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Circum-Pacific Minerals Maps

Maps portraying the mineral resources are being compiled as one of the series depicting the geology, tectonics, energy resources, and other features of the Circum-Pacific region at 1:10,000,000 on a quadrant-by-quadrant basis. The Minerals Map of the Northeast Quadrant is the first to be completed and will serve as the prototype for those to follow.

Land-based deposits are plotted over a simplified geologic/tectonic background that emphasizes the provenance of sedimentary rocks (oceanic, miogeoclinal, or continental) and the intrusive or extrusive nature of igneous rocks. Symbol shapes, colors, sizes, and ornamentation denote the metal/mineral content, relative importance, geologic class, and, for some, age of mineralization of the deposits. No distinction is made between active, exhausted, or unmined deposits.

The prevalence and transition-metal content of the ocean-floor manganese nodules are shown in relation to water depth and surficial-sediment character, the latter simplified from the Geologic map series. The rift and fracture-zone pattern reproduced from the Plate-Tectonic map serves to locate the sulfide deposits discovered by submersibles and deep drilling to the spreading centers where they are generated. Phosphate and other seabed resources are included.

When completed, the maps will provide an overview of the mineral resources of a region encompassing more than half the globe that should be useful not only for planning purposes, but also as stimuli for creative analysis of the relation of ores to major earth features and processes such as subduction, hot spots, and accreted terranes.

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Basins of the World and New Frontiers

Petroleum exploration in the coming decades must be concentrated toward discovering commercial supplies—large and small—of the oil and gas which lie untapped in both the known petroleum producing areas of the world and in the frontier regions. These frontier areas—the deserts, ice-covered lands, deep waters, and remote continental interiors—are estimated to hold vast hydrocarbon accumulations. It is in these sectors where future oil and gas discoveries could make the difference between energy survival and global catastrophe.

Explorationists must re-evaluate the mature and developing petroleum regions of the world; the vast ocean areas must be carefully and thoroughly investigated to ascertain their petroleum potential; the remote continental interiors must be properly assessed; and new and better uses of geology, geophysics, petroleum engineering, and technology must be employed in all aspects of petroleum exploration, development, and production. A unified exploration effort will result in greater success in finding the oil and gas supplies the world so vitally needs.

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Developing the Petroleum Resources of Bering Sea—Technology, Economics, and Geology

With estimated petroleum resources as high as 52 billion bbl of oil equivalent, the Bering Sea sedimentary basins together rank third in the nation's OCS (outer continental shelf) areas, behind only the Beaufort Sea and Gulf of Mexico in oil and gas potential.

For the first four Bering Sea OCS lease sales—Norton Sound (No. 57), St. George Basin (No. 70), North Aleutian Shelf (No. 75), and Navarin Basin (No. 83)—petroleum technology assessments have identified probable development (engineering) strategies (platform types, transportation options) and evaluated the economics of these engineering strategies and related geologic (reservoir), environmental, and locational parameters. The economic model has determined (1) the minimum field size needed to justify development under several oil and gas production strategies, (2) the minimum required price to justify development given field size and selected production technology, and (3) the unit costs of production and transportation.

The economics of petroleum development in the Bering Sea will be very sensitive (among other factors) to water depth and distance from shore (pipeline investment). For the more distant from land St. George and Navarin Basins, offshore loading may have to be seriously considered. Giant fields with favorable reservoir characteristics will have to be found to make development economically feasible.

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Oil Discovery in New Zealand Overthrusts

New Zealand's present hydrocarbon production is from two gas-condensate fields located onshore and offshore southern Taranaki, on the western side of the North Island, in a generally gas-prone area. In 1980, Petrocorp (Exploration) discovered the McKee oil field onshore in North Taranaki. The reservoir sequence of the McKee field comprises Kapuni Group lower coastal plain Eocene and early Oligocene sandstones, essentially similar to producing zones of the existing fields. McKee field is, however, structurally different in that it consists of a block of the Kapuni Group sequence thrust over lower Miocene marine mudstone and siltstone. The thrust, which is middle Miocene in age, is one of several similar structures in a zone immediately west of the eastern boundary fault of the Taranaki graben. Kapuni Group sandstones have been drilled in four of these structures and, in addition to the McKee production, significant gas shows were noted in two thrusts to the north of McKee. The potential for further oil and gas in these structures prompted revision of seismic techniques which resulted in delineation of further segments of the thrust system in the McKee area. Recent detailed seismic over the field shows the reservoir to consist of a complex series of small scale, fault-bound slices. The reserves of the field are estimated to be around 20 million bbl. The oil is wax based, with a pour point of 32°C, and a gas to oil ratio of around 150:1.

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Marine Geophysical Studies of Western Margins of Luzon, Philippines

Multichannel seismic reflection, gravity, and magnetic measurements were made during a reconnaissance study of the western margin of Luzon, between 15 and 19°N. Sixteen lines were run to investigate the along-strike variations in the nature of the accretionary prism and the style and intensity of deformation in the fore-arc region (West Luzon Trough).

There is an along-strike difference in the degree of deformation observed landward of the trench slope break. Subduction of the east-west-trending South China basin relict spreading center at the Manila Trench near 16°N appears to roughly define the boundary between two contrasting tectonic regimes of the margin. South of this boundary, deposition of terrigenous sediments in the fore-arc region has occurred in a relatively quiet tectonic setting. In contrast, north of the boundary, the sediments of the fore-arc region have been disturbed by ubiquitous faulting. Some of the faulting is probably associated with the offshore extensions of splays of the Philippine fault system. Furthermore, anticlinal folds, consistent in character and trend, are found both onshore and offshore along Lingayen Gulf near 16 and 17°N and probably formed in response to a common stress field.

MCS records reveal a basement ridge, trending northward from the western side of Lingayen Gulf, which we interpret as the likely offshore expression of the Zambales ophiolite exposed on land to the south.

We are attempting to reconstruct the tectonic evolution of this fore-arc region by extrapolating the limited stratigraphic information from onshore wells and outcrops onto the observed offshore seismic stratigraphy.

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Structural Styles of Mesozoic-Cenozoic Petroliferous Basins of China

The continental lithosphere of China is situated at the junction of the Marginal Pacific tectonic domain and the Tethys-Himalayan tectonic domain. The former is characterized by a series of extensional tectonics, including taphrogenesis and the latter by a series of compressional tectonics with orogenesis, all taking place during the Mesozoic and Cenozoic eras.

The Marginal Pacific crust of east China was attenuated by rifting and a north-northeast-trending of Mesozoic-Cenozoic basins developed, e.g., the Songliao basin, the North China basin, etc. Rifting followed mainly preexisting zones of basement weakness for the most part. Then, basin and range structures formed and large, fault-bounded basins subsided. Extensional structural styles have prevailed in Mesozoic-Cenozoic basins of east China: listric normal faults and tilted blocks in the basement; detached normal faults, rollover anticlines, and drape fold in the sedimentary cover. These structural styles are favorable for hydrocarbon accumulation, and indeed the famous Daqing and Huabei oil fields are located in the above-mentioned basins.

The crust of west China was thickened by collision and a series of Mesozoic-Cenozoic intermontane basins or foredeeps were formed, e.g., the Qaidam basin, Jinquan basin etc. Compressional tectonic styles are predominant in the Mesozoic-Cenozoic basins of west China; compressive fault blocks and ramps in the basement; detached reverse faults and parallel folds in the cover.

The Mesozoic-Cenozoic basins of China have undergone numerous tectonic events, with earlier structural styles always overprinted by later ones, e.g., compressional structural styles are sometimes converted into extensional ones. On the other hand, most basins of China have twofold mechanical behavior, e.g., extensional shear and subsequent compressional shear. The combination of taphrogenesis, orogenesis, shearing, and gravitation, which seems to have controlled the development of Mesozoic-Cenozoic basins, formed favorable traps for hydrocarbon accumulation in China.

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Copper Deposits—Frieda River Prospect, Papua New Guinea

The Frieda River Prospect is located within the New Guinea mobile belt, between the Frieda and Lagaip fault systems. Mineralization is associated with an andesitic volcanic complex, interstratified in the mid-Miocene Wogamush formation.

The volcanic edifice of the Frieda Igneous Complex was built up by two cycles of pyroclastic and flow deposition, and has been intruded by five phases of co-magmatic and post-volcanic porphyritic diorite, andesite, and trachyandesite intrusions.

Extensive hydrothermal alteration has given rise to a widespread assemblage, consisting of quartz, alunite, kaolinite, pyrite, and locally, native sulfur. Superimposed on this, and localized around centers of porphyry copper mineralization, is an assemblage which progresses from a central potassic core through a transitional zone into sericite-quartz-chlorite; sericite-quartz-andalusite; and eventually propylitic zones.

The known deposits are related to the same series of igneous events and represent a spectrum of physical and chemical conditions in a large hydrothermal system, ranging from deep level porphyry copper mineralization, to near surface, pyrite, luzonite/enargite, chalcocite, and barite mineralization. A halo of quartz-sericite-chalcopyrite-tetrahedrite-sphalerite-galena veins, peripheral to the porphyry copper deposits, appears to be an intermediate style in the system.

The porphyry copper reserves consist of a probable 760 million tonnes of mineralization, made up of 500 million tonnes at Horse and Ivaal, with an average grade of 0.5% Cu and 0.3% Au, and 260 million tonnes at Koki, averaging 0.41% Cu and 0.28 g/t Au.

Initial feasibility studies indicate that the high capital and operating costs of a project in this remote region, combined with current depressed copper prices, make the project uneconomic at this stage.

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Ok Tedi—A Gold-Copper Open Pit Development in Papua New Guinea

Construction is well under way on Ok Tedi Mining Ltd.'s gold-copper open pit development in Papua New Guinea. Start up is scheduled for mid-1984 at 15,000 tonnes of gold ore per day, expanding to 45,000 tonnes of copper ore per day by 1989.

Dramatic price increases for gold, at the time the feasibility study was submitted to the government in November 1979, heightened national expectations and led to further studies to satisfy government requirements, prior to formal agreement to proceed, reached in February 1981.

Difficulties encountered in implementing the project, so far, are due to various factors including lengthy financing negotiations, lease of tribal lands, community demands, normal bureaucratic delays, separated national and provincial administrations, and the State's position as regulator and shareholder.

The real challenge, however, is physical—remote location, rugged terrain, heavy rainfall, and jungle wilderness. In return, an enlightened agreement between state and company promises adequate returns to both developer and the people of Papua New Guinea.