

USA in that it occupies an area of late Cenozoic, north-trending grabens and half-grabens, with a very high geothermal gradient, near the western margin of a continent. Similarities in the tectonic setting of the two regions include their location east of an inactive magmatic arc, the presence of a late Cenozoic transform fault to the west, a marginal basin to the southwest, and existence to the southeast of a major plateau, uplifted in the late Cenozoic. These similarities suggest plate boundary events in and west of northern Thailand, comparable to those in the Great Basin region. Mineral deposits of probable late Cenozoic age in northern Thailand are confined largely to fluorite and antimony; comparison with the Great Basin suggests a possible lineament control on their location. Absence in northern Thailand of the late Cenozoic silver-gold deposits, so widespread in the Great Basin, may reflect the lack of late Cenozoic basaltic and rhyolitic flows forming potential source rocks, although the large basaltic bodies postulated at depth in the region suggest that subsurface precious metal or mercury deposits could be present.

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#### Tertiary Dismemberment of Western North America

Before coastal California began moving along the San Andreas fault, strike-slip faults displaced two other large terranes, thereby affecting petroleum maturation and migration. During the early Eocene, the Pacific plate converged against North America, because at that time it moved parallel to the Emperor Seamounts hot-spot trace. Later, when the Pacific plate began to move parallel to the Hawaiian Ridge (43 m.y. ago), the Pacific-Farallon spreading axis was contacting North America at Oregon. Strike-slip faulting, as evidenced by displaced Tertiary paleolatitudes in Alaska, then detached the Wrangellia-Chugach terrane from the Pacific Northwest and began to move it northward. Today, this block, with a pointed leading edge at the Alaska Peninsula, lies between the Aleutian Trench and the Denali fault. Local deformation indicates that during the Pliocene it curved to the west and came to rest along an ancestral Aleutian subduction zone. Magnetic lineations show that in the middle Tertiary another segment of the Pacific-Farallon spreading axis intersected the continent at northern Baja California. A terrane from Vizcaino Bay to the Olympic Peninsula, which included the Sierra Nevada and Klamath Mountains, moved northward along a fault that joined the earlier strike-slip fault near Vancouver Island. This terrane juxtaposed Obispo-block Franciscan rocks from Vizcaino Bay against Salinian-block potassium-rich plutons at the back side of the Sierra Nevada batholith. At the end of the Miocene, the East Pacific rift jumped east and established the present plate boundary, which is detaching continental rocks only from the Gulf of California to Cape Mendocino.

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#### Geology and Geothermal Energy Development at Coso KGRA

The Coso geothermal area, located east of the Sierra Nevada about 150 mi (240 km) north of Los Angeles, is in an oval structural basin 25 to 28 mi (40 to 45 km) across that is defined by arcuate faults. The basin is underlain by fractured Mesozoic granitic rocks that have been intruded and partly covered by late

Cenozoic basalt, dacite, and rhyolite. A partly molten silicic magma body < 1 m.y. old is interpreted to underlie the central part of the basin. Fumaroles are associated with the youngest volcanics (~ 0.3 m.y. old) which occur along the upfaulted north-trending Coso Range in the center of the basin. Snow melt patterns along the Coso fault zone, east of the range, indicate high heat flow. Measured heat flow values in exploratory wells indicate > 10 HFU in a 11.6 km<sup>2</sup> (30 km<sup>2</sup>) area within the basin. Several young faults cut Pleistocene lavas and offset Holocene alluvium by as much as 10 ft (3 m). The principal structural controls of subsurface fluid flow are fractures, dominantly of north-south, but also of northwest and northeast trend. Maximum measured temperature of surface water is 96.7°C. Compositions of test well fluids indicate reservoir temperatures as high as 250°C and suggest the presence of an extensive chloride-rich hot water system. Development of the geothermal power-generating potential of 3,000 acres (1,215 ha.) within the 72,640 acre (29,400 ha.) Coso KGRA by California Energy Co., under contract with the Department of the Navy, was begun with the siting of four wells in early 1981. The initial exploratory drilling phase will be completed by the 2d quarter of 1982. Commercial power production is anticipated by 1985.

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#### Recent Regional Studies in Central Eromanga Basin Area in Southwestern Queensland, Australia

Interest in the petroleum potential of the central Eromanga basin area has been stimulated by recent discoveries of oil and gas in the Eromanga and Cooper basin sequences in southwestern Queensland.

The Bureau of Mineral Resources, in cooperation with the Geological Survey of Queensland, is assisting in petroleum exploration of this area by providing new regional information on the structural and depositional history of the Eromanga and underlying Cooper, Galilee, and Adavale basins. Several regional seismic reflection traverses up to 186 mi (300 km) long are being recorded over major structural features in the Eromanga basin, over the eastern margin of the Cooper basin, the southwestern Galilee basin, and the underlying Adavale basin. The seismic surveys are tied to existing seismic data to provide good quality structural and stratigraphic information. Seismic refraction, gravity, and magnetic, and magneto-telluric surveys are providing additional information on both sedimentary and basement structures; Landsat imagery studies are providing new perspectives on many regional features; and geochemical and source rock maturation studies are providing a basis on which a sound assessment of the petroleum prospectivity of the areas can be made.

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#### Seismic Reflection and Mineral Prospecting

Prospecting for minerals becomes increasingly difficult when targets lie at depth, or where basement expression is masked by thick sedimentary cover. Geophysical techniques such as gravity and magnetics are generally used as aids in reconnaissance, but rarely yield unambiguous solutions, while electrical methods suffer because the often highly conductive overburden limits current penetration. Recent advances in extending the resolving power of the seismic reflection method suggest that it is ap-

appropriate now to consider its use in mineral prospecting. Its applications can include indirect ore-detection methods such as: tracing intrabasement horizons; qualitative interpretation of zones, using or adapting ideas of seismic stratigraphy; mapping structural features such as faults or folds; interpolating between or extrapolating from existing drill holes.

Direct detection may also be possible by using "bright" or "dim spot" techniques, or because some orebodies have characteristic reflection and diffraction responses.

In contrast with petroleum exploration, where variations in velocity are taken as a guide to reflection response, the evidence indicates that density contrast is more likely to be the governing factor. Thus, for example, increasing substitution of pyrrhotitic ore into a country rock consisting of siltstone does not substantially alter an intrinsic rock velocity of 5.5 km/s. The density, on the other hand, may change from 2.7 to 4.5 t/m<sup>3</sup>. This is in agreement with the known relationship between velocity, density and mean atomic weight. Therefore, in metamorphic, igneous or mineral-bearing rocks, where porosity is low and exists mostly as microcracks, it is the variations in density which occur in predominantly monomineralic layers which may contribute to a significant reflection response. The thicknesses of such bands, the relative sizes of the targets and the degree of resolution sought of structural features requires the use of high resolution techniques and the recording of frequencies in excess of 200 Hz.

Modeling of the responses of known orebodies confirms the notion that some may have characteristic seismic response. It is a useful approach which assists in the design of field surveys, particularly when one seeks to avoid spatial aliasing problems in areas of steep dip and structural complexity. Processing techniques suitable for a particular area may also be examined using modeling techniques.

The use of common-depth-point stacking is inappropriate in structurally complex areas. However, as some form of stacking is necessary to yield adequate levels of signal above noise, the application of so-called slant-stacking techniques should be considered. These also alleviate problems associated with offset-dependent waveforms and reflection coefficients. Examples from various areas in Australia illustrate these concepts.

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#### Energy Requirements of South Pacific and the Role of Renewables

During early 1982, a survey of the energy situation in ten countries of the South Pacific was undertaken to determine future energy policy options.

The ten survey countries fall into two natural size groups with larger countries (Papua New Guinea, Fiji, Solomons, Vanuatu) using 20 to 30% of export revenue to purchase imported oil. Western Samoa, however, showed an exceptionally high jump from 38% in 1979 to 60% in 1980. The smaller nations showed even greater balance of payment vulnerability with the most dramatic examples being Niue (where oil imports cost more than twice total exports) and the Cook Islands (where oil consumed 107% of export revenues). For all island nations, copra and other coconut products represent a substantial export earner which is relatively insensitive to energy costs so the possibility of a flow through of oil price increases to export revenues is considered to be unlikely.

Only in the region's largest countries do indigenous energy resources presently play a significant role with PNG and Samoa generating a significant (but declining) fraction of electricity from hydropower and Fiji utilizing bagasse for thermal genera-

tion. Many of the larger countries have hydropower schemes under construction or advanced study but the smaller and flatter nations have little hydro potential. For these nations, biomass potential will also be constrained by the limited land area and by competition with food export crops.

The energy survey concluded that feasible oil substitution strategies for South Pacific Island nations might focus on the generation of electricity and the provision of domestic fuels from biomass although a wide range of other options will play a part. One resource which has substantial potential throughout the Pacific are senile coconut trees well past their productive economic lifetimes which could be developed through gasification or directly to generate island electricity. Beyond special circumstances favoring ethanol in PNG and Fiji, little potential for liquid fuel production is anticipated for the transportation sector over the next 10 to 15 years for most Pacific countries. Identified, as well, are policy changes leading to more efficient use, more rational mixes of fuel supplies, and increases in security of existing petroleum imports.

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#### Tectonic Stress and Metallogenesis—Southwest Pacific Island Arc Region

In 1980, the author expressed a hypothesis that the extensional tectonic stress environment is favorable for volcanogenic massive sulfide mineralization, while the compressional stress environment is conducive to porphyry-type copper concentration. The genetic control of tectonic stress on major porphyry copper mines and prospects, with more than  $3 \times 10^5$  tons of metallic copper in the Southwest Pacific, has been investigated.

(1) The distribution of these deposits is generally confined to the island arcs formed by collision/accretion tectonics.

(2) Highly compressional tectonic stress environments of collision tectonics, if active at the time of porphyry intrusions and the ore emplacement, seem to be one of the most favorable controlling factors for copper concentration of this type.

(3) Highly compressive tectonic stresses produce higher confining pressures in the porphyry intrusive body than those produced under extensional deviatoric stress conditions. When intrusive stocks solidify by cooling, high confining pressures retard second boiling of the stage of lower temperature and higher crystal ratio. The fluid phase, separated by the second boiling, will be more saline and may have a higher partitioning ratio of chalcophile metals. When inner pressure overcomes the outer strength, brittle failure causes myriads of minute cracks, in the surrounding solid rock, which the metal-laden fluid will permeate. Copper sulfides will be disseminated as a stockwork deposit.

(4) Physico-chemical processes, governed by tectonic dynamics, seem to be very favorable for rich concentration of porphyry-type metal deposits.

Metal concentration of the extensional stress environment, such as they produced by exhalation of hot metallic solutions at ocean rifts, can be compared to that of the compressive type.

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#### Status of Geologic and Resource Mapping, Northwest Quadrant, Circum-Pacific Map Project

A draft of the Geologic Map was completed in 1978 with the