Reporoa, Broadlands, Tauhara, Orakei Korako, and Te Kopia in the central volcanic region of the North Island, and at Ngawha in Northland. At Broadlands the production potential of wells already drilled is about 130 MW, and other wells are being drilled.

Technical studies carried out in New Zealand indicate that capital costs per kW for small geothermal power plants are at least as cheap as those for large plants, making the former attractive for developing countries and isolated districts. Estimates of power-life of geothermal systems are not yet possible, but studies of the effect of draw-off rate show that a maximum power-life is obtained if wellhead pressure is allowed to fall to 75 p.s.i.g. over the life of a field. From a hot-water geothermal reservoir power output can be increased for the same rate of production if the steam-water mixture is conveyed to the powerhouse in a single pipeline and separated in two stages.

More than 500 shallow wells have been drilled in Rotorua and a few in Taupo to tap hot water and steam used in conjunction with heat exchangers to provide space heating and hot-water supplies for domestic and commercial users, for drying of timber lucerne, growing of mushrooms and fruit, and hydrotherapy in the treatment of patients.

Permission has been given to a Japanese group to make a feasibility survey, based on a study of the Broadlands field, of the possibility of using geothermal energy in the production of heavy water.

Hot spring discharges at localities in both islands have been augmented by drilled wells to extend facilities at swimming pools for public use. A recent development in the Bay of Plenty near Tauranga has been the drilling of wells to obtain warm water for public and private swimming pools in areas where the subsurface gradient is 1.5-4 times normal.

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## MINERAL TRADE IN CIRCUM-PACIFIC REGION

Few nations are endowed with all the mineral resources needed to maintain a vigorous economy. Domestic resources must be augmented for foreign supplies.

The Circum-Pacific region, with its rich mineral endowment and relative proximity to many mineral importing centers, accounts for a large segment of international mineral trade. In 1971, the value of all mineral commodities exported and imported by Circum-Pacific countries totaled $24.0 and $25.4 billion respectively. These totals amounted to approximately 32% of total world mineral exports and 34% of imports. Much of this mineral trade remained within the region. In 1971, the value of trade between Circum-Pacific partners amounted to approximately $12.2 billion.

The impact of the Circum-Pacific countries on mineral trade is further illustrated by trade in selected metallic ores, concentrates, and metals. The region traditionally has produced and exported large quantities of copper and tin. In 1971, the region accounted for about 46% of world copper exports and supplied about 85% of world tin exports. Indonesia, Malaysia, Thailand, and Bolivia accounted for almost all of this total. Nickel also has been a traditional export commodity of the region. Canada and New Caledonia are the leading world producers of nickel and Canada is the largest exporter. More recently, increased demand, particularly from Japan, has resulted in large exports of bauxite and alumina, and iron ore and concentrates from Australia.

The industrialized nations of the world not only have been the primary contributors to the demand for Circum-Pacific mineral resources, but also have been prominent in financing its mineral development. The types of foreign participation vary considerably within the region, including direct investment, long-term purchasing contract, and debt underwriting.

The investment climate throughout much of the region generally has been favorable. This is illustrated by the rapid development of mineral deposits in Australia and Canada. However, the possibility of a less favorable investment climate within the region and increased competition between mineral importers may raise the cost of regional investment. This could result in a shift of mineral activity to other areas of the world.

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## SOLAR DISTILLATION—PUERTO PENASCO EXPERIENCE

Since the late 1800s, there have been numerous attempts to develop economical systems for solar distillation. Initially these were simple single-effect, glass-covered stills. During the 1950s, as a result of support from the Office of Saline Water of the U.S. Department of the Interior, many efforts to develop a multiple-effect solar still were undertaken.

The University of Arizona developed a multiple-effect, humidification-cycle, solar-powered distillation unit that was installed in Puerto Penasco, Sonora, Mexico, in 1962. This unit operated successfully until 1965, when it was converted from solar energy to waste-thermal energy from a diesel-electric set. At the time of the discontinuation of its operation, it was the premise of the University of Arizona that the major obstacle to the development of an economical solar distillation system was inadequate low-cost materials that would provide a reasonable service life in a solar-energy application.

With the current renaissance of interest now in solar energy, it is hoped that the necessary long-term development programs will be established to improve the probability of successful solar-energy applications in the future. The paper presents some thoughts as to the direction in which future research should go.

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## STRUCTURAL STYLE AND HYDROCARBONS OF BASS, GIPPSLAND, AND OTWAY BASINS

The Bass, Gippsland, and Otway basins lie mainly offshore southeast of Australia. Offshore fields in the Gippsland basin contain recoverable reserves of approximately 8.0 Tcf of gas and 1.7 billion bbl of oil and currently supply two thirds of Australia's oil requirements. No commercial hydrocarbons have been discovered in the adjacent Bass and Otway basins.

The basins were created during the Jurassic to mid-Cretaceous continental breakup of Antarctica, Australia, and New Zealand. Their initial tectonic framework was primarily tensional with basining achieved by normal faulting.

The Otway basin has a classic "pull-apart" structural style with a series of normal faults parallel with the spreading axis. The Gippsland and Bass basins are similar but their complete pull-apart was prevented by the influence of the Tasmanian continental block (subplate). The separation of New Zealand from Australia had only a minor effect on the structural framework of the Gippsland basin in the shallow-slope areas.

Following the continental breakup and margin collapse, the Otway basin remained structurally quiescent but the Bass and Gippsland basins continued to subside and accumulate thick Tertiary sections. However, during the late Eocene and Miocene all basins were subjected to an east-west right-lateral-shear deformation. In Gippsland, the shear generated large en echelon anticlines and rejuvenated some of the old tensional faults. Hydrocarbons accumulated in these anticlines or their eroded remnants. In Bass and Otway the shear was less severe and confined to the northern margins. The deformation in these basins was correspondingly less intense.

However, structural styles in each basin are similar enough that their varying intensity does not explain fully the lack of success in the areas explored in Bass and Otway. Other factors such as the presence or absence of organic matter, maturation, and migration must have influenced hydrocarbon distribution.

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## EVOLUTION OF PORPHYRY COPPER PROVINCE OF NORTHERN CORDILLERAN OROGEN

In the area from the Columbia Plateau to the Wrangel Mountains of Alaska, porphyry copper deposits formed as adjuncts to differing magmatic and tectonic environments. The most important early event related to development of porphyry copper appears to have been the rifting of the Alexander terrain in Alaska away from the North American craton beginning in the late Paleozoic and continuing into the Jurassic. Introduced during this period of distensional tectonism were the "diorite" porphyry copper deposits and the composite zoned batholiths carrying porphyry copper deposits (the granitic-pluton type). Most deposits of these types are Triassic in age. Porphyry copper deposits are not present in the Upper Jurassic and Lower and middle Cretaceous rocks. The Late Jurassic and Early and middle Cretaceous appear to have contained periods of rapid sea-floor spreading and strong compression, as well as periods of intrusion of the large batholiths. This implies that magmas associated with porphyry copper deposits do not necessarily have an origin similar to that postulated for Sierra Nevada type batholiths.

Porphyry copper deposits also have been dated as Late Cretaceous and Tertiary. These deposits differ from their Triassic predecessors in that they tend to be smaller stocks or bosses, have some of the features of diapir or piercement, and mineralization associated with them tends to be associated with a quartz monzonite magma.

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## NICKEL- AND COPPER-RICH NODULES OF EQUATORIAL NORTH PACIFIC

The authors compiled a map of all available data on the distribution and metal content of ferromanganese deposits throughout the oceans which revealed only one geographic area where nodules were abundant and consistently rich in copper and nickel. It was an east-west band in the equatorial North Pacific between coordinates $8^{\circ}00'$N to $10^{\circ}00'$N and $125^{\circ}00'$W to $154^{\circ}00'$W. Nodular deposits were most abundant at the eastern and western ends of this rectangular province. Inspection of analytical data reveals that they are at least twice as rich in copper and nickel than the world average for nodules. Moreover, metal values suggest east-west axes of maximum values of both copper and nickel (2.5 to 3.0% dry weight of the nodules) at the northern and southern limits of the province.

In order to explain this unusually rich province, the east-west trends of maximum metal values, and variations in abundance of the nodules, a comprehensive study is underway. In order to quantify the data, many sea-floor parameters were established and each inserted as a viable controlling influence on the distribution and metal content of the deposits. They include gradient of sea-floor, water depth, submarine physiography, topographic grain of seabed, distribution of seamounts, distance from major fracture zones, substrate type, porosity and moisture content of substrate, and age of surficial sediment. Characteristics of the nodules, including average and range of size, percent of sea-floor covered and their concentration, were combined with the preceding measures.

Our study has led to the following conclusions: (1) the geographic limits of nodules rich in copper and nickel reflect the distribution of exposures of Tertiary sediments on the ocean floor. (2) The east-west trend of the province is a function of exposures of Miocene, Oligocene, and Eocene strata. (3) Copper and nickel content of nodules appear to increase with increasing age of substrate, *i.e.*, Eocene strata, and presumably "Eocene" nodules, are characterized by maximum values of these metals (3%). Miocene strata and associated nodules have lower copper and nickel values (2.5%), but contain greater amounts of these metals than other nodular deposits. (4) The regional patterns of major nodule fields are directly related to locations of seamounts and fracture zones. Presumably subsea weathering and explosive submarine volcanism release and disperse seed grains of basalt. Nodules are most abundant in the eastern and western thirds of the enriched zone where submarine volcanoes are common, and along a narrow band which follows the Clarion fracture zone. The central section has appreciably fewer nodules because of a limited number of volcanoes and the Clipperton fracture is a site of rapid sedimentation. (5) "Eocene" nodules represent potential mineable deposits. (6) Further evaluation of this resource should be directed toward definition of Eocene, Oligocene, and Miocene exposures close to sources of basaltic seed grains. (7) Porosity and moisture content of radiolarian deposits are higher than any other ocean sediment and may play a role in upward diffusion of metals within the substrate and into nodules. (8) Differential erosion and deposition within the area of Tertiary exposures during the past 55 m.y. may have imposed a secondary pattern of nodular concentration over crests of abyssal hills and dilution by burial in adjacent valleys.