

## China as an Energy Producer

**The International Energy Relations of China.**  
KIM WOODARD. Stanford University Press,  
Stanford, Calif., 1980. xxii, 718 pp. \$50.

The emergence of the People's Republic of China as a petroleum exporter at the time of the OPEC oil embargo of the United States in 1973-74 stimulated vastly increased Western interest in China's long-run potential as a source of additional energy supplies. Western attention to this potential has fluctuated widely in the ensuing years in response to variations in the rate of increase of crude oil prices levied by the cartel and the sporadic release of data by the Chinese government suggesting that China might contribute significantly to world energy supplies. This interest was piqued most recently in 1979 when China signed contracts with the major international oil companies for seismic studies of large portions of the continental shelf and in 1980 when it signed contracts with French and Japanese firms for joint oil development in the Bohai Gulf and Gulf of Tonkin.

These developments have stimulated many studies of China's petroleum industry and export potential, of which Kim Woodard's is both the most recent and by far the most comprehensive. The strengths of *The International Energy Relations of China* are several. First, the book analyzes not only petroleum but most related forms of commercial energy—coal, natural gas, and hydropower. Since these forms are frequently substitutes both in domestic uses and to some extent in export markets, analysis of their interrelationships is critical. Second, the book provides a wealth of data related to China's production and trade in energy products. Indeed, almost half of the text is devoted to a statistical profile of China's reserves, production, consumption, and trade in energy. Though much of the statistical material will be of interest only to specialists, Woodard has performed a Herculean task assembling and analyzing these data. The trade data, for example, are based not only on the standard sources published by the United Nations but also on an exhaustive search of the annual trade returns of the Soviet Union and the Eastern European countries as well as certain critical Asian countries. The re-

sult is the availability in one source of detailed time series data on Chinese bilateral trade relations in all important energy products (coal, coke, crude petroleum, refined petroleum products, lubricants, and petroleum by-products).

Finally, the core of the book—estimates of China's potential energy exports—is based on a model that is the most detailed yet to be published. It includes, for example, not just the usual assumptions regarding fossil fuel reserves, GNP and population growth rates, and conservation policies, but also a reserves discovery variable in the petroleum and natural gas subsectors. Adjustment of this parameter permits alternative assumptions regarding the future rate of discovery of new reserves that, in turn, influence the time path of energy production, since the model embodies an estimated linear relationship between average production growth rates and level of resource depletion.

The energy export projections generated by the model will not encourage those who are still sanguine about China's energy export potential. The base-line projection—which assumes economically recoverable oil and gas reserves of 62 billion barrels and 7.5 trillion cubic meters, respectively, per capita GNP growth of 3.5 percent, and a gradual improvement in energy use efficiency—shows energy export potential growing rapidly in the late 1970's and early 1980's, peaking at about 50 million tons of oil per year (1 million barrels per day) in the mid-1980's. That level of exports is low relative both to present levels of international oil trade and to projected levels of Chinese domestic energy production. Moreover, by the early 1990's China is projected to become a net importer of energy. Under far more optimistic assumptions that place China's recoverable oil and natural gas at roughly the original level of ultimately recoverable reserves of the United States (or about four times the resources assumed in the base-line projection) but build in more rapid domestic growth, the model shows China's export potential would reach 100 million tons of oil equivalent per year in the mid-1980's. But even this optimistic projection shows rapidly declining export potential in the 1990's.

All of the projections reflect two fundamental differences between China and present world-class petroleum exporters. First, although China's reserves of coal are clearly among the largest in the world and production will not be limited by reserves considerations for the foreseeable future, there is no indication that China's petroleum resources justify comparison with those of major Middle Eastern producers. Second, unlike several sparsely populated Middle Eastern countries where energy production far outstrips domestic demand, China has a population currently in excess of a billion. While its per capita energy consumption is similar to that of other Third World countries, its huge population means that simply maintaining moderate rates of GNP growth will absorb the bulk of incremental output over the next two decades under almost any reasonable set of assumptions.

While Woodard began his research when unfounded rumors that China would prove to be a second Saudi Arabia were commonplace, his balanced projections and caution on export potential have become widely shared in the last few years. Indeed, on the basis of the performance of China's energy sector since the analysis and projections for the book were completed in 1978, Woodard's analysis appears too optimistic. Coal and petroleum production have reached a plateau and even began to decline since 1978 rather than expanding by the 8 to 7 percent assumed in the base-line projection, and natural gas production is only about one-fourth of the levels estimated by the author. Total primary energy production is actually proceeding far below the pace of Woodard's low-growth "disaster" projection. Consequently China has already informed the Japanese that by 1982 it will be unable to meet the modest oil export levels called for in the long-term bilateral trade agreement signed in 1978.

Part of the discrepancy between the projection and actual performance reflects lack of adequate data. Though the Chinese government has released two major statistical communiques since this book went to press, thus revealing official data on production levels of oil, coal, and natural gas for the first time in two decades, most information related to the energy sector, particularly data on reserves, is treated as a state secret. A more fundamental problem of the analysis, however, is its failure to examine the Chinese petroleum and coal industries in detail. The author creates a black box in which production is determined by the level of resource depletion, an assumed

rate of discovery of new reserves, and an assumed level of ultimately recoverable reserves. But problems with the geographic distribution of China's energy resources, limits on China's capability to absorb foreign technology and equipment, continued reluctance to allow significant foreign participation in energy development, and lack of economic incentives to raise low levels of efficiency of energy resource utilization are glossed over. These and other complex factors will be the major determinants of China's energy production and should absorb the efforts of those who wish to predict China's energy future.

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## Terrestrial Processes

**The Continental Crust and Its Mineral Deposits.** A Volume in Honour of J. Tuzo Wilson. Proceedings of a symposium, Toronto, May 1979. D. W. STRANGWAY, Ed. Geological Association of Canada, Waterloo, 1980. viii, 806 pp., illus. \$30. Geological Association of Canada Special Paper 20.

The concept of crustal mobility or "plate tectonics" opened a new era in the earth sciences by offering a single global process that could account for a remarkable range of geologic features. One landmark paper that brought together evidence from many disciplines within the geologic sciences, "Did the Atlantic close and then re-open?" (*Nature* 211, 676 [1966]) by J. Tuzo Wilson, laid the groundwork for recognizing the effects of continental rifting and collision. As illustrated by many of the 41 papers contained in this book, Wilson's ideas on the importance of continental drift to crustal evolution have flourished in the earth sciences.

The papers in the volume are grouped into six sections. Section 1, The Early Earth, provides an informative discussion of the mechanics and thermal consequences of planetary accretion and core formation. Surprisingly lacking in this section is reference to evidence obtained from the study of other terrestrial planets, particularly the moon, where the effects of early planetary differentiation and meteorite bombardment on crustal formation are clearly displayed. The absence of these observations leads to discussions of early isotopic and tectonic evolution of the earth that are both incomplete and overly simplified.

Some of these deficiencies are reme-

died in section 2, Evolution of the Precambrian Crust, which vividly illustrates the diversity of opinions concerning the origin and evolution of the materials that make up the continental crust. Various papers stress the importance of "gravity" or vertical tectonics as opposed to "Wilson cycle" lateral mobility. With respect to the subject of continental "growth" and the rates thereof, estimates are presented that range from constant erosion by sediment subduction to continual growth by the addition of new, mantle-derived, sialic material. Enough pertinent data are presented that the reader may judge the strengths and weaknesses of the various arguments.

The structure of the crust is the subject of the third section. One paper discusses the intriguing observation that continental fragmentation seems to reoccur predominantly along pre-existing zones of crustal weakness. However, on the subject of crustal structure, this section contains only a single paper utilizing seismic refraction and reflection data and lacks any discussion of field evidence relating to this subject. Hence it does not give the reader a true feeling for the variable and complex structure of the continental crust.

The next section, Crustal Motions, details the evidence for, and results of, continental mobility. By the use of paleomagnetic, geochronological, and field structural data and biogeographic constraints, the various papers provide interesting and informative descriptions of a wide range of complex structural configurations interpreted as resulting from continental drift. There are also a series of papers dealing with the association of certain petrologic and metallogenic conditions with different plate tectonic environments. These discussions perhaps would fit better into the next section, The Global View, which also examines the effects of plate motions in determining the structural regimes that control magmatic and metamorphic conditions along plate boundaries.

The final section concerns itself primarily with the genesis of sulfide ore deposits. These papers give an interesting overview of ore genesis in a manner that keeps the presentations comprehensible to readers outside the field of economic geology. Again, though, this section concentrates on the origin of particular ore types and should not be considered a thorough discussion of the many mechanisms involved in ore genesis in the crust.

In summary, the papers contained in the book provide discussion of a broad range of topics from a variety of disci-

plines. However, by putting so little emphasis on important topics such as the crustal sedimentary record and the variable and complex nature of crustal structure and on crustal features in areas outside the Precambrian of North America, the book does not adequately represent several critical aspects of the nature and evolution of the continents. As long as the reader realizes that the volume concentrates on a rather limited region of the continents and that some of the papers present rather controversial interpretations, the volume and the comprehensive reference lists that follow each of the papers provide a good starting point for the study of various aspects of the continental crust.

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## Theoretical Particle Physics

**Unification of the Fundamental Particle Interactions.** Proceedings of a conference, Erice, Italy, Mar. 1980. SERGIO FERRARA, JOHN ELLIS, and PETER VAN NIEUWENHUIZEN, Eds. Plenum, New York, 1980. xii, 728 pp., illus. \$79.50. Ettore Majorana International Science Series (Physical Sciences), vol. 7.

The currently accepted theories of electromagnetic, weak, and strong interactions are all "gauge" theories. They view the fundamental interactions as being mediated by vector bosons (the photon, weak bosons, and gluons), which are coupled to the currents implied by the local symmetries of these theories. The general theory of relativity, which describes the gravitational interactions, has a similar mathematical form, at least classically. Since the structure of these theories is so similar, it is easy to speculate that there should exist some super theory that manifests all the known interactions in a correct and unified way. The search for that theory is more difficult. It has attracted much attention, and there has been some progress. There are theories proposed to unify electromagnetic, weak, and strong interactions that incorporate observed results in an economical fashion and predict novel effects such as proton decay and neutrino masses. The more ambitious goal of including gravity has been (so far) less successful, but there are models with gravity that appear to have a germ of truth in them. Papers discussing both of these endeavors are contained in this book; such knowledge may be necessary to carry out the search for a truly unified theory. We are in an