ground is essential in the interpretation of the imagery.

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Geology and Investment-Planning

Natural Resource Information for Economic Development. ORRIS C. HERFINDAHL. Published for Resources for the Future by Johns Hopkins Press, Baltimore, 1969. xvi, 212 pp., illus. $7.

How important to a country's economic development is information about its natural resources, and how should it decide how much and what kind of such information to gather? This is the question to which Herfindahl, "with the problems of developing countries in mind," addresses this book, relying much on his experience in Chile and Peru, countries that have governmental resource-planning agencies.

Herfindahl's key proposal is that expenditures on natural resource information should be judged as ordinary capital investments, competing with other investment opportunities on the basis of their rate of return. ". . . the goal should be to increase expenditure on information to the point where additional return generated is balanced by the cost of this information—but no further" [p. 94]. "The quantity of the information collected should be increased so long as the present value of the investment opportunity (or cost savings if this is the use to which the information is put) is increased by more than the cost of the information" [p. 124].

These objectives are correct in principle; the difficulty lies in applying the principle. The author conditions the undertaking of a resource survey to a specific investment opportunity previously singled out by a government planner, who would then decide when, how, and how much information is to be obtained. A feasibility study of the project would follow the resource survey.

Such a model, by replacing an unknown agenda of various investment possibilities by one, underestimates the potential economic benefits while charging all the cost of the resource information to one project. But to prepare an exhaustive agenda of potential projects is often not possible or not feasible. For how can the location and extent of mineral deposits, for example, be known ahead of the geologic mapping which is needed to find them? Government surveys of the resources of a region provide a common basis for the various facets of an economy—mining, oil and gas industry, forestry, water utilization, road construction, flood control, irrigation, land utilization, and so on. In some cases such surveys play a catalytic role in focusing the attention of the private sector on certain areas, which may be undeveloped or economically depressed. It would seem that such surveys are a precondition to any further planning or actions by government or private enterprise. They provide a minimum threshold of publicly available knowledge.

A second difficulty with the author's proposal is that, except in collectivist countries, one cannot assume a simple deterministic link between a decision to invest in resource information and the decision to invest in a specific project. The author says that "the appropriate division of functions between government and private enterprise does not bulk very large" in his discussion. What appears therefore to be overlooked is that private entrepreneurs are bound by considerations other than those of government planners and their investment decisions may break the simple chain of the author's model. The proper model is not a simple sequence but one involving multiple alternatives, with uncertainties and risks. To prepare it, however, would require a vaster and keener knowledge—of the various engineering, technological, and industrial factors, and of the investment opportunities—than is available to governmental natural-resource planning agencies.

On the basis of his experiences in Chile and Peru, the author recommends that a developing nation should maintain a central bureau to plan resource development and gather the necessary information. The history of Chile and Peru indicates, however, that their natural-resources planning bureaus have so far played a very much smaller role than the one he assigns them. In both these countries there are stronger specialized agencies that, as part of their activities, procure information on various aspects of natural resources. In Chile we can mention the National Development Corporation, the National Oil Company, the National Electricity Company, the Geological Institute, and the numerous technological organizations of the Agriculture Department. Moreover, nowadays in developing nations the truly effective economic planning, not merely in the resources field, rests in national planning offices usually attached to the office of the president of the nation.

The dangers of ignoring technological factors are evident from the author's comparisons of unit costs for various types of natural resource information. For instance, he is perplexed about the apparent wide disparities, in the costs per square mile of geologic mapping, between the U.S. Geological Survey and Canadian surveys. In his comparisons, he has ignored or inadequately allowed for the following factors that greatly influence the unit costs: (i) effect of map scale, (ii) effect of the size of the area mapped in a given campaign, (iii) extent of back-up office and laboratory work, (iv) differences between a two-dimensional and a three-dimensional geology, and (v) the number of consecutive mapping efforts that may be required to unravel the geology of an area.

Elaborating only on the first factor, we note that the choice of scale is a deliberate decision. There is a minimum dimension of the details which can be readily grasped with the naked eye on a map. This defines a minimum dimension of the details to be acquired in the field—their ratio being the scale, say, $1 : S$. Moreover, in selecting the field minimum detail we meet a situation similar to that in the sampling of a time function, wherein the sampling interval determines the Nyquist or high cutoff frequency. Now, the number of

details to be acquired in the field per unit square area varies as $1/S^2$. As the mapping effort per unit area can be expected to be proportional to the number of details to be acquired, the unit cost should vary inversely with the square of S. Herfindahl, by comparing Canadian maps mostly at the scale of 1 : 500,000 with U.S. Geological Survey maps at the scales of 1 : 250,000 and 1 : 62,500, in effect weights the data against the U.S. Geological Survey by a factor of 64, versus 16 and 1 respectively for the Canadian data.

The book's approach seems to be more relevant to collectivist societies than to the highly competitive private system of advanced Western nations. In the latter, private enterprise in the gathering of information about resources goes far beyond what is achieved in a general resource survey.

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Fossil Pollens

Aspects of Palynology. ROBERT H. TSCHUDY and RICHARD A. SCOTT, Eds. Wiley-Interscience, New York, 1969. x, 518 pp., illus. $24.95.

The field of palynology has undergone a profound metamorphosis since its first quantitative applications some 50 years ago. As currently interpreted, the discipline embraces a multitude of taxonomically unrelated "palynomorphs," an enormous span of geological time from the Precambrian to the present, and many applications (from stratigraphic correlation, to paleoecological inference, to reconstruction of evolutionary relationships, to analyses of pollen development). As the editors of *Aspects of Palynology* indicate, the literature has become so decentralized and voluminous that the neophyte is apt to encounter virtually insurmountable problems in perceiving the dimensions and directions of this burgeoning field.

Aspects of Palynology was designed to "summarize in one book the nature, scope, and applications of the study of fossil pollen and spores." Clearly a book of this nature was needed badly. In my estimation, the book achieves the stated objective, although, as the editors admit, there are the weaknesses that one might expect in a collaborative volume that was long in preparation.

Aspects is well organized, beginning with a variety of chapters that provide general background concerning the nature and representation of various "palynomorphs," problems of classification, sources of error, applications of palynology, and the like, and then proceeding to a chronological treatment of the fossil record.

From the standpoint of one interested in the Pleistocene, I find the latter half of the book especially valuable, as it provides ready access to an enormous literature on pre-Pleistocene palynological problems. The service this section of the book provides is incalculable, for up until now that literature could be assimilated only if one was willing to devote considerable time and energy. My one complaint concerning this section would be with the manner of presentation of photomicrographs. "Pre-Pleistocene" workers tend to crop photomicrographs by cutting closely around the outline of the microfossil. The contrast that one perceives then becomes that between the microfossil and the mounting paper rather than that between grain and mounting medium. This is apt to make interpretation of the wall more difficult. It is often impossible to discern the exact surface and sculpture of the grain, for one must distinguish between the cut outline and the real outline. No matter how carefully one cuts, this problem is likely to be engendered and sculptural features are apt to be distorted (by being inadvertently added or eliminated). These problems are evident on virtually every plate in chapters 11 through 16. However, weighed against the value of this section, this criticism is trivial.

The introductory chapters present a number of problems of coverage and overlap. For example, the nature of pollen grains (wall structure, etc.) is discussed in both chapters 2 and 3, but in neither chapter is there an adequate discussion of the chemical composition of the exine. Particularly disturbing is the evolutionary framework provided in chapter 2, a system of classification that is supposed to be "phylogenetically oriented." The system employed is archaic and obscures rather than reveals evolutionary relationships. There is no indication of the fundamental distinction between procaryotic and eucaryotic organisms, of the close relationships between bluegreens and bacteria, of the concept of a major assemblage of organisms that can be classified as "Protista." Furthermore, *Psilotum* is retained as a living representative of the Psilopsida whereas work of Bierhorst indicates that it probably belongs to the Schizaeaceae.

The major weakness of the book is the absence of material providing a theoretical background for palynology. The editors have omitted this consciously, indicating that it is available in a number of modern treatises such as the recent edition of Faegri and Iversen. Nevertheless, I think such information should have been included in a volume attempting such a sweeping synthesis. Much has been learned in recent years concerning mechanisms controlling pollen release and dispersal, factors influencing the incorporation of pollen into sediments, the relationship between pollen rain and vegetation, statistical artifacts in pollen diagrams, and the like. All of this background is absolutely essential for the interpretation of fossil spectra, yet it appears only in condensed form in Leopold's superb chapter on the Late Cenozoic.

These reservations will not prevent *Aspects* from becoming an extremely valuable reference book.

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Matter in Space

The Interstellar Medium. S. A. KAPLAN and S. B. PIKELNER. Translated from the Russian edition (Moscow, 1963), with corrections and additions by the authors. Harvard University Press, Cambridge, Mass., 1970. xiv, 466 pp., illus. $20.

The Harvard University Press is to be congratulated for having had the good sense to arrange for the translation and publication of this work. The translation is certain to become a part of the basic libraries of most astrophysicists in the English-speaking world. This is one of the three or four basic texts and compendia to which I shall direct the attention of graduate students who are about to become involved in studies of the interstellar medium, and I shall wish to refer to it often in connection with my own researches and lectures. I only wish that the Press had given the name of the translator, who has provided as fine a translation and interpretation as one could hope to have.